Commercial Fishermen's Observations of Ecological Change in Narragansett Bay

A Pilot Project

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INTRODUCTION

Estuarine habitats play a vital role in sustaining living marine resources and the economies based on these resources. Many coastal species use estuaries for spawning and nursery areas, and anadromous species migrate between the ocean and freshwater through estuaries and rivers (Beck *et al*. 2001, Boesch and Turner 1984, Hughes *et al.* 2002, Rose 2000). In fact, seventy-five percent of the total annual seafood harvest in the U.S. consists of fish and shellfish species that are dependent on estuaries and wetlands for some or all of their life stages (Dahl 2006).

Because of the importance of estuaries both as locations for small-scale fishing and as nursery and feeding grounds for commercially important fish and shellfish species, commercial fishermen have a strong interest in seeing that estuarine habitats are well cared for as food-producing environments. Moreover, their regular long-term use of estuarine waters gives many fishermen an intimate glimpse into ecological changes unfolding in these environments—an understanding that may be more holistic than that of individual scientists, who typically study only one aspect of these complex ecosystems at a time (Nixon *et al.* 2008). However, the anecdotal nature of this knowledge often prevents it from being integrated into assessments of environmental condition or used as a basis for estuarine management decisions.

The report that follows shines a spotlight on the environmental knowledge held by commercial fishermen whose daily work takes place in the waters of Narragansett Bay. The knowledge collected here includes detailed accounts of individuals' observations with regard to trends in abundance, distribution, and co-occurrences of invertebrate, vertebrate, and macroalgal species in the bay, as well as abiotic factors observed through both visual and olfactory senses. This work is the first of its kind to document whole-system (as opposed to species-specific) observational knowledge of Narragansett Bay's commercial fishermen in a detailed spatial and temporal framework.

This effort responds to a complex set of needs that have been gathering urgency in recent years. Over the last half-decade, members of the commercial fishing community have been expressing concern about Narragansett Bay's ecological health and long-term viability as a generator of food and jobs in the commercial fishing sector (Allard Cox 2018). Some have described dramatic changes within the macroalgae, fouling invertebrate, shellfish, and crustacean communities in the bay, along with changes in abiotic aspects such as water clarity and unusual smells. Many assert that these changes are unprecedented within their careers (Schumann 2016).

At a larger scale, anthropogenic climate change is driving accelerated ecological change around the globe, making it harder to disentangle the effects of localized stressors from global climate signals in estuarine systems (Cloern *et al.*2016). In Narragansett Bay, surface water temperature increased by 1.4-1.6°C between 1960 and 2006 (equivalent to 0.029°C per year), with this increase being particularly notable in winter (Fulweiler *et al.* 2015). Studies in Narragansett Bay have found evidence of climate-induced shifts in the abundance and timing of key ecological components including phytoplankton (Borkman and Smayda 2016, Melrose *et al.* 2009, Nixon *et al.* 2009), copepods (Sullivan *et al.* 2007), ctenophores (Costello *et al.* 2006, Slesinger *et al.* 2020), macroalgae/seaweed (Feehan *et al.* 2019), and finfish (Collie *et al.* 2008, Oviatt *et al.* 2003), with impacts on key ecological processes such as benthic-pelagic coupling (Nixon *et al.* 2009) and predator-prey dynamics (Sullivan *et al.* 2007). Given the increasing intensity and multidimensionality of ecological change in Narragansett Bay, it is more important than ever to draw upon *all* sources of information that can help paint a more complete picture of change as it unfolds.

Adding an additional layer of intricacy, declarations of concern by commercial fishermen have occurred at the same time that estuary management and monitoring entities have celebrated improvements to water quality in Narragansett Bay stemming from major initiatives to upgrade wastewater treatment facilities and stormwater infrastructure (NBEP 2017a). It is important to note that neither the fishing community, nor the professional scientific and management community, nor the bay itself, is a monolith; there are a multiplicity of trajectories across different indicators and components of the bay's ecosystem, and to paint the bay's stakeholders and caretakers as rival factions would be to dangerously oversimplify things. Nonetheless, an apparent incongruity of views among members of these communities regarding how the *current* status of Narragansett Bay compares to its *desired* status has become the subject of ongoing attention in recent years (Kuffner 2017, 2021), and it is against this backdrop that this pilot project seeks to make its mark.

Such differing outlooks present a variety of challenges, but they also provide a rich context to investigate how different groups form, validate, and interpret environmental information. In conducting this study, we posit that such an investigation has the potential to bring about greater mutual understanding and set the stage for deeper collaboration among these groups. Perhaps it may even reveal ways to convert the diversity of these groups' environmental knowledge bases into an asset instead of an impasse.

This investigation draws upon a growing body of studies from around the globe focused on collecting Fishermen's Ecological Knowledge (FEK) and comparing it to Scientific Ecological Knowledge (SEK). The objectives of such studies are typically to identify commonalities and discrepancies between these two forms of knowledge, to explore how to better integrate FEK into SEK-based fisheries management, and to pave a pathway for improved understanding between the bearers of these two types of knowledge regarding the resources that they share an interest in (e.g., Cardoso da Silva *et al.* 2020, McLean 2020, Schumann 2011).

In their 2012 review of Local and Traditional Knowledge (LTK) studies (of which FEK is a subset), Thornton and Sheer conclude that these studies have the potential to add value to resource management by increasing the available knowledge base about a given species or habitat and by improving the local capacity and power sharing that comes with including LTK holders as equal partners in research programs (Thornton and Sheer 2012). That review observed that a large proportion of LTK research has focused on species-specific information that is important for resource use, while a smaller proportion has focused on marine ecology, environmental change, and resource management practices. Lastly, it suggests that LTK research can be useful for a variety of objectives, such as production of historical and contemporary baseline information, exploration of new stewardship techniques, improvement of conservation planning and practice, and resolution of management disputes.

Drawing on this body of literature, the present study embraces a starting premise that in order for FEK to inform the knowledge base used in assessing and managing estuarine ecosystems, FEK must first be systematically collected and presented in a coherent fashion that makes sense and has validity to *both* the resource users who contribute their knowledge *and* to members of the management communities who will ultimately need to accept this knowledge if it is to be incorporated into environmental management.

With this goal in mind, we conducted a 2019 pilot project to catalogue the ways in which 17 Narragansett Bay fishermen have seen the bay's ecosystem change in recent years. This project sought not only to systematically gather observations from fishermen based in different ports throughout the bay who interact with the bay through a variety of fishing gear types, but to do so in a way that was as spatially and temporally explicit as possible in the type of data it gathered.

Interviewees provided their observations using a taxon-specific (for biotic observations) and a factor-specific (for abiotic observations) basis. For each taxon or factor of note, interviewees shared details on observed trends, spatial occurrence, temporal benchmarks, and observed associations with other events or trends, in as much detail as their memories afforded. Observations were presented both verbally and visually, through sketches on a nautical chart.

Where relevant, this report also draws on content from two previously conducted sets of interviews carried out by the lead researcher prior to the 2019 pilot project. The first set was conducted in 2014 with the purpose of informing a narrative work, *Rhode Island's Shellfish Heritage: An Ecological History* (Schumann 2015). The second set was conducted in 2016 with the goal of compiling a fishing industry resilience plan called the *Rhode Island Commercial Fisheries Blueprint for Resilience* (Resilient Fisheries RI project 2018).

Since detailed ecological observations about Narragansett Bay were relevant, but not central, to the *Rhode Island's Shellfish Heritage* and *Blueprint for Resilience* interviews, respondents were not as explicit in their treatment of these themes as they were in the 2019 pilot project, particularly with regard to their spatial and temporal dimensions. Nonetheless, inclusion of remined content from those interviews adds value to this report by increasing the number of individuals whose observations are represented and by enabling comparison of content across three different interview timeframes: 2014, 2016, and 2019.

The work represented in this report is just as much about piloting experimental methodological approaches as it is about the data generated through these approaches. Thus, in addition to preliminary findings from this work, we also present a reflection on lessons learned about the value and shortcomings of our methodological design. We hope that this pilot project will lay the groundwork for a larger FEK collection effort to better integrate fishermen's knowledge of the Narragansett Bay ecosystem, perhaps repeated at regular intervals to capture new observations as this ecosystem continues to change in response to new environmental realities.

METHODS

The primary data source for this project was a pilot project conducted between February and November 2019. During this timeframe, we conducted face-to-face semi-structured interviews with 17 commercial fishermen. Sixteen of these fishermen currently fish in Narragansett Bay, while one fished in the bay until 2014 before shifting his fishing efforts outside the bay, based on trends he experienced in his lobster catches. Sixteen of the 17 interviewees completed the full interview, while one interview was cut short by competing demands for time. A full interview is defined as one in which the interviewee exhausted the topics he wished to talk about. Interviews generally lasted between one and one and a half hours.

Our sampling strategy can be described as a combination of purposive and convenience sampling. We began by contacting fishermen whom we already knew and asking them to sit with us for an interview. We also visited fishing docks and asked fishermen who were present at the time to grant us an interview. Through our purposive sampling efforts, we targeted fishermen in higher age brackets because of their longer observational time series. Our convenience sampling did not favor any particular age group. We deliberately included a diversity of homeports and gear types in our sample.

Interview prompts solicited fishermen's recollections and interpretations of changes in the abundance, distribution, and other characteristics of invertebrate, vertebrate, and macroalgal species, as well as sensory impressions relating to physical aspects of the bay ecosystem. Each participant was prompted to select the specific taxa and abiotic factors that he wished to reflect on. Then, he was asked to recall everything he could about how this taxon or factor had changed, to the greatest level of detail possible. Appendix A contains the interview questionnaire that was used in these interviews.

Respondents were asked not only to verbally describe their observations of changes, but to draw these observations on a laminated nautical chart with dry erase markers, using different colors to indicate: locations where an organism/factor used to be present but is now absent or has decreased in abundance; locations where an organism/factor was previously absent but is now present or has increased in abundance; and locations where an organism/factor has always been present and has stayed about the same in abundance. Respondents were also asked to mark each area with the timeframe in which they observed this change, and to recall whether the particular change in question was associated with any other ecological changes that they had noticed. Maps were photographed for subsequent digitization and analysis.

To help ensure comprehensive coverage of a wide range of taxa, we presented interviewees with a list of common fish, invertebrates, macroalgae, and mammals known to exist in Narragansett Bay. This list can be found in Appendix A. Organisms included in this list had either been mentioned prior to the pilot project by fishermen or were recommended by scientists as being of particular interest to this study. To overcome the fact that fishermen use different colloquial names to describe some invertebrates and macroalgae, we offered them a set of laminated cards (subsequently called "photo ID cards") containing images, scientific names, and known common names for a variety of macroalgae and invertebrate species. Fishermen were asked to review these lists and cards, and to recall whether they had observed any noteworthy changes in these species' abundance, distribution, size, texture, seasonality, or other aspects. However, they were not limited to the listed species, and interviewees brought up several species (e.g., sea mouse, seahorse) that we had not anticipated in the species list.

Interviews were recorded, transcribed, and paired with photographs of the hand-drawn maps. Given constraints on time and funding, interviews were not transcribed verbatim in their entirety; rather, interview sections containing general observations or musings unrelated to the research questions were paraphrased, while interview sections containing detailed or specific observations relevant to the research questions were transcribed verbatim. In all, the 2019 pilot project produced 17 interview transcripts and 89 photographed maps.

In addition to data from the 2019 Narragansett Bay pilot project, we drew upon content from interviews conducted with Narragansett Bay commercial fishermen for the *Rhode Island's Shellfish Heritage* project (2014) and *Rhode Island Commercial Fisheries Blueprint for Resilience* project (2016). A search through these previous interviews uncovered data that was relevant to the present project within eleven interviews from the *Rhode Island's Shellfish Heritage* project and eight interviews from the *Rhode Island Commercial Fisheries Blueprint for Resilience* project. Six of the 17 individuals interviewed for the 2019 Narragansett Bay pilot project were also interviewed in the *Shellfish Heritage* project and four individuals interviewed for the 2019 pilot project were also interviewed for the *Blueprint for Resilience* project. We extracted relevant segments of those interviews and analyzed them as described above. Since the interview format for those two previous projects was less formally structured than the format of the 2019 pilot project, observational statements derived from the two previous projects tended to be less detailed in spatial and temporal terms. Throughout the remainder of this report, we will refer to these projects using the following shorthand:

- NB 2019: interviews performed in 2019 with 17 Narragansett Bay fishermen using a semi-structured interview and presented in this report for the first time
- RF 2016: interviews performed in 2016 for the *Rhode Island Commercial Fisheries Blueprint for Resilience* project and remined for the current report
- SH 2014: interviews performed in 2014 for the *Rhode Island's Shellfish Heritage* project and remined for the current report

Transcripts were analyzed using qualitative content analysis, "a research method for subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns (Hsieh and Shannon 2005)." We began by segmenting interview transcripts into "observational statements," a unit that we defined as any combination of "respondent," "organism/factor," and one or more of the following: trend description, spatial description, and temporal description. Each of these variables is explained in greater detail below. A spreadsheet listing all observational statements generated by interviewees can be found in Appendix G.

The “organism” variable was defined at the species level wherever possible. Organisms and abiotic factors described by only one respondent apiece in the 2019 Narragansett Bay interviews were grouped into five “miscellaneous” categories (finfish, invertebrates, mammals, seaweeds, and abiotic factors). The “miscellaneous seaweeds” category also includes seaweeds whose name was unknown, that did not appear in the photo ID cards provided during the interview, that were selected from the photo ID cards during the interview but unknown prior to the interview, or were identified only by a verbal description of their physical characteristics. We also included the seaweed *Desmarestia* in this category because although one interviewee identified it by name, it seemed likely that other interviewees describing un-named seaweeds may have also been referring to this species. Thus, the “miscellaneous seaweeds” category encompasses a number of potentially synonymous seaweed organisms.

Statements that included a spatial description were assigned to a “bay segment” category, determined by matching locations mentioned with the segment(s) of the bay in which these locations lie. For example, an observation taking place around Providence Point would be coded as “Upper Bay.” For this process, we also reviewed spatial information provided within maps drawn by respondents. “Bay segments” were defined using the Narragansett Bay Estuary Program’s “BAYSEGMENTS_NBEP2017” digital map (NBEP 2017b). Throughout this report, we have underlined place names that refer to specific “bay segments.[1]”

Statements that did not include a specific spatial designation were not assigned to a “bay segment”. These statements may or may not be extrapolatable to the entire bay. Conversely, observations that do include specific spatial designations cannot be assumed to be limited to the areas named. Few, if any, fishermen cover the entire bay in the course of their fishing activities; thus, observations provided by fishermen can be interpreted as “presence” data, but a lack of observations on other areas cannot be interpreted as “absence” data. Additionally, spatial designations may, in some cases, be examples offered by interviewees to illustrate a point, rather than an attempt by interviewees to bound their observations spatially. In instances where an interviewee made a general, non-spatially-denominated observation coupled with a spatially denominated observation to illustrate the larger observation, only the spatially denominated example was included in the table in Appendix G.

Biotic observational statements that included a description of a trend over time were assigned to one of eight “trend” categories: decline, increase, uptick, downtick, constant, cyclical/variable, boom, and collapse. These categories are described in Table 1.

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[1] Throughout this report, we utilize bay segment names and spellings assigned by the Narragansett Bay Estuary Program (NBEP 2017b). Commonly used alternative names and spellings are noted in Table 5.

Table 1. Definitions of "trend" categories used to sort observational statements.

Trend Type	Explanation
Decline	Definition: • A population has declined in abundance/frequency for two or more years; or • A population shifted from a state of greater abundance/frequency to a state of lower abundance/frequency two or more years ago. Notes: • All observational statements classified as showing a "decline" extend up to and include the present day. • Instances in which an interviewee described an organism as declining, but did not specify a time range for this decline, were assumed to have occurred for two or more years and were placed in the "decline' category. • When provided, the "time period" description for observations in the "decline" category will be phrased in a "since YEAR(s)" format or a "abundant in YEAR(s); scarce now" format. In the former case, the interviewee providing the observation stated either that a decline began in the YEAR(s) in question or that (s)he has not encountered the organism since the YEAR(s) in question. In the latter case, the interviewee phrased the observation in a "before/after" format, comparing the present to a point of time in the past with a higher abundance than the present.
Increase	Definition: • A population has increased in abundance/frequency for two or more years; or • A population shifted from a state of lower abundance/frequency to a state of greater abundance/frequency two or more years ago. Notes: • All observational statements classified as showing an "increase" extend up to and include the present day. • Instances in which an interviewee described an organism as increasing, but did not specify a time range for this increase, were assumed to have occurred for two or more years and were placed in the "increase" category. • When provided, the "time period" description for observations in the "increase" category will be phrased in a "since YEAR(s)" format or a "scarce in YEAR(s); abundant now" format. In the former case, the interviewee providing the observation stated either that an increase began in the YEAR(s) in question. In the latter case, the

	interviewee phrased the observation in a "before/after" format, comparing the present to a point of time in the past with a lower abundance than the present.
Uptick	Definition: • A population experienced a minor increase, often (but not necessarily) within a longer-term countervailing trend (i.e., decline or period of constancy); or • A population experienced a minor increase within a larger pattern of variability or cyclicity, which may be part of this cyclicity/variability; • A population experienced a small increase within the last two years; or • Interviewee observed a small increase in a population within the last two years, and has no knowledge of the population prior to this time. Notes: • All observational statements classified as showing an "uptick" extend up to and include the present day. • When provided, the "time period" description for observations in the "uptick" category will be phrased in a "since YEAR(s)" format.
Downtick	Definition: • A population experienced a minor decline, often (but not necessarily) within a longer-term countervailing trend (i.e., increase or period of constancy); or • A population experienced a minor decline within a larger pattern of variability or cyclicity, which may be part of this cyclicity/variability; • A population experienced a small decline within the last two years; or • Interviewee observed a small decline in a population within the last two years, and has no knowledge of the population prior to this time. Notes: • All observational statements classified as showing a "downtick" extend up to and include the present day. • When provided, the "time period" description for observations in the "downtick" category will be phrased in a "since YEAR(s)" format.

Constant	Definition: • A population has remained stable in its abundance within the time period during which the respondent has been fishing in the area. Notes: • All observational statements classified as “constant” extend up to and include the present day. • A “time period” description is not listed for observations classified as “constant.” The timeframe is assumed to be from the start of each interviewee’s fishing career (which varies by individual) until the present.
Cyclical/ Variable	Definition: • A population has shown repeated ups and downs within the time period during which the respondent has been fishing in the area; Notes: • No distinction is made in our classification scheme between ups and downs that recur regularly and with comparable magnitude (i.e., cycles) and those that are more random and irregular (i.e., variable). • Observational statements classified as “cyclical/variable” are general statements made without regard to particular times and places. • Frequently, an interviewee may make such a statement in combination with more specific observations that serve as examples of upturns and downturns within the cycle or history of variability. These instances will be double-classified as “cyclical/variable” (without any accompanying spatial or temporal details) and as whatever trend the example represents (e.g., boom, collapse, increase; decline; uptick, downtick; with accompanying spatial or temporal details).
Boom	Definition: • A population experienced a sharp increase followed by a sharp decline at one point in time, with relatively constant abundance before and after this time; or • A population experienced a sharp increase followed by a sharp decline at one point in time, within a longer-term trend of cyclicity/variability. Notes:

	• Observational statements classified as "booms" have an end date prior to the time of the interview, and are considered historical statements. • Some "booms" are notable in their scale (i.e., an organism experienced a massive and memorable set), but this is not a precondition to be classified as a "boom"; rather, what sets a "boom" apart is that it was a time of above-average abundance with a discreet beginning and end. • When provided, the "time period" description for observations in the "boom" category will be phrased in an "in YEAR/DECADE" or "between YEAR 1 – YEAR 2" format.
Collapse	Definition: • A population experienced a sharp decline followed by a sharp increase at one point in time, with relatively constant abundance before and after this time; or • A population experienced a sharp decline followed by a sharp increase at one point in time, within a longer-term trend of cyclicity/variability. Notes: • Observational statements classified as "collapses" have an end date prior to the time of the interview, and are considered historical statements. • Some "collapses" are notable in their scale (i.e., an organism experienced a massive and memorable die-off), but this is not a precondition to be classified as a "collapse"; rather, what sets a "collapse" apart is that it was a time of below-average abundance with a discreet beginning and end. • When provided, the "time period" description for observations in the "collapse" category will be phrased in an "in YEAR/DECADE" or "between YEAR 1 – YEAR 2" format.

Statements that included a temporal description (i.e., one or more years in which a trend, change, or steady state began, occurred, or ended) were paraphrased and translated into one of several consistent formats. For example, a statement made in 2019 that something occurred “starting about 5 or 6 years ago” would be translated into “since 2013-2014.” Temporal descriptions associated with trends varied in their phraseology. For instance, an interviewee describing the timeline of a decline might utilize any of the following sentence structures to convey this comparison:

- Inflection point when a trend began (e.g., “X started to decline in 2005”);
- Contrasting a “before” state with an “after” state: (e.g., “X was everywhere in the 1990s and early 2000s; by 2015, X was gone”);
- Description of the last memory of seeing a previous state: (e.g., “the last time I saw X in big numbers was in 2010”).

When inputting observational statements into our dataset and text summaries, we standardized these varying phraseologies, as referenced in the “notes” sections in Table 1.

Even after translation and standardization, temporal descriptions proved challenging to interpret and impossible to categorize. Therefore, in our analysis, we treated the temporal variable as a descriptive variable whose purpose is to place observations in context, but we stopped short of attempting to place observations within categories (e.g., decades) or sort them chronologically. The challenges of interpreting the temporal dimensions of fishermen’s observations will be discussed later in this report.

When summarizing and categorizing observational data, we utilized several filtering criteria to determine what kinds of statements to include in our dataset, and several splitting criteria to divide multi-layered anecdotal observations into one or more unique “observational statements.” These criteria included the following:

- Only observations including both an organism and one of the eight trends listed in Table 1 were included in our dataset.
- Static descriptive statements with no explicit trend were not included in the dataset.
- One-time sightings of an organism were not included in the dataset.
- Spatial and temporal aspects were attached to the observation where provided, but were not a prerequisite for inclusion in the dataset. As a result, some observational statements in our set are not specific with regard to where or when the observed trend took place.
- In cases where spatial information accompanied an observation, we assigned the observation to one or more “bay segments,” as defined in the Narragansett Bay Estuary Program’s “Bay Segments” classification system. If the spatial information provided by a respondent spanned two or more bay segments, we entered it into our dataset as two or more observational statements. If the spatial information encompassed two or more locations within the same bay segment, we entered it into our dataset as a single observational statement with multiple in-segment locations listed.
- In cases where temporal information accompanied an observation, we entered this information into our dataset as a descriptive variable. If a respondent described a trend

taking place for the same organism and same bay segment at two or more different time periods, then we entered it into our dataset as two or more observational statements.

Photographs of the laminated nautical charts were georeferenced in Esri ArcPro software. The hand-drawn shapes were digitized in 34 unique GIS layers. Each layer represents a single fisherman's observations about one species. When a respondent drew a polygon, the shape was digitized using the outside edge of the pen stroke. When they drew a line, the pen stroke was buffered around the outside edge of the pen stroke and outlined as a polygon. If the line abutted a coastline, the shape of the coastline was roughly followed (e.g., Figure 1, LN2-95). In some cases, the respondent indicated that a line represented an entire cove (e.g., Figure 1, AE2-176, 177, 175), and so the full cove was roughly delineated. Each polygon was assigned a Respondent ID, Observation Code, Trend, and Species/Abiotic Factor, which can be cross-referenced with Appendix G.

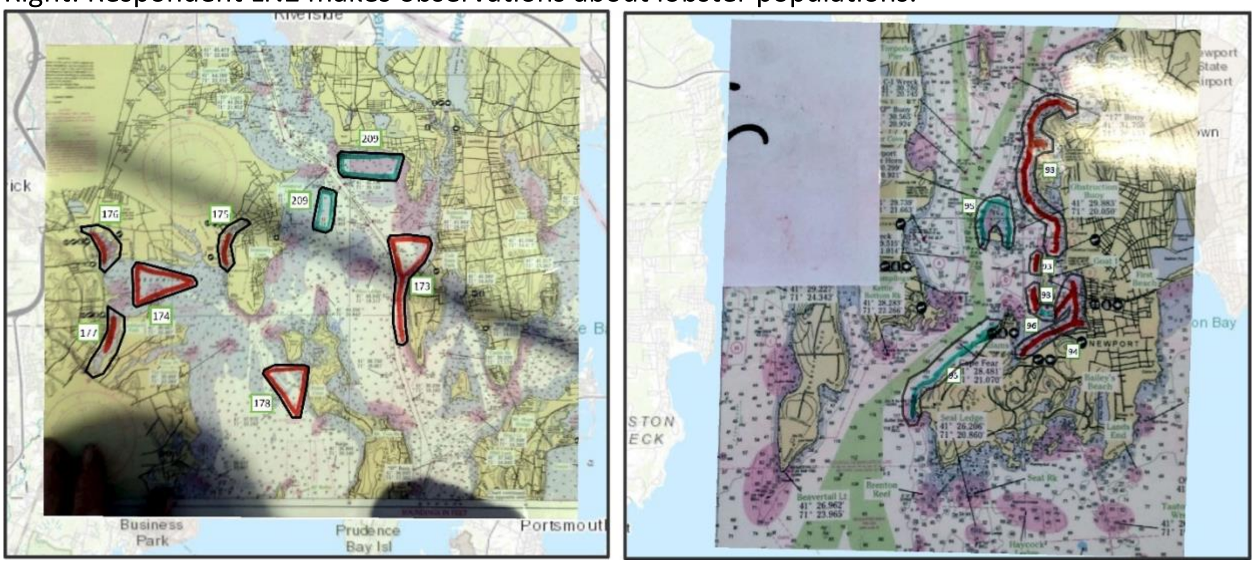
Data accuracy reflects digitization from rough pen strokes made with varying levels of accuracy on nautical charts at a scale of 1:60,000. Photographs of laminated charts were taken from various angles, different lighting, and low resolution, which also reduces the quality of georeferencing and thus the accuracy of subsequent digitization. Polygons were also smoothed and rounded to reflect the hand-drawn quality of the original pen strokes, rather than any particular geographic features other than general coastlines where relevant. The depicted boundaries were not verified at the site level during digitization. Given these constraints, data should be interpreted as general, rough areas taken "as is" from the information provided by respondents.

After processing the data as described above, we reviewed it for patterns that would enable us to construct a general description of how Narragansett Bay's commercial fishermen perceive the bay's changing ecology. Patterns of interest included, for example:

- Which organisms or abiotic factors were mentioned most frequently or consistently as having changed in significant ways? In contrast, which organisms/factors were observed to be more constant?
- Are there segments of the bay that have experienced a greater or lesser degree of change than others? Which ones and what are those changes?
- Are there time frames that seem to have experienced a greater or lesser degree of change than others? Which ones and what are those changes?
- Are there observed trends which respondents hold differing views on, and how do these views differ?
- Were there associations, either stated by respondents or emerging from the data, that suggest potential connectivity (e.g., a cause-effect relationship or a shared cause) among multiple changes or trends?

Additionally, this project was interested not only in *what* fishermen observed, but *how* they observed it. For instance, what types of ecological change are commercial fishermen most likely to pick up on their daily work activities? Which types of observation are associated with use of which gear types? Gaining a deeper understanding of how different fishermen take in observations about the marine environment may be informative when designing future studies to collect their observations or when planning cooperative research projects to engage fishermen in gathering data for inclusion in scientific datasets. We gleaned insights into these questions by reviewing relationships between the types and locations of observed changes, on one hand, and the gear type and port location of respondents, on the other.

Figure 1. Sample maps showing how polygons and lines were digitized (digitized polygons are shown as black outlines). Left: Respondent AE2 makes observations about quahog populations. Right: Respondent LN2 makes observations about lobster populations.



ANALYSIS PART I. SYNTHESIS OF FISHERMEN'S OBSERVATIONS OF CHANGE IN NARRAGANSETT BAY

Data overview

Our analysis draws on content from 37 interviews conducted with 26 individuals during three projects (NB 2019, RF 2016, and SH 2014). These individuals represent a mix of quahoggers, lobstermen, trawl fishermen, dredge fishermen, and aquafarmers, with quahoggers and lobstermen forming the majority of our sample. Table 2, Table 3, and Figure 2 provide additional data on the combined samples from the three projects.

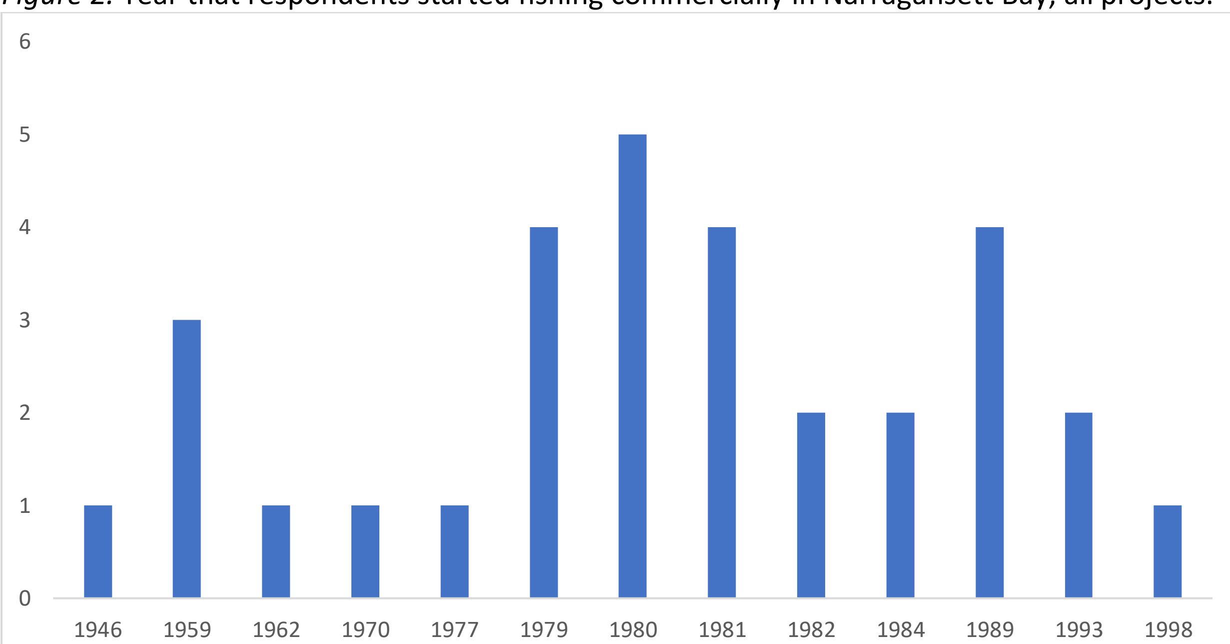
Table 2. Number of respondents by primary gear type and project.

Project	Quahoggers	Lobstermen	Trawl	Aquafarmers	Dredge
NB 2019	8	6	1	2	0
RF 2016	0	2	2	0	0
SH 2014	5	0	0	0	1

Table 3. Number of respondents by homeport and project.

Project	East Bay	Newport	West Bay	N. Kingstown	Pt. Judith
NB 2019	5	5	3	4	0
RF 2016	2	5	0	2	0
SH 2014	2	0	5	4	1

Figure 2. Year that respondents started fishing commercially in Narragansett Bay, all projects.



The 37 interviews that we analyzed from the three respective projects yielded a dataset of 432 observational statements about the biota of Narragansett Bay and a smaller number of observations related to abiotic factors in Narragansett Bay. Observations are presented as a text summary in Appendix D through Appendix F and as a spreadsheet in Appendix G. Throughout this report, specific observational statements are tagged with anonymized respondent identifier codes representing the individuals who contributed each observation. Details about the home port, gear type, fisheries, and career history associated with each respondent code are presented in Appendix B.

Of the 432 biotic observations in our dataset, 297 were spatially explicit, 251 were temporally explicit, and 181 were both spatially and temporally explicit. Figure 3 shows the distribution of spatially explicit observations across bay segments. Most frequently mentioned segments were the Upper Bay (frequently described by quahoggers) and the Lower East Passage (frequently described by lobstermen homeported in Newport).

Figure 4 illustrates how these 432 biotic observations break down across organism. As Figure 4 indicates, the organism receiving the greatest and most detailed attention from Narragansett Bay fishermen was the quahog. This is no surprise, given the quahog's economic importance to the bay's fisheries and the related fact that shellfishermen dominated the interview pool. For instance, in 2019, the Rhode Island General Assembly declared, "The quahog is the most economically important marine resource harvest from Narragansett Bay (RI General Assembly 2019)," and a 2004 report by Save the Bay stated that "The most profitable fishery of Narragansett Bay is the quahog (hard clam), accounting for 84 percent of the Bay's total fishing revenues." Figure 5 depicts the prevalence of the eight trend types in our dataset. As shown in this tree plot, the most common trend mentioned by interviewees was "decline" (n=179).

Patterns of data clustering were observed due to relationships among the type of fishing practiced by interviewees, the organisms observed, and the spatial dimensions of these observations. For instance, a large number of observations focused on quahogs in the upper half of the bay. This can be explained by the fact that half of our interviewees were quahoggers, and the upper half of the bay is currently where the majority of quahoggers work (this was not always the case, as we will explain later). Another cluster included observations by lobstermen of changes in the Lower East Passage. These clusters can be visualized in Tables 4 and 5.

In the sections that follow, we summarize interview-derived data on Narragansett Bay's biotic community (broken down into sessile benthic invertebrates, mobile benthic invertebrates, fouling invertebrates, seaweed/macroalgae, and the finfish community) and abiotic factors. We then summarize trends and patterns which interviewees described as linked, in an attempt to shed light on the role of interrelationships among species and environmental stressors in shaping the current configuration of the Narragansett Bay ecosystem. Then, we synthesize interviewees' perceptions and interpretations of the trends they described. Finally, we reflect on some of the methodological challenges that we experienced while completing this project.

Figure 3. Number of unique observational statements per bay segment.

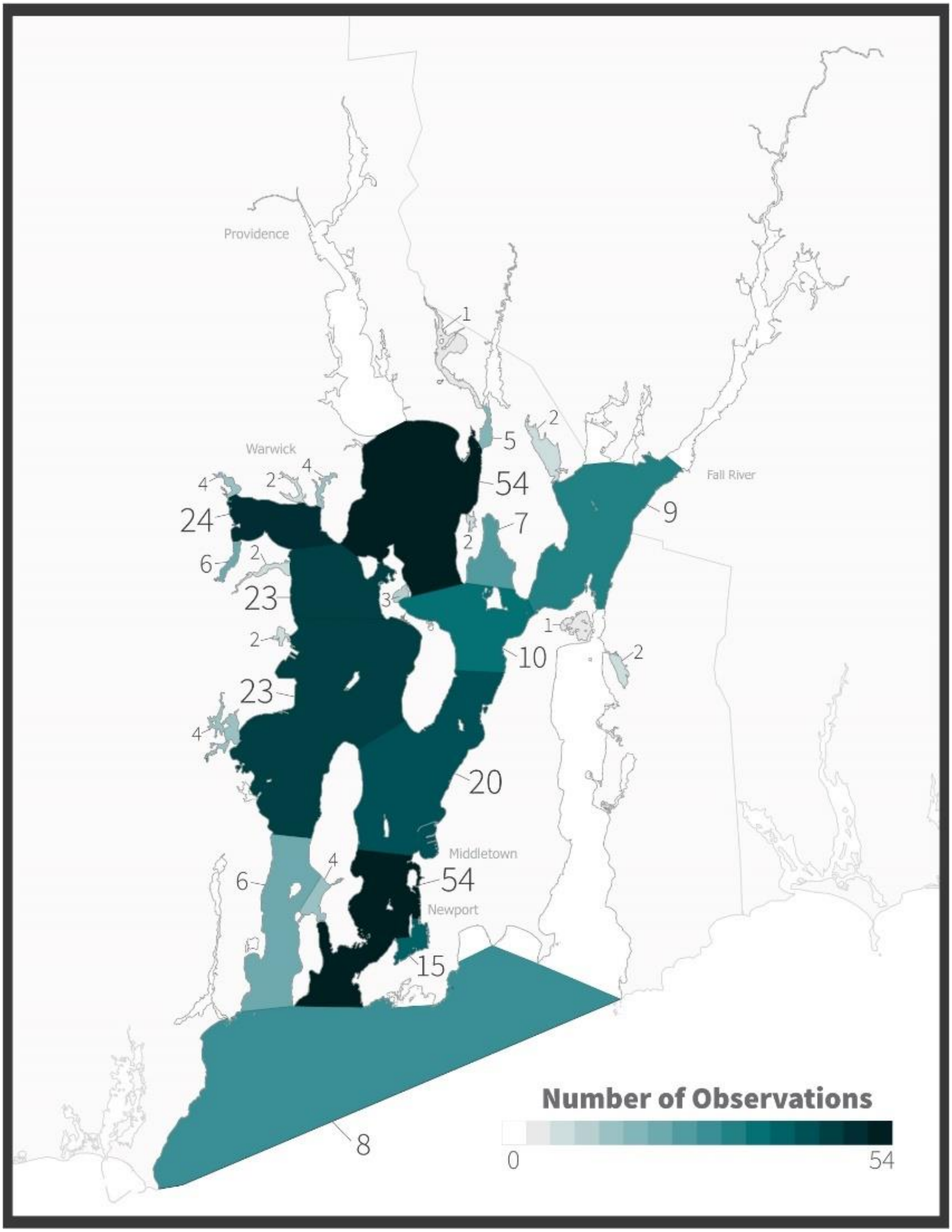


Figure 4. Number of observations per organism per project, all spatial segments combined.

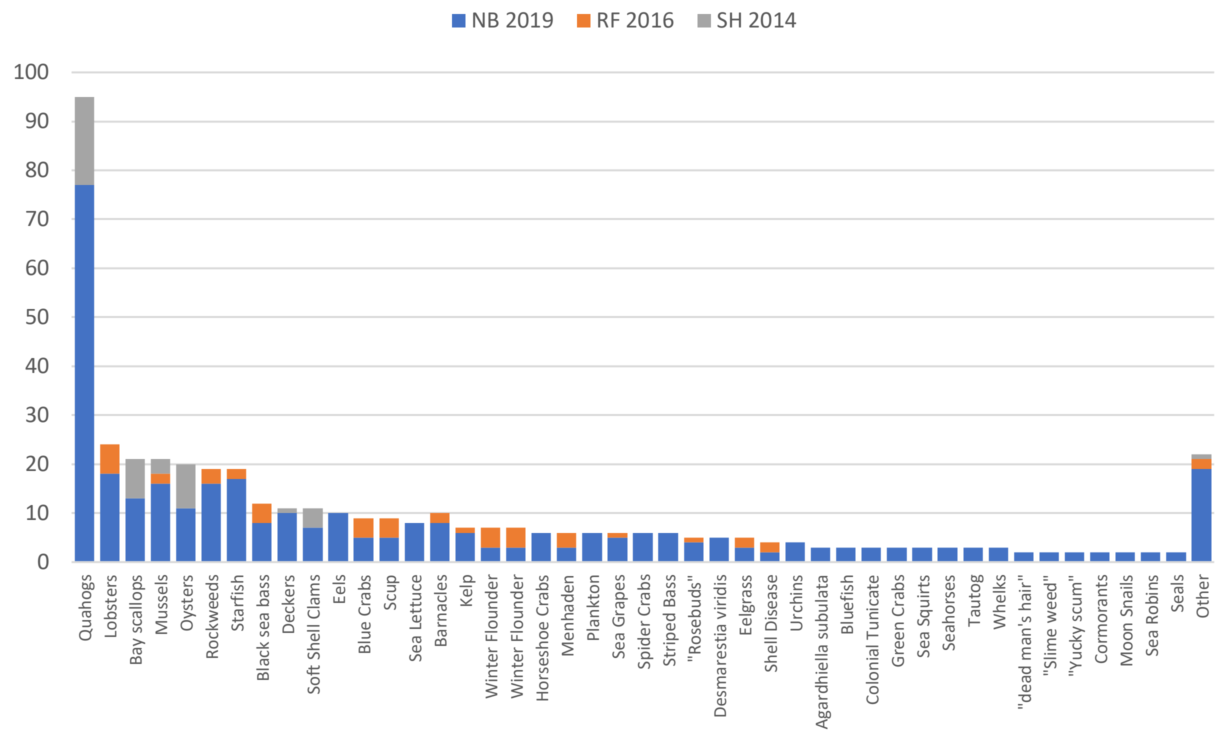


Figure 5. Breakdown of biotic observations by trend type.

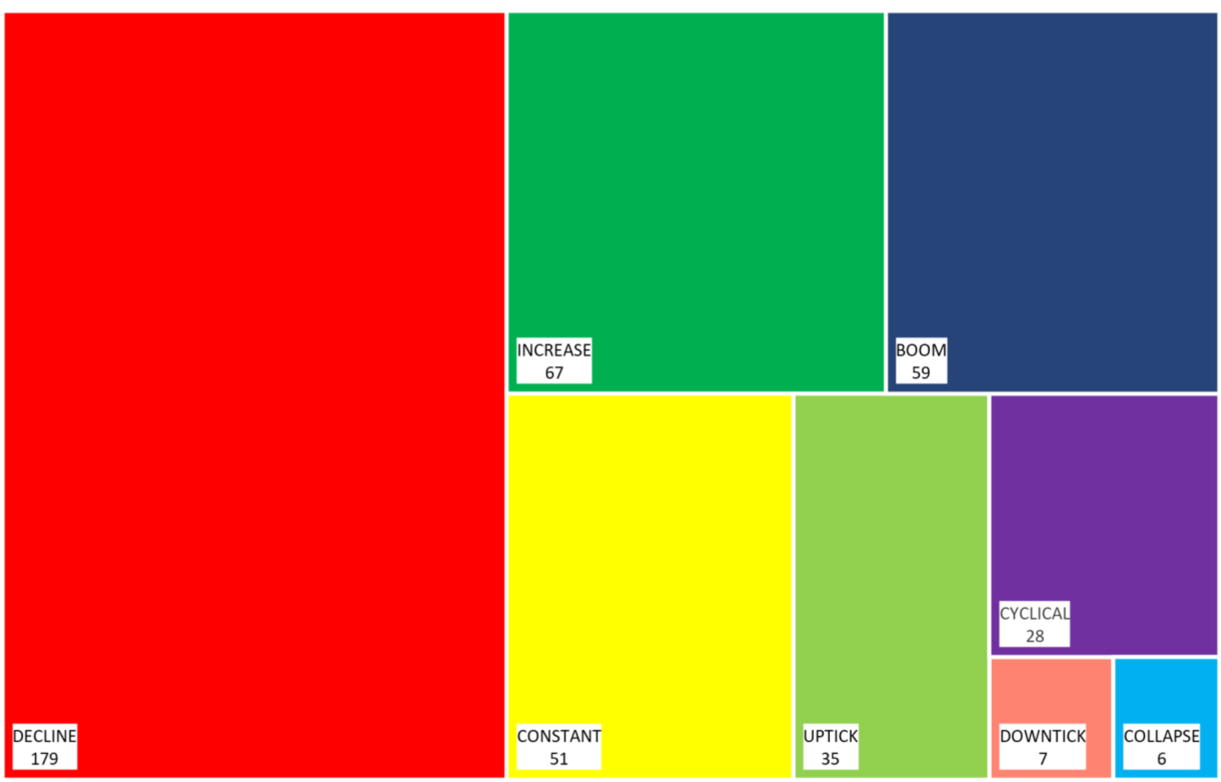


Table 4. Gear type by organism matrix. Bubble size corresponds to the number of observations made by fishermen practicing each gear type (column) about each organism (row).

	Trawl (n = 3)	Quahogger (n = 13)	Lobsterman (n = 8)	Aquafarmer (n = 2)
"Dead man's hair"		●		
"Rosebuds"			●	
"Slime weed"			●	
"Yucky scum"		●		
Agardhiella subulata		●		
Barnacles			●	●
Bay scallops		●		●
Black sea bass	●	●	●	●
Blue Crabs	●	●	●	
Bluefish		●		●
Colonial Tunicate			●	
Cormorants		●	●	
Deckers		●		
Desmarestia viridis	●	●		
Eelgrass		●	●	●
Eels		●		
Green Crabs		●	●	
Horseshoe Crabs	●	●		
Kelp	●		●	
Lobsters			●	
Menhaden	●	●	●	●
Moon Snails		●		
Mussels		●	●	●
Oysters	●	●		
Plankton			●	
Quahogs		●		●
Rockweeds	●		●	
Scup	●	●	●	●
Sea Grapes			●	
Sea Lettuce		●	●	
Sea Robins		●		●
Sea Squirts			●	
Seahorses			●	
Seals			●	

Table 5. Gear type by bay segment matrix. Bubble size corresponds to the number of observations made by fishermen practicing each gear type (column) about occurrences within each bay segment (row).

[2] Also spelled "Nanaquaket."
[3] Also called "Allen's Harbor."

Sessile Benthic Invertebrates

Quahogs (*Mercenaria mercenaria*). Eleven individuals shared observations related to quahogs. Because quahogs were the primary target species for so many of our interviewees, our dataset includes a remarkable 95 observational statements related to trends in quahog abundance, as well as a number of statements related to other attributes, such as shell thickness and spawning behavior. Seventy-seven of these observations derived from the NB 2019 project, and 18 observations derived from the SH 2014 project.

The main thrust of these observations is that quahogs were at a historic bay-wide low at the time of the NB 2019 interviews. Interestingly, this did not appear to be the case at the time of the SH 2014 interviews. As an indication of this change, 50% of all present-tense observational statements in the SH 2014 project (i.e., excluding historical booms and collapses) referred to an increase in quahog abundance. In contrast, 56% of present-tense observational statements in the NB 2019 project referred to a decline in quahog abundance. Effectively, this “before and after” comparison lends support for a view voiced by many interviewees that the quahog population shrank during the years leading up to the 2019 interviews.

At the time of the SH 2014 interviews, respondents shared the following observations:

- In general, quahog abundance was on the rise (n=2).
- In the Upper Bay, quahogs had been increasing since 1999-2004 (n=1) or 2010-2011 (n=1)
- In Greenwich Bay, quahogs were either declining (n=1) or holding steady in abundance (n=1)
- In some parts of the Middle West Passage, quahogs had been declining since sometime after 2009 (n=1). In Friar’s Cove, however, quahogs were experiencing an increase (n=2).
- In the Lower West Passage and Dutch Harbor, quahogs had been declining since the early 1980s (n=1).

Observations gathered in the NB 2019 painted a more detailed, but on the whole less rosy, picture of quahog abundance. Table 6 to Table 11 break these observations down by region and trend. Figure 6 to Figure 10, beginning on page 37, present visual summaries of these observations.

We can see from these tables and figures that some of the earliest declines in the bay occurred in its southern regions—the Lower West Passage and Dutch Harbor, which according to one quahogger, declined in the 1990s and have not come back (see Table 6 and Figure 7). According to one interviewee, many quahoggers worked in these areas in the 1970s and 1980s. From the lack of descriptions of constant or increasing quahog populations in these areas, we may infer that there are few or no quahoggers working in these areas today.

Table 6. Quahog trends in the Lower West Passage area, NB 2019 project.

Segments: Lower West Passage, Dutch Harbor		
Decline or Downtick	Constant	Increase or Uptick
• Dutch Harbor, since 1990s (n=1) • shoals just south of Jamestown Bridge, since 1990s (n=1) No timeline given: • Lower West Passage in general (n=1) • Dutch Harbor (n=1)		

With the exception of Friar's Cove and a few other small areas, the Middle West Passage and its coves have also experienced a predominantly downward trend in quahog abundance (see Table 7 and Figure 7). Three individuals reported a decline at Pine Hill, traditionally a well-known quahog hotspot. An observed decline at Johnson's Ledge in the 1-2 years preceding the interview was particularly striking in that, according to the interviewee who reported it, quahogs did not simply fail to recruit in this location; they died. As this quahogger explained:

> I went down there a few times, and the stuff that I was bringing up, I was bringing up full baskets, but they were all dead. They were all dead. I told Roger Williams [University]. I called people up. I said, "There's something wrong." Nothing ever came of it. Nothing. The reason I noticed is because this is a very sheltered area on the Northeast, and I loved it. I used to come down here all the time, and it was like when fishing was good elsewhere, I used to save this area. It's mostly big [quahogs]. I can bring you down there right now, and bring up a basket, and you'd go, "Oh my God, this is a great rake!" but they're all dead. They're still in the mud, but dead (QW2-198).

Friar's Cove appears to be a notable exception to the general trend of decline in the Middle West Passage (see Figure 11). Two interviewees commented on an increase in quahogs in Friar's Cove in the SH 2014 interviews, and in the NB 2019 interviews, one of these individuals, as well as a third individual, brought up Friar's Cove, saying that quahog abundance there was holding constant. In fact, one quahogger said that he had one of his best winters ever in Friar's Cove in 2017.

Table 7. Quahog trends in the Middle West Passage area, NB 2019 project.

Segments: Middle West Passage, Quonset Harbor		
Decline or Downtick	Constant	Increase or Uptick
• just north of Jamestown Bridge, since 1990s (n=1) • an area north of Plum Point, since 2004 (n=1) • Pine Hill, since 2004 (n=1) or 2010 (n=1) • Allen's (Quonset) Harbor, since 2016-2017 (n=1) • Johnson's Ledge, since 2017-2018 (n=1) No timeframe given:	• Western Friar's Cove (n=1) • Friar's Cove (n=1) • Northeast coast of Jamestown (n=1)	• Western side of Middle West Passage, since 2017 (n=1) • Western Friar's Cove and Calf Pasture Point (n=1), since 2017

• Pine Hill (n=1) • off Quonset (n=1) • Hope Island (n=1) • Area near the northern edge of Middle West Passage (n=1)		

In the Upper West Passage (see Table 8 and Figure 7), several interviewees reported declines in quahog abundance in former hotspots, including the High Banks and Magic Mountain (note, however, that another interviewee described Magic Mountain as having a relatively constant population; see Figure 9). One interviewee explained that in recent years, shellfishermen worked with the RI Department of Environmental Management (RIDEM) to transplant quahogs out of polluted waters into the High Banks to replenish the area, but "It seemed like we only got back what we put in there (QW1-195)."

Table 8. Quahog trends in the Upper West Passage area, NB 2019 project.

Upper West Passage		
Decline or Downtick	Constant	Increase or Uptick
• High Banks, since early 2000s (n=2) or 2010 (n=1) • parts of Shellfish Management Areas 3W, since 2004 (n=1) • area just south of Patience Island, since 2010 (n=1) • Hunt's Ledge and Middle Ground since 2015 (n=1) • an area north of Pine Hill, since 2016-2017 (n=1) No timeline given: • Upper West Passage in general (n=1) • near southern edge (n=1) • Hunt's Ledge, Middle Ground, and Magic Mountain (n=1)	• Magic Mountain (n=1)	• small area south of Sandy Point (n=1)

Quahog abundance in the Upper East Passage and its adjacent coves and harbors seems to generally be more constant than in the segments discussed above (see Table 9 and Figure 9), according to interview evidence. Potter's Cove and the northeast shoreline of Prudence Island were mentioned several times as good quahogging areas. For instance, one quahogger said that Potter's Cove "has been very good. I don't know why… It closes in May, Memorial Day weekend, and opens Columbus Day weekend. I don't think that's even six months. But, boom! Good again (QE2-229)." This interviewee contrasted the abundance in Potter's Cove with the state of the quahog population in western Bristol Harbor, saying "The wintertime in Bristol Harbor was always a good place. You could always make it a day in the wintertime. But now, I've poked all along the shore, up the cove, along Usher's Cove. I haven't found much (QE2-208)."

Table 9. Quahog trends in the Upper East Passage area, NB 2019 project.

Upper East Passage, Potter's Cove, Bristol Harbor		
Decline or Downtick	Constant	Increase or Uptick
• Western side of Bristol Harbor, since 2013-2014 (n=1)	• Potter's Cove (n=1) • Mount Tom/Homestead (n=2) • Between the entrance to Potter's Cove and Mount Tom (n=2) • Death Valley (between Hog Island and Bristol Point; n=1)	

Greenwich Bay presents a mixed picture (see Table 10, Figure 7, and Figure 9). This in itself is notable, because Greenwich Bay has traditionally been known among quahoggers as a go-to spot. One quahogger estimated that the quahog population in Greenwich Bay is now down to about 10% of what it used to be. For many years, RIDEM has reserved Western Greenwich Bay for wintertime harvest, with the purpose of offering quahoggers a lee in which to work on windy days. One interviewee stated that after RIDEM decided to open up this area for summertime harvest one year, the area never returned to its prior productivity.

Interviewees also mentioned declines in the coves around Greenwich Bay (Apponaug, Greenwich, Warwick, and Mary's Creek), which are only open for transplant relays. For example, one quahogger said:

> When we used to go into the coves to dig, it was like a holiday. You could get a lot. The most I ever did was a hundred bags. Most of the time I could get sixty, eighty, or ninety bags in four hours. The last time we had a transplant, it was in East Greenwich, and I got thirty or thirty-three bags. It was horrible. So, what's happening with the biomass (QW1-197)?

Despite these declining trends, there are small pockets of Greenwich Bay which are reported to be more productive (see Figure 9). For instance, three individuals mentioned that quahogs along the northern edge of Greenwich Bay, in the hard bottom, have been remaining stable. Thus, it seems there may be microhabitats that are able to retain quahog populations longer than others.

Table 10. Quahog trends in the Greenwich Bay area, NB 2019 project.

Greenwich Bay and its coves		
Decline or Downtick	Constant	Increase or Uptick
• Eastern Greenwich Bay in general, since the 1990s (n=1) • Western Greenwich Bay in general, since 2009-2011 (n=2) or 2016-2017 (n=1) • Warwick Cove, since 2010 (n=1) • Apponaug Cove, since 2010 (n=1)	• Northern edge of Western Greenwich Bay (n=3)	No timeline given: • Small area north of Sandy Point (n=1)

• Mary's Creek, since 2016-2017 (n=1) • Greenwich Cove, since 2010 (n=1) No timeline given: • Greenwich Cove (n=1) • Western Greenwich Bay in general (n=2) • Eastern Greenwich Bay in general (n=2)	• Northern edge of Eastern Greenwich Bay (n=1) • Mouth of Greenwich Cove (n=1)	

The Upper Bay and its tributaries stand in contrast to the more southern and middle parts of the bay (see Table 11, Figure 9, and Figure 11). Although interviewees mentioned several areas in this segment that have experienced a decline in quahog abundance, their observations were by and large in the "constant" category, and they even named some areas that experienced upticks in the years just prior to the interview. It is quite clear from the interviews that the best quahogging in Narragansett Bay is now taking place at Barrington Beach and Rocky Point and adjacent areas (the Seminary and Longmeadow). In fact, one interviewee stated that 99% of his quahogging activity is now taking place in these two areas. Interviewees displayed a divergence of views on whether the quahog population on Ohio Ledge is holding steady or declining.

Table 11. Quahog trends in the Upper Bay area, NB 2019 project.

Upper Bay, Warren River		
Decline or Downtick	Constant	Increase or Uptick
• Longmeadow, since 1993 (n=1) • Rumstick Point, since 2003 (n=1) • Colt State Park to Poppasquash, since 2010 (n=1) No timeline given: • Ohio Ledge (n=2) • north end of The Gut between Patience and Prudence Islands (n=1)	• Rocky Point (n = 7) • The Seminary (n= 1) • Barrington Beach (n= 7) • Ohio Ledge (n = 1) • Mouth of the Warren River (n=1)	• edge of shoreline at Barrington Beach, since 2017 (n=1) • small area in Longmeadow, since 2017 (n=1)

Figure 6. Summary figure of changes in the quahog and juvenile quahog (*Mercenaria mercenaria*) populations, according to respondents AE2, QK1, QK2, QK3, QW1, QW2, and QE2. Larger versions of these maps are presented in Figure 7 to Figure 11.

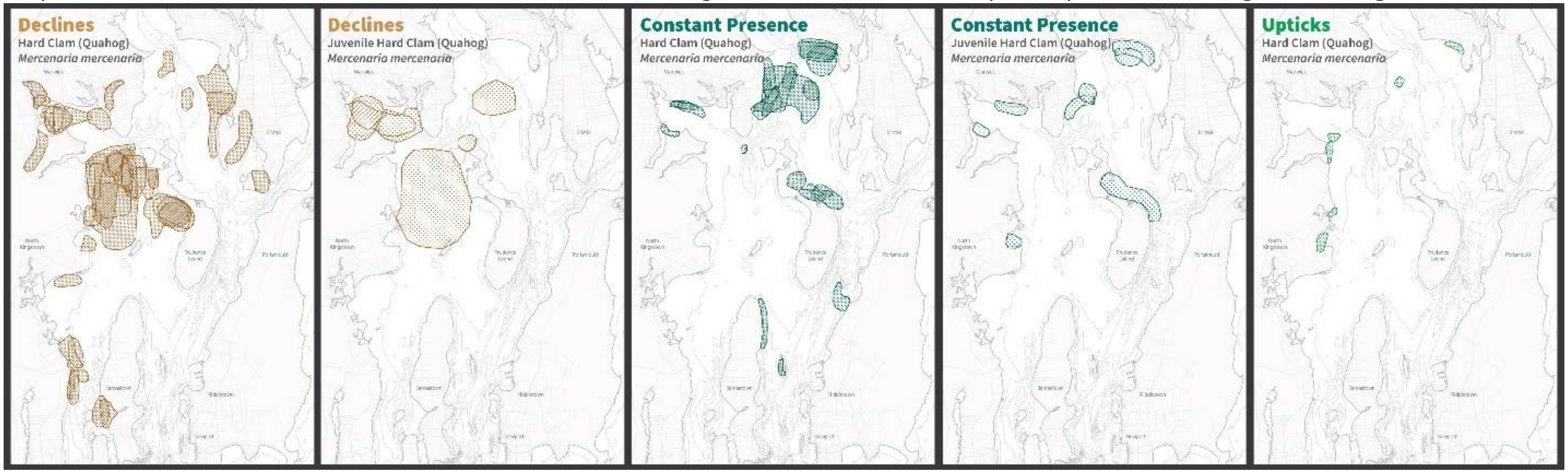


Figure 7. Declines in quahog (*Mercenaria mercenaria*) populations, according to respondents AE2, QK1, QK2, QK3, QW1, QW2, and QE2.

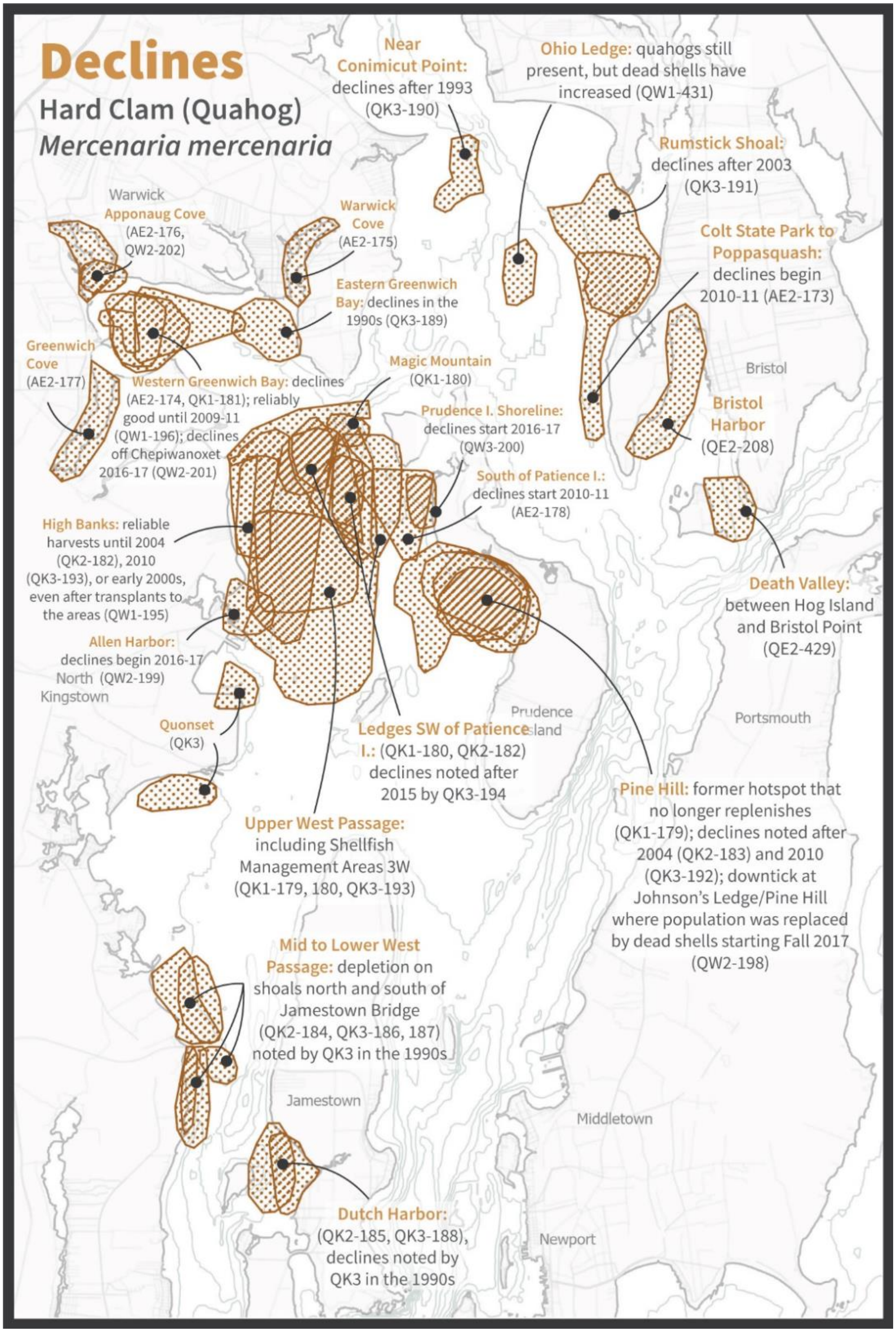


Figure 8. Declines in juvenile recruitment of quahogs (*Mercenaria mercenaria*), according to respondents QW2 and QW3. These are areas that used to experience good recruitment of juvenile (seed) quahogs, but no longer do today.

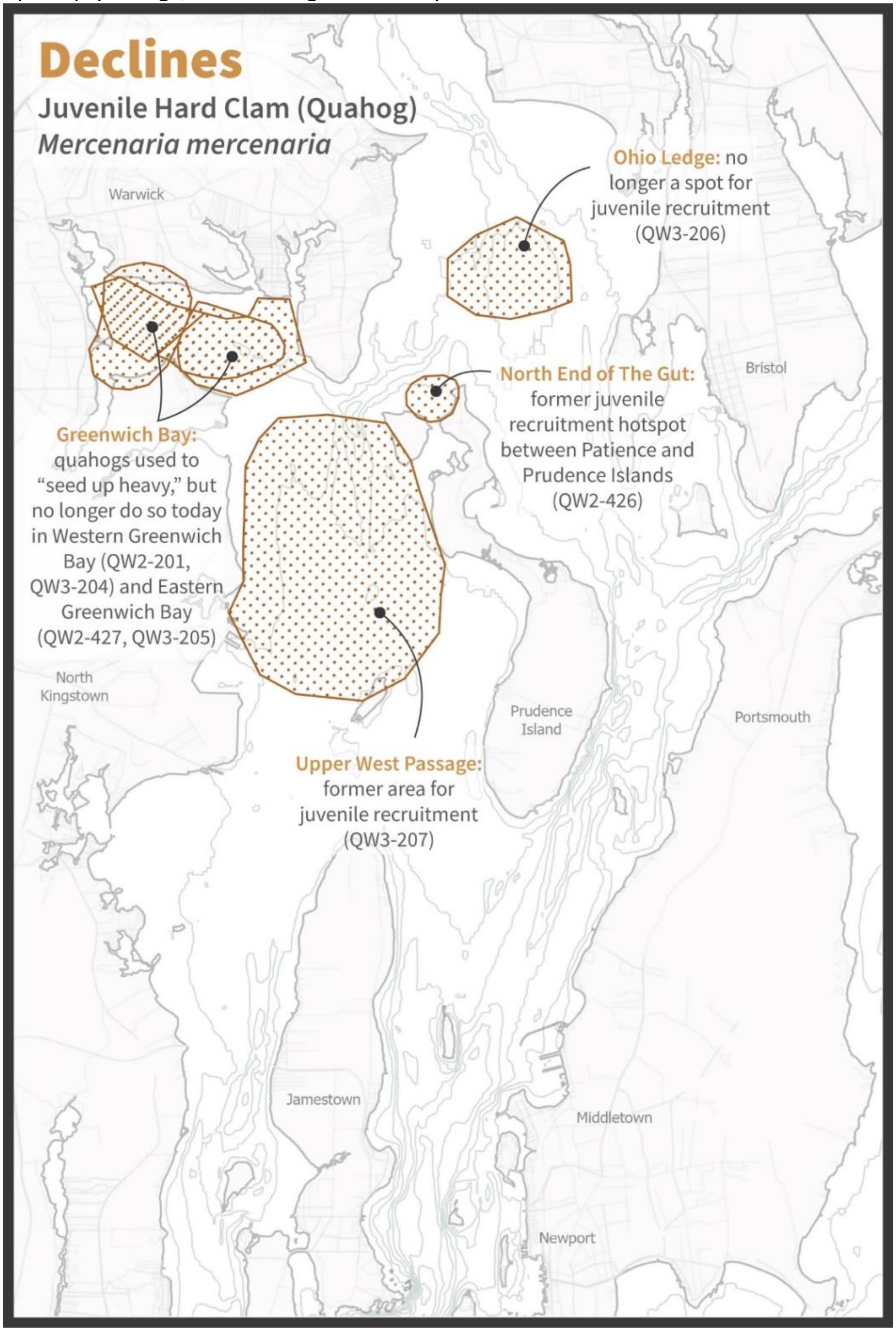


Figure 9. Areas where quahog (*Mercenaria mercenaria*) populations have had a constant presence, according to respondents AE2, QK1, QK2, QK3, QW1, QW2, and QE2. QK2 also mentioned, but did not draw, Friar's Cove (215).

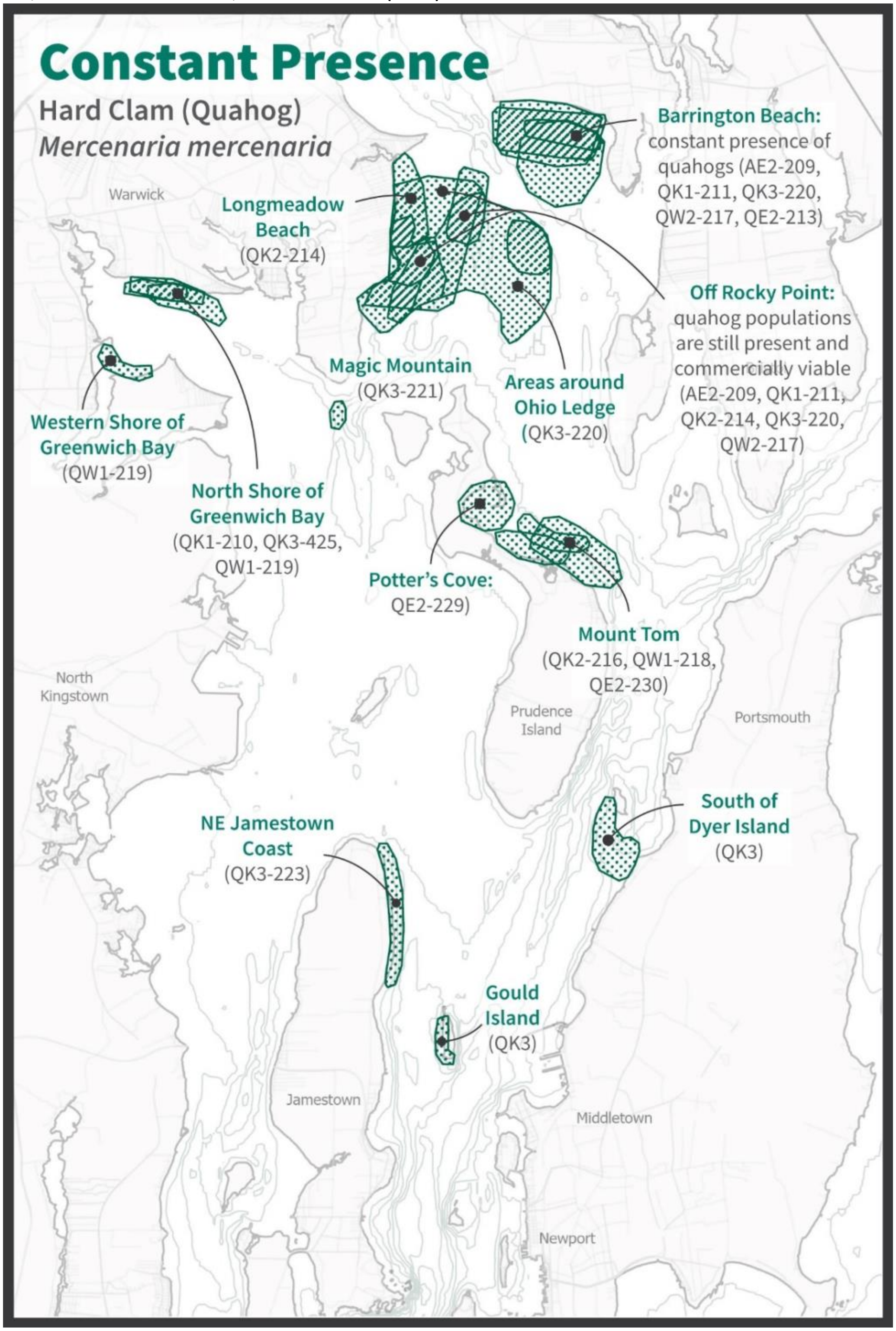


Figure 10. Areas where recruitment of juvenile quahogs (*Mercenaria mercenaria*) has been constant, according to respondents QW2 and QW3.

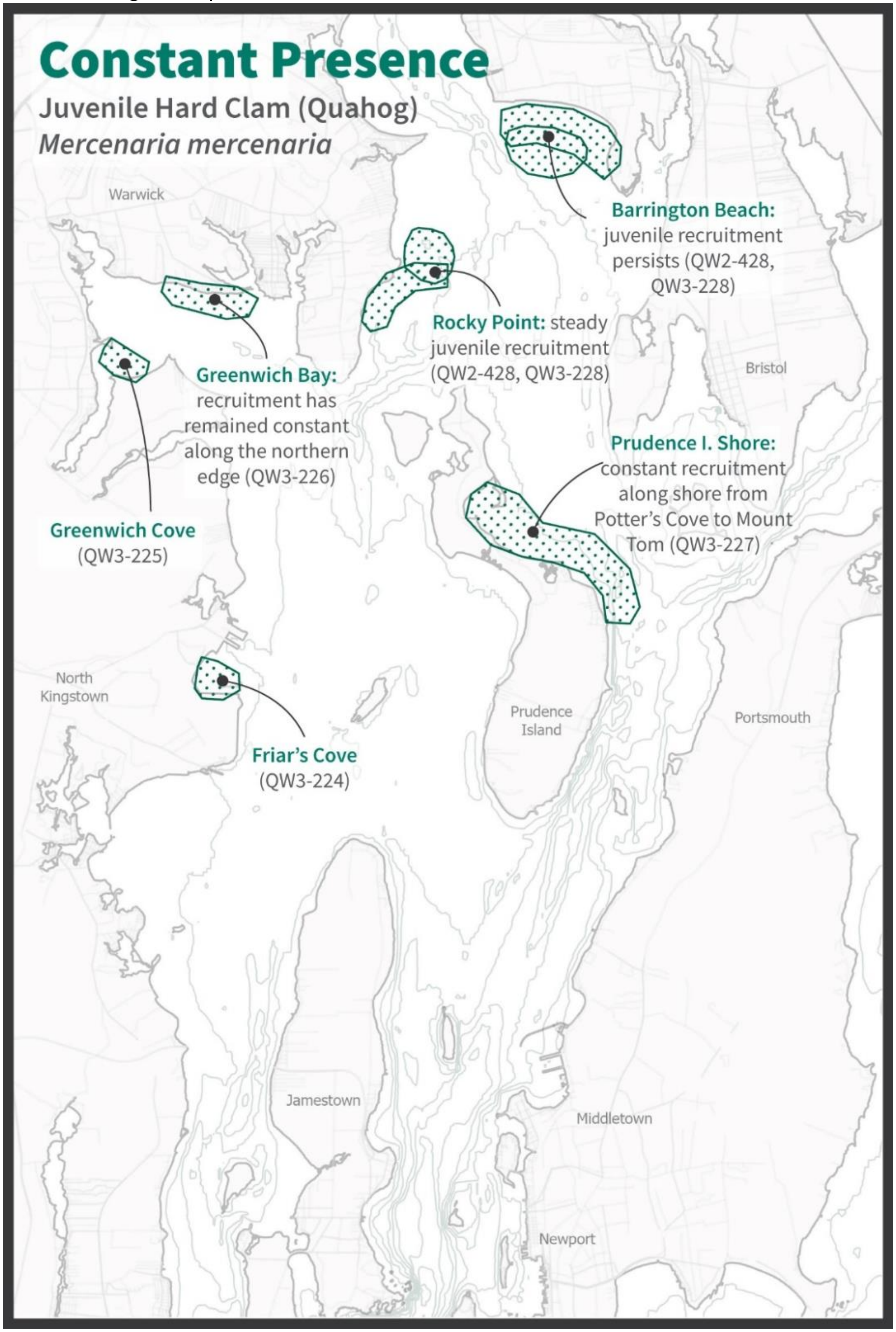
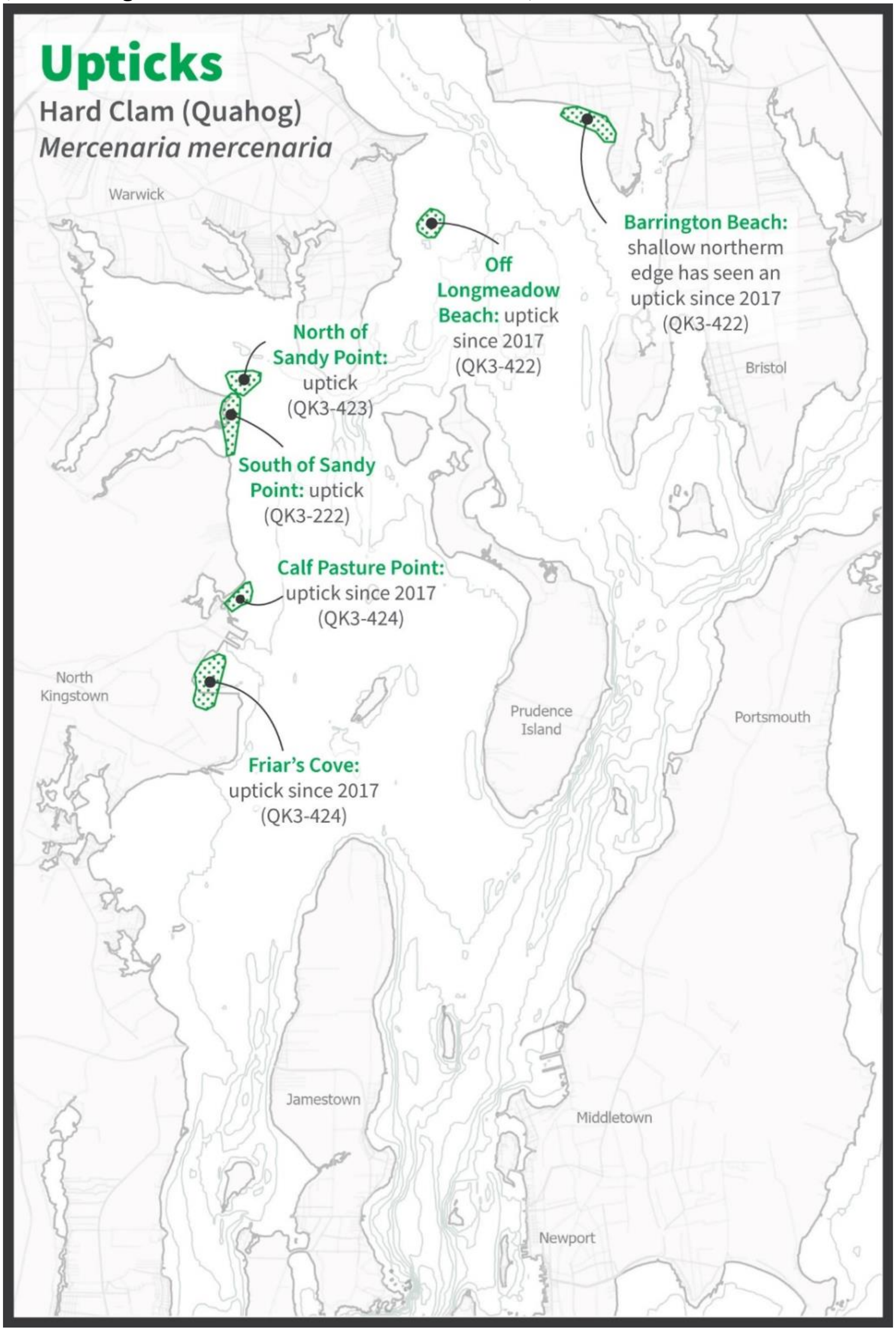


Figure 11. Recent upticks observed in quahog (*Mercenaria mercenaria*) populations, according to respondent QK3. QK3 noted several small nearshore areas that have experienced upticks in quahogs, describing these as “old areas that came back,” at least for a time.



In sum, among the nine quahoggers interviewed for the NB 2019 project, there was universal consensus that quahogs have become far less abundant in many parts of the bay over the last decade or so, and that this is the result of a decline in recruitment of seed quahogs. As one interviewee explained, “What I’ve noticed is traditional areas that I fished in the ‘90s and early 2000s to 2010, now we go there, back to those same spots, and there’s really nothing there. Maybe you’ll find some chowders. But no set of clams (AE2-173, 174, 175, 176, 177, 178).”

Many of today’s quahoggers have several decades of quahogging under their belts, and they have seen ups and downs in the quahog population and harvests previously. Three interviewees in the NB 2019 project expressed a view that quahog populations are cyclical. For instance, one said:

> I’ve been around long enough to know that things are cyclical. I’ve seen it when there were no quahogs. I’ve talked to old-timers who are way older than me, when I was young. They remember having to go to Jamestown because there was nothing. They would have to go to the north end of Jamestown in a skiff with a ten-horse because they needed to make money. There was nothing, nothing. They would come out of Warren. There was nothing. Then I’ve seen quahogs where you put in the rake and [count] “one, two, three, four” and you pick it up and they’re falling out like crazy. Two hundred littlenecks in the rake. And then go back to nothing again (QE1-417).

Five interviewees in the SH 2014 and NB 2019 projects described specific peaks and lows in the quahog harvest that they have witnessed within their careers. The most notable of these booms occurred in the 1980s (n=5) and was linked to locations in the Upper Bay, particularly Barrington Beach (n=3). The bonanza at Barrington Beach in the 1980s was legendary. One quahogger recalled:

> Oh, my word! Barrington Beach! I took my daughter the first day, picking for me. We filled the boat up. We had about 1,500 pounds. It was hard to stop. We went home, went up to Wheatie’s for lunch and dropped my stuff off. She was pooped, so I dropped her off at home, and I went back out and got another 700 pounds. I had over a ton of quahogs that day. I wasn't high man by any means. I think three of four guys sank. All that weight. But it’s never done like that since (QE2-234).

As documented in Schumann (2015), the boom of the 1980s occurred in large part due to water quality closures, which created *de facto* protected areas. The opening of these areas after several years, combined with advancements in outboard motors and the widespread arrival of fiberglass boats, created the perfect conditions for unprecedentedly high quahog harvests. Improvements in quahogging technology also played a role, as one interviewee explained:

> There were millions of pounds of quahogs all stretched through these areas that we didn't harvest, because you couldn't make any money harvesting it. But we were able to start fishing out there, because of the better equipment, and also simultaneously we had a good set of small ones that mixed in with them. You could make money on the small ones and the big ones. That biomass of larger and mixed clams that were out in

> those deeper areas got harvested. We took a huge percentage of the total biomass of the West Bay out in ten years (QK3).

Following those boom years, interviewees stated that the population collapsed in the 1990s (n=3). One interviewee believes that this collapse was the result of overfishing on the quahog resource that occurred because so many new people flocked to quahogging during the 1980s. According to this interviewee, many quahoggers exited the industry in the 1990s as their catches dried up, facilitating a recalibration of fleet size to the available resource.

Two interviewees described a second boom that occurred in the mid-2000s. One interviewee linked this mini-boom to the menhaden die-off that occurred in Greenwich Bay in 2003. "The best fishing I've seen was after the pogy [menhaden] kill," he recalled. "Two years after that, we had a super [quahog] set that came in (QW2-237)." Through informal conversations with other quahoggers in the past, we have heard a theory that the hypoxia that caused the menhaden die-off also caused the death of quahog predators such as starfish. Quahogs themselves, which are able to withstand hypoxic conditions by hunkering down in the mud and closing their feeding siphons, are thought to have survived the event to live relatively free of predation for a time.

Despite widespread agreement among interviewees that the quahog population is naturally cyclical, two interviewees expressed a feeling that the downturn they are witnessing today is qualitatively different from downward trends of the past. For instance, one interviewee stated that the collapse of the 1990s was driven by overfishing, but with far fewer quahoggers working on the bay now than in the 1980s, the current downturn must be driven by something else. This quahogger provided additional evidence that something odd is happening in the bay by referencing the presence of dead shells mixed in with live quahogs in certain locations. "They're not laying on top," he said. "You bring the basket up and they look beautiful. They're still black with the white. They look gorgeous. But the more you shake them, it's a basket of dead shells. What happened (QW2)?"

In addition to changes in abundance, three interviewees also observed that quahog shells had become more brittle in certain parts of the bay. One interviewee stated that shells were at their most brittle about ten years before the interview, while another stated that shells continued to be quite brittle at the time of the interview. Both mentioned the Upper Bay as an area with a high concentration of brittle shells. A third interviewee explained that quahog shells seemed to be more brittle in areas where quahogs are more crowded or where they don't get as much nutrition.

Lastly, one interviewee shared an observation about changes in quahog spawning behavior:

> A few years ago, I found that during the spawning season, I didn't feel that they were producing the amount of spat that they used to. I brought this up with one of the Sea Grant things and they kind of looked at me like I was out of my mind. Typically, in the summer, years ago, if you put water in a pail, the top of the pail would get slimy white. I

> mean, you could almost not even see the quahogs in the pail. I'm going to go out on a limb, but I'm going to say conservatively, the last five years, the water's as clean as you just poured it in the bucket. They don't seem to be producing the spat (QW2).

Interviewees put forth several hypotheses as to why a downturn in quahog populations may be occurring, even in the absence of strong fishing pressure. Several interviewees mentioned an increase in the population of deckers (*Crepidula fornicata*), which we will discuss in greater detail below.

One interviewee focused on the presence of a new seaweed. "I don't even know how to describe it," he said. "It's like scum. It sticks to the rake. It makes it real hard to work. I kind of gave up on it (QE2)." According to this interview, this seaweed has inundated Bristol Harbor and appears to be tied to a decrease in the abundance of quahogs there. "It seems like it smothers the quahogs. But maybe it's just that something else got the quahogs, and that's what's left. It just seems like the bottom is no good (QE2-208)." In contrast, he added, areas that are free of this slime, such as Potter's Cove, still experience reliable yearly sets of quahogs (QE2-229).

Another interviewee focused on a temporal link between the decline of quahogs and a "chlorine smell" that sometimes permeates the atmosphere in Narragansett Bay. Describing this smell, he said:

> It's new. It's maybe two or three years old. And it seemed to me—and again, I'm not a scientist—but I'm just telling you, when the quahogs stopped spawning, I started smelling it. Right hand of God. Not just me, it's everybody. There's a decrease in the littlenecks. We got that stink. It's not septic either. It's like bleach, like chlorine. I don't know. I know we're trying to make the bay really clean. But on the other side, these are organisms, these little animals, they grow up on stuff that's not so clean (QW2).

The presence of this "chlorine smell" will be discussed in greater detail in the section on abiotic factors below.

Bay scallops (*Argopecten irradians*). Nine quahoggers and aquaculture farmers discussed bay scallops in the NB 2019 and SH 2014 projects. Five interviewees stated that bay scallops are cyclical in nature. Six individuals provided descriptions of historical scallop booms that took place in the Upper Bay in the Middle East Passage and in several small embayments around the bay. These historical booms are listed below in chronological order (n=1 for each):

- Rocky Point (Upper Bay; 1930s)
- across from Common Fence Point (Mount Hope Bay; mid-20th century)
- Nannakuaket Pond (mid-20th century)
- Potter's Cove (mid-20th century)
- Spectacle Cove in The Cove (mid-20th century)
- Potter's Cove (1980s)
- Aquaculture lease in the Middle East Passage (2008)
- Scofield Ledge (off Rumstick Point in the Upper Bay; 2014)

- Aquaculture lease in the Middle East Passage (2014-2015)

According to interviewees, many of the mid-20th century scallop booms were remarkable in their abundance, and supported intermittent but vibrant commercial and recreational fisheries. For instance, a quahogger recalled:

> Potter's Cove was plastered with scallops. There was everything from little dories with ten-horse outboards on them, Manchester's boats were in there, there were some pleasure boats, cabin cruisers, 25-, 40-footers. Everybody was hauling a dredge. It looked like a circus out there. I don't remember how many days it lasted (QE2).

More recent booms seem to have been shorter in duration and smaller in volume. For instance, a quahogger said:

> Right here, at the end of my street, we had scallops show up for the first time since I've been fishing. We had a ton of them in the summer. When you catch them in your bull rake when you're bullraking for quahogs, that means there are a lot there. I'd get maybe 20 a day. That's enough where you could tow a dredge through there and get a limit. But they pretty much died out. I haven't seen any down there in months, not since the end of the summer (QW3).

Interviewees also provided evidence for several upticks in localized scallop populations in the years just prior to the NB 2019 interviews. In general, they seemed to view these upticks as chance blips, rather than harbingers of a pending boom.

- Middle West Passage (2018-2019; n=2)
- Upper Bay (2018-2019)
- Off Jamestown (not sure which side; 2018-2019)

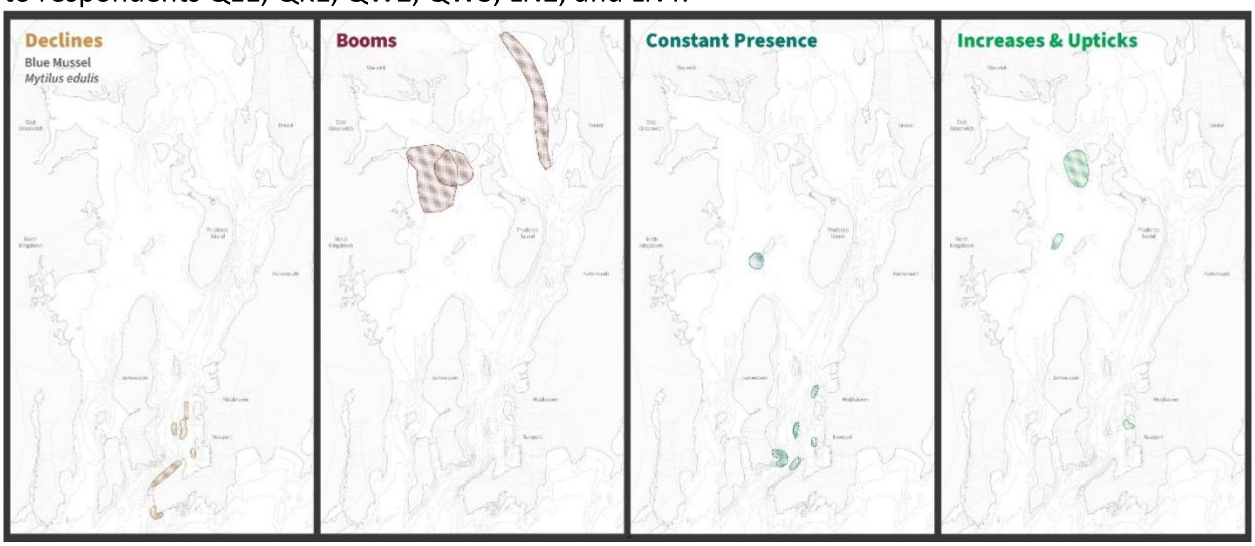
Mussels (*Mytilus edulis*). Nine interviewees mentioned trends in the mussel population of Narragansett Bay. They included fishermen whose primary gear types were lobster traps, quahog bullrakes, and oyster aquaculture farms, illustrating that mussels interact with a number of different fisheries. Six of these interviewees stated that mussel populations tend to be cyclical over time. Three recalled historical booms and busts (see Figure 14), including a collapse (no segment specified) in the 1960s; a boom in the Upper West Passage in the 1990s; a boom on the eastern side of the Upper Bay and in the Upper West Passage in 2004; and a boom (no segment specified) in 2009.

Interview-based evidence on the present-day status of mussels is mixed. The most detailed interview data comes from the Lower East Passage and its embayments (see Table 12, Figure 13, and Figure 15). Observations were less detailed for other geographical segments of the bay. An aquaculture grower stated that mussels had increased at the site of his farm in the Middle East Passage, a quahogger stated that mussels had increased in the Upper West Passage, and another quahogger stated that mussels have increased at The Hump in the Middle West Passage (see Figure 16). All of these changes occurred within a year or two prior to the 2019 interview.

Table 12. Mussel trends in the Lower East Passage area, NB 2019 project.

Lower East Passage, Newport Harbor		
Decline or Downtick (all n=1)	Constant (all n=1)	Increase or Uptick (all n=1)
• Brenton Point (since the 1980s) • the southwest corner of Goat Island (since the 1980s) • Long Wharf (since 2016); No timeline given: • along the west side of the Naval War College • along the edge of the shoals near Rose Island • from Fort Adams to Castle Hill	• House on the Rocks • Fort Adams • the west side of Rose Island in the shoals • Coddington Point • the northwest corner of Goat Island	• along the south side of the Naval War College (since 2015)

Figure 12. Summary figure of changes in the blue mussel (*Mytilus edilus*) population according to respondents QE1, QK1, QW2, QW3, LN2, and LN4.



In addition to commenting on mussel population trends, interviewees highlighted perceived ecological relationships between mussels and several other species. For instance, a lobsterman provided evidence of an inverse relationship between cycles of abundance of mussels and their starfish predators:

> The starfish and the mussels are opposite… It was like a five- or six-year cycle: one year of mussels; the next year there'd be mussels and a couple stars; the third year there'd be less mussels and a few stars. Starting the fourth year, there's be primarily starfish, because they'd wipe out ninety percent of the mussels. Then the fifth year or the sixth year, they would start the whole cycle all over again, where the mussels would get a toehold (LN4).

Figure 13. Areas of decline observed in the blue mussel (*Mytilus edulis*) population, according to respondents LN2 and LN4.

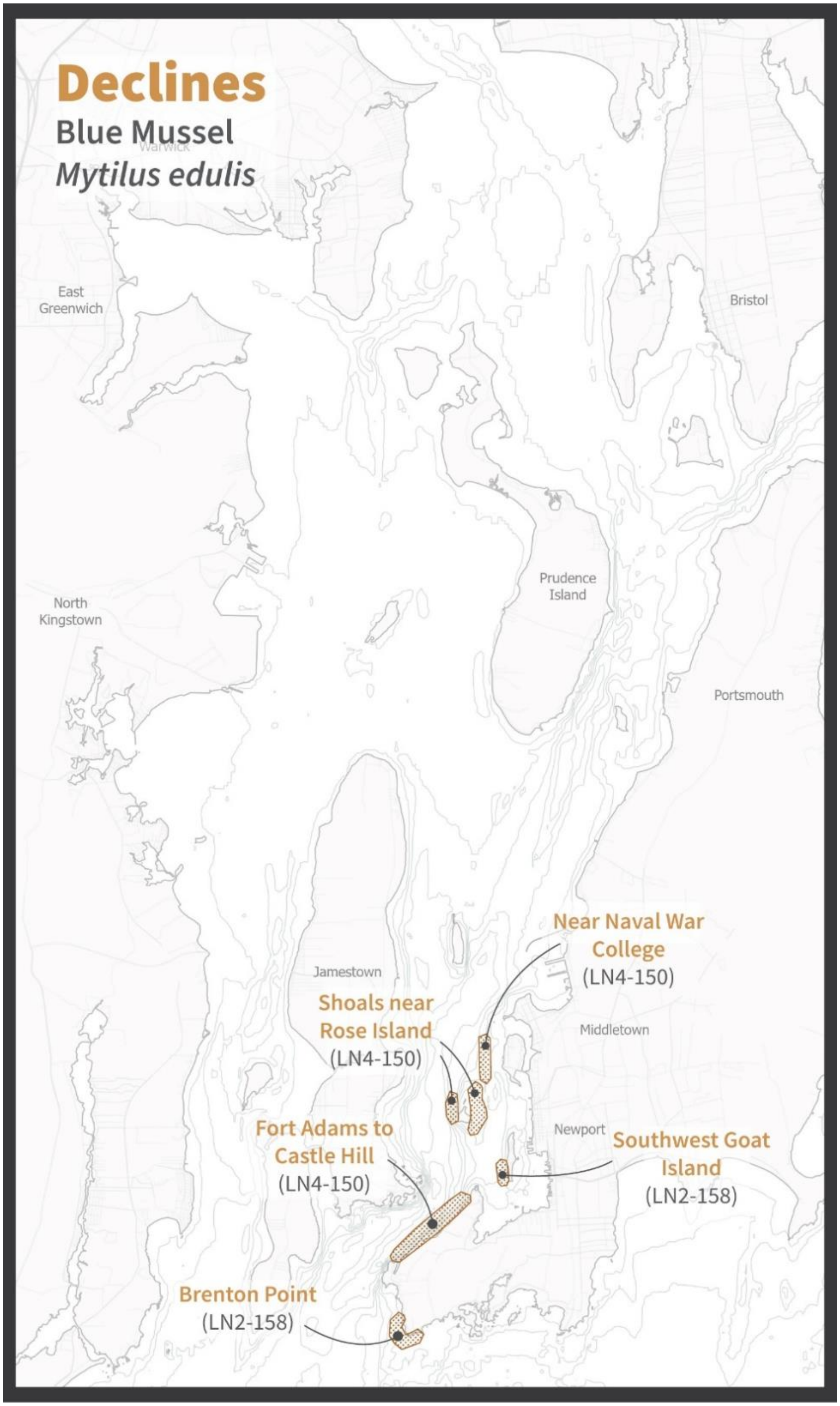


Figure 14. Historical booms of blue mussel (*Mytilus edulis*) sets, according to respondents QE1 and QW3.

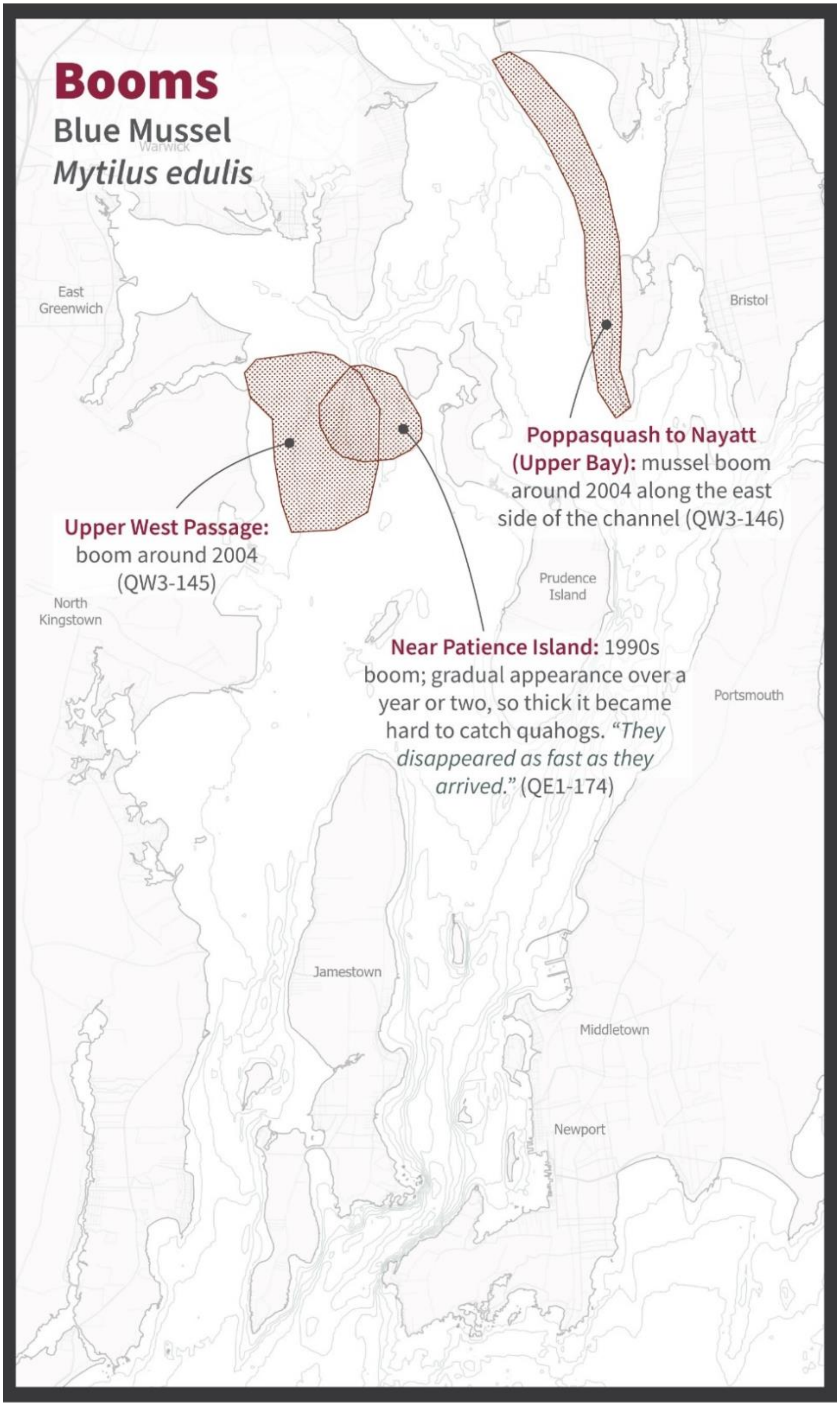


Figure 15. Areas where mussels (*Mytilus edulis*) have historically been present and remain present today, according to respondents QK1 and LN2.

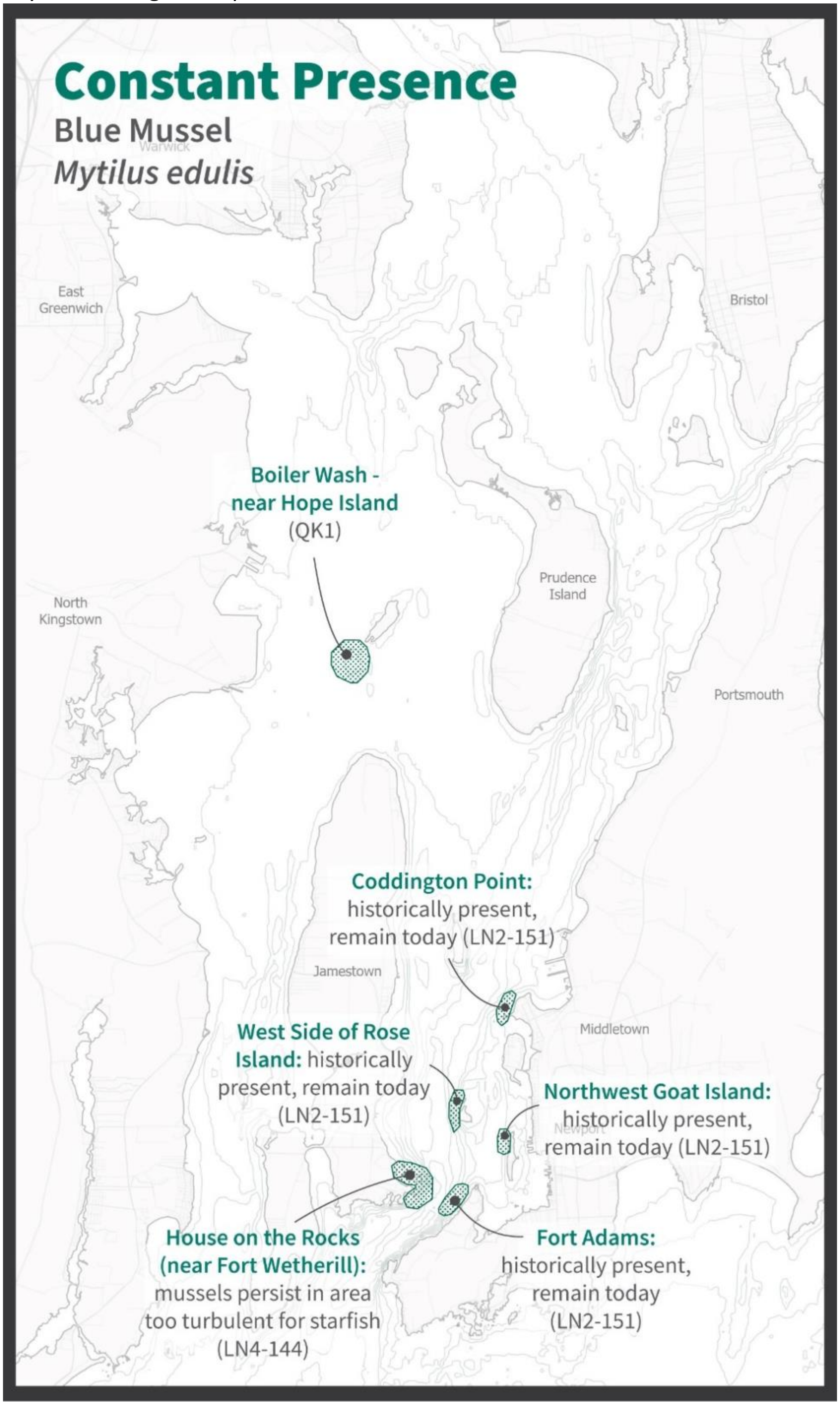
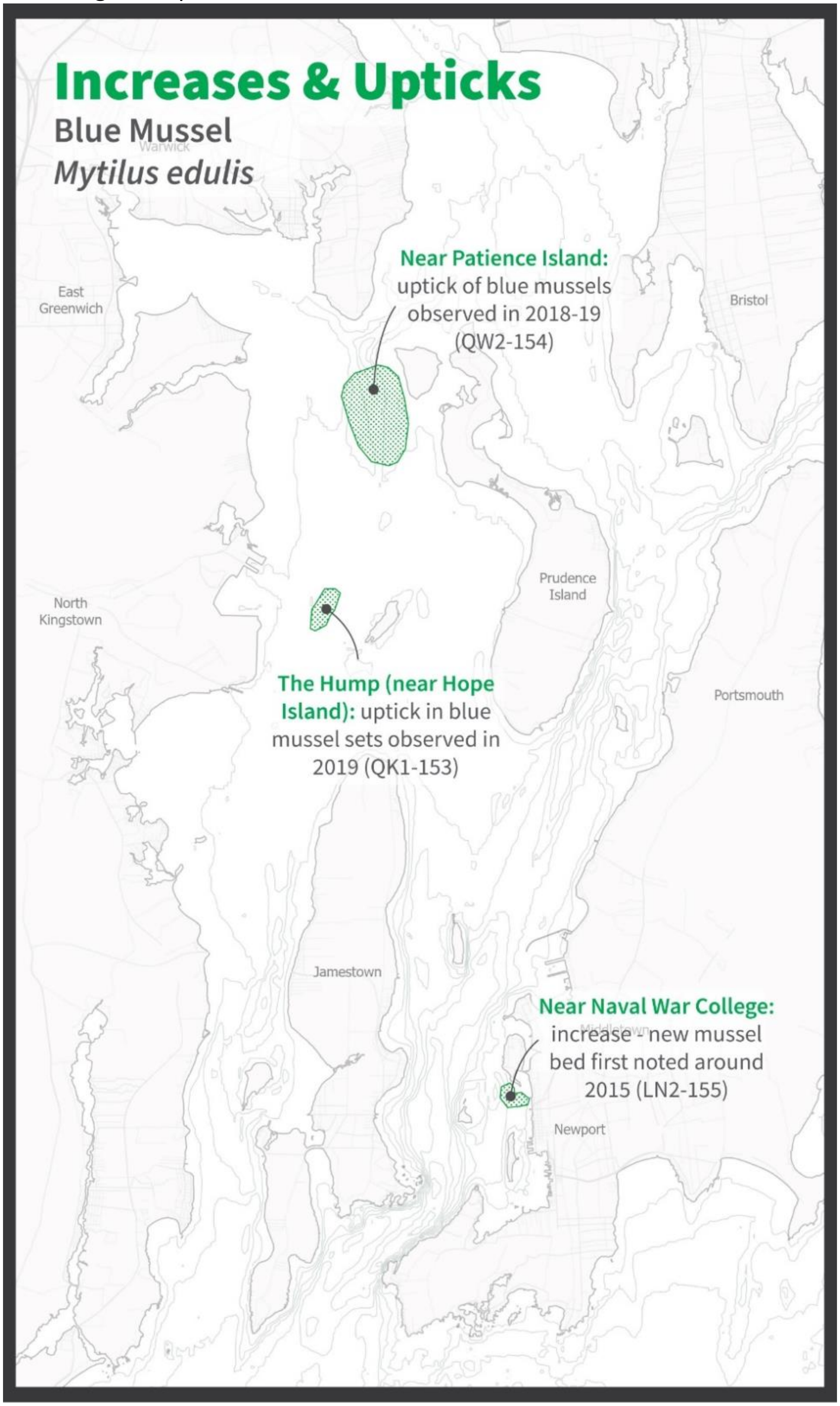


Figure 16. Areas where an increase or uptick of blue mussel (*Mytilus edulis*) sets have been observed, according to respondents QK1, QW2, and LN2.



However, this lobsterman remarked, mussel populations have stopped cycling in recent years, likely as a result of the disappearance of starfish in Narragansett Bay. This lobsterman also stated that in locations that are too turbulent for starfish, such as the House on the Rocks (Lower East Passage), mussel populations are more permanent than cyclical (see Figure 15).

Other interview-based evidence suggests that predation is not the only cause for cyclical mass mortality in mussels. A quahogger whose father was known as the "mussel king" of Narragansett Bay in the 1940s and 1950s explained that mussel beds often die off of their own accord:

> They set so thick, and once they start dying, they contaminate themselves. Because once they start dying, you could have been getting twenty bushels to a dredge, but the next week you'd fill it up and it would be all shells, and the belly would be hanging off of them. It's Mother Nature that makes them come and go. When conditions are wrong, they're going to die, and that's that (QK5).

A scallop fisherman who dabbled in mussel dredging in the mid-2000s stated that the mussel populations in the south end of the bay died off at one point after a storm that dumped silt on the beds (DP1). In sum, it seems that a variety of top-down and environmental factors may be responsible for shaping trends in mussel populations in Narragansett Bay.

Interview evidence suggests that mussel die-offs can play a role in facilitating localized growth in quahog populations. A quahogger explained, "You'd get a massive set of mussels and they'd smother in their own excrement... When those mussels smothered and died, the shells broke down a bit and we'd get a phenomenal set of necks (QW3)." This quahogger concurred with the lobsterman in the previous cited previously in this section, saying, "But we haven't had any sets of mussels like that [in a while] (QW3)."

Oysters (*Crassostrea virginica*). Eight interviewees discussed oysters in the NB 2019 and SH 2014 projects. Two interviewees stated that oyster populations are cyclical, and eight described a bay-wide oyster boom that took place around the turn of the millennium. The timeline of this boom varied by interviewee, ranging from the late 1980s to the mid-2000s, with most descriptions concentrated in the late 1990s. No observations were made about the present-day status of oysters, suggesting that there is not much of an oyster population to talk about, outside of aquaculture farms and restoration sites.

The boom that took place around the turn of the millennium was widespread, with interviews providing evidence for its occurrence in many tributaries and coves, such as the Barrington River (n=1), Warren River (n=2), Kickemuit River (n=1), Mill Gut (n=2), Nannakuaket Pond (n=1), Greene's River (n=1), and Wickford Harbor (n=2), as well as open-water areas such as Ohio Ledge (n=1), Rumstick Point (n=1), Hog Island (n=1), and in the Middle West Passage near Davisvile (n=1).

Many quahoggers shared fond memories of this oyster boom. It was typical at the time for quahoggers to go out and catch their daily limit of quahogs in the morning, and then go out again and catch a daily limit of oysters (three bushels). Comments like the following illustrate the magnitude of this boom and the shellfishing bonanza that it precipitated:

> There were so many oysters. The more mature ones were in the water, the ones that got exposed at low tide were smaller because they didn't get fed as much. I saw a guy drive his truck down to the water, right over all the small oysters. They got the idea that, "This is never going away. This is always going to be here." … It was literally paved with oysters. They were driving on them! There were so many (QE1).

Other comments, like this one from an individual who has been shellfishing since the late 1950s, highlight the unprecedented nature of this boom:

> When I first started doing this, you didn't see many. Just great big ones that had been there for 100 years. Once in a while you'd get two or three. That was about it… Then, all of a sudden! I don't think anybody knows why they came back. Oh man, was that fun! The limit, you could get three bushels a day (QE2).

Four interviewees concurred that after that famous oyster boom subsided, wild oysters have been essentially absent from the bay. Two individuals voiced an opinion that the bay no longer contains suitable oyster habitat. For instance, a quahogger who helps organize the RI Shellfishermen's Association oyster restoration project said:

> The Shellfish Association keeps putting oysters out, trying to help them grow, and we get spots that they sustain, but they don't mass-produce. If you put oysters in a certain area and they have what they need, they explode. But we're not seeing it. I planted them, so I go back and check them. You might find one here, a couple there. But where I'm putting them, I'm putting them in notoriously famous oystering beds, and they're not coming back…. I'm putting them where the booms were…. I know, because I planted them, and they're not there…. I'm not going to say they're dying; they're just not doing anything (QW2).

<u>Deckers (*Crepidula fornicata*).</u> Five interviewees discussed the abundance of deckers. Two stated that deckers are cyclical in abundance. A comparison between SH 2014 and NB 2019 interview data suggests that an inflection point in this cycle may have been reached during the time laps between these two projects. We base this hypothesis on a 2014 interviewee comment that deckers were declining at Barrington Beach and two 2019 comments that deckers were increasing at this location, as well as many other spots in the <u>Upper Bay</u>, Upper and <u>Middle West Passage</u>, and <u>Eastern Greenwich Bay</u> (see Figure 17).

Deckers and quahogs share the same muddy bottom habitats, with quahogs buried in the sediment and deckers lying on top. In the SH 2014 project, one interviewee posited that deckers are beneficial to quahog populations, as long as their numbers are moderate: "Quahogs do well in decker shells, because they can breath through the layer of shells and they protect them. Unless they're too thick; if you get two feet of decker shells on top of the quahogs, forget it (QW4)." Another said, "If deckers are there, starfish eat them. They don't dig for quahogs. But if deckers aren't there, they'll dig (QK2)."

By the time of the NB 2019 project, interview evidence suggests that a tipping point may have been reached at which deckers were no longer helpful to quahogs, and may in fact have become deleterious. For instance, one quahogger said, “They seem to be so thick that I just don't think it's easy for quahogs to even set in a lot of places (QK2).” Another said, “They’ve started to fill in places that seemed to be heavily fished, and all of a sudden you’d go back and it was just full of those decker shells (QW2).”

Additionally, interviewees suggested that today’s super-abundance of deckers has a negative impact on the fishery itself, by making it difficult for quahoggers to access quahogs:

> To be honest, it’s put guys out of work, because there are certain guys who just cannot get through them. They just can’t get underneath them. There are some guys, like myself, who we get around them. But there are some guys who just cannot get underneath them, so they’ve left the business. There were guys who were telling me, “I can’t go to work, because it’s blowing too hard and I can’t get underneath the deckers. The deckers! The deckers (QW2)!”

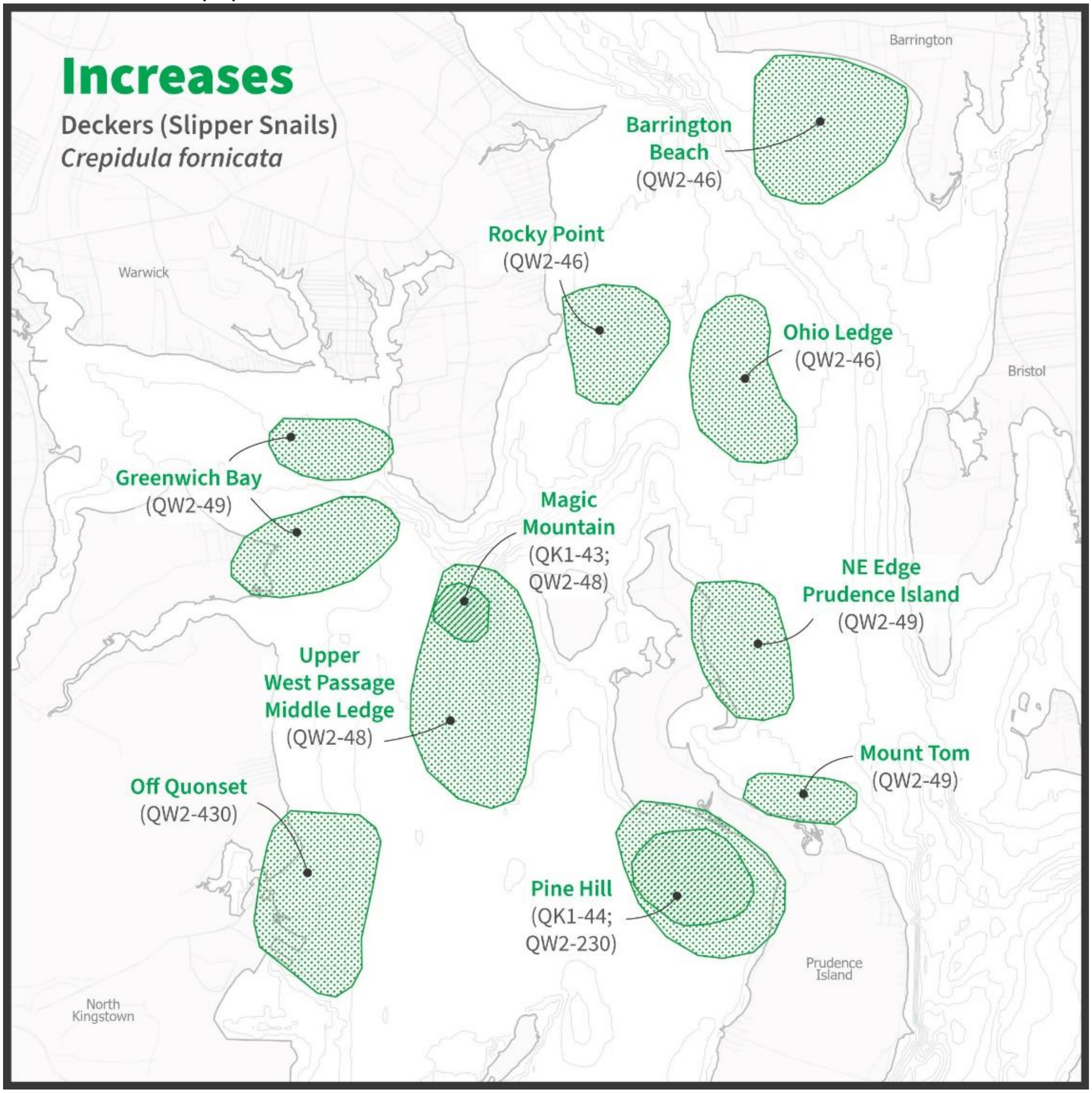
Quahogs and deckers are filter feeders, so why might one species do poorly while another seems to thrive? One interviewee, who bullrakes for quahogs and sets traps for conchs, proposed an explanation related to a decline in predation by starfish (many interviewees commented on a near-total disappearance of starfish from the bay, described in the next section). This individual explained:

> To me, that kind of happened at the same time that the starfish went away. [Deckers] have always been around. What used to happen is they would kind of die off or they'd get eaten. There were so many starfish. I mean, there was a time when you could put your pots in a place where there were too many starfish, and you could barely pull your pot up overnight. It'd be like, instead of your pot weighing 30 or 40 pounds, it would weigh close to 100, because the thing would be completely covered in starfish. It really kind of coincided. Then all of a sudden, the starfish all died. What used to happen a lot is that places would get covered up with deckers or mussels. Then they would die off or get eaten, and it would be really good [for quahogs]. But it was like a much shorter time, like a year or two (QK2).

The predator-prey cycle that this interviewee describes seems to have been halted by the steep and prolonged decline in starfish, enabling deckers to dominate the bottom in a way they previously could not. We will discuss additional trophic implications of the starfish collapse in the next section.

Soft shell clams (*Mya arenaria*). Five individuals discussed soft shell clams in the NB 2019 and SH 2014 interviews. The overall picture that emerges from these interviews is of a species that is highly variable in its abundance and spatial distribution, but that may have also been experiencing a downward trend in the frequency and/or magnitude of its upcycles over the last several decades. This decline, however, had one importance exception: a historically important boom that took place at Conimicut Point and Longmeadow in the Upper Bay. The timeline of this boom was linked by several respondents to years lying between 2000 and 2009.

Figure 17. Increases in decker (*Crepidula fornicata*) populations, according to respondents QK1 and QW2. Neither individual specified the timeframe during which they observed these increased decker populations.



Encapsulating the overall dynamics of soft shell clams, an individual who has been shellfishing since 1959 said:

> You'd dig some clams, steamer clams. There was a lot of them then. In the late '50s, you could catch 15 or 30 bushel a day. As far back as I can remember, there were steamers around. There were people catching steamers. That kind of tapered off a lot through the 1960s and 1970s (QW4-369). You couldn't catch as many. Just about 5 years ago (i.e. around 2009), there was a good set. But it's gone now (QW4-369).

The soft shell clam boom at Conimicut was legendary for shellfishermen, and it drew many new people into the industry for a time. One quahogger described it this way:

> It was unbelievably great… The spat was like a carpet. Thick. It was like you had to part it so you could get at the adults. And of course, you didn't want to hurt the babies. That happened for two or three years, where we got carpets of them. I was like, "Holy smokes. This is going to be enough for forever." …All of a sudden, the water got warm… All of a sudden, their necks are hanging out in the water. Kind of stressed out or something. We dug a whole pile of them, and I just wanted to sell them as fast as I could. They don't have a good shelf life as it is. We had two or three days of that, and then it rained and we weren't up there for a week or ten days. We get up there, and all the shells are empty. They had died and emptied out. I kept thinking, did some chemicals come down and go over that sand bar (QW1-281)?

Mobile Benthic Invertebrates

Lobsters (*Homarus americanus*). Lobsters were the second most often mentioned species in the NB 2019 project, likely due to the fact that lobstermen were the second largest group represented in our sample of fishermen. As was the case with quahoggers, lobstermen provided numerous observations related to their target species. In total, six lobstermen produced 24 observational statements related to lobsters. The picture that emerges from these 24 observational statements is one in which lobsters declined from a bay-wide peak in the 1990s to a career low in the mid-2010s, with the decline beginning in the Upper Bay and working its way in fits and starts to the Mouth of Narragansett Bay. However, some hotspots in the lower bay remained well populated, and several lobstermen mentioned an uptick in the year or two preceding the interview (i.e., 2017-2018). These patterns are depicted in Figure 18 to Figure 22.

Three lobstermen described a stepwise decline in lobsters that began in the Upper Bay around the early 2000s and worked its way southward over the course of the intervening years (see Figure 19). One lobsterman said, "It just progressively, year after year, got worse as we went down the bay. That was strange. It definitely came from the north and worked its way south (LN3-85; LN-86)." Another said, "Every year for the last ten, the fall has been progressively worse (LN4)." A West Passage lobsterman described a persistent decline from the 1990s to today, punctuated by two blips of abundance in 2004-2008 and 2012-2013 (see Figure 20). However, he believes that the latter blip was made up of lobsters originating from a different stock than the stock usually found in the bay.

Within Newport Harbor and the Lower and Middle East Passage, interviewees provided spatial data on lobster abundance at a finer spatial scale than elsewhere, and this data highlights pockets of habitat where lobsters continue to persist in spite of a broader decline (see Figure 21). According to three lobstermen, locations that still contain a harvestable abundance of lobsters in these segments include: the old mussel farm near Melville; the area around Gould

Island; an area west of Rose Island; the Navy break wall; a few deep holes in the channel between Prudence and Aquidneck Islands; the southwest coast of Newport from the Newport Bridge to Castle Hill; and the coast of Jamestown from Kettle Bottom to Taylor Point. Two lobstermen reported an uptick in lobster populations in 2018-2019 along the coastline from the Newport Bridge to Castle Hill and the area around Rose Island.

In contrast, locations in these segments where lobsters have declined (see Figure 19) include: a small area west of Goat Island where the cruise ship anchorage is located (declined sometime pre-2012); a large area between Gould Island, Prudence Island, Jamestown, and Aquidneck Islands (declining since 2012-2013); Newport Harbor (declining since 2012-2013); and the coastline between the Naval Base and the Naval War College and along the west of Goat Island (declining since 2010-2014).

In addition to changes in the lobster population, several interviewees in the NB 2019 and RF 2016 projects mentioned changes in lobster phenology, saying that the lobster harvest season now begins later than it used to (e.g., June instead of April) and that the peak of the fall run now occurs in late December, a time when the season used to be wrapping up.

Additionally, several interviewees commented on a perception that lobster predators now outnumber lobsters by many orders of magnitude, giving the lobster population little chance of bouncing back. These predators include black sea bass (n=3) and scup (n=1).

Starfish (*Asterias forbesi*). Starfish were one of the most frequently discussed organisms in the NB 2019 interviews, observed by fifteen individuals. Twelve respondents, representing all four primary gear types, concurred that starfish have experienced a dramatic decline in Narragansett Bay. Dates for this decline ranged from the late 2000s to 2014, with most converging around a 2011-2013 timeframe. Based on the variety of bay segments mentioned by interviewees, this decline seems to be bay-wide.

Figure 18. Summary figure of changes in the lobster (*Homarus americanus*) population according to respondents LN2, LN3, LN4, LN5, LK1.

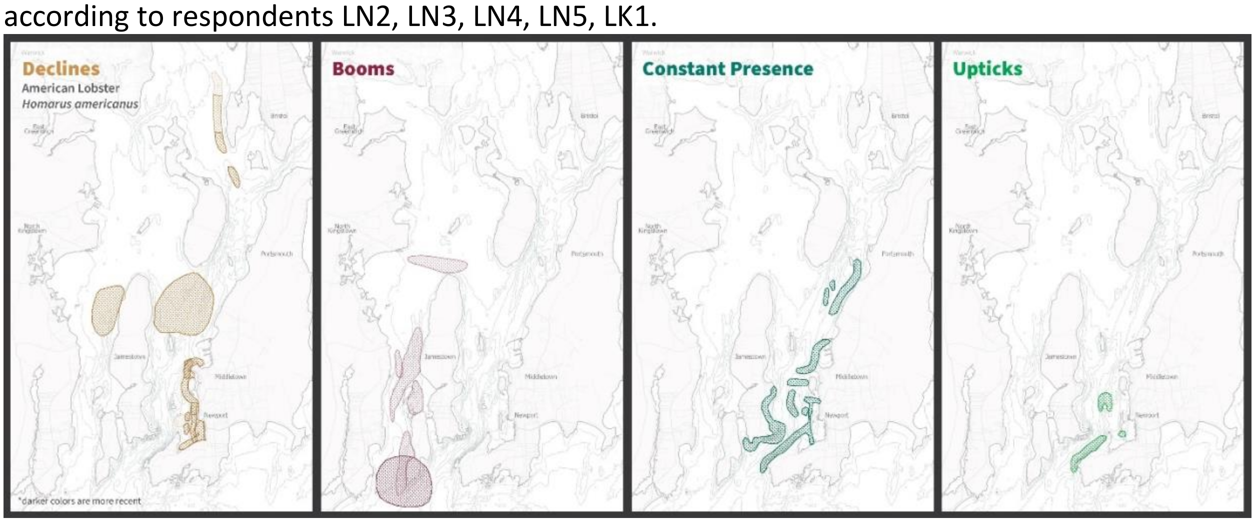


Figure 19. Declines in the lobster (*Homarus americanus*) population, according to respondents LN2, LN3, LN4, and LK1.

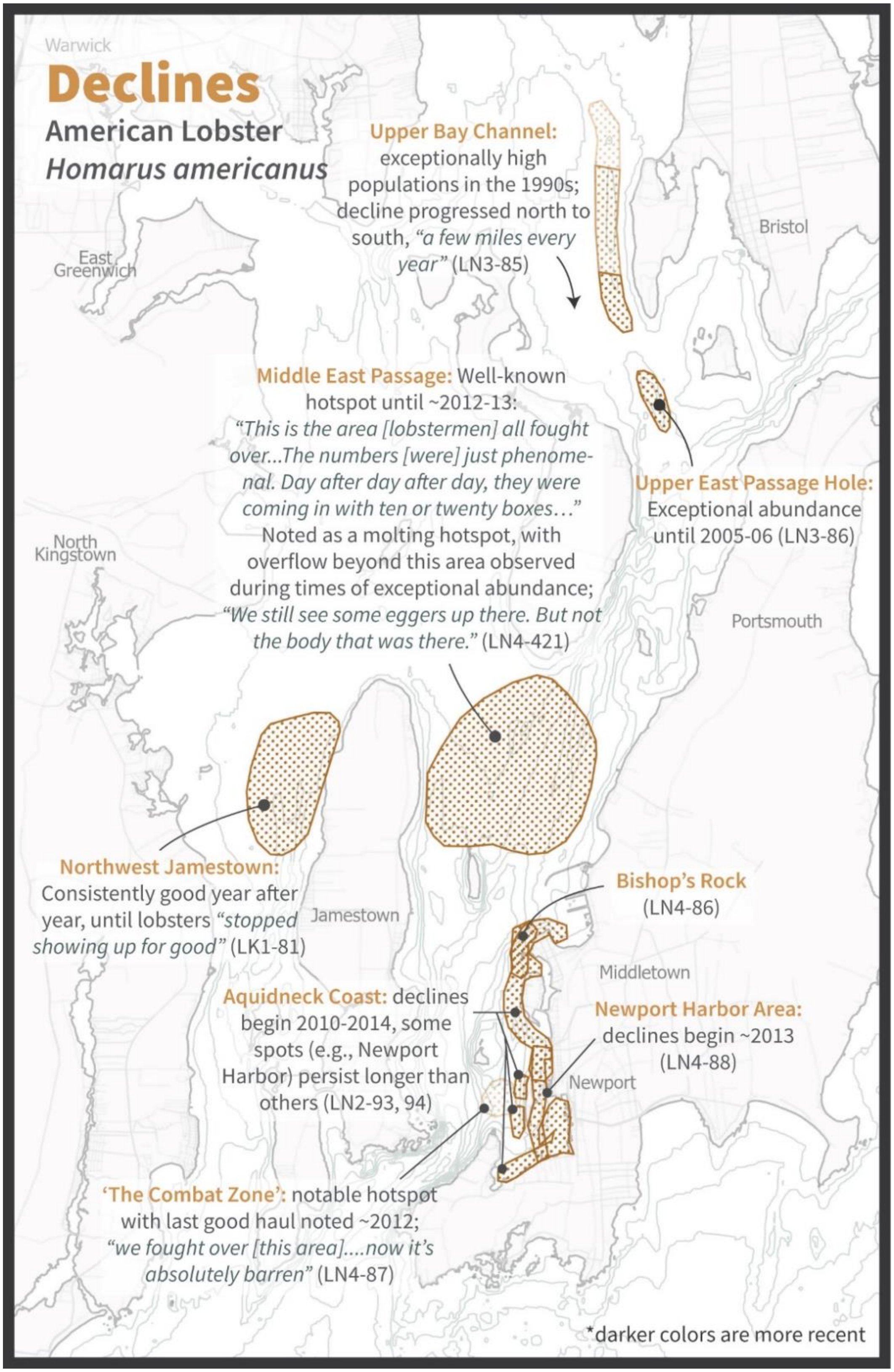


Figure 20. Short-lived lobster booms reported by respondent LK1 in the Middle West Passage and Lower West Passage over the last two decades

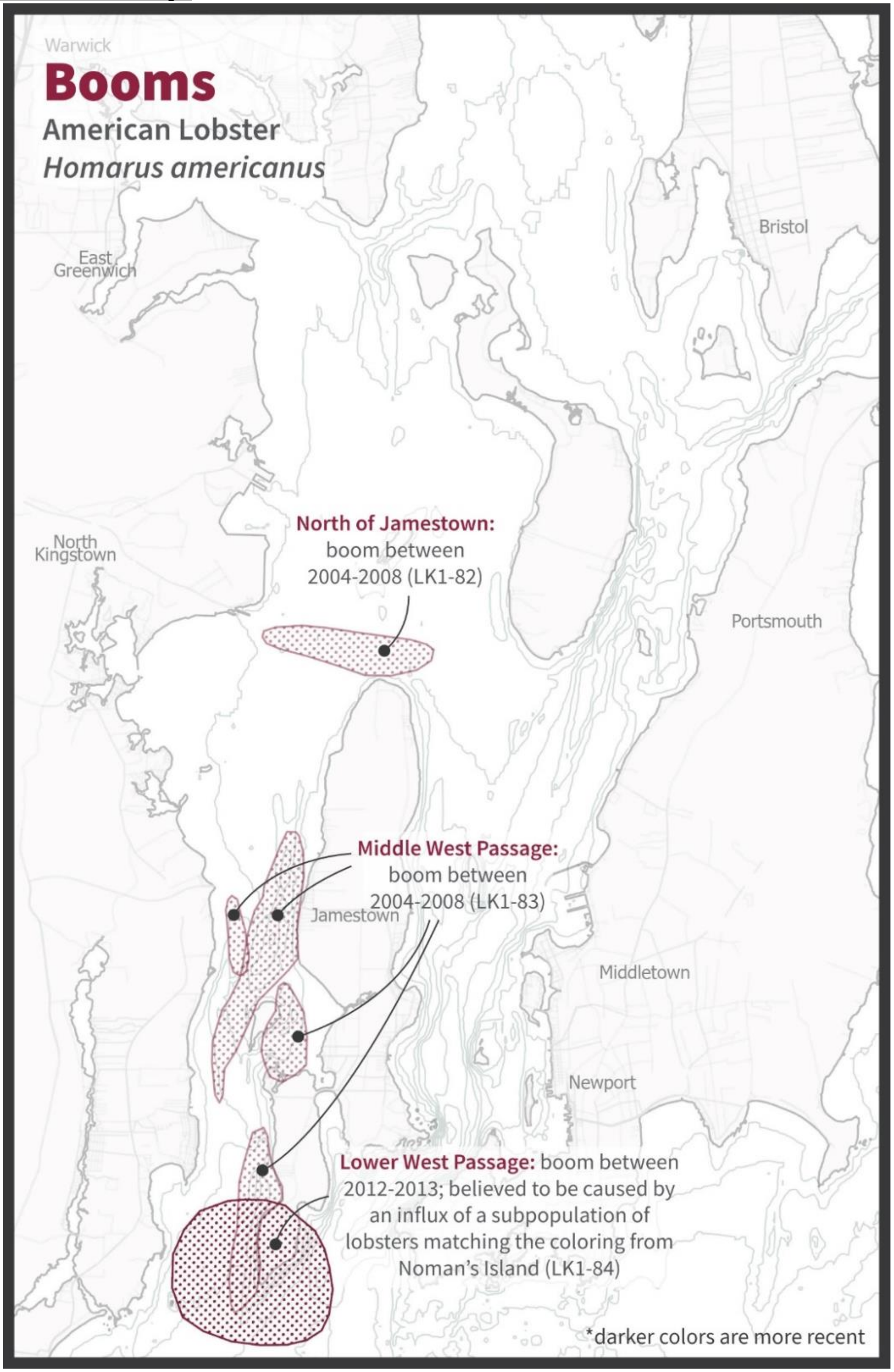


Figure 21. Areas of constant presence for lobsters, reported by respondent LN-4. In some of these areas, LN4 indicated populations are not as abundant as they used to be.

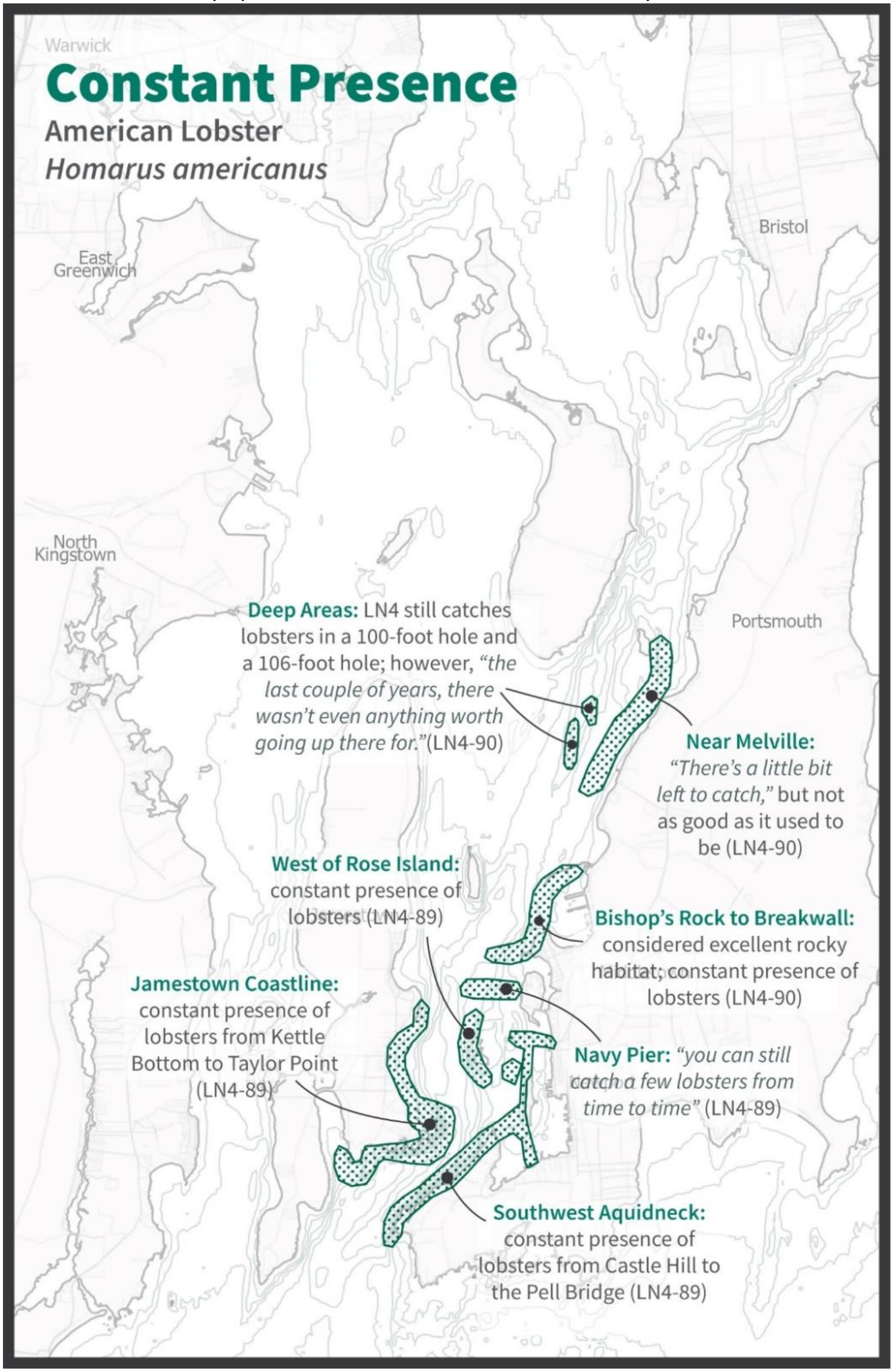
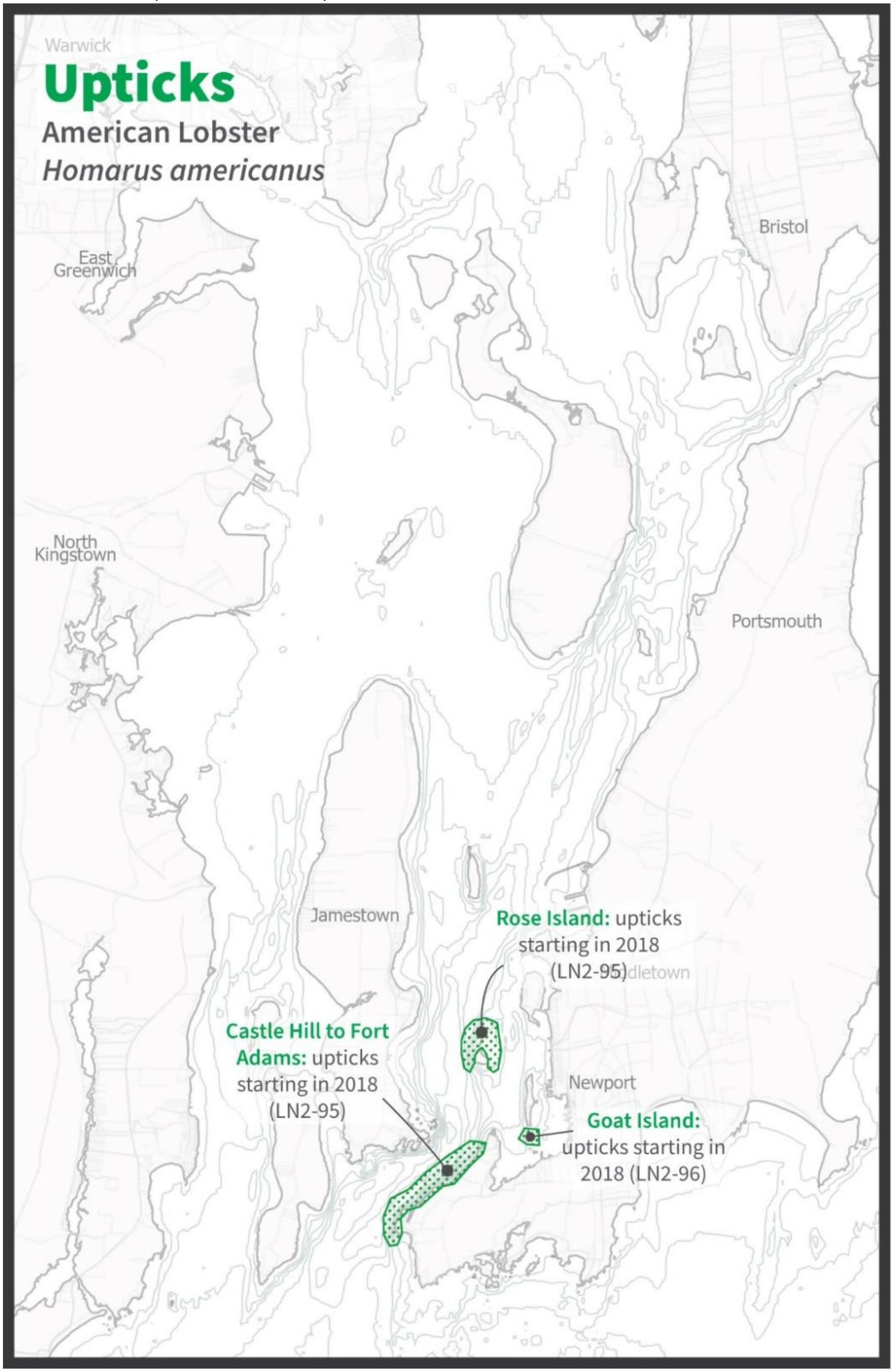


Figure 22. Recent upticks in lobster abundance, reported by respondent LN2, starting a year before the interview (i.e., since 2018).



It also seems that this decline in starfish was sudden and drastic. For example, one oyster farmer reported:

> They've been non-existent. I'll give you an example from back when I started – 2007, 2008, those years. We'd plant our [oyster] seed right on this dock, and we put it out into the bay. It's usually about June when we plant them. I don't know how the starfish must have smelled that seed, but they knew. They didn't bother the regular oysters, but I counted 85 starfish in a cage [of seed oysters]. They would stick their stomachs through the mesh and get the oysters. They didn't have to be in. They just would sit on top of the bags. I pulled 85 [starfish] and stopped counting. It was probably over 100 on one cage. They were all big ones. There were that many starfish around. Then something happened, and they couldn't reproduce anymore. They kind of disappeared, and they almost went extinct. Last year (i.e., 2018), I probably counted about a half dozen (AE2-295).

Three individuals shared a view that starfish populations have always been cyclical. However, one individual stated that previous cycles may have been related to fishermen intentionally removing starfish as a form of predator control. Another individual stated that he has seen starfish cycles in the past, but does not believe the current decline is part of a recurring cycle.

Interviewees mentioned negative associations between starfish abundance and other species, positing that starfish exert predatory control over sessile shellfish such as of quahogs, mussels, and deckers, and competitive control over other mobile benthic predators such as whelks, moon snails, and spider crabs. In addition, a lobsterman stated that the decline in starfish coincided with the disappearance of sea grapes, barnacles, and hydroids, which he placed around 2013-2014 (LN-5). Another lobsterman described a positive relationship between starfish and urchins, which are found together in the same habitats (LN-4). He stated that both species have declined, but the urchins started to decline first (around 2007-2009), while the starfish started to decline later (around 2011).

<u>Blue crabs (*Callinectes sapidus*).</u> Six individuals in the NB 2019 and RF 2016 projects mentioned blue crabs. By and large, their observations suggest that blue crab populations have been cyclical or variable in Narragansett Bay. Two individuals mentioned specific times when this cycle has peaked: 2010 and 2017. One interviewee shared a perception that the overall abundance of blue crabs has declined since he started fishing in the 1970s, while another shared a perception that the overall abundance of blue crabs has increased since he started fishing in 1998. It was not clear whether these latter two individuals view these trends as superimposed on an underlying cyclical pattern or as linear trends.

Since blue crabs are a bycatch species rather than a target species for commercial fishermen, it seems plausible that these individuals' views are defined by recollections of particularly memorable highs and lows, rather than by a sustained year-to-year focus on species abundance. An example of a memorable cycle peak was recounted by a quahogger:

> Two years ago (i.e., around 2017), there were blue crabs, millions of them, at Barrington. Greenwich was loaded, and even out at Rocky Point in the mud. Loaded with blue crabs… I mean millions of them. You'd see them all on top of the water. And then they were gone. Something got at them or they didn't have enough to eat… They were little. They were young ones. A couple of jumbos too. We were actually going to start potting them and getting them going. And then it just went away. It went almost as fast as it came. It was almost like massive, and then gone. Two years they lasted, and then no more (Western Greenwich Bay, Upper Bay; QW2-35, QW2-36).

Horseshoe crabs (*Limulus polyphemus*). Three individuals mentioned horseshoe crabs, and all three characterized the abundance of this species as declining. "I've seen an immense decline in horseshoe crabs," said one quahogger. Based on timelines provided by two individuals, it appears that horseshoe crabs were high in abundance in the 1980s ("thick as fleas," said a trawl fisherman), but they began to decline by the late 2000s. This decline seems to have been consistent across several areas of former abundance: Greenwich Bay, Upper Bay, Mount Hope Bay, and Upper West Passage.

Spider crabs (*Libinia emarginata*). Five individuals mentioned spider crabs. Their observations varied widely, with two describing a declining trend in abundance (no timeline given), one describing a constant abundance, one describing spider crab populations as cyclical, and one describing observations of increasing spider crab abundance (no timeline given) in three locations: Barren Ledge and the deeper ledge near the shipping channel (Upper Bay) and Warwick Cove.

Urchins (*Arbacia punctulata*). Although only two individuals mentioned urchins, their observations were consistent with one another. Both were lobstermen who work in Newport Harbor and the Lower East Passage, and both perceived a decline in urchins beginning in 2007-2009. One of these lobstermen also perceived a small uptick in urchins in 2018-2019. It is notable that this timeframe coincides with an uptick in kelp abundance described by two other lobstermen, taking place in the same areas where this lobsterman observed an uptick in urchins.

Green crabs (*Carcinus maenas*). Although only two individuals mentioned green crabs, their observations were consistent with one another. One was a lobsterman who reported a decline in green crabs in locations where they were previously plentiful in the Lower East Passage and Newport Harbor (since 2014-2015), and one was a quahogger who reported a decline in green crabs in Wickford Harbor.

Whelks: Channeled and Knobbed (*Busycotypus canaliculatus, Busycon carica*). Two individuals mentioned whelks. One stated that whelks exhibited cyclical population trends and were currently undergoing a downtick, while another stated that whelk populations had remained fairly constant.

Fouling Invertebrates

Barnacles (Cirripedia: Thoracica). Barnacles were mentioned in the NB 2019 and RF 2016 projects by five individuals. Two individuals shared a perception that barnacle spat continues to settle on surfaces in the bay every winter around February, but that mature barnacles have become scarce in recent years. Comments on the decline of mature barnacles were focused on the Lower East Passage and Newport Harbor. As was the case with much of our data, there was little consistency across individuals in terms of the temporal dimension of these observations: one individual said that the decline in barnacles occurred around 1999, while another recalled it happening in 2014:

> No barnacles grew on our traps from the Newport Bridge north, starting in 2014… The traps out front towards the ocean and the mouth of the bay still had a full set of barnacles on them. Full growth of adult barnacles. From the Newport Bridge north, not one barnacle grew on the traps, starting that year (LN5-8).

Findings from the NB 2019 interviews echo comments made by two interviewees in the RF 2016 project, who said, "Barnacles are not living, period. They're not even growing (LN5)." To provide their point, these individuals displayed a photograph of a lobster trap that had been in Narragansett Bay for an entire year and did not have a single barnacle or other organism growing on it.

Tunicates: sea grapes (*Molgula manhattensis*), sea squirts (*Styela clava*), and *Didemnum spp.* Observations of tunicates in the NB 2019 and RF 2016 projects were centered in the Middle East Passage, Lower East Passage (north of Newport Bridge), and Newport Harbor. Three individuals mentioned sea grapes, and all three described a decline. Two individuals reported a decline in sea squirts in Newport Harbor, but one mentioned an increase in sea squirts around Rose Island. One individual mentioned a decline in *Didemnum spp*. in Newport Harbor and Goat Island (Lower East Passage) but added that *Didemnum spp*. had begun appearing at Rose Island (Lower East Passage) during the year before the interview (2018).

In some cases, these events were not independent of one another. According to one lobsterman, sea grapes and sea squirts declined simultaneously in Newport Harbor around 2007-2009. According to a second lobsterman, sea squirts and *Didemnum spp*. both disappeared from Newport Harbor and Goat Island (Lower East Passage) around 2013-2014. A third lobsterman stated that the decline of sea grapes coincided with a disappearance of starfish, barnacles, and hydroids in the Lower and Middle East Passage in 2013-2014. This individual contrasted this observation with accounts of stable sea grape populations south of the Newport Bridge and at the Mouth of Narragansett Bay.

Seaweed/Macroalgae

Rockweeds (Order Fucales). Five individuals in the NB 2019 and RF 2016 projects mentioned rockweed, and all five agreed that the predominant trend facing these species is one of decline. According to interviews, this decline has been widespread, occurring in equal measure across former hotspots in Bristol Harbor, the Kickemuit River, the Upper Bay, the Warren River, the Middle East Passage, and the Lower East Passage (see Figure 24). The only area mentioned by respondents as *not* experiencing a decline in rockweed was the Mouth of Narragansett Bay, where two respondents asserted that rockweed populations continue to thrive (see Figure 25). In fact, one lobsterman drew a sharp contrast between the decline of rockweed north of the Newport Bridge and the relative stability in rockweed populations south of the bridge:

> There's no rockweed growing in the basin around Fort Wetherhill, where they tie up the John H. Chafee, the research vessel. But yet, when you go right around the corner, to the first cove going to the west of Fort Wetherhill—we call it Skindiver Cove and East Skindiver Cove—there's two of them, east and west, [there are] multiple layers of rockweed growing on the shore there… You go around the corner to the open ocean, where you get away from the bay, and it's prevalent… The rockweed also, on Ocean Drive and Beavertail Point is prevalent. There's tons of it growing there. If you go from the bridge going up, there's no more rockweed growing (LN5).

Interview data does not pinpoint a precise time at which rockweed began to decline in these locations, but does suggest years when it was more abundant. One respondent recalled rockweed being present in abundance dating back to the 1960s, another to the 1970s, and another commented on its abundance in the 1990s. At least four interviewees once harvested rockweed commercially for clambakes during its years of peak abundance.

In contrast to this general declining trend, however, two lobstermen noticed an uptick in rockweed populations in some areas during the year preceding the 2019 NB interview (i.e, 2017-2018; see Figure 26). Interestingly, this is the same time period that two lobstermen mentioned an uptick in kelp populations, an abnormally wet winter, and a phytoplankton bloom documented by the University of Rhode Island.

One interviewee stated that *Fucus spp.* has taken over locations formerly occupied by *Ascophyllum nodosum*, such as the east side of Bristol Harbor (TE1-133), and around Seal Rock in Mount Hope Bay (TE1-134).

Sea lettuce (*Ulva spp.).* Five individuals mentioned sea lettuce in the NB 2019 project. Reports in the Lower East Passage were mixed, but in the northern parts of the bay, reports coalesced around an uptick in the abundance of sea lettuce in the year or two preceding the interview (i.e., 2018-2019). According to three quahoggers, these upticks have taken place in in Greenwich Cove (n=1) and several Upper Bay locations: Barrington Beach (n=2), Longmeadow (n=1), and The Gut between Prudence and Patience Islands (n=1). The sea lettuce bloom at

Barrington Beach was apparently so bad that quahoggers would joke, “I’m going to go fight the lettuce today (QW1),” as they set out for work.

Kelp (*Saccharina latissima*). Four individuals in the NB 2019 and RF 2016 projects mentioned kelp, and all described a major decline in the abundance of this species. Observations related to kelp were concentrated in the Lower East Passage (see Figure 27). The timeline ascribed to this decline varied across respondents. One individual said that this decline began as early as 1995, but three others pinpointed it as taking place since the early 2000s to 2011.

The astounding abundance of kelp in the 1990s was evident in several interviewee comments. For example, one lobsterman said that he “hauled up pots that would come up bigger than the table and chairs,” and another said, “there’d be balls of kelp the size of pick-up trucks on every trap in the channel.” In contrast, a lobsterman interviewed for the RF 2016 project stated that, at the time of that interview, “You can’t even find a strand of kelp.”

However, between the time of the RF 2016 interviews and the NB 2019 interviews, two interviewees detected a small uptick in kelp abundance in certain parts of the Lower East Passage (see Figure 27). “We actually saw more this year than I’ve seen in decades,” explained a lobsterman. “There was a change that took place this year.” This interviewee noted that the year in question experienced high precipitation levels over the winter, which also resulted in a phytoplankton bloom documented by the University of Rhode Island.

Interviewees also made note of other temporal correlations in abundance between kelp and other species. One lobsterman stated that peak kelp abundance coincided historically with peak lobster abundance, in the 1990s. Another noted a co-occurrence of the decline in kelp and a decline in starfish and urchins.

Figure 23. Summary figure of changes in rockweed (*Ascophyllum nodosum*) according to respondents LN2, LN3, LN5, and TE1.

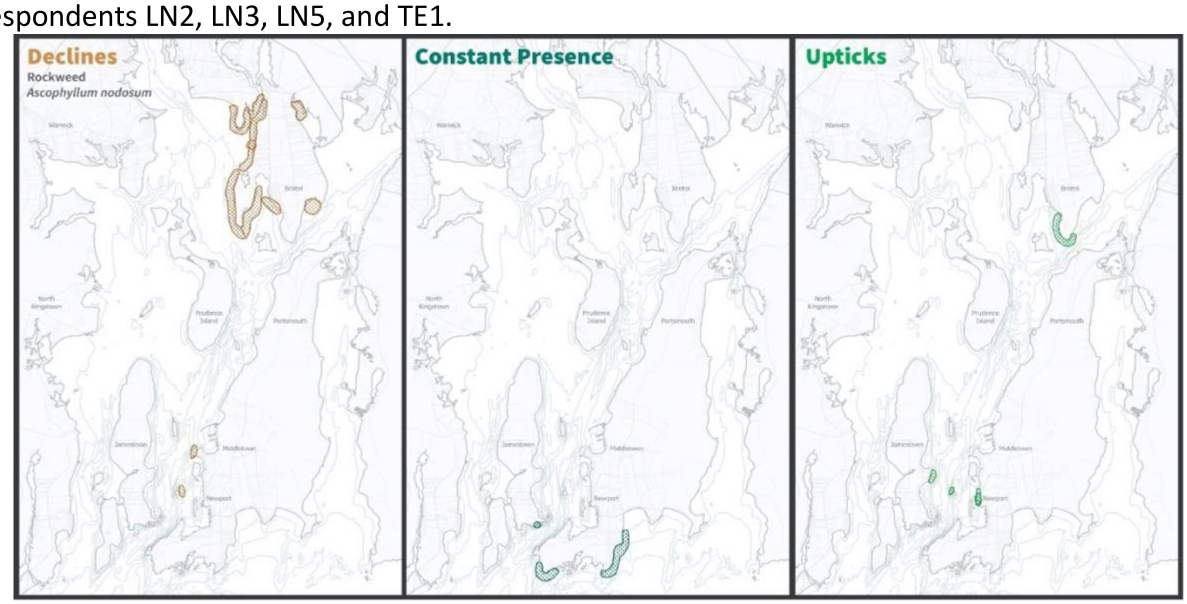


Figure 24. Declines in the population of rockweed, according to respondents LN3, TE1, and LN2.

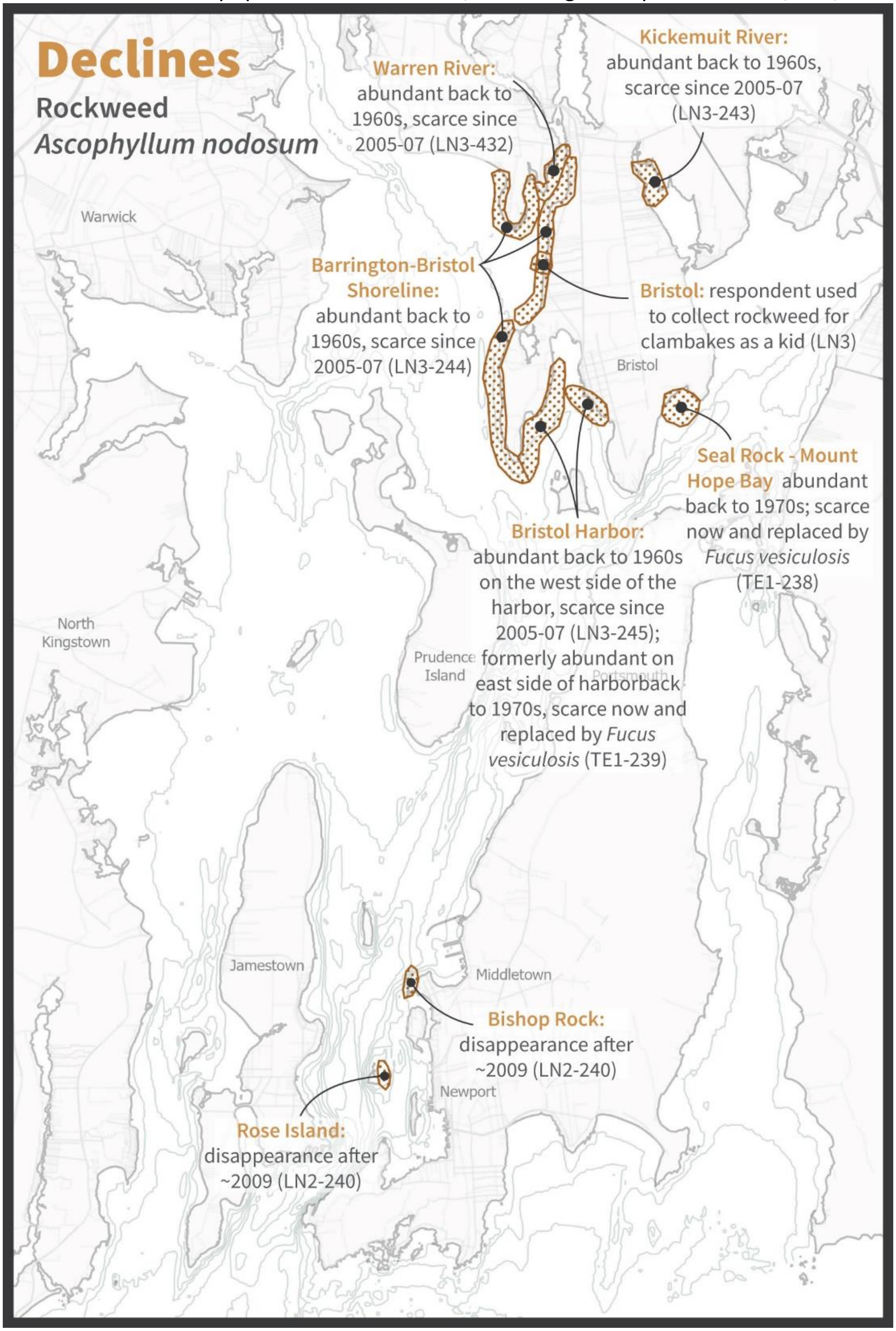


Figure 25. Areas where rockweed has had a constant presence, according to respondents LN2 and LN5. Respondent LN5 also mentioned, but did not draw, Ocean Drive and Beavertail Point in the Mouth of Narragansett Bay (LN5-247, not shown).

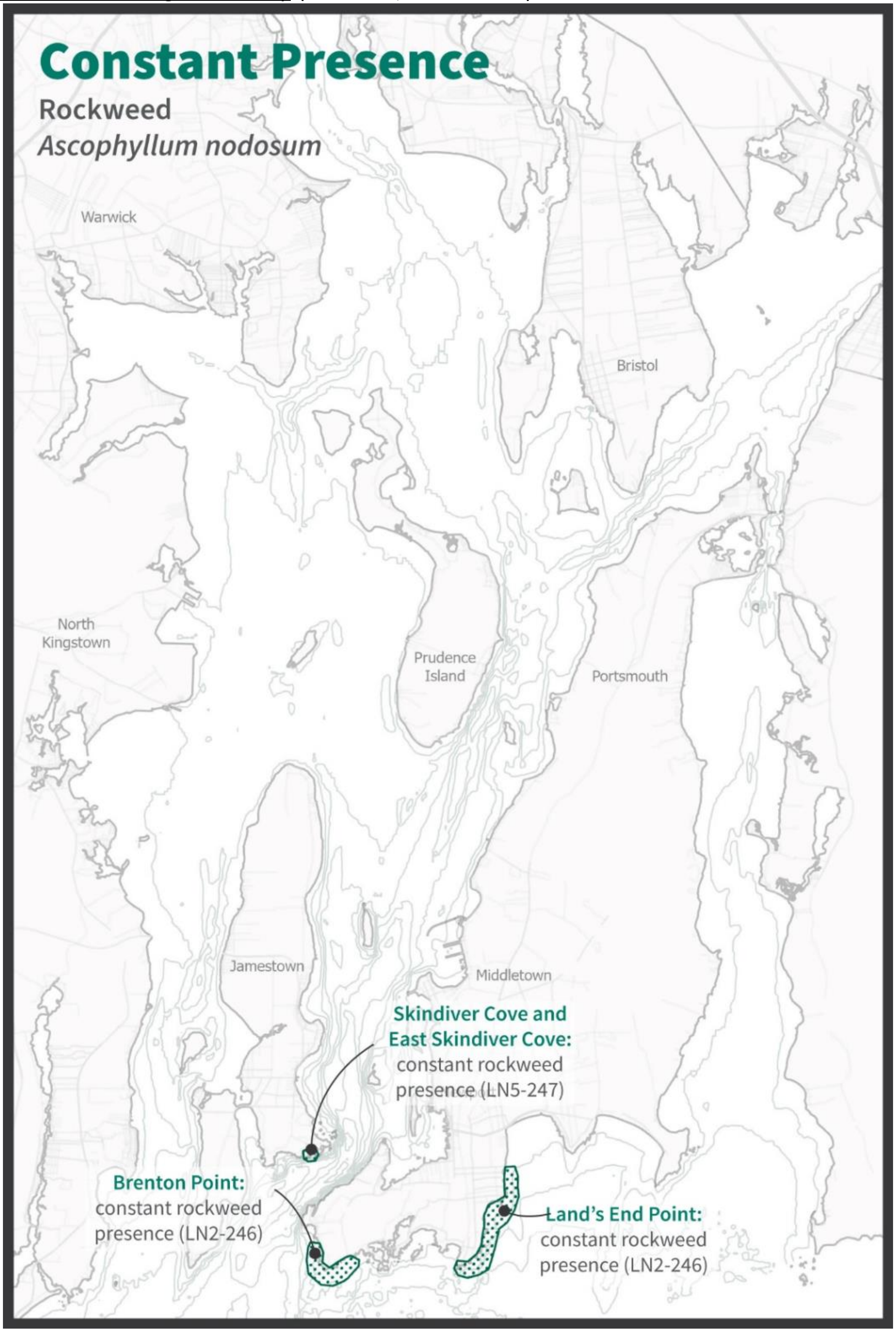


Figure 26. Areas that experienced an uptick in the population of rockweed around 2018-2019, according to respondents LN3 and LN5, who added that rockweed had not been present in these areas since at least the mid-2000s.

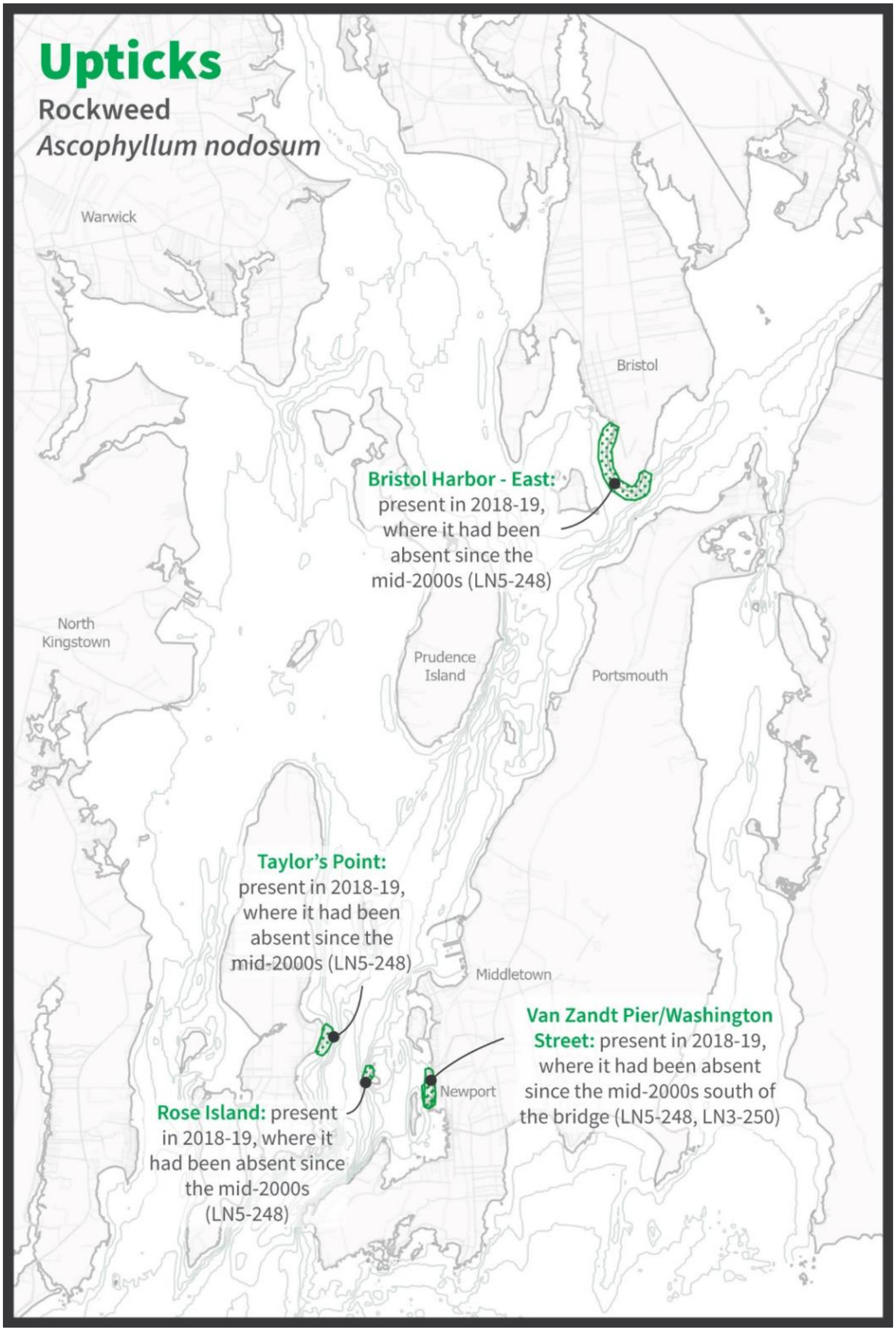
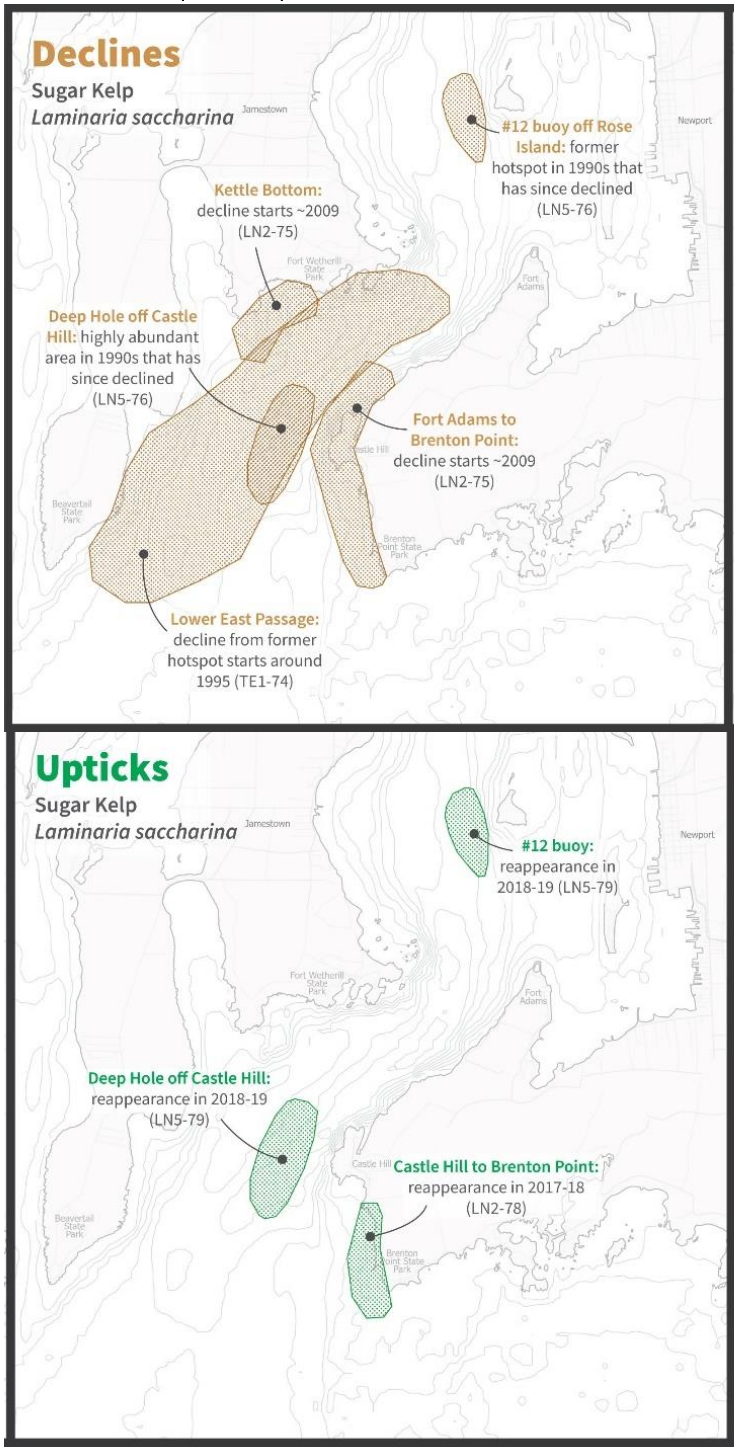


Figure 27. Changes in sugar kelp (*Saccharina latissima*), according to respondents TE1, LN2, and LN5. Top: Former kelp hotspots in the Lower East Passage that have experienced declines. Respondent LN5 also mentioned, but did not draw, declines since the 1990s near Fort Wetherhill and Kettle Bottom (LN5-76). Bottom: Areas in the Lower East Passage where kelp experienced a slight uptick in the last two years. Respondent LN2 also mentioned, but did not draw, an uptick at Kettle Bottom (LN2-78).



Miscellaneous seaweed. In addition to the observations of kelp, rockweed, and sea lettuce described above, interviewees provided a variety of observations of other types of seaweed in Narragansett Bay. Eleven interviewees in the NB 2019 and RF 2016 projects shared accounts of types of seaweed that were less "traditional" or well-known than kelp, rockweed, and sea lettuce, providing support for a comment made by one lobsterman, who said, "We see more seaweed than we ever used to. Not all the same seaweed we used to see (LN4)."

In this section, we summarize seaweed-related observations related to these less-familiar types of seaweed. Most of the seaweeds discussed here, with the possible exception of *Chondrus crispus* (Irish moss) and *Codium fragile* (dead man's fingers), are unfamiliar by name to the commercial fishing public. In only two cases did an interviewee know a name for a species in the miscellaneous category prior to the interview. In most cases, interviewees offered a verbal description (e.g., "dead man's hair," "kale") and/or picked out a photo ID card that appeared visually similar to the type of seaweed he was describing.

Early on in the NB 2019 project, a lobsterman provided a photo from his phone showing a type of seaweed that he calls "slime weed" (see Figure 28). In subsequent interviews, we showed this photo to other interviewees any time they described types of seaweed that matched this description. This enabled us to confirm whether or not various interviewees felt they were describing the same species.

Figure 28. Photos of "slime weed" provided by interviewee LN5.

Unfortunately, interviewees' verbal descriptions and attempts to match memories with photo ID cards and a smartphone photo of a clump of nondescript seaweed provided little more than the coarsest overview of changes in the seaweed community in Narragansett Bay. In effect, these conversations yielded more hypotheses than findings, and they fell far short of providing a foundation for reliable taxonomic categorization of the observed seaweeds.

Nonetheless, the varied descriptions offered by interviewees suggest that the variety of different seaweeds in Narragansett Bay is increasing. They also suggest that these seaweeds are fundamentally different in their morphology, growth patterns, and interactions with other species and with commercial fisheries than the common seaweeds of yesteryear, such as kelp and rockweed. This itself is a valuable finding that may generate future research questions.

Of the 25 observational statements placed into the miscellaneous seaweed category, 16 referred to taxa characterized by overlapping verbal descriptions that frequently included adjectives like “slimy,” “brown,” and “hairy.” These descriptions are summarized in Table 13. It is not clear whether the eleven interviewees who described these seaweeds were referring to the same or different taxa. Since one interviewee provided physical descriptions for two different seaweeds in this category, we can be sure that there are at least two species represented in this table. One interviewee affixed the name *Desmarestia viridis* to his description, based on a longstanding familiarity with this species. Another picked *Desmarestia* out of the photo ID cards. Seven interviewees reviewed the photo ID cards but did not find a match. Three did not review the cards for a match. Six believed that the species they were describing matched the “slime weed” depicted in Figure 28.

In addition to the descriptions of various “brown,” “slimy”, and/or “hairy” seaweeds summarized in Table 13, interviewees also described observations relating to *Chondrus crispus* (n=2), *Codium fragile* (n=1), *Dasysiphonia japonica* (n=1), *Ectocarpus sp.* (n=1), *Grateloupia turuturu* (n=1), *Grinnellia americana* (n=1), and *Agardhiella subulata* (n=2). Species in this list were not known by name previously to interviewees, and were picked out of the photo ID cards presented during the interview. This, and the small number of observations of these species, make it challenging to draw even the roughest of taxa-specific findings from these observations.

Despite the taxonomic coarseness of the seaweed observations gathered through these interviews, it is nonetheless possible to discern some rough trends in the seaweed community as a whole. First, as evidenced by the preponderance of “slimy” and/or “hairy” seaweeds in our observational statements, we can conclude from the evidence that, regardless of whether these statements represent one, two, or thirteen different species, taxa with a “slimy/hairy” morphology have become one of the dominant morphological types of seaweed in Narragansett Bay, replacing structure-providing species like kelp and rockweed.

Interview evidence suggests a belief that the ecological function of these taxa is different from the ecological function of kelp and rockweed. Whereas these formerly abundant species were perceived by interviewees to provide critical habitat for species such as juvenile lobsters, these newly abundant “slimy/hairy” seaweeds are perceived to have negative impacts on the shellfish community, for example, by smothering quahogs. One interviewee reported a perception that *Desmarestia*, which “burns your arms and eyes because it has sulfuric acid in it,” kills or chases away all other species when it colonizes an area or sweeps through an area with the currents after it is detached from its substrate:

Table 13. Descriptions of “brown,” “slimy,” and/or “hairy” seaweeds in Narragansett Bay.

ID	**Name** Scientific or colloquial name	**Description** Physical description of the seaweed in question	**Locations and trends** Places, habitats, and times where the seaweed in question has been abundant	**Seasonality** Times of year when the seaweed in question is present	**Match cues** Whether the seaweed matched a photo ID card or Figure 28 or was described as acidic. Green = yes, red =no, blank = NA
TE1	*Desmarestia* (known previously)		- appeared just north of Jamestown Bridge in 1969 - spread to a larger area of the Lower West Passage and finally to the Lower East Passage - grows in areas 40 feet deep - does best in sandy, gravelly bottom	begins growing in December; turns into a big sail by May and detaches from the bottom and gets caught on gear into July	[green] ID card? [blank] Figure 28? [green] Acidic?
QW2	*Desmarestia* (selected from ID card)		north end of Prudence Island (2018)	first bloom in spring; second bloom in summer	[green] ID card? [blank] Figure 28? [blank] Acidic?
LN2	"brown slime"	"slimy crap"	- used to be present at Bishop's Rock" but disappeared 15-20 years ago - is still present at Goat Island	NA	[red] ID card? [green] Figure 28? [blank] Acidic?
AE1	"brown stuff"	- brown stuff all over everything on the bottom in springtime - 3-4 weeks after it appears, it's gone		appears in springtime	[blank] ID card? [green] Figure 28? [red] Acidic?

ID	Name	Description	Locations and trends	Seasonality	Match cues
AE2	"stringy brown hair"	- very heavy because it holds a lot of water - gets on the oyster gear but falls right off when you rinse the bags in the water - gets clumped on the ropes when you're pulling up a cage		appears in winter-springtime; then disappears	ID card? Figure 28? Acidic?
LN3	"slime weed"	slimy; nasty; comes up in big balls	- Once caught a ton if it east of Prudence Island - No longer fishes inside the bay, but sees it around Brenton Point; thinks it washes into that area, rather than growing there	appears in springtime	ID card? Figure 28? Acidic?
QE2	"yucky scum"	- like a slime - smothers quahogs - makes it impossible to rake	- started appearing a few years back in Bristol Harbor - is beginning to appear between Potter's Cove and Mount Tom	NA	ID card? Figure 28? Acidic?
LN5	"horsehair"	- believes it is free-floating, rather than attached to the bottom - on the moon tides, gets wrapped around the lobster gear	- was abundant for 4-5 years - was supplanted by "slimeweed" about 10 years ago	appears in springtime	ID card? Figure 28? Acidic?

ID	Name	Description	Locations and trends	Seasonality	Match cues
LN5	"slime weed"		- started appearing 10 years ago - continues showing up to the present day - spring 2017 was the most abundant it's ever been - abundant in shoal waters at Hull Cove, Mackerel Cove, Rose Island	appears in springtime; sticks around until early summer	ID card? Figure 28? Acidic?
QK2	"brown weed" or "mermaid hair"	- looks like Ulva spp., but it's brown - really heavy - "nasty" - is "out of control" in some places; really dense - giant balls that stick to his conch pots		appears in springtime; doesn't last long	ID card? Figure 28? Acidic?
QW3	"dead man's hair"	- reddish brown - mats the bottom and smothers everything	- used to show up at Friar's Cove, Allen's Harbor, and Quonset - was abundant 10 years ago - stopped appearing sometime after that	appears in springtime	ID card? Figure 28? Acidic?
LN4	"brown hairy weed"	- used to set gillnets and the weed would make the nets so heavy he could barely haul - acid turns the deck plates on his boat shiny	- started appearing 5-8 years ago - stayed late in summer 2018, showed up early in spring 2019 - stays around longer than before - prevalent west of the Naval War College, east of Rose Island, around Fort Wetherhill, and from Fort Adams to Castle Hill	appears in springtime; sticks around into summer	ID card? Figure 28? Acidic?

> I'll be catching good fish, and as soon as that stuff comes by, everything disappears. Everything chases away from it. Crabs, everything. It all gets burnt… No matter where you go, wherever it's been, it's devoid of life. No fish! They smell it, they're gone… I think it's herding everything. That seaweed's actually pushing them. You'll say "Wow, I can't wait to go out the next day!" The next day, you get the seaweed, and after that, you don't see nothing (TE1).

This individual also reported that *Desmarestia* kills off kelp, thereby helping to achieve its own expansion:

> It's like clear-cutting the forest. Everything that it lays against. Because we used to get some nice big kelp. It was loaded with kelp in here. Now, once that stuff started traveling through here and getting caught on the roots structures and laying there, it burned it right off. It clears everything right off. Sulfuric acid. And for some reason, when it breaks loose, that's when it really starts to give off its acid (TE1).

Interview evidence also suggests that seaweed taxa have begun cycling in and out of abundance more quickly than in the past and that the dominance of particular taxa is short-lived. Observations of patterns in the succession may prove revealing even in the absence of taxonomic specificity. For example, a Lower East Passage lobsterman described a species he called "horsehair" seaweed that came into prominence four to five years after the decline of kelp. On the moon tides, he said, "It was ridiculous, the amount that would wrap up on our lobster gear, like the kelp used to." Around 2008-2010, he said that "horsehair" was replaced by a species he calls "slime weed," which continued to appear every spring.

Lastly, interview evidence suggests that changes in seaweed abundance may illuminate fine-scale changes in habitat quality, particularly when multiple taxa experience a similar directional change at the same time. This reflection is prompted by an account shared by a lobsterman, who noted that until sometime around 1999-2005, he regularly encountered a mix of various seaweed taxa around Bishop's Rock in the Lower East Passage. One year, all of the seaweed in that location suddenly disappeared. This interviewee added that lobsters disappeared from the area at the same time, and that at present, there is "nothing" in this area. In contrast, he said, the same seaweed taxa that he used to observe at Bishop's Rock continue to be present at Rose Island, which is also in the Lower East Passage. This type of multi-taxa change occurring in specific locations may be useful for shedding light on micro-scale changes in habitat fitness. For example, the interviewee whose observations are represented in this paragraph stated that the Bishop's Rock area is close to an outfall pipe from a wastewater treatment plant; he hypothesized that the dramatic changes that he observed in this spot may result from alterations in the chemical composition of effluent emanating from this outfall pipe.

The Finfish Community

The finfish community was not as well represented or as detailed as it might have been if we had included a greater number of finfishermen in our sample. Nonetheless, a number of interviewees participate in fish potting, rod and reel fishing, and gillnetting as a secondary gear type, and the NB 2019 and RF 2016 projects paint a fairly clear picture of declines and increases in several finfish species in recent years. In this section, we summarize interview evidence for declines in eels, tautog, and winter flounder and increases in black sea bass and sea robins. We also discuss mixed observations related to scup and menhaden.

In addition to these species-specific observations, interviews shed light on community-level changes in the Narragansett Bay ecosystem. In the RF 2016 project, a trawl fisherman asserted that, compared to decades past, the finfish community had become more transient than in the past, with year-round residents like tautog, winter flounder, and lobsters replaced by migratory species like black sea bass and scup. Additionally, he perceived that this new community of finfish is less diverse than the finfish community of the past: “There was more variety. I would catch the same weight, but it would be a little bit of everything. Instead of all scup, all sea bass. That’s what we’re doing now (TN1).”

Black sea bass (*Centropristis striata*). Nine individuals mentioned black sea bass in the NB 2019 and RF 2016 interview projects, and all nine described an astounding increase in the black sea bass population in Narragansett Bay. These interviewees used words like “inundated,” “overrun,” “everywhere,” and “out of control” to describe the abundance of black sea bass. The RF 2016 project also interviewed many fishermen who fish in waters from Rhode Island and Block Island Sounds out to the continental shelf, and many of those fishermen shared the view that black sea bass are on the rise. This suggests that the increase of this species is not limited to Narragansett Bay, but is occurring on larger spatial scales.

In terms of the time period of this increase, one interviewee said that it has been occurring gradually since he began fishing in 1998, while two others pinpointed the increase as beginning in the 2010s and two others specified a 2013-2014 timeframe. Most interviewees spoke of this increase in general spatial terms, but four individuals focused their comments on the Lower and Middle East and West Passages, suggesting that the increase may have been more pronounced in the southern half of the bay.

The surge in black sea bass is a notable ecosystem-level change. Driving home this point, a trawl fisherman said:

> Sea bass, right now, is just out of control. Everybody’s told you that. [It’s been that way for] 2 years (i.e., since about 2014). Well, I saw it coming. For the last 15 years, we would catch 100 pound a tow in May in the bay. For 15 years, 20 years (i.e., from about 1994-1999 through 2014). Then the last couple of years (i.e., 2014-2016), it’s been like 2,000 pounds a tow. And all we can have is 50 pounds… The schools have to be huge. Numerous schools of black sea bass coming in and out of our bay (TN1-375).

Because fishermen feel that the regulatory limits that they must adhere to have not gone up in tandem with this increase, they tend to view the black sea bass explosion with frustration. Several interviewees shared a concern that surging populations of black sea bass would devour other species in the bay, including lobsters (n=2) and squid (n=1). Two expressed a view that sea bass compete with scup (n=2). These views were shared by fishermen who work outside Narragansett Bay who were interviewed for the RF 2016 project.

It is not yet clear whether this surge in black sea bass is part of a long-term increase or a short-lived boom. One lobsterman interviewed in the NB 2019 project commented that the black sea bass population seemed to be tapering off at the time, providing evidence for the latter; only time will tell.

Eels (*Anguilla rostrata).* Eels were mentioned by four individuals, and their collective memories depict a sharp decline. Two individuals recalled eels being particularly abundant in the coves around Greenwich Bay in the 1980s, but said that eels have become scarce in these locations in the intervening years. Three interviewees harvested eels commercially in the years when the resource was at its peak, but they stopped setting eel pots once their pots started coming up empty.

Scup (*Stenotomus chrysops*). Eight individuals discussed their views on the trends in scup abundance during the NB 2019 and RF 2016 projects, and these views present a decidedly mixed picture. In the RF 2016 project, two individuals stated that scup were increasing, while two others suggested that scup were experiencing a slight downtick in abundance. At the time of the NB 2019 project, two individuals stated that scup were increasing, while another suggested that scup had been declining since around 2011-2012, at least in one location (Bishop's Rock, Lower East Passage). This individual also stated that scup populations were constant at Fort Adams, Rose Island, and House on the Rocks (Lower East Passage), specifying that the House of the Rocks is excellent scup habitat due to the steady abundance of mussels in this wave-swept area. Thus, it is challenging to piece together a coherent picture of trends in scup abundance in Narragansett Bay.

Aside from the abundance of scup, one interviewee mentioned a change in the average size of scup, saying, "The average size seems to be a lot bigger than it was just a few years ago... In the last few years, the size of scup has gone from what we call smalls or mediums to large and jumbos. I haven't seen a medium or small scup in the bay in a couple of years (AE1)."

Winter flounder (*Pseudopleuronectes americanus).* Seven individuals in the NB 2019 and RF 2016 projects reported a declining trend in winter flounder in Narragansett Bay. Four interviewees pinpointed the 1980s as times of high abundance for winter flounder, and said that this species' numbers had waned in the decades since. Interviewees mentioned Mount Hope Bay and Newport Harbor as former winter flounder hotspots. Due to conservation measures, fishermen are not allowed to keep winter flounder, so they no longer target them. As a result, they no longer have as keen a sense of the winter flounder's abundance as they once did.

Several interviewees hypothesized causes for this decline. One individual described it as a "boom-bust" pattern in which the population got too large to sustain itself. Another said that the collapse happened suddenly and appeared to be linked to environmental factors. Two individuals attributed the decline in winter flounders at least in part to a surge in cormorant (*Phalacrocorax auritus*) populations in Narragansett Bay.

<u>Menhaden (*Brevoortia tyrannus*).</u> As was the case with scup, the picture that emerges from our interviews about menhaden is not altogether clear. Five individuals discussed trends in the menhaden population in their interviews for the NB 2019 and RF 2016 projects. In the RF 2016 project, two individuals provided evidence for an uptick in menhaden populations beginning a year or two before the interviews (i.e., around 2015). But in the NB 2019 project, one individual stated that menhaden had been declining since around 2014-2016. Another also asserted a decline, without providing a timeline, while a third asserted that an uptick began in 2018.

Aside from the abundance of menhaden, one interviewee mentioned a change in the average size of menhaden, saying that from 2014 to the time of the NB 2019 interview, he had seen plenty of small menhaden, but very little in the way of large menhaden in the bay.

Abiotic Factors

In the NB 2019 and RF 2016 projects, fishermen brought up two abiotic factors of note. The first of these was an increase in the clarity of the water column in Narragansett Bay. Nine respondents in the NB project commented on this change. Whereas in the past, water clarity would change on a seasonal cycle, with winters being clearer and summers being murkier, several respondents said that the water column is reliably clear now year-round and they are able to see to greater depths in summer. Several respondents also commented on this change in the RF 2016 project.

"The water seems ridiculously clean," said one individual. "There are days up there that I can see bottom in 17 or 18 feet of water. Just crazy. Just really seems too clean. Almost like pool water (QK2)." "Some days, it's really, really clear—like Caribbean clear," said another. "On some days, you can see 10 or 12 feet down. You can see the rake. Whereas years ago, you couldn't see it (QW2)." Most of the fishermen who spoke of water clarity interpreted it as a worrisome sign, making comments like, "There's something wrong. There's no life in the water (LN3)."

The second most frequently mentioned abiotic change was a smell that respondents compared to the smell of "bleach," "chlorine," or "a swimming pool." The smell was reported by five fishermen in the NB 2019 project, including quahoggers, lobstermen, and a trawl fisherman. These individuals had encountered the odd smell in almost all main segments of the Bay, north to south (see Figure 29).

Respondents put forth different accounts of the locations and conditions under which they most frequently detected this smell. According to these individuals, the smell is most apparent: on flat-calm mornings (n=2); when boats speed by, stirring up spray (n=2); near Warwick Light, a high-energy area with a lot of tidal mixing (n=1); on mornings "after a big tourist weekend" in Newport (n=1); near Barrington Beach and Longmeadow in the Upper Bay (n=1); along the west shore of Aquidneck Island in the Lower East Passage (n=2); and near Fall River in Mount Hope Bay (n=1). Some interviewees assumed that the smell was related in some way to wastewater treatment, while one hypothesized that it comes from gasoline additive used in outboard motors.

The timelines put forth by interviewees when describing the "chlorine" smell were radically different. One said that he has detected this smell since 1971, and that it has decreased since around 2013-2014, while another said that the smell had only been around since about 2016-2017. Three individuals described temporal correlations between the onset of this smell and biotic changes they observed in the bay. One perceived a temporal link between this smell and an observed decline of the Narragansett Bay food web. Another asserted a link between this smell and an observed decline in quahog productivity.

Associations and Proposed Relationships

Throughout the observations summarized in this report, we have made mention of a number of ecological associations reported by interviewees, as well as a number of hypothesized relationships between biotic elements (e.g., predation, competition) and biotic and abiotic elements (e.g., the role of environmental factors in driving food web change) that might explain these associations. In this section, we offer a summary of these observed associations and hypothesized relationships. Table 14 presents observed associations and hypothesized relationships between organisms, while Table 15 presents observed associations and hypothesized relationships between organisms and environmental factors, including anthropogenic stressors.

Interpreting Ecological Change

As noted in the introduction to this report, recent years have seen the emergence of differing views among members of the resource science and management community and members of the commercial fishing community over how the *present* status of the Narragansett Bay ecosystem compares to the *desired* status of the bay ecosystem (Allard Cox, 2018, Kuffner 2017, 2021). To help understand this divergence, we sought to glean information on fishermen's ecological value sets and interpretive frames.

Figure 29. Locations where a "chlorine smell" is sometimes apparent, according to respondents QW2, QW3, and TE1.

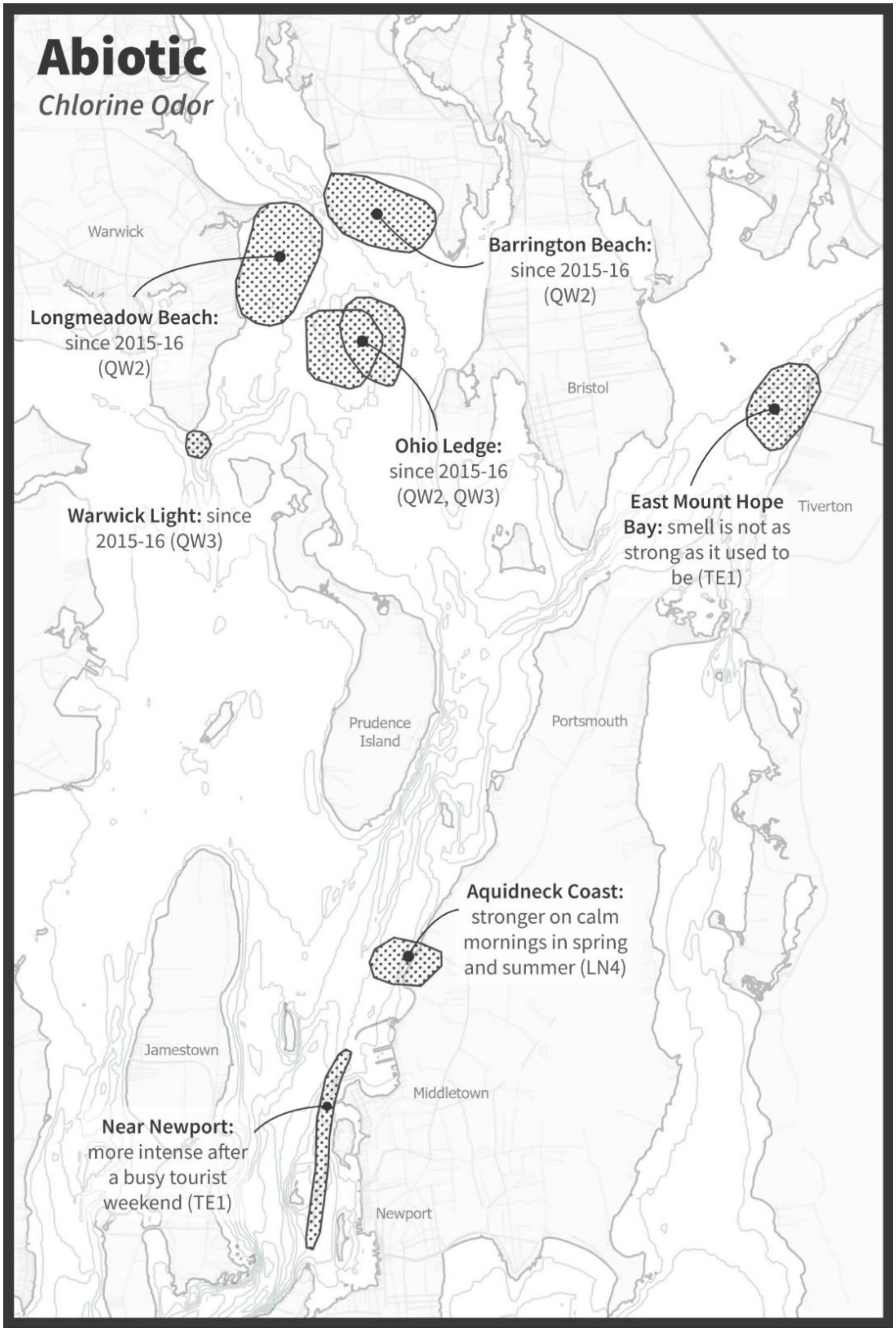


Table 14. Observed associations and proposed relationships between species pairs.

Organism		Observed Association	Proposed Relationship	Source
1	2			
starfish	deckers	negative	starfish prey on deckers	QK2
starfish	mussels	negative	starfish prey on mussels	LN2, LN4
starfish	quahogs	negative	starfish prey on quahogs	AE2
starfish	whelks	negative	starfish and whelks compete for food	AE1
starfish	moon snails	negative	starfish and moon snails compete for food	AE1
starfish	spider crabs	negative	starfish and spider crabs compete for food	QW2
spider crabs	quahogs	negative	spider crabs prey on quahogs	LN2
spider crabs	lobsters	negative	spider crabs and lobsters compete for food	LN2
deckers	quahogs	positive when deckers are moderately abundant; negative when deckers highly abundant	deckers provide a predatory refuge for quahogs, but they also outcompete quahogs for food	QK2, QW2, QK3, QW4
mussels	quahogs	positive	mussels provide a predatory refuge for quahogs, and when they die and decompose, they create good sediment for burrowing	QW3
cormo-rants	winter flounder	negative	cormorants prey on juvenile winter flounder	QE1, LN5
black sea bass	lobsters	negative	black sea bass prey on lobsters	LE1, TK1, TN1
scup	lobsters	negative	black sea bass prey on lobsters/larvae	LK1
quahogs	"slime"	negative	slime smothers quahogs	QE2
Desma-restia	finfish	negative	Fish avoid *Desmarestia* because of its acidity	TE1
Desma-restia	kelp	negative	*Desmarestia*'s acid burns kelp	TE1

Table 15. Observed associations and proposed relationships between species and abiotic factors.

Organisms, Factors	**Observed Association**	**Proposed Relationship**	**Source**
barnacles, starfish, hydroids, sea grapes	disappeared around the same time in the Lower East Passage (~2013-2014)	believes there was a change in composition of wastewater effluent	LN5
lobsters, cold winter	Lobsters experienced an uptick in 2015	cold winter was beneficial to lobster population	LN4
kelp, rockweed, phytoplankton	increased in ~2017-2018 after a wet winter; water was green	precipitation caused a bloom in phytoplankton and macroalgae; also hear rumors there had been a change in wastewater treatment at this time	LN5
quahogs, "chlorine" smell	quahogs disappeared at the same time chlorine smell became noticeable	chlorine smell is associated with something that is killing the quahogs or their larvae	QW2

In this section, we summarize perceptions of overall ecosystem health and resilience offered by interviewees in the NB 2019 project. We hope that the information presented here can help identify analytical questions that can be subsequently addressed by the science, management, and fishing communities *together* through "joint fact finding," which Karl *et al.* (2007) define as "a procedure for involving those affected by policy decisions in a continual process of generating and analyzing the information needed to shape scientific inquiry and to make sense of what it produces. It allows for the consideration of local and cultural knowledge as well as expert knowledge."

In our interview questionnaire, we offered interviewees a chance to define ecosystem "health" or "resilience" in their own words. Eight interviewees provided definitions in response to this question. The definitions they provided generally revolved around three criteria:

- community composition: presence of native species that settle and spend their whole lives in the bay, not just transient species that migrate in and out seasonally (n=3)
- water quality: an estuary without manmade chemical inputs (n=2) or with a healthy concentration of nitrogen to support the bottom of the food chain (n=1)
- employment: a greater number of fishermen are able to make a living (n=1) or a moderate number of fishermen are able to make a better, steadier income (n=1)

Tellingly, none of the interviewees who put forth these definitions felt that Narragansett Bay currently meets them.

When asked whether Narragansett Bay was becoming healthier or less healthy at the time of the NB 2019 project,

- Four interviewees asserted that the bay was in poor health (AE2, LN3, LN5, QW3). Several individuals referred to the bay's increase in water clarity as a reason for forming this opinion.
- Two interviewees asserted that the bay was becoming healthier (AE1, QE1). Interestingly, these individuals also referred to the bay's increase in water clarity as a reason for forming this opinion.
- Two interviewees asserted that the health of the bay was declining over the long term, but that it had experienced a slight improvement during the year before the interview (LN2, LN4). These individuals mentioned upticks in lobsters, urchins, and starfish in the Lower East Passage as reasons for forming this opinion.

Echoing a feeling that the Lower East Passage ecosystem rebounded slightly during the year before the NB 2019 project, another lobsterman said of the future, "I think it can bounce right back. The evidence was this last year with the rockweed and the kelp. Once you start having that habitat, that healthy habitat, it makes everything else fall in place. I think this bay could bounce right back to being a real healthy, real resilient Narragansett Bay (LN5)." However, all three of these lobstermen acknowledged that it was too soon to tell whether this apparent improvement was a trend or just a temporary blip.

When asked to describe changes over time in the perceived health of Narragansett Bay, interviewees named the following periods as low points: before the Clean Water Act (n=1); 2014 (the last year the respondent fished in the bay; n=1); and today (i.e., 2019; n=3). Interviewees named the following periods as high points: the 1980s (n=4); the 1990s (n=3); the 1990s to 2005 (n=1), and today (n=1). Those who mentioned the 1990s explained that during those years, there were plenty of lobsters and quahogs, rockweed was plentiful, phytoplankton and zooplankton were visible in large quantities, and species diversity was high, including rare species like seahorses. In sum, although we did not find consensus among interviewees, fishermen's perceptions generally seem weighted towards a feeling that the bay was much healthier in the latter decades of the twentieth century than it is today.

When asked to reflect on spatial aspects of health or resilience, many interviewees referenced a north-south gradient. Two patterns emerge from their answers. Quahoggers and others who fish in the upper half of the bay expressed a notion that healthy habitat is shrinking northward within the bay. "I think that parts that were the worst thirty or forty years ago have come back the most," said an aquafarmer. "Down here [below Quonset], I think it's pretty much stayed the same. But up here [above Quonset], where it was horrible, I think it's gotten a lot better (AE1)."

In contrast, lobstermen and those who fish in the lower parts of the bay expressed a notion that healthy habitat is shrinking southward. Specifically,

- One lobsterman placed a dividing line in the Lower East Passage, halfway between Gould Island and the Newport Bridge: "North of that, it's a dead zone," he said. "The mouth of the bay is still resilient to a certain extent…. But from the middle bay going north, we call it 'Chernobyl' (LN5)."

- Another lobsterman put the dividing line at the Newport Bridge itself. South of the bridge, he described relatively healthy habitat, but north of the bridge, he said, it's "a dead zone (LN2)."
- A third lobsterman pointed to southern Jamestown around Fort Wetherhill and the Dumplings as the most resilient area in the bay, saying this area has strong tidal flow and upwelling: "That corner is its own little ecosystem. There's a lot of big rocks that stick out of the water, and there's a lot of rocks buried in the water, that's why they call it the dumplings… It's a hundred thirty feet and then all of a sudden you hit the dumplings. You get the nutrients rushing right through there and then back out. Where the rest of the bay, there's tide, but nowhere near."

Unlike most interviewees, who drew upon a north-south framework when expressing variations in ecosystem health, a trawl fisherman differentiated the bay by its channels. Of the three channels making up Narragansett Bay's mid and lower portions, he said, the Sakonnet River is the least healthy, while the East Passage is the healthiest. He attributed these differences to the amount of tidal flow moving through each channel.

In sum, interviews made it clear that most fishermen share concerns about the health and resilience of Narragansett Bay. Additionally, many interviewees conveyed a perception that these changes are manmade. Hypothesized anthropogenic stressors mentioned by interviewees related to: wastewater treatment (n=9), specifically to the use of chemicals in treatment processes (n=5) and the intentional reduction of nitrogen entering the bay (n=2); runoff, such as pesticides and fertilizers (n=2); groundwater inputs (n=1); atmospheric deposition from coal-burning power plants (n=1); and site-specific physical impacts such as the construction of the Quonset container port (n=1) and the use of an area in Newport Harbor as a cruise ship anchorage (n=1). Two individuals also mentioned warming waters, specifically as a contributor to the increase in black sea bass populations, but they did not explicitly categorize temperature change as an anthropogenic impact. Table 16 presents interview excerpts that illuminate the concern that many fishermen expressed with regard to wastewater treatment.

Table 16. Excerpts from NB 2019 interviews highlighting wastewater treatment as an anthropogenic stressor affecting the Narragansett Bay ecosystem.

Excerpts expressing a feeling that the bay was healthier when it was "dirtier"
"I honestly think what would be the best thing for the bay is if Providence let it go every once in a while. I just think the water is too clean. I think clams really thrive on having sewage. They're filter feeders. That's how they eat. They don't have enough to eat. You know? I mean, they are hardy. I think they probably eventually adapt. But seems like it was way better than it is. The price is really good. But it's not that good digging (QK2)." "When we were digging during the '70s and '80s, the water was turbid all year long. It was almost like muddy river water. It's cleared up. That probably was kind of an anomaly too, because if it had been that way all the time, you had a hard time getting your rake in the

bottom because there's be so many old quahogs down there. And it wasn't. It was a mix of some old quahogs and new set (QK3)."
Excerpts expressing concern about the chemicals utilized in wastewater treatment
"When I first started smelling the straight chlorine, that's going back twenty years maybe. We caught lobsters, even though there was chlorine in the water…. That's when these guys were still doing gangbusters up in the bay, as well as out front. In the years since they've said, 'You can't discharge chlorine that we can detect over a certain percentage,' and they've put that chemical, that bisodium phosphate, it seems to correspond to me that we've gone down in catch of pretty much everything. It's an acid… I don't believe it's the chlorine, because like I told you, we've had chlorine forever and the fisheries were solid. I think it may be that acid that they use to neutralize the chlorine or to mask it (LN4)." "When I was young, 1970, '69, Sakonnet River was unbelievable with quahogs. One of the most plentiful. As soon as that [treatment plant] went in, I think it was in '71, '72, and started dumping the chlorine into it, you could smell it. I used to ride by and you could smell it. The river just died. Sakonnet River died. Now, they've turned around and dug a big cave with a big tank, and any rainfall or any discharge when there's too much water will go into the tank and they'll chlorinate it constantly, where before it would run off. We are dumping in so much more of this harmful chemical. This river is never coming back (TE1)." "To me, the rockweed was the red flag. Then I started thinking about it, and I started putting the timeframe together with when they started doing those underground tanks. My opinion is that it's got something to do with what they were treating the water with (LN3)."
Excerpts expressing concern over managed reductions in anthropogenic nitrogen inputs
"It's five parts per million, I think is what it works out to. That's the level that they want it at… At five parts per million, it might be too low. It might be doing some damage to the mid and lower bay (LN3).'" "If you want to support a quahogging industry, you can't take all the food out of the water—the algae, the plankton, and everything else that the quahogs eat. They're not going to have as much to eat if you start taking the food out of the water (QW3)." "Another thing that ties into that is what kind of plankton you get. You can have plenty of plankton in the water and the quahogs can starve because they don't like the kind of plankton that's in there. If you alter the mix, you might change something in the nutrient mix that you're dumping in to the bay, and if it results in something that gets stuck in the quahog's filtering system, or it's too big or too small… (QW3)."

Although wastewater and its various treatment technologies emerged as the top stressor of concern among Narragansett Bay fishermen interviewed in the NB 2019 project, it is also apparent that many fishermen situate this stressor among a range of concurrent and interacting impacts affecting the bay ecosystem. In an interview from the RF 2016 project, a lobsterman summed up this feeling with the statement, "It's all of the above. It's all of those things. There's nothing you can put your finger on and say 'That's what's happening… You got to take everything into account (LN2).'"

Moreover, as a quahogger pointed out in the NB 2019 project, the impacts of anthropogenic stressors are not always consistent or intuitive:

> Every time I make a story up, there's something else that contradicts it… Like they're talking about the nitrates, but then how can we get all these thick batches of garbage weed? That contradicts the nitrate [theory]. I mean, at Barrington beach this summer, you couldn't get through the lettuce grass up there. If there were no nitrates, that stuff wouldn't be growing. That contradicts the whole thing… It was probably at its least healthy as an ecosystem in the 1970s, when it had all that pollution. But somehow we didn't see the effects of it like we do now. It depends on what you're looking at. You know? Like I say, I see all those little menhaden and all that stuff, and that's tremendous. But the quahog recruitment is gone. These anomalies. There's always that weird thing. That's nature, I guess (QK3).

Methodological Lessons and Challenges

Temporal Ambiguity. Perhaps the most challenging aspect of the NB 2019 project was aligning the events and changes described by interviewees along a universal timeline. Having an adequate understanding of the timing and pace of ecological changes seems critical when contemplating possible drivers of change and assessing possible implications. Unfortunately, we found that temporal precision often proved elusive in fishermen's attempts to reconstruct ecological observations from memory.

As an illustrative example, we explore temporal consistency across multiple individuals describing two discreet historical events: a bay-wide wild oyster boom and a soft shell clam boom at Conimicut Point. Many interviewees share vivid memories of these events, but our interview data suggests that they do not always share the same recollection of when these events took place. Figure 30 and Figure 31 show estimated timeframes when these booms took place based on interviewee recall. As these figures show, timeline estimates for the oyster boom span twenty years, while estimates for the soft shell clam boom span a decade.

Because fishermen opportunistically targeted these two shellfish booms for harvesting, landings records from the time provide a reliable external dataset against which we can compare interviewees' estimations (see Figure 32 and Figure 33). According to these records, it would appear the oyster boom took place between 1996-2000[4] and the soft shell clam boom took place between 2003-2010 with a conspicuous peak in 2007. These timeframes more or less line up with the *centers* of the estimates provided by interviewees, but they also make clear that some interviewees' estimates are well outside the actual timeframe during which these events took place. This exercise demonstrates the fallibility of human memory when it comes to recalling temporal dimensions of ecological change.

Figure 30. Timeline estimates for a wild oyster boom, derived from eight interviews.

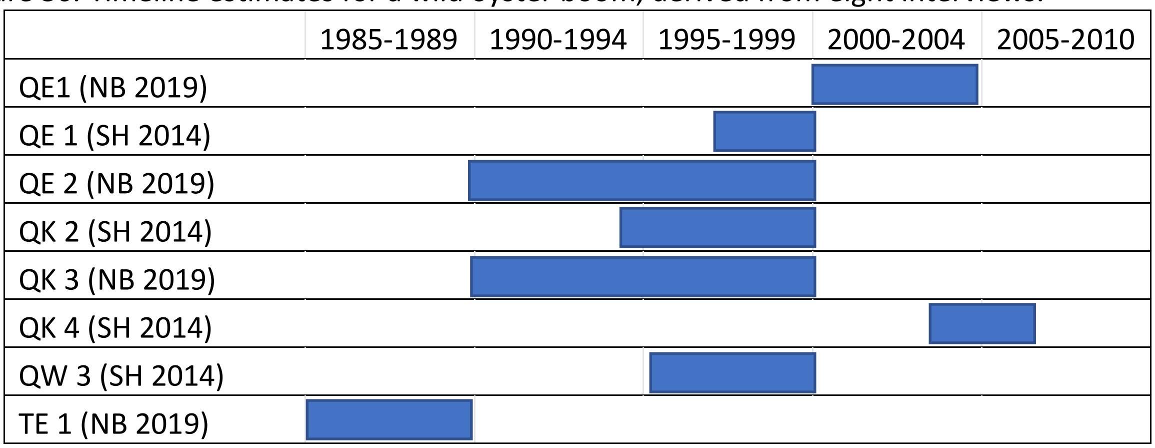


Figure 31. Timeline estimates for a soft shell clam boom, derived from three interviews.

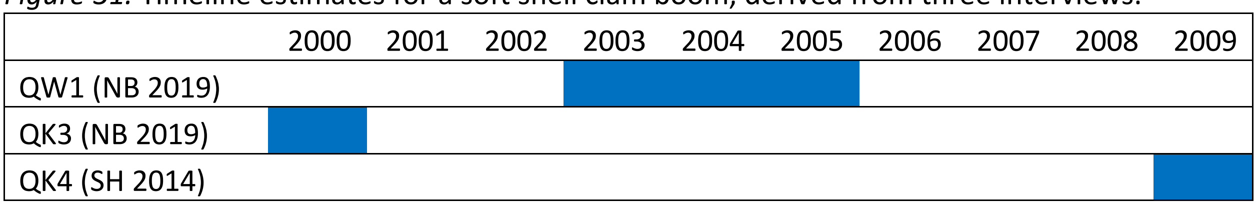
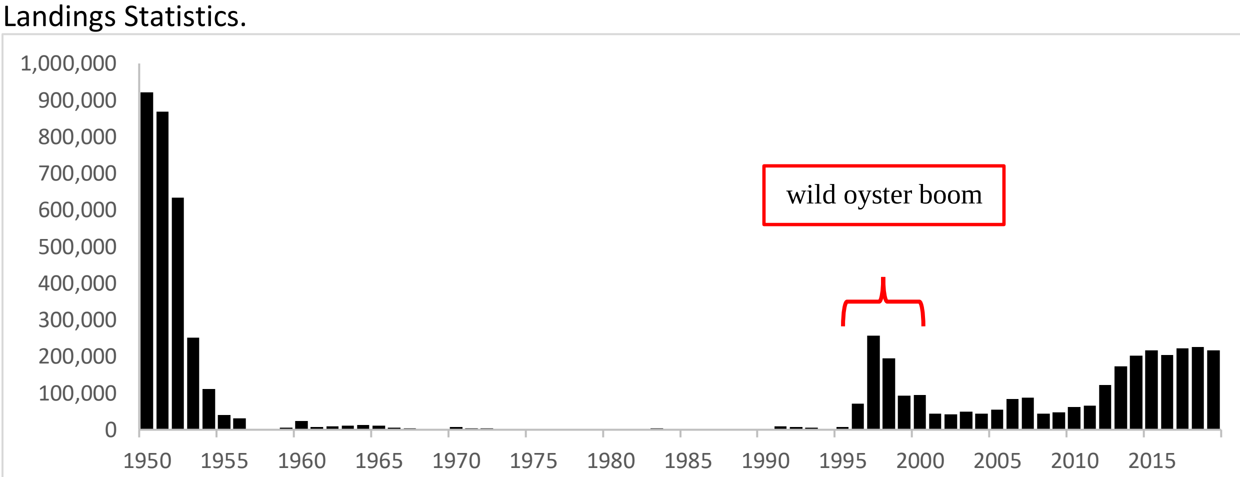
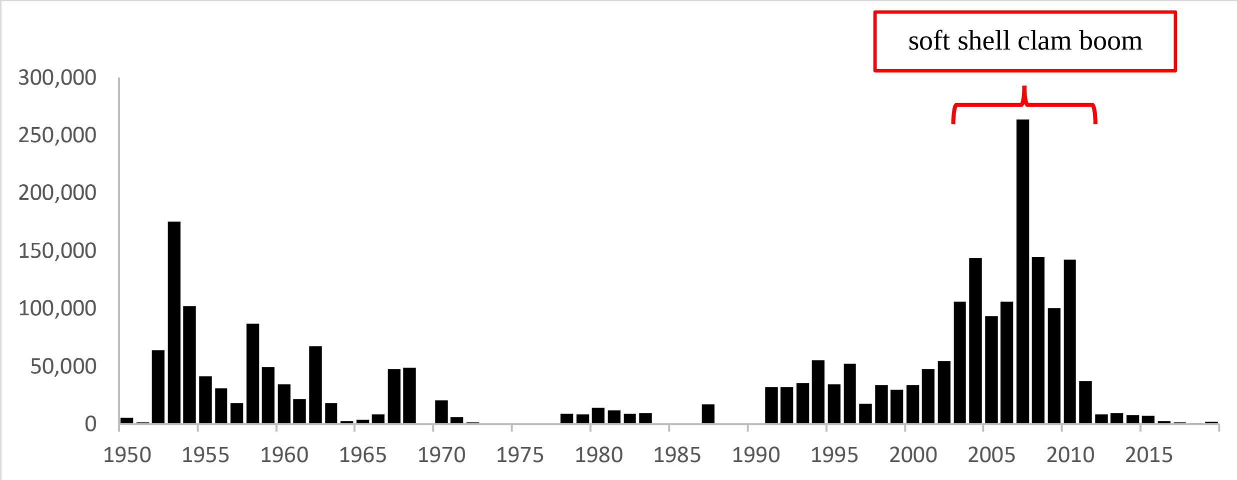


Figure 32. Rhode Island oyster landings, 1950-2020. Source: NOAA Commercial Fisheries Landings Statistics.



[4] The Rhode Island aquaculture industry began a phase of development around 2000; thus, it can be assumed that landings from 2000 onward contain a large proportion of farmed oysters.

Figure 33. Rhode Island soft shell clam landings, 1950-2020. Source: NOAA Commercial Fisheries Landings Statistics.



Of the "what" (organism, trend), "where" (spatial dimensions), and "when" (temporal dimensions) information that we asked interviewees to retrieve from their memories, the "when" aspect was by far the least accessible to interviewees as they plumbed the depths of their memory banks. Often, the information they provided did not go much further than an educated guess. It was not unusual for a respondent to provide a wide range of years or to second-guess himself on the timeline he provided, as one lobsterman did when commenting on an unusual event he saw "ten or twelve years ago—nah, fifteen to twenty years ago." In this example, the lobsterman had a clear recollection of something that happened and where it happened; he even recalled other ecological changes that happened at the same time. But when asked to place this event on a timeline of years, he encapsulated his answer within verbal "error bars" spanning an entire decade—far longer than the duration of the change itself.

In other cases, interviewees provided very precise recollections of the timeline on which a change occurred. Unfortunately, our methods of processing, sorting, and analyzing interview data did not distinguish between responses based on the confidence or specificity with which respondents uttered them. Precise memories were lumped in with imprecise memories, perhaps negating the potential of these precise memories to reveal more. At the same time, the highly imprecise nature of many of the memories volunteered by interviewees raises questions about the reliability of those that *were* precise. Why were these particular memories so specific, when most others were vague? Does their precision imply accuracy, or not?

A second challenge relating to the temporal dimensions of this analysis is that interviewees relied on various different phrasings when expressing the temporal dimensions of their memories. As mentioned in the data overview above, an interviewee describing the timeline of a change might utilize a variety of sentence structures, including:

- Inflection point when a trend began (e.g., "X started to decline in 2005");
- Contrasting a "before" state with an "after" state: (e.g., "X was everywhere in the 1990s and early 2000s; by 2015, X was gone");

- Description of the last memory of seeing a previous state: (e.g., "the last time I saw X in big numbers was in 2010").

Each of these phrasings communicates slightly different information, which prevents them from being converted into the sort of uniform format that would be required to reveal temporal patterns within the dataset. Observations phrased in terms of a "before" state and an "after" state lack information on when the shift between the two states took place. Observations phrased in terms of an inflection point do not always make it clear whether this point represents the beginning of a directional trend or an acute transition to a new steady state. Observations phrased in terms of a last or first memory effectively offer a single data point as an exemplary surrogate for a broader trend or change. In sum, each of these phrasing structures presents only a partial picture of change, and the differences among them make it hard to assemble them into a coherent narrative.

A third complicating factor is that although we divided "trend" and "time" into two distinct variables in our analysis, the timing during which an observer makes a set of observations has a high degree of influence over the type of trend that this observer may perceive. For instance, a problem of perspective may occur in which different individuals see different "parts of the elephant," as in the Indian fable in which several blind men try to guess at the overall shape of an elephant by touching only a part of the elephant's anatomy, and wind up coming up with very different conclusions about what an elephant is.

Since trends in populations of living marine resources are rarely linear, a fisherman who fishes in an area for a short amount of time may observe changes that he interprets as an increase or decrease, while another fisherman who fishes in the same area for a longer period of time may read the same events as an uptick or downtick within a much longer trend in the opposite direction, or as part of a cycle of ups and downs. A related issue is the phenomenon of "shifting baselines," in which a fisherman's perceptions of what an ecosystem "should" look like may be heavily colored by what the ecosystem looked like at the time that he started fishing. Another bias may occur if a fisherman changes the location of his fishing: ecological differences between the old location and new location may be mis-interpreted as changes over time, when in reality they are simply differences in the respective characteristics of two places.

<u>"Sampling" Coverage and Bias.</u> In this section, we use the term "sampling" to refer not to the criteria we used to select our interviewees, but to the ways that the fishermen themselves effectively "sample" the ecosystem of Narragansett Bay through their fishing activities. We are using this term metaphorically, because fishermen by and large do not choose when, where, and how to fish based on the desire to contribute data to research projects; rather, they make these decisions based on an objective of catching as many marketable fish or shellfish as possible while complying with regulations, minimizing expenses, and staying safe on the water.

While ecologists typically utilize random sampling of a variety of places or longitudinal sampling of a single place, fishermen's incidental collection of ecological information during their fishing activities can be described as "opportunistic sampling." It is worth considering how this shapes the information that fishermen contributed through the NB 2019, RF 2016, and SH 2014 interview projects, and how it should guide our interpretation of this information and design of future research projects.

To ruminate on this question, we revisit Table 4 and Table 5, which illustrate the relationships between gear type, species, and the spatial distribution of observations. It is almost self-evident that fishermen possess a greater amount of knowledge on their target species, and thus it is not surprising that lobstermen were the only group to volunteer information about lobsters or that shellfishermen were the only group to volunteer information on bay scallops, deckers, oysters, quahogs, and soft shell clams, as well as eels and horseshoe crabs, which some shellfishermen formerly targeted as sideline fisheries when these species were abundant. These relationships are reflected in Table 4.

It is also not surprising, given what interviews revealed about the north-south gradients of shellfish and lobster abundance, that observations volunteered by shellfishermen are concentrated in the upper half of Narragansett Bay, while observations made by lobstermen are concentrated in the lower half of the bay. These relationships are apparent in Table 5.

What is less self-evident, and therefore more interesting from the point of view of understanding how gear types constrain the amplitude of fishermen's ecological knowledge, are the ways that fishermen collect information on the incidental species that they interact with. For instance, as shown in Table 4, only lobstermen and trawl fishermen volunteered observations on kelp and rockweed during their interviews, while all types of fishermen volunteered information on sea lettuce and miscellaneous seaweeds.

What factors might explain why *all* fishermen seemed equally familiar with a variety of "nuisance" seaweeds, while only *some* seemed to possess information on rockweed and kelp? It seems unlikely that this disparity is related to gear type, since there is no reason to think that kelp and rockweed are any less available to shellfishing gear than sea lettuce, *Chondrus crispus*, *Agardhiella subulata*, and the variety of other unnamed species that shellfishermen did describe in their observations. Rather, it seems more likely that this disparity may be explained by a greater abundance of rockweed and kelp in the regions and/or habitats where lobstermen work compared to the regions and/or habitats where shellfishermen work. It may also be the case that rockweed and kelp are more important to lobstermen than to shellfishermen, due to their perceived importance as lobster habitat, and as a result, lobstermen are more likely to notice and recall observations related to these species.

Table 4 also affirms, not surprisingly, that lobstermen and oyster growers are uniquely positioned to make observations on fouling invertebrates. Their fixed gear, with its wire traps and cages, vertical lines, and buoys, remains in the water for prolonged durations, providing surfaces at every water depth for fouling species to settle on. Thus, it is no surprise that only these fishermen volunteered observations on barnacles, hydroids, sea grapes, and sea squirts.

Aside from miscellaneous seaweeds, the only major species that all types of fishermen seemed to interact with and make note of, regardless of gear type, were starfish and mussels. This suggests that these species are equally susceptible to being caught incidentally in lobstering and shellfishing gear, and that their distributions are equally likely to overlap with the distributions of lobstering and shellfishing activities. Because of the association between gear type and spatial distribution of fishing activities, interviews collectively gathered a more spatially complete picture of trends in starfish and mussel abundance than for many other species.

A final caveat relates to the potential for bias to occur in the dataset as a result of limited "sampling" by fishermen of some areas of Narragansett Bay. By and large, spatially explicit observational statements in our dataset were concentrated in a few segments—primarily the Lower East Passage and Upper Bay, and to a lesser extent, the Upper West Passage, Middle West Passage, and Middle East Passage. At the opposite end of the spectrum, some segments were represented only by one fisherman (e.g., Mount Hope Bay) or referenced in a single observation (e.g., Barrington River). These patterns complicate efforts to draw inferences about the bay as a whole or about underrepresented segments. The same issue applies to underrepresented species. In future studies of this type, it may be worth structuring the interviewee sample in a way that makes the best and broadest use of fishermen's effective ecological "sampling," to assure a sufficient volume of data for each species and bay segment of interest.

Taxonomic Identification. To ensure data consistency, it is important that all interviewees contributing to a dataset share a commensurate ability to distinguish among taxa and to draw upon a common nomenclature to describe these taxa. However, as described previously in this section, this was not the case in our interview data pertaining to seaweeds, particularly "brown," "slimy," and/or "hairy" varieties, and our ability to interpret these results was hampered by this lack of a common frame of reference.

Given the apparent increase of non-traditional seaweeds in the Narragansett Bay ecosystem, it is important that future FEK studies like this one attempt to standardize fishermen's seaweed observations by either training fishermen to identify a greater variety of seaweeds or working with them to collect seaweed samples that can be identified by trained scientists in the laboratory. Only in this way can fishermen's seaweed observations be labeled with the appropriate names and compared with observations made by other fishermen and by scientific researchers.

Certainty and Credibility. Some FEK studies account for the fact that not all knowledge possessed by humans is equally certain or credible. For example, when Doherty (1995) gathered interview data on the historical presence of eelgrass in Narragansett Bay, she assigned one of three "reliability scores" to each observation that was shared with her, with a score of 1 representing fair secondhand information, a score of 2 representing fair firsthand or good secondhand information, and a score of 3 representing good firsthand information. In this way, she was able to weight her data to give greater precedence to the most reliable information.

Our study did not distinguish among the information we gathered according to its certainty or reliability (except inasmuch as we excluded from our dataset any information that was identified by respondents as hearsay). Nor were we in a position to gauge the certainty or reliability of information based on the questions we included in our semi-structured interview questionnaire. However, there may be reason to believe that our dataset contains information that varies in its degree of certainty and/or reliability. For example, as mentioned above in the section on temporal ambiguity, some respondents demonstrated great precision when describing the timeline of a particular change, while others more or less ventured educated guesses.

Additionally, it seems reasonable to expect that some fishermen or types of fishermen may know more about some topics or areas than others. For example, a fulltime shellfisherman likely knows much more about changes in quahog abundance than a trawl fisherman who occasionally harvests shellfish recreationally. However, our research design did not differentiate between the levels of familiarity and knowledge that two such individuals might possess, and we treated their observations indiscriminately. When reflecting on the overall success of this project or designing future projects that build off of this one, it is worth considering whether it might be valuable to solicit information on certainty and reliability in our interview process and allow this information to inform our data interpretation.

Magnitude of Change. One final reflection relates to the question of scale. Qualitative data like the observations gathered through this project may be perfectly apt for describing the character of ecological changes, but it may not lend itself as readily to capturing and comparing the magnitude of these changes. And yet, when making sense of changing ecological dynamics, it seems vital to consider scale; for instance, whether the changes mentioned by interviewees are within the range of "normal" change, or whether they exceed this range.

In our interviews, some sense of scale is evident in comments provided by interviewees, for instance by the shellfishermen who voiced a feeling that a current decline in the quahog population is unlike anything they’ve observed before, or in the comments of fishermen who expressed a sense that the current downturn in the starfish population exceeds the normal range of variability for this species. Inclusion of historical observations, such as those relating to historical booms and collapses, is also helpful for placing present-day changes in a larger context. When contemplating future studies, it may be worth considering a more standardized approach to capturing information on the scale of observed changes.

ANALYSIS PART II. SCIENTIFIC MONITORING IN NARRAGANSETT BAY: WHAT KINDS OF DATA ARE BEING GATHERED?

The interviews summarized in the previous section showed that fishermen accumulate observational data on a number of different taxa in the course of their working lives. While they understandably focus a great deal of mental attention on their target species (e.g., quahogs, lobsters, finfish), they also pick up on trends and anomalies in organisms that they catch as bycatch (e.g., deckers), organisms that grow on their gear (e.g., barnacles, sea squirts, sea grapes) or become entangled in their gear (e.g., seaweeds), and even organisms drifting in the water column as they work (e.g., plankton). They also make note of changes in abiotic factors, such as water clarity and odors.

In this section, our objective is to compare scientific monitoring of Narragansett Bay's ecological components to fishermen's observations of these components, in terms of *what kinds of data* are collected, *how* they are collected, and *where* and *when* they are collected. This exercise is a first step in identifying overlaps and gaps between the two information streams, which will in turn help pinpoint opportunities to integrate fishermen's observations into long-term estuarine monitoring.

Below, we summarize extant scientific datasets pertaining to taxonomic groups referenced by fishermen in their interviews: sessile benthic invertebrates, mobile benthic invertebrates, fouling invertebrates, macroalgae, submerged aquatic vegetation, plankton, finfish, birds, and seals, as well as abiotic factors. At the end of this section, we highlight monitoring gaps that fishermen and their ecological knowledge may be able to help fill.

Sessile Benthic Invertebrates

<u>DEM Shellfish Dredge Survey</u>. DEM has conducted a Shellfish Dredge Survey since 1993. Data collected through the dredge survey is used to monitor the relative abundance and distribution of quahogs within Narragansett Bay, support stock assessments and development of fishery management plans, and to characterize and map essential quahog habitat within the bay. The survey samples 17 strata, located primarily in the northern portions of Narragansett Bay, on an annually rotating basis. In Appendix H, we draw upon data from the DEM Shellfish Dredge Survey to visualize changes over time in the quahog population in Narragansett Bay. A map of Shellfish Dredge Survey strata can be found in Figure 34.

<u>DEM Shellfish Landings Data</u>. DEM has collected spatially explicit shellfish landings data since 2006. Shellfish landings are categorized according to the "tagging area" where they were harvested. A map of tagging areas is shown in Figure 35. Landings data are subject to the "rule of three" to protect confidentially, so landings are not available for all shellfish species. In Appendix H, we draw upon data from the DEM shellfish landings to visualize changes over time in the populations of quahogs, oysters, and soft-shell clams in Narragansett Bay. We also

queried the data for mussels and bay scallops, but there were insufficient landings of these species in recent years to support multi-year time series.

Figure 34. DEM Shellfish Dredge Survey strata. Numbered areas within each stratum are randomly sampled in alternating years.

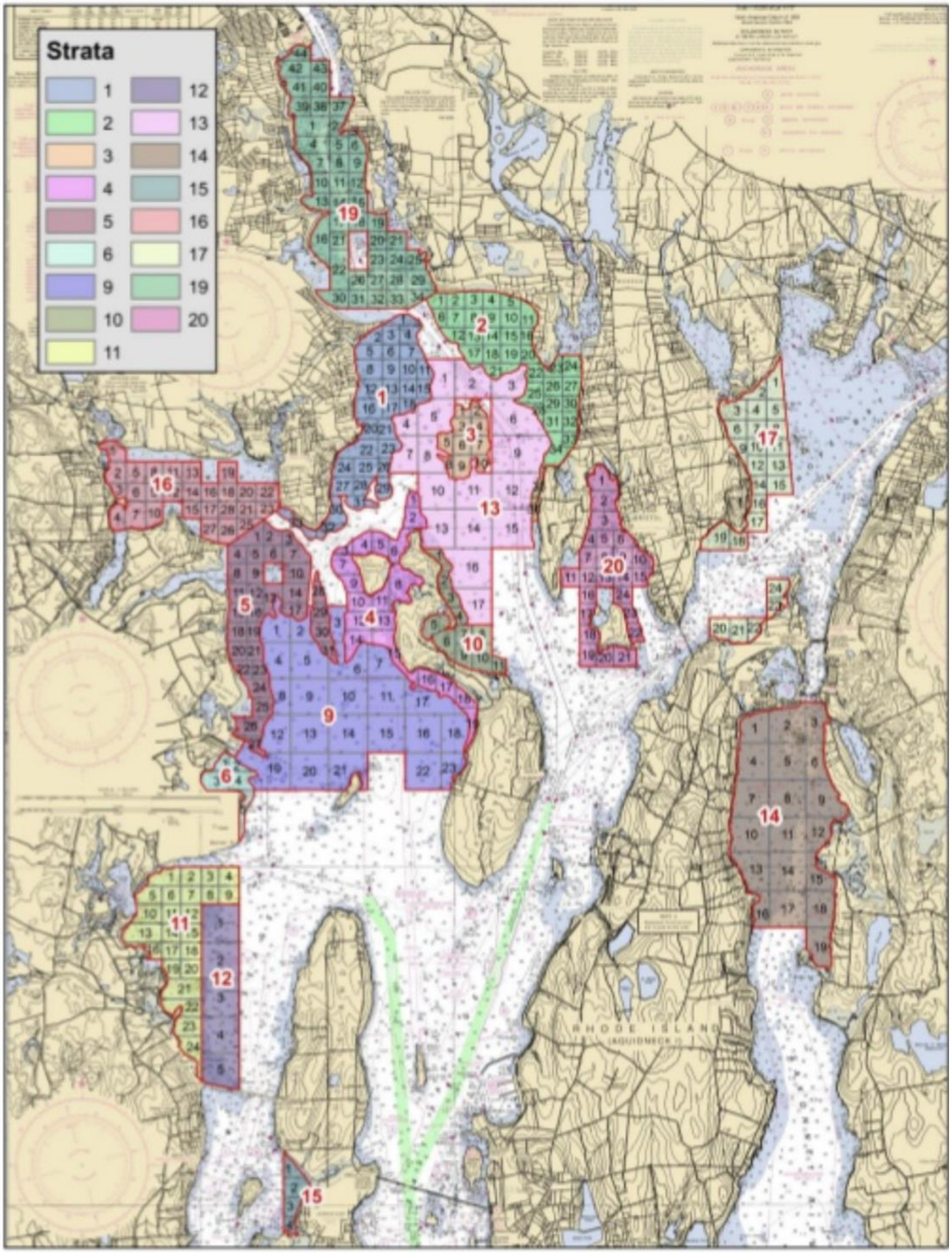
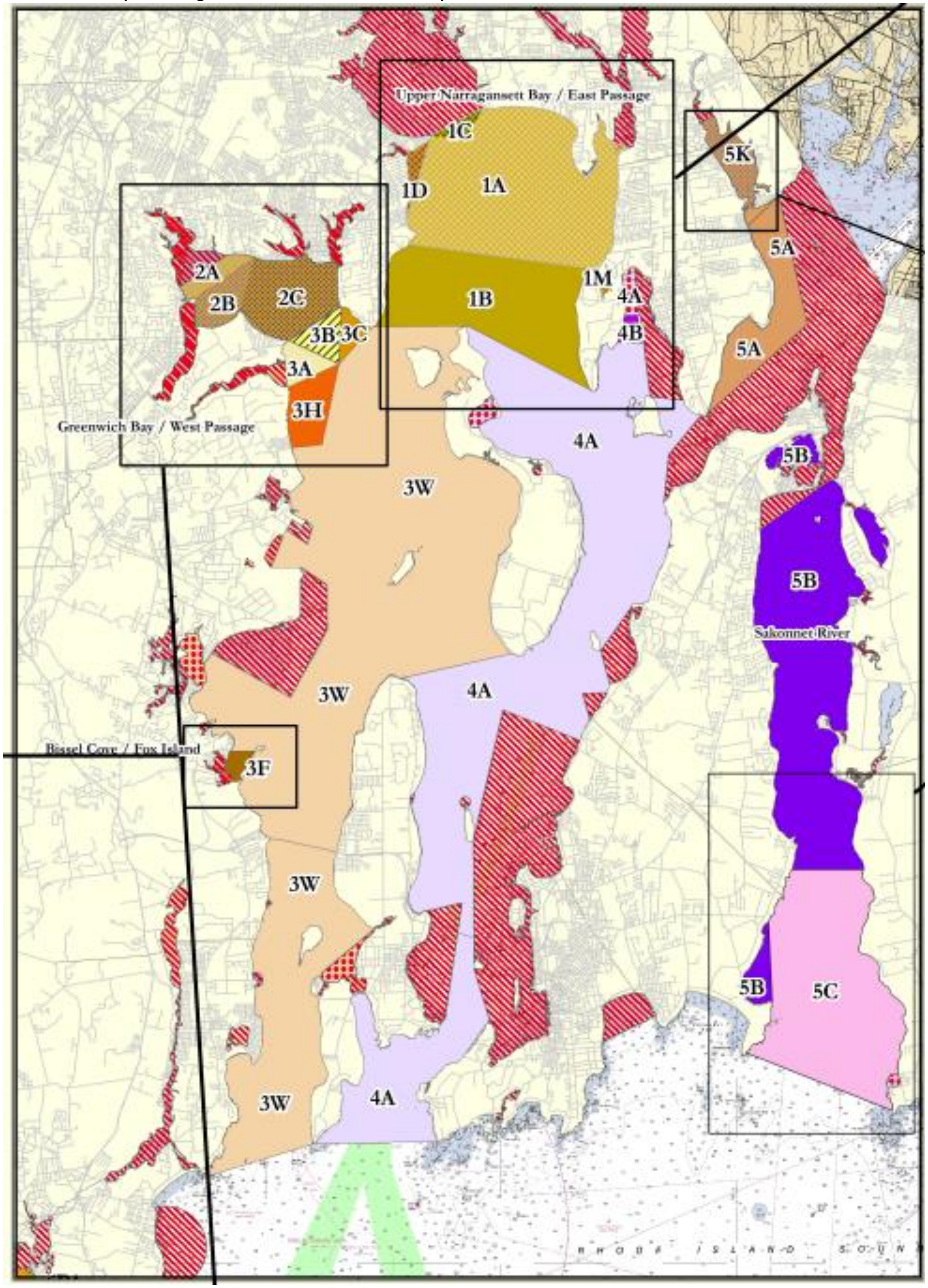


Figure 35. DEM shellfish tagging areas. All commercially harvested shellfish are tagged with a label corresponding to the area where they were harvested.



URI GSO Narragansett Bay Long-Term Plankton Time Series. Data on the abundance of larval shellfish can be found in URI GSO's Narragansett Bay Long-Term Plankton Time Series in the Middle West Passage. These data may be useful when comparing year to year variability in spawning and recruitment. For species without a long-term trawl survey data series, such as deckers, zooplankton data may be the only available sources of scientific information on abundance trends. In Appendix H, we present plots of larval abundance of deckers captured by the URI GSO Narragansett Bay Long-Term Plankton Time Series.

Mobile Invertebrates

Trawl Surveys. Finfish surveys such as the URI GSO Fish Trawl Survey and the DEM Coastal Trawl Survey are capable of capturing invertebrates such as lobsters, crabs, whelks, and starfish. These surveys are described in greater detail in the section on finfish. In Appendix H, we draw upon these surveys to visualize changes in the abundance of lobsters, blue crabs, horseshoe crabs, starfish, and whelks.

DEM Lobster Ventless Trap Survey. DEM has carried out a Lobster Ventless Trap Survey since 2006. This survey is designed to capture data on juvenile lobster abundance by placing traps on rocky substrates that are inaccessible to the DEM Coastal Fish Trawl. The ventless trap survey contains seven stations in Narragansett Bay, which are randomly sampled between June and August each year. Although the purpose of this survey is to collect data on lobsters, it also collects abundance data on a variety of other mobile benthic invertebrates. In Appendix H, we present Ventless Trap Survey data on lobsters, spider crabs, green crabs, starfish, blue crabs, and whelks.

DEM Juvenile Fish Seine Survey. DEM has carried out a Juvenile Fish Seine Survey since 1988, with the purpose of monitoring the relative abundance and distribution of juvenile commercial and recreationally important species. Seines are deployed from shore at 18 fixed stations within Narragansett Bay. In addition to counting juvenile fish by species, the survey records weather conditions, water temperature, dissolved oxygen, and salinity at each station. In Appendix H, we draw upon data from the Juvenile Fish Seine Survey to provide estimates of relative annual spider crab abundance in Narragansett Bay.

DEM Horseshoe Crab Survey. In DEM's annual Horseshoe Crab Spawning Survey, DEM scientists count spawning horseshoe crabs during the new and full moons of May along the beach at Conimicut Point. In Appendix H, we present annual maximum density values for horseshoe crabs, derived from DEM's Horseshoe Crab Spawning Survey.

DEM Blue Crab Dredge Survey. In 2021, DEM initiated a dredge survey for blue crabs, which is intended to start a long-term monitoring program for this species. While data from this new survey are not available to compare with interview data from the NB 2019, RF 2016, and SH

2014 projects, it will be available moving forward to fill data gaps on blue crab abundance in Narragansett Bay.

CFRF Jonah Crab and Lobster Research Fleet. The Commercial Fisheries Research Foundation (CFRF) has coordinated a cooperative research lobster and crab survey with commercial fishermen since 2013. The research fleet gathers data on biological parameters such as carapace length/width, sex, shell disease severity (lobster), shell hardness (hard/soft), presence or absence of eggs, presence of absence of v-notch, and disposition (kept or discarded). Spatial disaggregation of the data to the Narragansett Bay or within-bay level is complicated by the fact that collection takes place during fishermen's normal fishing operations, and thus disclosing the location of data collection would also disclose private information on fishing location. Additionally, fewer than three participants fish in Narragansett Bay, so their data is subject to the "rule of three" to protect harvester confidentiality.

DEM Shellfish Dredge Survey. Densities of channeled and knobbed whelk are collected in the DEM Shellfish Dredge Survey. This dataset is described above in the section on Sessile Benthic Invertebrates. In Appendix H, we present data on whelk density reproduced from Angell (2020).

DEM Shellfish Landings Data. Landings of channeled and knobbed whelk are collected in DEM's shellfish landings data, and organized by tagging area. This dataset is described above in the section on Sessile Benthic Invertebrates. In Appendix H, we present data on whelk density reproduced from Angell (2020).

Fouling Invertebrates

CRMC Aquatic Invasive Species Monitoring. The Rhode Island Coastal Resources Management Council (CRMC) conducts two invasive species monitoring programs annually: a survey of floating docks and a settlement plate survey. Both studies involve the collaboration of volunteers and scientists supervised by CRMC staff and are carried out at a range of sites both inside and outside the bay, chosen to represent broad geographic coverage and located along a salinity gradient. Both surveys utilize categorical rankings to estimate relative coverage by species. Although these studies are primarily oriented towards the goal of assessing invasive organisms, they also detect native fouling organisms.

Floating dock monitoring has taken place since 2009. Every four to five weeks during the growing season, volunteers inspect each site for one hour, noting the presence of known introduced species, any new introductions, and common members of the native fouling community.

Settlement plate monitoring has taken place since 2012. In this survey, small PVC settlement plates are attached to bricks and hung from floating docks. At each site, two plates are left in the water for a full growing season, while three others are replaced every four to six weeks in order to track in-season changes in settlement. Organisms that have settled on the plates are identified, photographed, and assigned categorical coverage rankings, as described in Table 17.

The CRMC is currently completing the final steps of a ten-year summary of the floating dock and settlement plate monitoring surveys (CRMC, in publication).

Table 17. Summary of CRMC's floating dock and settlement plate monitoring surveys.

	Floating Dock Monitoring	**Settlement Plate Monitoring**
Sampling season	April – October, with some years extending to November	April - October
Time series	Since 2009	Since 2012
Survey sites in Narragansett Bay	• Save the Bay docks • Allen Harbor Marina • Fort Adams • Melville Marina (since 2014) • Roger Williams University (prior to 2014) • Port Edgewood Yacht Marina (occasional) • Colt State Park (occasional)	• Save the Bay docks • Allen Harbor Marina • Fort Adams • Melville Marina • Roger Williams University (early years only) • URI Graduate School of Oceanography (early years only) • T-Wharf on Prudence Island (early years only) • Sakonnet Point Marina (early years only)
Categorical rankings	0: absent 1: rare (only one specimen found at site) 2: few (a few individuals found at site) 3: common (species if fairly well distributed or very common in one or two parts of the site) 4: abundant (species is found on all parts of the site and/or is dominant over most other species)	0: absent 1: rare or single occurrence 2: few, or less than a third of plate coverage 3: common, or a third to two-thirds plate coverage 4: abundant, with more than two-thirds coverage

Since their inception in 2009 and 2012, respectively, data from CRMC's floating docks and settlements plate surveys have been integrated into a larger regional invasive species monitoring effort called the Marine Bioinvasive Species Rapid Assessment Survey, which has taken place every two to six years since 2000. This effort, which is led by collaborators from universities and agencies across the region, tracks the distribution of non-indigenous and cryptogenic species from Maine to New York. Sites included from Narragansett Bay are listed in

Table 18. In Appendix H, we present presence data on a suite of non-indigenous and cryptogenic tunicate and hydroid species from Narragansett Bay sites in the 2010, 2013, and 2019 Bioinvasive Species Rapid Assessment Surveys.

Table 18. Sites sampled within Narragansett Bay as part of a recurring regional Bioinvasive Species Rapid Assessment Survey, 2000-2019.

Year(s)	Sites Surveyed in Narragansett Bay (Bay Segment)	Location of Data
2000, 2003, 2005, 2007	Narragansett Boat Club, Providence (Seekonk River); Bootleggers Marina, Providence (Providence River); Edgewood Yacht Club, Cranston (Providence River); Cove Haven Marina, Barrington (Bullocks Cove); Warwick Cove Marina, Warwick (Warwick Cove); Allen's Harbor Marina and Yacht Club, North Kingstown (Quonset Harbor); Wickford Marina, North Kingstown (Wickford Harbor); Fort Getty Park (Lower West Passage); Roger Williams University, Bristol (Mount Hope Bay); Battleship Cove, Fall River (Taunton River); Colt State Park, Bristol (Upper Bay); Potter's Cove, Prudence Island; (Tevharf Float, Prudence Island (Middle East Passage); Coasters Harbor Navy Yacht Club, Newport (Lower East Passage), Newport Shipyard, Newport (Newport Harbor)	Pederson *et al.* (2005) Mathieson *et al.* (2008 a,b)
2010	Allen's Harbor Marina, North Kingstown (Quonset Harbor); Fort Adams State Park, Newport (Lower East Passage); Kings Beach, Newport (Mouth of Narragansett Bay)	McIntyre *et al.* (2013)
2013	Port Edgewoord Marina, Cranston (Providence River); Allen's Harbor Marina, North Kingstown (Quonset Harbor); Fort Adams State Park, Newport (Lower East Passage)	Wells *et al*. (2013)
2019	Save the Bay docks, Providence (Providence River); Allen's Harbor Marina, North Kingstown (Quonset Harbor)	Pederson *et al.* (2021)

Seaweed/Macroalgae

Intermittent surveys. Compared to fauna and phytoplankton, quantitative macroalgal monitoring in Narragansett Bay is more limited (Harlin *et al.,* 1996, Raposa *et al.* 2011) and multidecadal time series are not available. However, several one-time and multi-year surveys have been conducted. In chronological order, these include:

- Wood and Hargraves (1969) led a SCUBA quadrat survey in six aquatic environments in Rhode Island, including two sites within Narragansett Bay: Fort Kearney / URI GSO Bay Campus (Lower West Passage) and Quahaug Rock / Black Point, Narragansett (Mouth of Narragansett Bay). Sites were sampled periodically between June 1963 and August 1965. Species present were identified, counted, measured, weighed, and analyzed for nitrogen content.

- Brady-Campbell *et al.* (1984) assessed kelp (*Saccharina latissima)* abundance in 1980 two sites: Land's End (Mouth of Narragansett Bay) and Fort Wetherhill (Lower East Passage). Feehan *et al.* (2019) repeated the same survey in 2018 to test for change over time. Data from these two studies are presented in Appendix H.
- Peckol *et al.* (1988) tracked populations of rockweed (*Ascophyllum nodosum*) from September 1983-February 1984 in an unnamed cove near Newport, in order to evaluate growth and survivorship of intertidal and subtidal plants.
- A 1989-1990 inventory by French *et al.* (1992) counted 97 species of macroalgae in Narragansett Bay.
- Harlin and collaborators assessed six macroalgal species (*Saccharina latissima*, *Chondrus crispus*, *Codium fragile*, *Fucus spp*., *Ascophyllum nodosum*, and *Ulva spp.*) at 54 stations in Narragansett Bay and adjoining waters during one week of spring low tides in the early 1990s, to offer an instantaneous assessment of percent cover by each species at each station. They also monitored 10 additional stations over four seasons (1989-1990), where they recorded 94 macroalgal species (Harlin and Rines 1993; Harlin *et al.* 1996; Villalard-Bohnsack and Harlin 1992).
- The Narragansett Bay Estuarine Research Reserve (Raposa *et al.* 2011) conducted a proof-of-concept survey along the shores of Prudence Island in 2009-2010, with the purpose of developing protocols for a rapid macroalgae assessment that could eventually be expanded to the whole bay.
- Since 2005, Carol Thornber and colleagues at URI have conducted monthly or bimonthly ground surveys of macroalgae in and around Greenwich Bay. Ground surveys include a quadrant study on the beach to measure percent cover and species composition, as well as sample collection in shallow water (<1m deep) to analyze species composition. The Greenwich Bay area was selected because of high public interest in using the beaches for recreational purposes and the frequent occurrence of macroalgal blooms. These surveys are currently paused due to lack of funding.
- From 2007 to 2012, between May and October each year, the Carol Thornber lab coordinated a monthly aerial survey of macroalgae along the upper and western portions of Narragansett Bay, including portions of the Providence River, Upper Bay, Greenwich Bay, Warwick Cove, Buttonwoods Cove, Apponaug Cove, Greenwich Cove, Potowomut River, Upper West Passage, Middle West Passage, Wickford Harbor, and Lower West Passage. Aerial photographs were recorded every ten seconds, tagged with the GPS locations of each image, and later processed and visually analyzed for ordinal density classification of Chlorophyta, Rhodophyta, and Phaeophyceae on a scale from 0 (absent) to 4 (very dense). Within three days of each trip, ground-truthing surveys were conducted at low tide at up to 17 sites spread across the aerial trackline, and dominant species at each site were photographed, recorded, and if necessary, identified in the lab through a thorough morphological examination.
- Guidone and Thornber (2013) conducted monthly surveys of *Ulva spp*. from May–September 2009 and February-May 2010 at four sites: Brushneck Cove (Buttonwoods Cove), Chepiwanoxet (Western Greenwich Bay), URI GSO Lower West Passage), and Pier

5, Narragansett (Mouth of Narragansett Bay). Monthly surveys were subsequently continued at two bloom-impacted sites from June 2010 to November 2011.
- In 2018-2019, the Carol Thornber lab at URI assessed kelp and rockweed abundance using video surveys and SCUBA at 24 sites.
- In 2019, Green-Gavrielidis *et al.* surveyed 5 sites within Narragansett Bay to evaluate presence of the invasive sea potato *Colpomenia peregrina*. These sites were located in the Upper Bay, Greenwich Bay, Middle West Passage, Lower West Passage, and Lower East Passage. The research team detected the presence of *C. peregrina* only at the sites in the Lower West Passage and Lower East Passage.

CRMC Aquatic Invasive Species Monitoring. The Rhode Island Coastal Resources Management Council (CRMC) conducts two invasive species monitoring programs annually: a survey of floating docks and a settlement plate survey. Although these studies are primarily oriented towards the goal of assessing invasive organisms, they also detect native fouling organisms, including seaweeds. More information about CRMC's Aquatic Invasive Species Monitoring program, and the regional Marine Bioinvasive Species Rapid Assessment Survey that integrates data from the CRMC program approximately every two to six years, is presented in the section on Fouling Invertebrates, above. In Appendix H, we present presence data on a suite of non-indigenous and cryptogenic macroalgae species from Narragansett Bay sites in the 2010, 2013, and 2019 Marine Bioinvasive Species Rapid Assessment Surveys.

Submerged Aquatic Vegetation

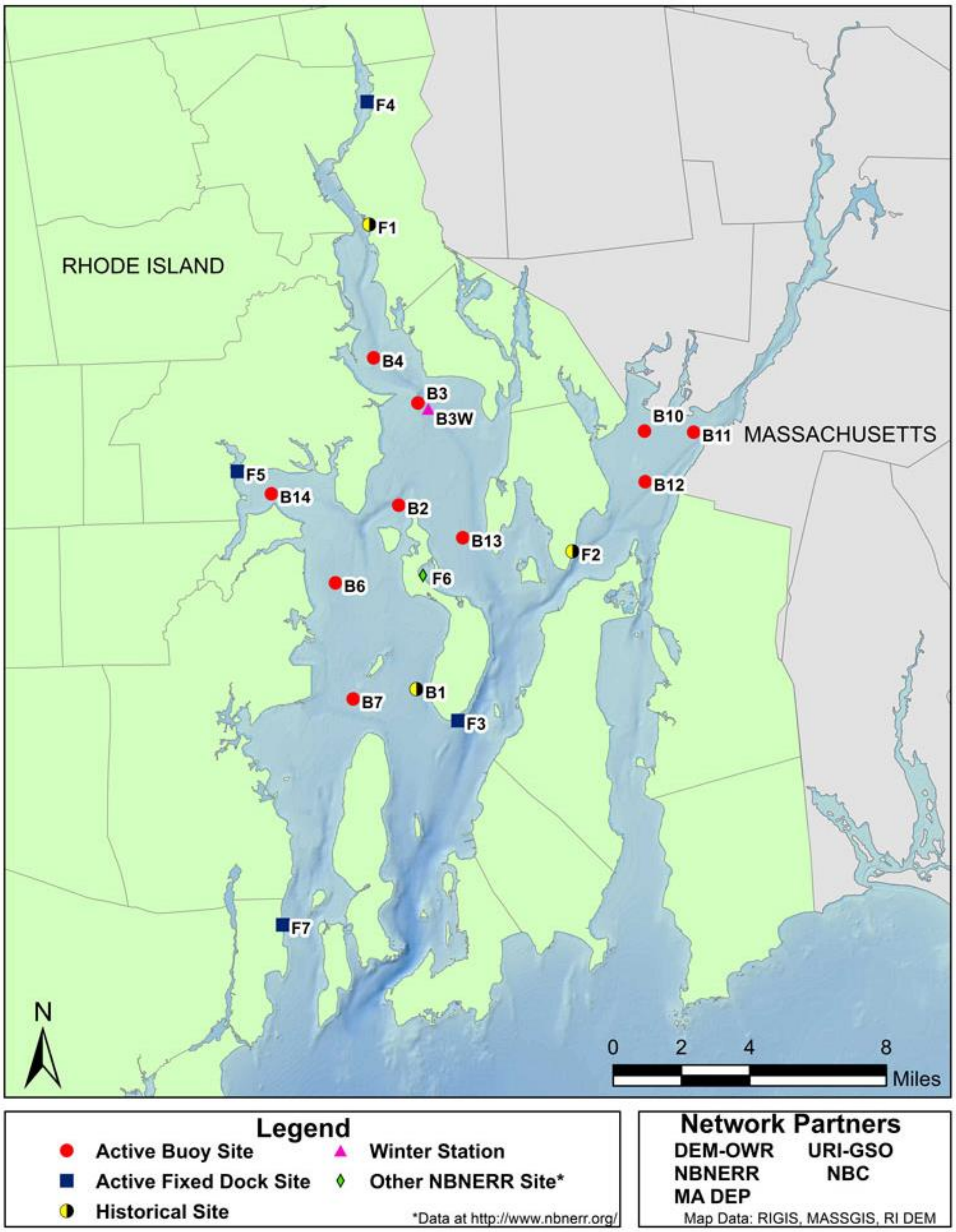
Aerial Surveys and Ground-truthing. The NBEP led an aerial survey of eelgrass coverage in 1996. Subsequently, various partners under the umbrella of the Eelgrass Mapping Taskforce (CRMC, Save the Bay, Narragansett Bay National Estuarine Research Reserve) conducted surveys in 2006, 2012, and 2016. These three more recent surveys included aerial surveys ("Tier 1") as well as field-based rapid assessment monitoring ("Tier 2") and intensive monitoring ("Tier 3") at two locations: Fort Getty (Lower West Passage) and T-Wharf on Prudence Island (Middle East Passage).

Underwater Surveys. In 2020, the Naval Undersea Warfare Center (NUWC) Division Newport began sonar-based eelgrass survey in the Stillwater Basin area, near Division Newport's waterfront range. Results were ground-truthed using divers.

Plankton

Narragansett Bay Fixed Site Monitoring Program. The Narragansett Bay Fixed Site Monitoring Program is a joint effort of the DEM Office of Water Resources and a number of collaborating agencies. The program deploys a network of buoys placed at 15 stations during the summer months and 4 stations year-round to collect continuous information on chlorophyll as well as temperature, salinity, dissolved oxygen, and pH. The stations, shown in Figure 36, are located strategically to transect the length of the bay and serve as sentinels of changing conditions. The greatest concentration of sites is located in the upper part of the bay to capture information on the discharges from both wastewater treatment facilities and large tributary rivers. The program began in 2004 with 9 stations and has grown steadily since then as additional partner agencies have become involved.

Figure 36. Narragansett Bay Fixed Site Water Quality Monitoring Network locations.



URI GSO Narragansett Bay Long-Term Plankton Time Series. The URI GSO Narragansett Bay Long-Term Plankton Time Series collects direct counts of phytoplankton samples as well as data on temperature, salinity, turbidity, chlorophyll *a,* and nutrients. These collections have been made weekly since 1959 at a station near Wickford (41°34.2′ N, 71°23.4′ W) in the Middle West Passage. URI GSO also conducts weekly zooplankton monitoring at the same station, and samples of zooplankton are taken back to the lab for counting and identification. The modern GSO zooplankton count dates to 2001. A previous zooplankton count (using slightly different methods) was carried out by GSO between 1972 and 1997. The zooplankton survey counts copepods, larvae, and gelatinous zooplankton such as the ctenophore *Mnemiopsis leidyi*. In Appendix H, we draw on the URI GSO Narragansett Bay Long-Term Plankton Time Series to present a time series of chlorophyll concentrations and zooplankton densities.

Narragansett Bay Commission Phytoplankton Monitoring. The Narragansett Bay Commission has collected phytoplankton samples every two weeks at its Bullocks Reach (Providence River) fixed site monitoring station since 2012. In Appendix H, we draw upon data from the Narragansett Bay Commission Phytoplankton Monitoring program to show densities of phytoplankton from 2012 to 2019.

The Finfish Community

URI GSO Fish Trawl Survey. The longest running time series on finfish in Narragansett Bay is the Fish Trawl Survey conducted by URI GSO, which has collected data weekly since 1959. Data are collected at two sites: Fox Island (41°34.5′ N, 71°24.3′ W) and Whale Rock (41°26.3′ N, 71°25.4′ W), enabling comparison of a site in the Middle West Passage with a site at the Mouth of Narragansett Bay. The GSO Fish Trawl Survey collects data on finfish, invertebrates, surface and bottom temperature, dissolved oxygen, and salinity at each survey site, as well as total length measurements and sex determination of winter flounder. In Appendix H, we draw upon the URI GSO Fish Trawl Survey to visualize changes over time in the abundance of several finfish species in the Middle West Passage.

DEM Fish Surveys. DEM collects finfish data through a Seasonal Coastal Trawl Survey (since 1979), a Monthly Coastal Trawl Survey (since 1990), a Narragansett Bay Seine Survey (since 1988), a Menhaden Monitoring Program (since 2008), and a Fish Pot Survey. Details on each survey are presented below.

The Coastal Trawl Survey's purpose is to provide fisheries independent data for a comprehensive resource assessment of finfish and crustaceans in state waters. The Seasonal Coastal Trawl Survey samples 12 monthly stations as well as an additional 14 randomly chosen stations in Narragansett Bay and 18 fixed stations in Rhode Island Sound and Block Island Sound. The Monthly Coastal Trawl Survey monthly survey samples 13 fixed stations distributed throughout Narragansett Bay. Station locations are shown in Figure 37. In Appendix H, we draw about the DEM Coastal Trawl Survey to visualize changes in abundance of a suite of commercial and non-commercial finfish in Narragansett Bay.

The Narragansett Bay Juvenile Fish Seine Survey's purpose is to monitor the relative abundance and distribution of the juvenile life history stage of commercial and recreationally important species. Seines are deployed from shore at 18 fixed stations within the bay. In addition to counting juvenile fish by species, the survey records weather conditions, water temperature, dissolved oxygen, and salinity at each station. Station locations are shown in Figure 38.

The Menhaden Monitoring Program tracks the biomass and distribution of Atlantic menhaden within Narragansett Bay by combining data from floating fish traps, landings, and aerial surveys. This data is used to open and close the menhaden fishery.

The Fish Pot Survey utilizes ventless fish pots to assess and standardize a time series of relative abundance for structure-oriented finfish (e.g., scup, black sea bass, tautog) in Narragansett Bay. Pots are set monthly at randomized stratified locations throughout the bay between April and October each year. The Fish Pot Survey has been conducted seasonally since 2013.

Mount Hope Bay Survey. Normandeau Associates operated a trawl survey in Mount Hope Bay in conjunction with the operation of the New England Power Brayton Point Station in Somerset, MA, which operated between 1963-2017. A standard trawl setup was used to monitor 6 fixed stations from 1972-2014. From 1996-2016, a second survey using a Wilcox trawl setup was used to monitor an additional 12 stratified random stations.

Birds

EPA Winter Waterfowl Survey. The EPA's winter waterfowl survey takes place on a single day each January, when six teams of volunteers visit 67 sites around the bay to count waterfowl from shore. The EPA survey has been taking place since 2005. Site locations are shown in Figure 39. In Appendix H, we present data from the EPA Winter Waterfowl Survey to visualize trends in cormorant abundance in Narragansett Bay.

Mammals

Save the Bay Seal Count. Long-term data on seal abundance is collected by Save the Bay and its network of volunteers in collaboration with EPA's Atlantic Ecology Division and the Narragansett Bay Estuarine Research Reserve. Save the Bay conducts two types of survey: an annual bay-wide seal count (since 2009), which takes place on one day per winter, and a seasonal monitoring survey (since 1994) that surveys certain sites regularly over the course of the seal season.

The bay-wide count takes place on a day with good weather at low tide around the peak of seal season (late March – early April). This spatially expansive and temporally limited survey produces an indicator of the minimum number of the seals present in the bay (not including those in the water), without duplication. The 2019 seal count visited 25 haul-out sites around the bay. Sites used for the bay-wide count are shown in Figure 40. In Appendix H, we present data from the bay-wide to visualize trends in seal abundance in Narragansett Bay.

The seasonal survey focuses on haul-out sites that are consistently accessible to volunteers and are regularly used by seals, such as Church Cove, Brenton Point, and Rome Point. This survey takes place regularly or daily at these locations from September to May in order to capture changes in abundance over the entire seal season.

Figure 37. Locations of DEM Coastal Trawl Survey stations: monthly (red) and seasonal (green).

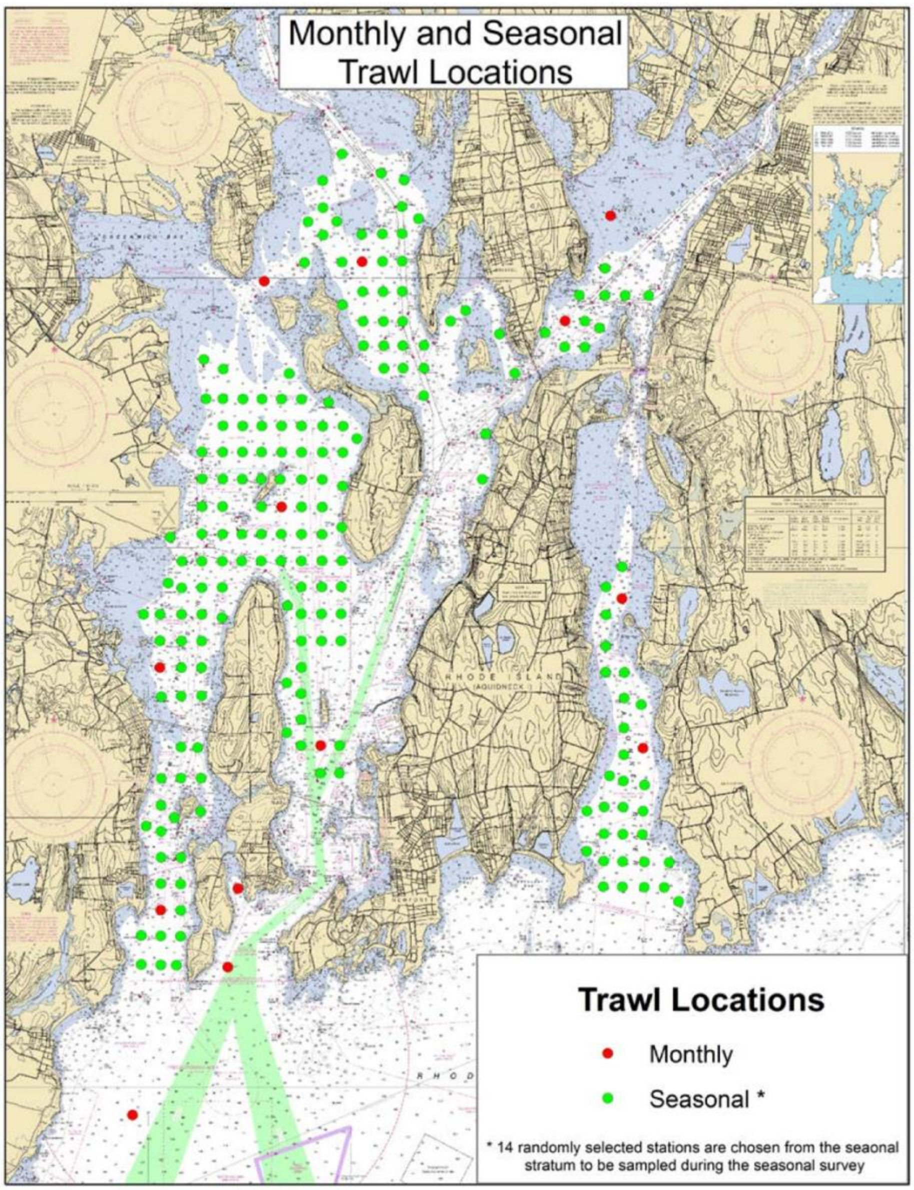


Figure 38. DEM Narragansett Bay Juvenile Finfish Seine Survey stations.

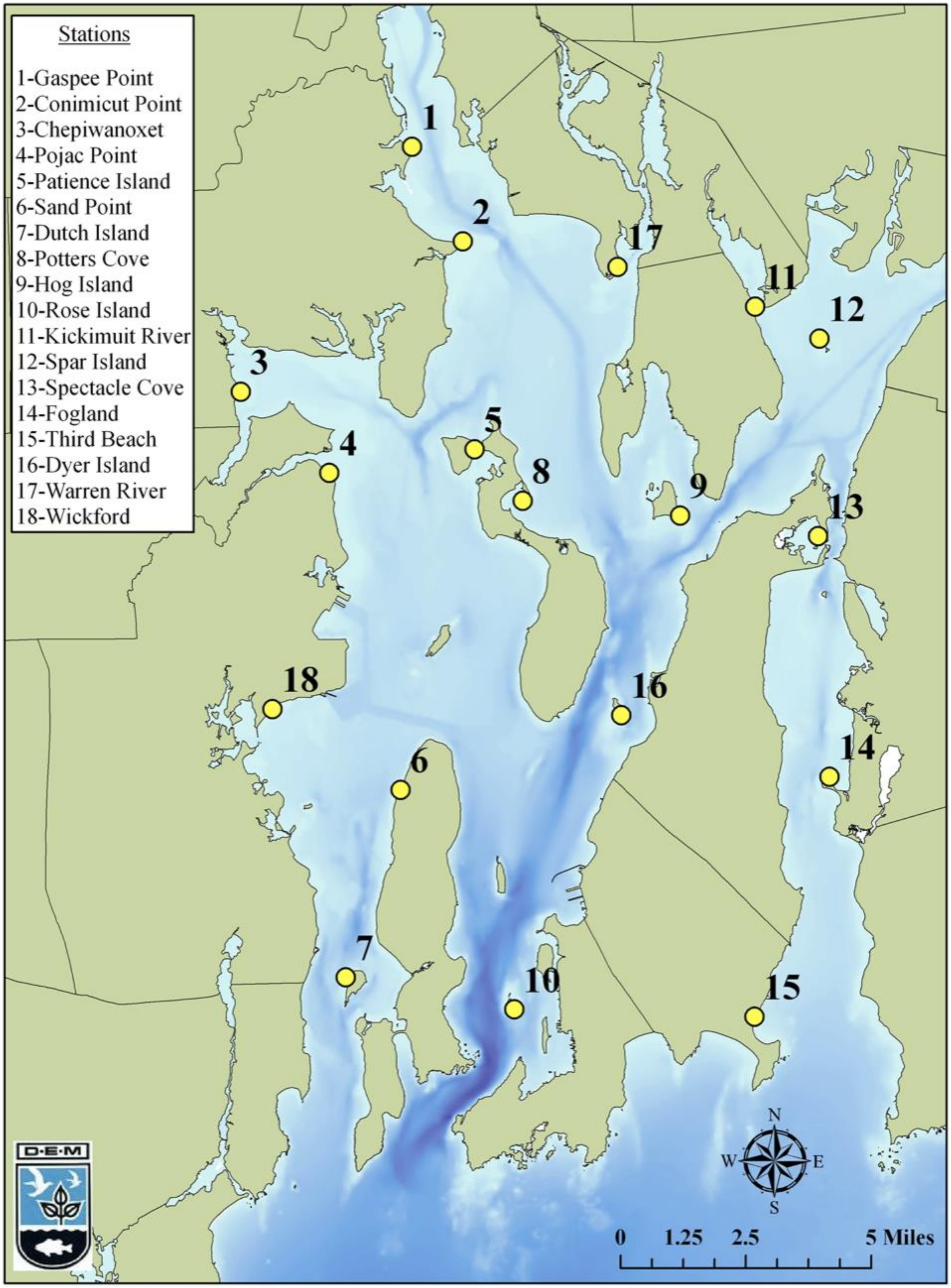


Figure 39. EPA Winter Waterfowl Survey sites (black dots). Reproduced from Kreakie *et al*. (2015).

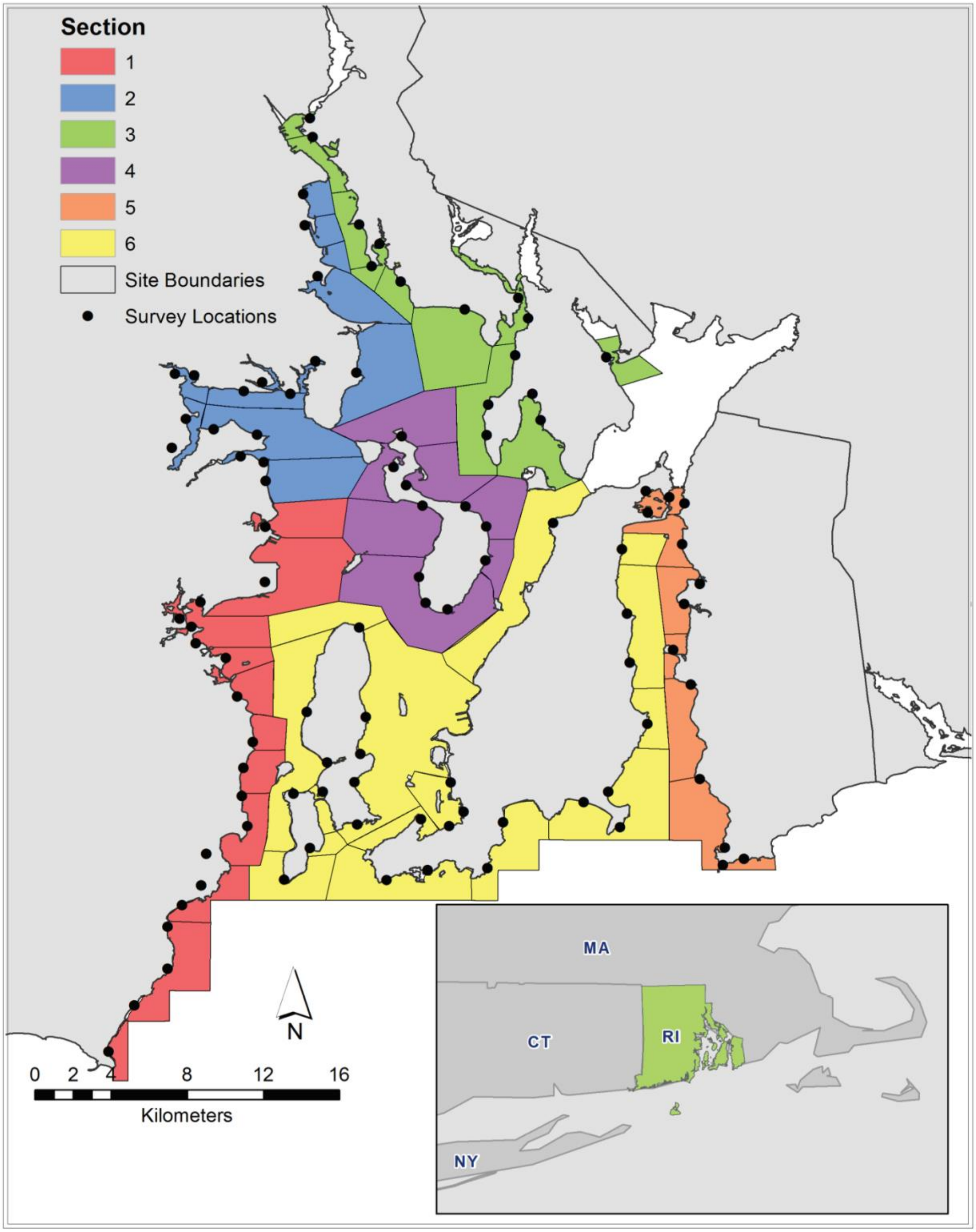
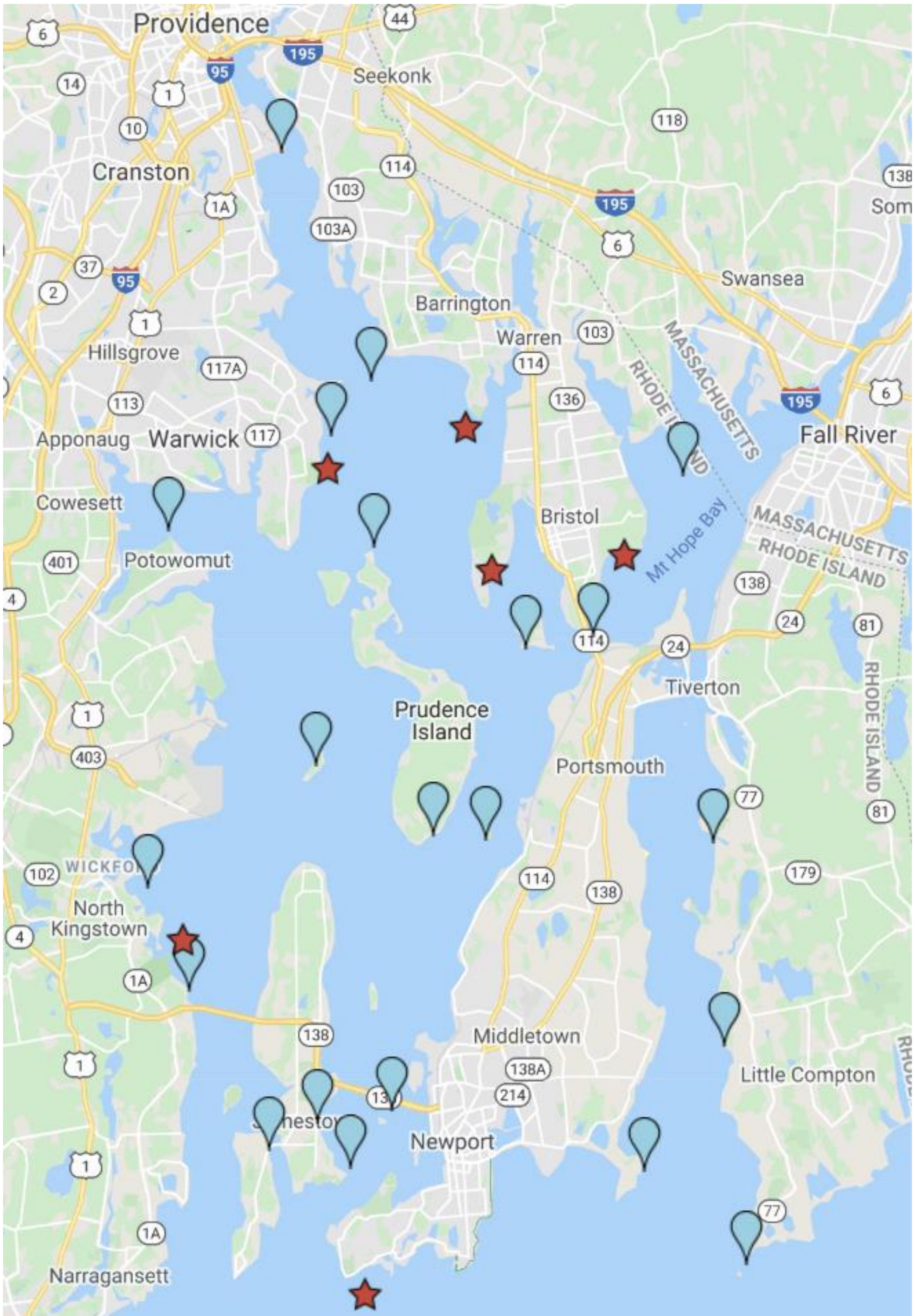


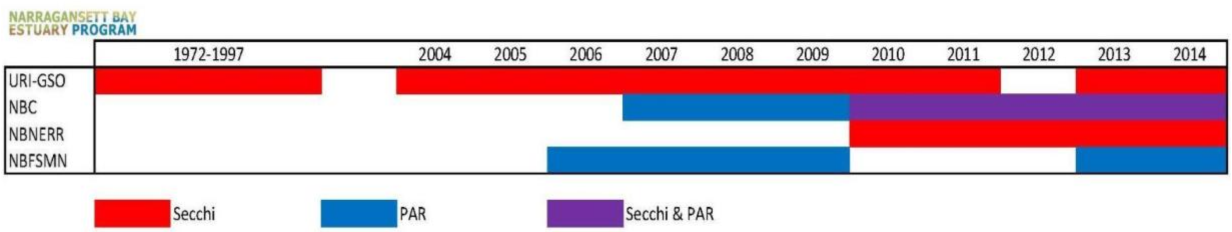
Figure 40. Sites monitored by Save the Bay's annual citizen science seal count (reproduced from Save the Bay 2019). Blue balloons and red stars were utilized in the original to represent sites corresponding to different data displays in their report. For the purposes of the present report, there is no difference in the meaning of these symbols.



Abiotic Factors

Water clarity. Water clarity data is collected in Narragansett Bay using two different methods: (1) Secchi disk readings and (2) underwater light-meter measurements of photosynthetically active radiation (PAR). Secchi disk measurements are taken by lowering a disk through the water column by a rope or chain; the depth at which the disk or disk definition is no longer visible to the human eye is taken as a measure of the transparency of the water. Secchi disk readings do not provide an exact measure of water clarity, as there can be errors and subjectivity. In contrast, underwater light meters make it possible to precisely quantify the PAR available at particular depths in the water column. Both types of measurements can be converted to light extinction coefficients, *k*, to provide a standard metric of water clarity. Clear water has a low *k*, and turbid water has a high *k*.

Figure 41. Summary of water clarity data sources *used in the NBEP's State of Narragansett Bay and Its Watershed (NBEP 2017a), showing temporal coverage. Sampling methods include Secchi disk (red), photosynthetic active radiation (PAR, blue), or both (purple). Datasets include the University of Rhode Island Graduate School of Oceanography (URI-GSO), Narragansett Bay Commission (NBC), Narragansett Bay National Estuarine Research Reserve (NBNERR), and Narragansett Bay Fixed Site Monitoring Network (NBFSMN).*



In Narragansett Bay, water clarity data is regularly collected by the following survey programs:

University of Rhode Island's Graduate School of Oceanography (URI-GSO) Phytoplankton Survey:
Website: https://web.uri.edu/gso/research/plankton/ (1998 to present); https://www.nabats.org/nabats-data.html (prior to 1998)
Years Available: 1972-1997; 1998-present
Type: Secchi
Description: Since 1959, the University of Rhode Island – Graduate School of Oceanography has maintained a phytoplankton survey time series in the West Passage of Narragansett Bay. They collect phytoplankton and environmental data, including water clarity, weekly from the same location.

Narragansett Bay Commission (NBC):
Website: http://snapshot.narrabay.com/app/WaterQualityInitiatives/WaterClarity
Years Available: 2010-present
Type: PAR and Secchi; PAR meter is down currently, so most recent data (2019-2020) is

Secchi only
Description: The Narragansett Bay Commission operates the two largest wastewater treatment facilities in Rhode Island. They also routinely take environmental data to support their efforts to reduce nutrient and bacterial pollution from wastewater. The water clarity data focus on the Providence-Seekonk River Estuaries. The data are collected monthly during the fall, winter, and spring, and weekly during the summer.

Narragansett Bay National Estuarine Research Reserve (NBNERR):
Website: none available; contact NBNERR directly
Years Available: 2010-present
Type: Secchi
Description: NBNERR collects Secchi depth measurements at two stations on Prudence Island. They collect data year-round, approximately twice per month. NBNERR also participates in the Narragansett Bay Fixed Site Monitoring Network using the T-Wharf station, and provides additional nutrient and environmental data to a NERR network through their central data management organization.

Narragansett Bay Fixed Site Monitoring Network (NBFSMN):
Website: http://www.dem.ri.gov/programs/emergencyresponse/bart/netdata.php
Years Available: 2006-2009; 2013-2019
Type: PAR
Description: The NBFSMN maintains PAR data at all buoy sites. Data were collected mostly during June through September twice per month. Certain years do have more PAR data, and Secchi depth information. Additional data are collected through this network as well, including chlorophyll fluorescence and dissolved oxygen concentrations

Other sources of water clarity data include: URI's Watershed Watch, the EPA's National Coastal Conditions Assessment, the EPA Atlantic Environmental Science Division's Bay Ecosystem Time Series initiative, and remote sensing data.

In Appendix H, we present water clarity findings compiled by the NBEP for the 2017 *State of Narragansett Bay and Its Watershed*. It is important to note that the data used by NBEP were collected mostly in the mainstem of the bay. Small coves and embayments do not have as much coverage in terms of water clarity data.

ANALYSIS PART III. HOW CAN FISHERMEN'S KNOWLEDGE AND OBSERVATIONS HELP FILL GAPS IN SCIENTIFIC MONITORING?

The previous section presented an exhaustive overview of scientific monitoring programs covering sessile benthic invertebrates, mobile benthic invertebrates, fouling invertebrates, macroalgae/seaweed, submerged aquatic vegetation, plankton, finfish, birds, mammals, and water clarity. In contrast, the 37 interviews conducted with 26 individuals summarized in the first part of this report do not constitute an *exhaustive* summary of fishermen's ecological knowledge on these taxa. To accomplish such a goal, we would need to interview all commercial fishermen who utilize Narragansett Bay as a workplace. Nonetheless, this interview data represents a modest indicator of the species, spatial, and temporal coverage that we might expect to see if we fully cataloged the ecological knowledge possessed by Narragansett Bay commercial fisherman. As such, it provides clues into how FEK might be able to help fill existing gaps in scientific monitoring coverage in Narragansett Bay.

Appendix I presents a series of side-by-side comparisons of scientific monitoring programs with fishermen's knowledge in terms of species, spatial, and two types of temporal coverage (longitudinal and seasonal). The purpose of these tables is to help identify gaps in scientific monitoring that fishermen's knowledge might be able to help fill, particularly if a more robust program is developed to collect this knowledge over time. In the paragraphs that follow, we highlight some of these gaps and reflect on the value of fishermen's ecological knowledge to help fill them.

Sessile Benthic Invertebrates

<u>Species gap: deckers.</u> To our knowledge, no data is currently collected on the abundance and distribution of deckers in Narragansett Bay. Since this species is rarely if ever landed commercially, it does not show up in landings data, and the DEM Shellfish Dredge Survey does not collect data on deckers as bycatch. Given the high frequency of observations related to deckers by fishermen interviewed for this project (quahoggers provided 11 observational statements pertaining to deckers), and the scientific evidence suggesting this species is likely to thrive in a changing climate (see Analysis Part IV). This is a potentially important data gap that fishermen's observations may be able to help fill.

<u>Species gap: mussels, soft shell clams, oysters, bay scallops</u>. No fisheries-independent monitoring of mussels, soft shell clams, oysters, and bay scallops takes place in Narragansett Bay. Since the only source of data on these populations derives from landings records, data is only available for times and places where these species have been present in large enough abundances to be harvested and where fishermen have chosen to harvest them. Unsold incidental catches, which go unreported, may present a useful additional source of information, particularly for species such as bay scallops where a small uptick in abundance may be of interest to the scientific community. Quahoggers provided a total of 58 observational

statements on these species combined, lobstermen provided 9 observational statements on mussels, and aquaculture farmers provided 4 statements on bay scallops. All three types of fishermen appear poised to provide insights into these species to fill any potential gaps in scientific monitoring that may exist. Bay scallops may be of particular interest as a subject for a fisherman monitoring program, since they are a relatively rare species that is often considered an indicator of ecological health.

Spatial gap: East Passage and small embayments. The DEM Shellfish Dredge Survey only samples specific strata, mostly located in the northern half of Narragansett Bay. By and large, these sampling strata correspond to the areas where quahogs are present in sufficient densities for harvest, and therefore, it is unlikely that fishermen would possess many observations pertaining to areas outside the sampling strata. However, there may be exceptions to this generalization. For example, small embayments, like the Kickemuit River, Wickford Harbor, and The Cove in Portsmouth, are not sampled by the dredge survey, and specific fishermen who fish in these areas may be able to fill gaps in knowledge about quahog abundance there. In addition, the DEM Shellfish Dredge Survey does not sample the Middle East Passage and Lower East Passage.

Mobile Invertebrates

Species: starfish. Interviewees made 19 observational statements regarding starfish, yet starfish are tracked by only two scientific monitoring efforts: the URI GSO Fish Trawl Survey, which samples only the Middle West Passage, and the DEM Ventless Trap Survey, which covers the Upper Bay, East Passage, and West Passage. Since starfish are encountered by all types of fishermen, this species represents low-hanging fruit that could be incorporated into a fishermen-led monitoring program to complement the slim levels of scientific monitoring that take place for this species. Given this species' current scarcity, it would be fairly easy for fishermen to begin to track them.

Species: urchins. There is no scientific monitoring of sea urchin populations in Narragansett Bay. Although only two fishermen mentioned catching sea urchins (as an incidental catch in lobster pots) and this species does not appear to be common in Narragansett Bay, its rarity makes it particularly conspicuous to fishermen when they do encounter it. If sea urchins can be considered a useful ecological indicator species, then fishermen's observations may be able to provide useful information on their occasional occurrence.

Spatial: Greenwich Bay, smaller embayments, Mouth of Narragansett Bay. Scientific monitoring tends to be concentrated in open waters that are accessible by boats large enough to pull a dredge or a trawl. While the DEM Narragansett Bay Juvenile Fish Survey and the DEM Coastal Trawl Survey each sample some of Narragansett Bay's smaller embayments, the coverage of these areas is not as high as other areas. None of the trawl or seine surveys samples Greenwich

Bay or the Mouth of Narragansett Bay. Targeted programs in collaboration with fishermen who work in these areas might help fill some of these spatial gaps.

Fouling Invertebrates

Species: barnacles and other native fouling invertebrates. The CRMC floating docks and settlement plate surveys primarily monitor the presence and distribution of invasive fouling organisms. There are no dedicated scientific monitoring programs in Narragansett Bay that track populations of native fouling organisms, such as barnacles and sea grapes (*Molgula manhattensis*). Lobstermen and aquaculture growers in particular, with their fixed pots/cages, buoys, and lines, are well positioned to capture data on fouling organisms, both native and invasive. These fishermen reported observations on barnacles, tunicates, and hydroids. While they did not name any sponges or bryozoans in their recollections, it is likely that with proper training they could also be relied upon to track changes in these species as well. Aquaculture growers may remove and clean their cages multiple times per season using a variety of different cleaning methods, while lobstermen typically pressure-wash their pots once at the end of the season. Cleaning methods and frequencies should be taken into account in the design of any research protocols analyzing fouling coverage of these surfaces. A useful model can be found in the Salem Sound Coastwatch's Marine Invasive Species Benthic Fouling Study (Hobbs and Azadan 2010).

Spatial: open water areas, at depth, and other unsampled sites. The CRMC floating docks and settlement plate surveys focus on organisms on or near water's surface and close to shore, and only at four regular sites within Narragansett Bay. With their fixed pots/cages, buoys, and lines, which cover every depth from surface to benthos in locations all over Narragansett Bay, lobstermen and aquaculture farmers may be able to help fill these gaps.

Seaweed/Macroalgae

Due to the lack of a fully funded long-term macroalgae monitoring program in Narragansett Bay, sampling has been intermittent and often spatially limited. Through collaboration with trained scientists, fishermen may be able to contribute useful data to help fill this gap. Since there is no comprehensive long-term macroalgae monitoring in place for Narragansett Bay, it is difficult to identify specific gaps that fishermen's knowledge can help fill. Instead, we suggest that fishermen can partner with scientists to plan and execute a comprehensive long-term macroalgae monitoring plan for Narragansett Bay.

However, translating fishermen's knowledge of macroalgae into terms that can be readily integrated into scientific monitoring is not straightforward, because of the lack of a common lexicon for naming different taxa and the difficulty of distinguishing among similar taxa using the naked eye. Another difficulty is that when fishermen collect seaweed in their gear, they do not know whether it was attached or drifting when it entered their gear, and thus, they cannot pinpoint its point of origin. These challenges can be overcome through a detailed planning process co-led by fishermen and scientists.

In conclusion, the potential to integrate data or sample collection into fishermen's harvesting activities seems promising, and fishermen's recollections of macroalgae abundances and distributions may help backfill scientific understandings of how this component of the Narragansett Bay ecosystem has changed over time.

The Finfish Community

Species: seahorses. Although seahorses are bony fish, they are distinct in many ways from the other members of this category. Seahorses are a minor component of Narragansett Bay fauna and they are not typically caught in fisheries surveys. However, they are caught from time to time in fishing gear, especially in the southern reaches of the bay. As with sea urchins, it is worth exploring whether seahorses may be a valuable indicator species whose rareness makes them notable. If so, perhaps fishermen's observations may be able to provide new data on the presence of this rare species in Narragansett Bay.

Spatial: embayments. Finfish monitoring tends to be concentrated in open waters that are accessible by boats large enough to pull a trawl. While the DEM Narragansett Bay Juvenile Fish Survey and the DEM Coastal Trawl Survey each sample some of Narragansett Bay's smaller embayments, the coverage of these areas is not as high as other areas. Moreover, none of the trawl surveys samples Greenwich Bay or the Mouth of Narragansett Bay. Targeted programs in collaboration with fishermen who work in these areas might help fill some of these spatial gaps.

Birds

Seasonal: spring, summer, fall. Although only two fishermen mentioned birds (the species was cormorants in both cases), it seems that fishermen might potentially be able to fill gaps in waterbird monitoring if given proper training and direction. The EPA Winter Waterfowl survey is spatially comprehensive, but it offers only a single snapshot in time, by surveying birds once per year in January. With proper training, commercial fishermen might be able to gather data on seasonal waterbird use of Narragansett Bay throughout the year, providing valuable insights into changes in migratory timings and other aspects of interest.

Mammals

Seasonal: spring, summer, fall. As with birds, there is only one ongoing scientific monitoring program that tracks mammal usage of Narragansett Bay (Save the Bay's annual seal count and haul-out survey), and it takes place in the winter when seals are most prevalent. With proper training, commercial fishermen might be able to gather data on seasonal seal use of Narragansett Bay in other seasons, providing valuable insights into changes in migratory timings and other aspects of interest. In fact, the earliest scientific data on seal abundance in Narragansett Bay from 1966-1974 (described in Schroeder 2000) were recorded by the captain of the URI research trawl vessel, who counted seals hauled out at Rome Point (Kenney, personal communication).

ANALYSIS PART IV. COMPARING FISHERMEN'S OBSERVATIONS TO SCIENTIFIC MONITORING: WHERE DO THEY ALIGN AND DIFFER?

The purpose of this section is to compare environmental data collected by scientific monitoring programs to the observations shared by fishermen in the NB 2019, SH 2014, and RF 2016 interviews, in terms of *what these data show*. For example, for species that both fishermen and scientists have observed, have the two groups typically perceived *similar* ecological patterns, or have they perceived *different* patterns? In cases where they see *different* patterns, what might explain these differences? We focused our comparison on species for which fishermen interviews resulted in 10 or more observational statements.

This exercise was meticulous, but also subjective. Subjective interpretation was necessary for several reasons. First, both scientific monitoring and fishermen's observations tell mixed stories; neither paints a uniform picture. For example, different fishermen may have provided slightly different observations about a single species or place. The lack of internal uniformity *within* each body of knowledge makes it difficult to make precise comparisons *between* the two bodies of knowledge.

Second, fishermen's observations were usually phrased in unilinear fashion (partly as an artefact of the interview structure), while scientific datasets typically showed considerable variation across time. The vagary of fishermen's temporal descriptions made it difficult to select specific years of scientific data with which to compare these descriptions.

Third, the spatial delineations of fishermen's observations varied from individual to individual. On top of this, there was sometimes a mismatch of scales between fishermen's observations and scientific monitoring surveys, with fishermen more likely to spatially link their observations to bathymetric features or nearby landmarks and scientific surveys more likely to collect and present data randomly within a grid structure.

We dealt with these challenges in several ways. To overcome spatial mismatch as much as possible, we grouped scientific data in ways that aligned with the spatial delineation of fishermen's observations, or vice-versa. When interpreting fishermen's and scientific observations in terms of trend type for a given species, we inferred a "dominant" trend type for each body of knowledge that could be compared to a "dominant" trend type from the other body of knowledge. For fishermen's knowledge, this was the trend type described by the largest number of respondents for a particular population, while for scientific datasets, it was the direction that a particular population trended on balance over the time series or relevant portion thereof. In sum, by incorporating a certain degree of simplification into our interpretations, we were able to draw rough comparisons between fishermen's observations and the data derived from scientific monitoring programs.

Where possible, we complemented data from scientific monitoring programs with evidence gleaned from scientific reports and academic articles.

Sessile Benthic Invertebrates

Quahogs (*Mercenaria mercenaria*). Interview evidence suggests that at the bay-wide level, quahogs were at an all-time low in abundance at the time of the NB 2019 interview project, and that the distribution of this species had receded northward in recent years, with only certain areas continuing to produce in abundance: the northernmost reaches of the Upper Bay (Rocky Point, Barrington Beach), the northeastern corner of Prudence Island (Upper East Passage) including Potter's Cove, and Friar's Cove (Middle West Passage).

To compare these observations to SEK datasets, we obtained data from two sources:

- DEM Shellfish Dredge Survey, 1993-present, arrayed by survey strata
- DEM quahog landings, 2012-present, arrayed by tagging area

We then compared these two datasets (summarized in Figure H - 1 through Figure H - 17) with fishermen's observations (summarized in Table 6 through Table 11). When comparing fishermen's observations with time series data on quahog density from the DEM Shellfish Dredge Survey, we grouped survey strata and their constituent stations (see Figure 34 for a map of strata and stations) in ways that aligned with the areas utilized by fishermen in their descriptions and drawings, which were often based on bathymetrical features, coastline indentations, or riparian land forms. When comparing fishermen's observations with DEM Landings Statistics, we grouped fishermen's observations to align with the generally larger tagging areas (see Figure 35 for a map of DEM tagging areas).

Comparisons of fishermen's observations and data from the DEM Shellfish Dredge Survey are presented side by side in Table 19. Comparisons of fishermen's observations and data from the DEM Landings Statistics are presented in Table 20. Based on a subjective evaluation of evidence provided by fishermen and the DEM Shellfish Dredge Survey dataset, we color-coded each spatial area referenced in each of these tables, so as to indicate whether we deemed the two bodies of knowledge to be in agreement (blue) or disagreement (orange) for the given area. Interestingly, we found more consistent agreement between fishermen's observations and landings data (Table 20) than we did between fishermen's observations and dredge survey data (Table 19). In fact, all areas for which we plotted landings data seemed to tell the same stories that were described by fishermen interviewees. In contrast, we found general agreement between fishermen's observations and dredge survey data for only seven out of thirteen spatial areas evaluated.

It would be valuable to bring fishermen and DEM scientists together to discuss why these discrepancies and inconsistencies seem to have occurred. For instance, are they a result of our qualitative interview structure, the loose timelines provided by interviewees, the increasingly infrequent sampling by DEM (the Shellfish Dredge Survey took place yearly until the late 2000s, but is now more intermittent in most areas), the subjective comparisons conducted in the present analysis, all of the above, or something else?

In addition to the observations on recent quahog abundance referenced in the previous pages, interviewees also provided qualitative data on historical booms and busts, changes in shell thickness, changes in spawning, and presence of dead quahogs in harvest areas, discussed in detail below.

Historical booms and busts. Interviewees referenced historical booms and busts in the quahog fishery, such as the legendary quahog bonanza of the 1980s. Echoing these statements, Desbonnet and Lee (1991) described an earlier peak in 1955 that declined through 1974, due to overfishing caused by a large number of clammers working in limited areas within the bay. From 1974 until 1984, landings increased, driven by technological improvements (e.g., the bullrake), that enabled clammers to work in deeper and more varied bottoms, as well as the opening of previously unexploited clam beds thanks to reductions in fecal coliform contamination from sewage discharges in the Blackstone, Seekonk, and Providence Rivers (Desbonnet and Lee 1991). These technology- and pollution-related drivers were also mentioned by fisherman interviewees in the NB 2019 and SH 2014 interviews.

Shell thickness. Interviewees shared a perception that shells had become more brittle at various times in certain parts of the bay. We did not find any data or published literature relating to changes in the thickness of quahog shells.

Changes in spawning. One interviewee shared a perception that the quahogs that make up his catch seemed to be spawning less than in previous times, saying that he used to see the water in his pails turn milky when quahogs were sitting in them, but no longer observed this color change. This observation might help explain a perception prevalent among shellfishermen that quahogs no longer “set up” in areas where they used to be prolific. The only scientific data related to quahog spawning that we were able to find was conducted in the Providence River, an area closed to shellfishing (Marroquin-Mora *et al*. 2008). That study found that clams in densely populated areas closed to fishing displayed signs of reduced fecundity, as evidenced by low indices of gonadal condition in closed areas relative to conditionally open areas of the bay. In addition to population density, the authors of that study point to low dissolved oxygen and poor bottom conditions as possible explanatory factors for reduced reproductive potential. However, their findings do not help explain the observation by a shellfisherman that quahogs in open and conditionally open areas have experienced a reduction in spawning frequency in recent years.

Presence of dead quahogs. One interviewee described raking up dead quahog shells that appeared alive until shaken, at which point they broke apart and revealed the lack of a living animal inside. We did not find any references to this type of phenomenon in the scientific literature from Narragansett Bay, but we did find a description of from Rehoboth and Indian River Bays in Delaware, where Tyler (2007) described finding “recently dead clams, identified as such by their shells being still hinged together” in areas that had undergone prolonged smothering by drift macroalgae. Tyler contrasted these with “no-hinged dead” quahogs that were the norm in areas with no or light seaweed coverage.

Table 19. Comparison of fishermen's observations with data from the DEM Shellfish Dredge Survey. Rows highlighted in blue are areas for which there is general agreement between the two sources, while rows highlighted in orange are areas for which there is general disagreement between the two sources. Determination of “agreement” and “disagreement” was a subjective exercise based on comparing verbal statements and map drawings provided by fishermen with visualization of data from the DEM Shellfish Dredge Survey. Survey strata and stations were selected to match, as closely as possible, the areas sketched by fishermen in their map drawings.

Area (NBEP Segment) DEM Shellfish Dredge Survey Stratum: Stations	**Trends Observed by Fishermen in NB 2019 Interviews**	**Trends Observed in DEM Shellfish Dredge Survey**
Barrington Beach (Upper Bay) 2: 1-14, 17-20	Many respondents described the quahog population at Barrington Beach as consistently abundant in recent years (n=7). One added that he had observed an uptick along the shoreline since 2017 (n=1). See Table 11, Figure 9, and Figure 11.	The DEM survey shows a decline in 1996 from a peak in 1994 of 5.95 legal-sized quahogs/m^2, followed by several decades of smaller fluctuations between 0.51-2.73 quahogs/m^2. The years 2013-2017 saw a >50% decline in density to 2.37 quahogs/m^2. The available data do not seem to line up with fishermen’s observations that quahog populations at Barrington Beach have been consistently abundant in recent years. The DEM survey was not conducted in 2018 or 2019, so we cannot compare scientific data to fishermen’s most recent observations. See Figure H - 1.
Conimicut to Rocky Point (Upper Bay) 1: 1-18	Many respondents described the quahog population at Rocky Point as consistently abundant in recent years (n=7). One respondent added that an area east of Longmeadow had declined starting around 1993, but had experienced an uptick starting around 2017. See Table 11, Figure 9, and Figure 11.	The DEM survey indicates that legal-sized quahog density fluctuated significantly in the 1990s and early 2000s, between 0.37-7.12 quahogs/m^2 with trends reversing themselves every 1-4 years. The years from 2005-2015 saw greater stability, with quahog density staying between 3.4-4.68 individuals/m^2. Between 2015 and 2017, density declined to 2.27m^2. This recent decline does not coincide with fishermen’s observations of a steady quahog population in recent years. The DEM survey was not conducted in 2018 or 2019, so we cannot compare scientific data to fishermen’s most recent observations. See Figure H - 2.

Ohio Ledge (Upper Bay) 3	Two respondents stated that quahog populations had declined in recent years at Ohio Ledge (n=2), and one stated that populations had remained stable (n=1). See Table 11, Figure 7 through Figure 9.	The DEM survey suggests that legal-sized quahog density fluctuated between 0.57-2.48 quahogs/m^2 between 1993 and 2008, with trends reversing themselves every 1-3 years. The years 2008-2017 showed a steady decline, to a 2017 low point of 0.66 quahogs/m^2, coinciding with fishermen's observations of a decline in this area (note that not all fishermen agreed, with one saying that populations were stable). The DEM survey was not conducted in 2018 or 2019, so we cannot compare scientific data to fishermen's most recent observations. See Figure H - 3.
Western Greenwich Bay 16: 1-12	Four respondents stated that they had observed a decline in quahog populations in this area (n=4). Two gave no timeline, while one stated that the decline had occurred since 2009-2011 and another since 2016-2017. However, respondents also mentioned that populations had remained constant at the shallow northern edge of this area (n=3). See Table 10 and Figure 7 through Figure 10.	The DEM survey suggests that legal-size quahog density has fluctuated considerably over the years, ranging from 0.49-3.91 quahogs/m^2. Density showed a declining trend from 2006-2019, from all-time high of 3.91 quahogs/m^2 in 2006 to around 1 quahog/m^2 in recent years, coinciding with fishermen's observations of a decadal decline. The shallow northern portion of this area, where fishermen have observed an increase, is not well sampled by the DEM survey. See Figure H - 4.
Eastern Greenwich Bay 16: 13-27	Four respondents stated that they had observed a decline in quahog populations in this area (n=3). Two gave no timeline, while one stated that the decline had occurred since the 1990s. However, one also mentioned that populations had remained constant at the shallow northern edge of this area (n=1). See Table 10 and Figure 7 through Figure 10.	The DEM survey suggests that quahog density in this area fluctuated between 0.94-4.79 quahogs/m^2 between 1993 and 2007, with trends reversing themselves every 1-4 years. Since 2007, density has remained relatively stable between 1.21-2.46 quahogs/m^2. The DEM survey does not provide evidence for a decline in recent years, but it does provide evidence of a general decline in peak numbers since the 1990s. The shallow northern portion of this area is not well sampled by the DEM survey. See Figure H - 5.
High Banks (Upper West Passage)	Three respondents stated that they had observed a decline in quahog populations in this area (n=3), with two stating that the decline occurred since the early 2000s and	The DEM survey suggests that legal-sized quahog density in this area was low in the 1990s, peaked sharply and briefly in 2002 at 5.88 quahogs/m^2, and then dipped again to 0.83 quahogs/m^2 in 2004. From 2005-2017, it was relatively stable at between 1.46-3.2

5: 11-12, 15-16, 18-21	one stating that it occurred since 2010. See Table 8, Figure 7, and Figure 8.	quahogs/m^2, before increasing in 2019 to 4.47 quahogs/ m^2. DEM survey data tell a very different story from the observations provided by fishermen, which suggest a decline in this area. See Figure H - 6.
Hunt's Ledge, Middle Ground, Magic Mountain (Upper West Passage) 5: 10-17, 18-30	Two respondents stated that they had observed a decline in quahog populations on Hunt's Ledge and Middle Ground (n=2). One stated that this decline occurred since 2015, and the other did not specify a timeline. There was disagreement over the status of quahog populations on Magic Mountain, with one respondent stating they had declined (n=1; no timeline given) and another stating that they had held constant (n=1). See Table 8, Figure 7, and Figure 8.	The DEM survey suggests that quahog density in this area has been highly variable, ranging from 1-5 quahogs/m^2. Density was relatively stable from 2006-2017 at 2.5-4 quahogs/ m^2, but experienced a sharp increase between the 2017 and 2019 surveys to over 5 quahogs/m^2. See Figure H - 7.
Pine Hill (Middle West Passage) 4: 16-18 9: 7, 11, 15-18	Three respondents mentioned a decline in quahog populations at Pine Hill (n=3). One gave no timeline, one said the decline occurred since 2004, and one said that it occurred since 2010. Another mentioned a die-off of quahogs at nearby Johnson's Ledge (n=1). See Table 7 and Figure 7.	The DEM survey suggests that legal-sized quahog density in this area fluctuated between 0.41-4.18 quahogs/m^2 between 1994-2004, and then settled into a more stable pattern between 1.14-2.04 quahogs m^2 until 2013 (note, however, that this apparent stability may be an artefact of the fact that fewer surveys were conducted during this period). After a few minor dips and peaks in the 2013-2017 period, density declined to an all-time low of 0.23 quahogs/m^2 in 2019, providing evidence that corroborates fishermen's observations of a decline in this area in recent years. See Figure H - 8.
Potter's Cove to Mount Tom (Upper East Passage) 10: 5-11	Respondents agreed that quahog populations in Potter's Cove (n=1), Mount Tom (n=2), and the shoreline between Potter's Cove and Mount Tom (n=2) had held constant in their abundance in recent years. See Table 9, Figure 9, and Figure 10.	The DEM survey suggests that legal-sized quahog density in this area has fluctuated between 0.18 and 2.44 quahogs/ m^2 since 1995. Density remained stable around 1.5 quahogs/m^2 from 2016-2018, the last year of the survey prior to the NBEP interviews. Evidence from the dredge survey coincides with fishermen's observations of stable populations in this area. See Figure H - 9.

Western Bristol Harbor 6: 1-5, 7-8, 11-13	One respondent mentioned that quahog populations in Western Bristol Harbor had declined considerably since around 2013-2014 (n=1). See Table 9 and Figure 7.	The DEM survey suggests that quahog density in this area has declines since 1999, though not in a uniform fashion. The years 2012-2018 saw consistently low density at 0.09-0.-64 quahogs/m^2, corroborating observations by fishermen of a decline in this area. See Figure H - 10.
Friar's Cove (Middle West Passage) 6	Two respondents reported excellent catches in Friar's Cove, and said that quahog populations in this area had remained stable in recent years (n=2). One respondent described an uptick in quahog populations in western Friar's Cove since 2017 (n=1) See Table 7, Figure 10, and Figure 11.	The DEM survey suggests that legal quahog density in this area fluctuated between 0.81-4.66 quahogs/m^2 from 1993-2006, and has been stable between 2.3-2.8 quahogs m^2 since 2007, corroborating observations by fishermen of stable quahog populations in this area. See Figure H - 11.
Rome Point to Plum Point (Middle West Passage) 11: 23-24 12: 4-5	Respondents described a decline in quahog populations in this area (n=2), with one stating that this decline occurred since 2004 and another since the 1990s. See Table 7 and Figure 7.	The DEM survey suggests that legal-sized quahog density in this area fell from 1.03 quahogs/m^2 in 1995 to under 0.5 quahogs/m^2 until 2003. After a peak at 1.2 quahogs/m^2 in 2004, it fell again in 2006 to 0.09 quahogs/m^2, then rose gradually to 0.69 quahogs/m^2 by 2018, the most recent year in the dataset. The DEM survey partially corroborates fishermen's observations declines after high points in the 1990s and 2004, but the more recent decadal increase in the survey dataset is not reflected in fishermen's observations of a continued decline. See Figure H - 12.
Dutch Island Harbor 15	Two respondents noted a decline in quahog populations in this area (n=2), with one providing no timeline and another stating that the decline occurred since the 1990s.	The DEM survey suggests that legal-sized quahog density in this area peaked at 1.66 quahogs/m^2 in 1996. After plummeting to 0.09 quahogs/m^2 in 1998 and 1999, it has remained low, with none of the years 2005-2018 exceeding 0.27 quahogs/m^2, coinciding with fishermen's observations of a sustained decline since the 1990s. See Figure H - 13.

Table 20. Comparison of fishermen's observations with data from the DEM Landings Statistics. Rows highlighted in blue are areas for which there is general agreement between the two sources. Determination of "agreement" and "disagreement" was a subjective exercise based on comparing verbal statements and map drawings provided by fishermen with visualization of data from the DEM Shellfish Dredge Survey. Areas described and sketched by fishermen in their map drawings were grouped to match DEM tagging areas; both are listed in the left-hand column.

DEM Tagging Area Descriptive Areas (NBEP Segment)	**Summary of Fishermen's Observations (Number of Respondents)**	**Summary of DEM Landings Statistics**
Tagging Area 1A Rocky Point, Longmeadow, Barrington Beach, Rumstick Shoals (Upper Bay)	Decline in Longmeadow (n=1), e.g., since 1993; decline at Rumstick Point (n=1), e.g., since 2003. Constant at Rocky Point (n=7); constant at Barrington Beach (n=7). Uptick in part of Longmeadow (n=1), e.g., since 2017; uptick along the shoreline of Barrington Beach (n=1), e.g., since 2017. See Table 11.	This area has experienced steady landings since 2012. See Figure H - 14.
Tagging Area 1B Seminary, Ohio Ledge (Upper Bay)	Decline at Ohio Ledge (n=2); decline from Rumstick Point to Poppasquash (n=1), e.g., since 2010; decline at the north end of The Gut between Patience and Prudence Islands (n=1). Constant at Ohio Ledge (n=1); constant at The Seminary (n=1). See Table 11.	This area has experienced declining landings since 2012. See Figure H - 14. .
Tagging Area 2 Western and Eastern Greenwich Bay	Decline (n=5), e.g., since 1990s or 2009-2011. See Table 10.	This area has experienced declining landings since 2013. See Figure H - 15.
Tagging Area 3H High Banks	Decline (n=3), e.g., since early 2000s or 2010. See Table 8.	This area has had very few landings since 2012. It may have produced more landings

(Upper West Passage)		before that point, but data are not available. See Figure H - 16.
Tagging Area 3W Hunt's Ledge, Middle Ground, Magic Mountain, Friar's Cove, Wickford, Romer Point, Plum Point, Dutch Island Harbor (Upper, Middle, and Lower West Passage)	Decline in most of area 3W (n=1), e.g., since 2004; decline in the Upper West Passage (n=1); decline near the southern edge of the Upper West Passage (n=1); decline just south of Patience Island (n=1), e.g., since 2010; decline at Hunt's Ledge and Middle Ground (n=2), e.g., since 2015; decline at Magic Mountain (n=1); decline north of Pint Hill (n=1), e.g., since 2016-2017; decline at Pine Hill (n=3), e.g., since 2004 or 2010; decline at Johnson's Ledge (n=1), e.g., since 2017-2018; decline off Quonset (n=1); decline off Hope Island (n=1); decline at an area near the northern edge of Middle West Passage; decline from Rome Point to Plum Point (n=2), e.g., since 1990s or 2004; decline at shoals south of Jamestown Bridge (=1), e.g., since 1990s; decline at Dutch Island Harbor (n=2), e.g., since 1990s; e.g., since 1990s; decline in Lower West Passage in general (n=1). Constant at Friar's Cove (n=2); constant at Magic Mountain (n=1). Uptick at a small area south of Sandy Point (n=1); uptick along the western side of the Middle West Passage (n=1), e.g., since 2017; uptick in Western Friar's Cove and Calf Pasture Point (n=1), e.g., since 2017. See Table 6 to Table 8.	Landings from Tagging Area 3W have declined substantially since 2012. See Figure H - 16.
Tagging area 4A Potter's Cove, Mount Tom, Homestead, Bristol Harbor, Death Valley (Upper East Passage, Middle East Passage, Lower East Passage)	Decline in western Bristol Harbor (n=1). Constant in Potter's Cove (n=1); constant between Potter's Cove and Mount Tom (n=2); constant at Mount Tom and Homestead (n=2); constant at Death Valley (n=1); constant at northeast coast of Jamestown (n=1). See Table 9.	Landings from Tagging Area 4A (East Passage, including most of the open areas of Bristol Harbor) have been steady since 2012. See Figure H - 17.

Bay scallops (*Argopecten irradians).* Interview evidence suggests that bay scallop population dynamics are cyclical in nature, and that the peaks of these cycles have become much diminished since the mid-20th century. Since scallops are not surveyed, and Narragansett Bay-specific landings were not available from DEM, we were not able to compare interview data to SEK in a very direct way. As a surrogate, we plotted bay scallop landings from NOAA Landings Statistics for Rhode Island as a whole from available years between 1950 to 2018 (see Figure H - 18). The time series is too irregular to draw meaningful conclusions, but what little data is available does appear to corroborate the trajectory described by fishermen in their interviews: a series of ups and downs during the mid-20th century, followed by minimal landings since the mid-1990s. Landings data are not available for seven out of the eight years between 2008-2018, due to fewer than three fishermen in the state as a whole making commercial landings; this in itself may be an indicator of the scarcity of bay scallops during latter years.

Mussels (*Mytilus edulis*). Interview evidence suggests that mussel populations experience cyclical dynamics in Narragansett Bay. We could not empirically compare SEK and FEK on this subject because no long-term time series are collected on mussel abundance in Narragansett Bay, and DEM mussel landings are sparsely available because of the low number of fishermen harvesting mussels, which makes landings data subject to confidentiality limitations. However, Brown University biologist Mark Bertness states that this species experiences massive recruitment events about once per decade (Bertness, personal communication, 2021), which he attributes to bay flushing patterns.

Relationship with starfish. One interviewee provided anecdotal evidence of an inverse relationship between mussels and starfish. We did not find any SEK data or literature on this relationship in Narragansett Bay specifically, but Witman *et al.* (2003) describe an inverse cycling relationship between starfish and mussels in the Gulf of Maine. This relationship is well established on the West Coast as well (e.g., Menge *et al.* 2016).

Relationship with quahogs. One interviewee provided anecdotal evidence that mussel die-offs facilitate growth of quahog beds. We did not find any SEK literature on this subject.

Oysters (*Crassostrea virginica).* Interview evidence suggests that oyster populations experience cyclical dynamics in Narragansett Bay, and that a major bay-wide oyster boom took place around the turn of the millennium. We obtained DEM landings data on wild oyster landings from Narragansett Bay from 2016-2019, as well as NOAA landings data on overall oyster landings for Rhode Island as a whole (wild and farmed) from 1950-2019 (Figure H - 20 and Figure H - 21). While it is hard to make a direct comparison between these landings data and the observations shared by interviewees, there does not seem to be any evidence in the landings data to support the conjecture that oyster populations are cyclical. However, a bump in landings is evident in the late 1990s, before the onset of oyster aquaculture in Rhode Island; we can assume that this is the historical wild oyster boom referenced by many shellfishermen in our interviews.

Additionally, we found one mention of this famed boom in the scientific literature. Oviatt (2003) described the historical boom mentioned by many shellfishermen as “a natural repopulation of the bay in the 1990s [that] has succumbed to disease and exploitation.”

Deckers (*Crepidula fornicata*). Interview evidence conveys an impression that the abundance of deckers was increasing in Narragansett Bay at the time of the NB 2019 interviews, with potentially negative impacts on the quahog population via smothering and competition for food. Unfortunately, no scientific monitoring of the decker population takes place in Narragansett Bay, so we were unable to compare fishermen’s observations with a robust scientific dataset.

The only scientific data that were able to find that might provide an inkling of decker abundance in Narragansett Bay is the count of decker larvae captured in URI GSO’s Narragansett Bay Long-Term Plankton Time Series (see Figure H - 22). However, these data are limited to four years (2002-2004 and 2018), and they do not provide discernible visual evidence of trends in the abundance of decker larvae. If anything, 2018 had a lower count of decker larvae than 2002-2004.

Interviewee evidence also supported a notion that decker abundance is cyclical in nature. While we were not able to find any long-term datasets to compare with these statements, the observation was confirmed by Brown University biologist Mark Bertness, who stated that this species experiences massive recruitment events about every fifteen years (Bertness, personal communication, 2021), which he attributes to bay flushing patterns.

Relationship with other sessile invertebrates. Some interviewees in the NB 2019 project conveyed a hypothesis that the high abundance of deckers at that time was exerting a negative impact on quahog abundance. Since there are no scientifically collected data on decker abundance in Narragansett Bay, we could not empirically compare SEK and FEK on this subject. However, studies of decker population dynamics in areas where the species is invasive, such as Europe, have shown that this species can alter substrate habitat, outcompete native species for space, and limit the survival of native species such as scallops (Ménesguen and Grégoris 2018).

Soft shell clams (*Mya arenaria).* Interview evidence suggests that soft shell clam populations are highly cyclical in nature, and that a historical soft shell clam boom took place at Conimicut Point around the early 2000s. We obtained DEM landings data on soft shell landings from Narragansett Bay from 2016-2019, as well as NOAA landings data on soft shell clam landings for Rhode Island as a whole (wild and farmed) from 1950-2019 (Figure H - 23 and Figure H - 24). Both show clear evidence of the boom in the early 2000s, and indications of previous cyclical peaks.

Mobile Benthic Invertebrates

Lobsters (*Homarus americanus*). According to interview evidence, lobsters in Narragansett Bay have declined from a bay-wide peak from the 1990s to the present, with the decline beginning in the Upper Bay and working its way southward to the Mouth of Narragansett Bay. However, interviews suggested that specific hotspots in the lower bay remain well populated, and several lobstermen mentioned an uptick in the year or two preceding the interview (i.e., 2017-2018).

Data from the URI GSO Fish Trawl Survey (Figure H - 25) align with these observations. Collected in the Middle West Passage, this time series shows a clearly discernible peak from 1989-2000, and another smaller peak from 2004-2007. This second smaller peak was mentioned by one interviewee who lobsters in the Middle and Lower West Passage (LK1).

Data from the DEM Coastal Trawl Survey (Figure H - 26) also align with fishermen's observations. Figure H - 26 illustrates mean annual lobsters per tow for 10 regions of the bay. According to the data, regions peaked and declined sequentially from north to south, supporting statements made by respondent LN3, who described a southwardly declining progression that resulted in his choice to quit lobstering in Narragansett Bay in 2014 (the DEM Coastal Trawl Survey time series bottoms out for all regions of the bay by 2012). The largest peak in the DEM Coastal Trawl Survey time series occurred in the Middle East Passage in 2001. Interestingly, this area was described as experiencing a "phenomenal" boom of lobsters until 2012-2013 (LN4). In other words, the trend described by fishermen and illustrated in data from the DEM Coastal Trawl Survey align, but the timelines differ.

Data from the DEM Ventless Trap Survey (Figure H - 27 and Figure H - 28) encompass a shorter time series than the two trawl surveys (2006-2019), but these data add nuance by distinguishing between legal-size (>$3^3/_8$" carapace length) and sublegal (<$3^3/_8$" carapace length). At the bay-wide level, they show that although legal lobster abundance has been very low since the beginning of the time series, sublegal lobster abundance rose in the late 2000s before falling to lower levels in the 2010s. This perhaps further aligns with fishermen's observations that by 2014, the lobster resource in Narragansett Bay was at rock bottom levels.

When analyzed by bay segment, the DEM Ventless Trap Survey lobster data also corroborate other fishermen's observations. Here too we see a boom in the Middle West Passage in 2006-2008 (coinciding with respondent LK1's recollection of a boom in 2004-2008) and a boom in the Lower West Passage in 2008-2012 (perhaps loosely coinciding with respondent LK1's recollection of a boom in 2012-2013). As in Figure H - 26 and the observations of several fishermen, we see that lobster abundance in the Upper Bay, Upper East Passage, and Middle West Passage declined earlier than the more southerly portions of the bay. We can also see an uptick in 2018 in the Lower East Passage that was referenced by two lobsterman interviewees (LN2 and LN4).

Starfish (*Asterias forbesi*). According to interview evidence, starfish seem to have drastically declined in Narragansett Bay in recent years. Interviewees also mentioned a general perception that starfish abundance is cyclical.

Data from the URI GSO Fish Trawl Survey (Figure H - 29) show a drop-off in starfish around 2012, but the years prior to that do not align with fishermen's observations of cyclical abundance. Instead, the GSO data hints at only two up-cycles in the last 40 years: one in 1995 and one in 2009-2011. This does not match one lobsterman's comments that starfish cycles usually last about 5 years before starting again. However, the URI GSO Fish Trawl Survey collects data in only one site in the bay, and does not necessarily reflect trends occurring in other areas.

Data from the DEM Ventless Trap Survey (Figure H - 30) also show a sharp drop-off in starfish abundance, with the population bottoming out from 2014 to 2019, confirming both that the data from URI GSO Trawl Survey coincide with bay-wide trends as well as the observations shared by many fishermen that starfish have become exceedingly scarce in recent years.

Scientific literature offers an explanation for the drastic decline in starfish observed by interviewees. Bucci *et al*. (2017) explain that starfish on both the West Coast and the East Coast succumbed in 2012 to a mysterious Sea Star Wasting Disease (SSWD). Symptoms of SSWD include lesions, flaccid body, curled limbs, and disintegration of the central disc. Bucci *et al.* (2017) also cite anecdotal reports that starfish populations in Rhode Island seemed to be increasing again by 2015. This purported uptick was not supported by interview data in RF 2016 or NB 2019 projects.

Predation on mussels, quahogs, and deckers. Interview evidence suggests a negative relationship between starfish populations and the populations of mussels, quahogs, and deckers, caused by predation by the former on the latter. By and large, scientific literature supports these relationships. For instance, Mackenzie and Pikanowski (1999) describe a sharp decrease in starfish abundance coincident with a large increase in the abundance of quahogs in Raritan Bay (New Jersey) and Long Island Sound (Connecticut).

Blue crabs (*Callinectes sapidus).* According to interview evidence, blue crab populations tend to be cyclical in Narragansett Bay. Interviewees mentioned specific peaks around 2007-2009, 2010, and 2017.

Data from the URI GSO Fish Trawl Survey (Figure H - 31) show potential evidence of a population cycle that peaks about once a decade, with each peak becoming progressively larger. A peak in 2010 reached levels of about 5-10 times the average level of abundance in Narragansett Bay on off-peak years. The GSO time series shows no evidence for a peak in 2017.

Data from the DEM Coastal Trawl Survey (Figure H - 32) also show a steep peak in 2010, with a return to baseline levels of less than one crab per tow from 2012-2019. As with the URI GSO

Fish Trawl Survey, DEM data corroborate fishermen's observations of a 2010 peak, but not a 2007-2009 peak or a 2017 peak. Perhaps the 2007-2009 peak – one interviewee's rough estimation - actually took place in 2010, and the 2017 peak was spatially isolated (this peak was observed by one fisherman in Western Greenwich Bay). The DEM Coastal Trawl Survey has only collected blue crab data since 2009, too short a timeframe to show decadal cycles of the type described by fishermen and evidenced by the URI GSO Fish Trawl Survey.

Data from the DEM Ventless Trap Data (Figure H - 33) align with other datasets and with the fishermen's observation of a peak in blue crab abundance in 2010. As with other datasets, there is no evidence for a peak in 2007-2009 or 2017. The 2010 peak appears to have been a remarkable anomaly, exceeding all other years in the time series by an order of magnitude.

Horseshoe crabs (*Limulus polyphemus*). Interview evidence suggests that horseshoe crabs experienced a steep decline from a peak in the 1980s.

Data from the URI GSO Fish Trawl Survey (Figure H - 34) support these observations, suggesting that higher numbers of horseshoe crabs were caught in this trawl survey from the 1980s to mid-1990s than since that time.

Data from the DEM Coastal Trawl Survey (Figure H - 35) date from 1998 onward, and as a result, the mean number of crabs per tow in this time series is about an order of magnitude lower than the mean number of crabs per tow in the URI GSO Fish Trawl Survey data from the 1980s. However, the DEM dataset illustrates that even at low levels, crabs have continued to decline.

The DEM Horseshoe Crab Survey (Figure H - 36) provides direct and targeted counting of horseshoe crabs at their Conimicut Point breeding grounds; however, this time series did not begin until 2000, after the time at which interview evidence suggests that horseshoe crabs began to decline.

Spider crabs (*Libinia emarginata*). Fishermen's observations with regard to spider crabs were inconsistent from individual to individual. As a result, it is not possible to evaluate their degree of similarity or dissimilarity as a whole with data from scientific monitoring programs.

Long-term data from the URI GSO Fish Trawl Survey (Figure H - 37) lend evidence for one fisherman's assertion that spider crab populations are cyclical. Between 1980 and 2019, there were two peaks in spider crab abundance in this survey in the Middle West Passage, taking place in 1995 and 2009-2010.

Data from the DEM Juvenile Fish Seine Survey (Figure H - 38) suggest three waves of increased abundance during the available time period: one of 1994-1995, one in 2003-2004, and one in 2010-2017. The length of this last peak, combined with a smaller uptick in 2019, suggest that the population as a whole may be increasingly prevalent in Narragansett Bay.

Data from the DEM Ventless Trap Survey (Figure H - 39) suggest that within the available time series (2006-2019), there has been an overall increase in spider crab abundance in the main body of Narragansett Bay.

Just as with fishermen's observations, no clear conclusion emerges from scientific monitoring datasets about trends in abundance of spider crabs in Narragansett Bay.

Green crabs (*Carcinus maenas*). Interview evidence suggests a decline in abundance of the invasive green crab in Narragansett Bay.

Data from the DEM Ventless Trap Survey (Figure H - 40) echo this assertion, showing that green crab numbers in the traps have declined from a large peak that took place in 2010-2011. Although data from the DEM Ventless Trap Survey do not extend back further than 2006, these data suggest that perhaps green crab populations experience multi-year cycles of abundance, a theory that was not voiced by fishermen but would not be inconsistent with their limited observations.

Whelks: Channeled and Knobbed (*Busycotypus canaliculatus, Busycon carica*). Interview evidence suggests either cyclicity or consistency in whelk populations; it is hard to generalize because only two fishermen commented on trends in whelk abundance.

Angell (2020) presented from the DEM Coastal Trawl Survey, URI GSO Fish Trawl Survey, and DEM Shellfish Dredge Survey (reproduced in Figure H - 41 through Figure H - 44). The URI GSO Fish Trawl Survey lends evidence for one interviewee's contention that whelk populations are cyclical, while both the URI GSO Fish Trawl Survey and the DEM Shellfish Dredge Survey corroborate his assertion that whelk underwent a downtick in 2018-2019.

Fouling Invertebrates

Barnacles (Cirripedia: Thoracica). Interview evidence suggests that barnacle growth on commercial fishing gear has declined in the Lower East Passage and Newport Harbor. Specifically, interviewees suggested that barnacle spat may settle in high numbers on these surfaces as they always have, but that spat fails to grow to maturity.

To our knowledge, there is no scientific long-term monitoring of barnacles in Narragansett Bay that we can compare with these observations. However, a series of studies on the factors shaping barnacle population dynamics were conducted in the 1980s-1990s by Mark Bertness and collaborators at Brown University. One of those studies (Gaines and Bertness 1992) concluded that barnacle recruitment in Narragansett Bay is characterized by extreme variability. This variation, the article explained, is dictated by interannual variation in bay flushing, which varies with the degree of rain and snow melt occurring during late winter months. In years of high precipitation or snow melt, barnacle recruitment is quite low, as larvae are washed out to the ocean rather than settling in the bay.

It is not clear whether interview evidence aligns with or can be explained by the generalized findings by Gaines and Bertness (1992). Unlike Gaines and Bertness (1992), interviewees did not mention cyclical dynamics of barnacle populations. Rather, they expressed with consternation a view that barnacles had precipitously disappeared from the bay in the years running up to the NB 2019 project, at a time when barnacle coverage of fishing gear in Rhode Island Sound remained unaltered. Moreover, one interviewee made a distinction between the recruitment of barnacle *spat*, which continued to occur in large numbers each spring, and the maturation and survival of *adult* barnacles.

In sum, little empirical scientific data on trends exists for barnacles in Narragansett Bay, and the mechanistic studies that were done in the 1980s do not appear to offer a thorough explanation for fishermen's observations.

<u>Tunicates: sea grapes (*Molgula manhattensis*), sea squirts (*Styela clava*), and *Didemnum sp.*</u> Interview evidence suggests a recent decline in several tunicate species in the <u>Middle East Passage</u>, <u>Lower East Passage</u> (north of Newport Bridge), and <u>Newport Harbor</u>. CRMC's floating dock and settlement plate surveys have monitored changes in the tunicate populations in Narragansett Bay since 2009 and 2012, respectively. Data from these surveys will be published in a forthcoming ten-year report (CRMC, in publication).

Seaweed/Macroalgae

<u>Rockweed (Order Fucales).</u> Interview evidence suggests a dramatic decline in rockweed along all shores of Narragansett Bay, except at the <u>Mouth of Narragansett Bay</u>. Interviews also provided qualitative evidence for a slight uptick in rockweed in the year immediately preceding the NB 2019 interviews. We did not find any temporally aligned SEK time series on rockweed abundance to compare with these observations, and data from the rockweed survey conducted in 2018-2019 by the Carol Thornber lab at URI is too new to compare with our retrospective interview-based evidence.

<u>Sea lettuce (*Ulva spp).*</u> Interview evidence suggests a recent uptick in sea lettuce blooms in the northern parts of Narragansett Bay in the year or two preceding the NB 2019 project. We are not aware of any scientific data on *Ulva* collected in 2017-2019.

<u>Kelp (*Saccharina latissima*).</u> Interview evidence suggests a major decline in kelp biomass in the <u>Lower East Passage</u>, an area where it was once quite abundant. Interviews also hinted at a slight uptick in kelp during the year immediately preceding the NB 2019 interviews (i.e., 2018-2019). Although there has been no long-term scientific monitoring of kelp in Narragansett Bay that would enable visualization of changes on a year-to-year basis, several one-off studies of

kelp coverage in the southern part of the bay enable a "before-after" comparison that confirms interviewees' observations. In a 1980-1981 study, Brady-Campbell *et al.* (1984) found that despite being located at the southern end of kelp's natural range, Fort Wetherhill (Lower East Passage) and Land's End (Mouth of Narragansett Bay) supported thriving kelp forests that contributed substantially to the primary productivity of Narragansett Bay. By 2017, however, kelp coverage at these locations was at least an order of magnitude lower than in the previous study, and kelp had been replaced by turf-forming algae such as *Phyllophora pseudoceranoides, Polysiphonia spp.,* and *Gracilaria spp.* (Feehan *et al.* 2019). Figures comparing the two surveys are reproduced from Feehan *et al.* (2019) in Figure H - 46. Data from the kelp survey conducted in 2018-2019 by the Carol Thornber lab at URI is too new to compare with our retrospective interview-based evidence.

Relationships with lobster, urchin, and starfish. Interview evidence suggests a link between the decline in kelp in Narragansett Bay and a simultaneous decline in lobster, urchins, and starfish. Although the absence of time series on the abundance of kelp (as well as urchins and starfish) in Narragansett Bay prevents us from comparing population-level trends among these species, there is abundant scientific literature supporting mechanistic relationships among these species in general.

For instance, Bologna and Steneck (1993) showed that lobsters prefer kelp forests over equivalent unvegetated habitats in the Gulf of Maine, due to the structure they provide, and that the highest concentrations of lobsters tends to occur at the edges of kelp forests. They concluded that the presence of kelp in an area – particularly when found in small and numerous patches providing large amounts of edge habitat - can increase the local carrying capacity for lobsters. They also concluded that "changes in the abundance of kelp could influence the distribution of local lobster populations."

Miscellaneous seaweed. Interview evidence suggests that macroalgal diversity in Narragansett Bay is increasing, and that many of today's species are different in their morphology from habitat-forming seaweeds of the past, such as kelp and rockweed. Interviewees variously described the common seaweeds of today as "slimy," "yucky," "brown," and "acidic," but did not offer common or scientific names, and were frequently unable to identify these seaweeds visually using the identification cards provided.

The general observation of an increase in non-habitat-forming seaweeds is consistent with the findings of Feehan *et al.* (2019) and Filbee-Dexter *et al.* (2020), who provide evidence for a decline in kelp in the southern part of the bay where it was once plentiful, and a replacement by a variety of turf-forming macroalgae such as *Phyllophora pseudoceranoides, Polysiphonia spp*. and *Gracilaria spp.*

Thornber *et al.* (2017) also note that macroalgae blooms persist in Narragansett Bay, despite predictions that blooms would subside after the completion of wastewater nutrient reduction plans. These blooms are largely made up of Chlorophyta (green algae), especially *Ulva spp.,* in northern portions of the bay. This finding is consistent with the observations of quahoggers who joked about going to Barrington Beach to "fight the lettuce." In contrast, aerial surveys by Thornber *et al.* (2017) show that Phaeophyceae (brown algae, such as rockweeds) distribution is patchy and much diminished from the distribution described in 1993 by Harlin and Rines.

Interview evidence also suggests that macroalgal species richness may be increasing, that turnover of dominant species is occurring more rapidly, and that some of the "new" dominant seaweeds instigate positive feedback loops that prevent "traditional" habitat-forming seaweeds from reestablishing themselves. Interviews also provided qualitative evidence that some drift seaweeds exert a negative impact on benthic shellfish and demersal finfish.

SEK studies support these hypotheses. For instance, as mentioned above, prolonged coverage by drift macroalgae mats has been shown to have sublethal and lethal effects on quahogs and other shellfish (Tyler 2007). Feehan *et al.* (2019) found that turf-forming macroalgae benefit from mechanisms that stabilize their own populations and make it harder for kelp to reestablish itself even if environmental conditions become favorable to kelp again. MacKenchie *et al.* (2015) suggest that blooms of *Ulva spp.* release chemicals that lead to reductions in the diversity of other macroalgae.

Plankton

Interviews provided qualitative accounts of a decrease in the quantity of both phytoplankton and zooplankton in the water column in Narragansett Bay over approximately the last decade. Interviewees described this decrease as occurring only in the bay, and not in Rhode Island Sound. Some evidence also suggests an uptick in phytoplankton abundance in the year preceding the NB 2019 interviews. Lastly, interviews suggested a shift in the community composition of the phytoplankton in the bay, with rust tides and harmful algal blooms becoming more frequent in recent years.

SEK monitoring programs quantify phytoplankton abundance in Narragansett Bay directly through phytoplankton surveys and indirectly by measuring chlorophyll *a* concentration in the water column. Time series showcasing both approaches are contained in Figure H - 47 through Figure H - 49. Chlorophyll *a* concentrations have been declining significantly over time (Thibodeau, personal communication 2021), as shown in Figure H - 47 and Figure H - 48. Phytoplankton counts, as well, have shown a declining trend in some northern locations (Figure H - 49).

In addition, scientists sometimes estimate annual primary production for the Narragansett Bay ecosystem; primary production is mostly made up of phytoplankton, but also includes other sources such as macroalgae and submerged aquatic vegetation. Oviatt and collaborators have estimated annual bay-wide primary production on several occasions over the last five decades (see Oviatt *et al.* 1981, Oviatt *et al.* 2002, Melrose *et al.* 2009, Smith *et al.* 2011, and Oviatt *et* *al.* 2017). These estimates collectively suggest that annual production remained stable from the 1970s until the mid-2000s, but declined in the early 2010s after completion of managed wastewater nutrient reductions, as seen in Table 21. This is consistent with interview-based evidence describing a dramatic decline in phytoplankton within the last decade.

Table 21. Area-based estimates of bay-wide annual production from four different time periods.

Source	**Years**	**Bay-wide production**
Oviatt *et al.* 1981	1971-1973	269 $gC/m^2/y$
Oviatt *et al.* 2002	1997-1998	323 $gC/m^2/y$
Smith *et al.* 2011	2006-2008	290 $gC/m^2/y$
Oviatt *et al.* 2017	2013-2015	224 $gC/m^2/y$

However, these bay-wide figures gloss over important within-bay differences. Various studies have shown that a gradient in primary production exists from north to south within the bay, with higher primary production occurring in the nutrient-enriched Providence River and lower production occurring in the oligotrophic mid- and lower-bay (Oviatt *et al.* 2002; Oviatt 2008).

Studies also suggest that lower-bay regions experienced declines in primary production decades earlier than upper-bay portions, and that these trends were driven by different physical factors. Reviewing mean annual chlorophyll values calculated from weekly measurements from the URI GSO Narragansett Bay Long-Term Plankton Time Series, Li and Smayda (1998) and Fulweiler *et al*. (2007) demonstrated that chlorophyll concentrations at the sampling site in the Middle West Passage declined from 1973 to 1990 (Li and Smayda 1998) and from 1973 to 2005 (Fulweiler *et al.* 2007), prompting Fulweiler *et al*. (2007) to estimate that primary production in this area decreased by 40% during this period of their study.

Since nutrient concentrations in the Middle West Passage had been constant since the beginning of the URI GSO Narragansett Bay Long-Term Plankton Time Series in 1957, Li and Smayda (1998) ruled out a dose-response relationship between nutrients and production. Instead, researchers have found a strong relationship between chlorophyll concentrations and sea surface temperature (Li and Smayda 1998), irradiance (Nixon *et al*. 2009), and large-scale oceanographic/atmospheric circulation patterns (Borkman and Smayda 2009).

The mechanisms by which climate-related factors influence phytoplankton are various. For instance, warmer water temperatures can lead to increased rates of grazing activity by zooplankton, leading zooplankton to deplete phytoplankton blooms more rapidly, a relationship empirically confirmed by Li and Smayda's (1998) finding of an inverse relationship between chlorophyll concentrations and zooplankton biomass in the mid-bay. Rising atmospheric temperatures, on the other hand, have been associated with an increase in the number of cloudy days over Narragansett Bay, which may limit the amount of light available to fuel phytoplankton growth (Nixon *et al.* 2009). These two leading hypotheses are not mutually exclusive.

In contrast to the mid-bay, chlorophyll concentrations in the Providence River during the last three decades of the 20th century and first decade of the 21st century time showed no upward or downward trend, remaining consistently higher than in lower parts of the bay, leading Melrose *et al*. (2009) to conclude that the Providence River has not followed the same pattern as the mid-bay with regard to long-term changes in productivity associated with climate. However, this segment then experienced a declining trend in phytoplankton production in the 2010s, apparently resulting from the managed nutrient reductions undertaken between 2006-2012 at wastewater treatment facilities located along the Providence River and the bay's tributaries. According to Oviatt et al. (2017), these reductions achieved a 58% decrease in total nitrogen bay-wide. After the reductions, chlorophyll concentrations declined and summer apparent production bay-wide decreased by 33%. These lower values were found to decrease the steepness of the north-south production gradient within the bay (Oviatt *et al.* 2017; see Figure H - 47).

In addition to spatial dynamics, there have been significant changes in the seasonal dynamics of phytoplankton and zooplankton in Narragansett Bay. Most notably, the mid-bay decrease in primary production described above coincided with a dampening of the traditional winter-spring diatom bloom in this area. Once "the signature ecological event in Narragansett Bay" (Oviatt *et al*. 2002), the winter-spring diatom bloom took place annually from November to June and was dominated by the diatom *Skeletonema costatum* (Pratt 1965). In the decades since the 1970s, however, the bloom has either failed to occur or has been reduced in intensity in most years (Oviatt 1994, Oviatt *et al*. 2002, Melrose *et al.* 2009). The loss of the winter-spring boom has been correlated with warmer winter water temperatures (Oviatt 1994), and all of the climate-related factors described in previous paragraphs may play a role in suppressing the duration and intensity of the winter-spring bloom.

This loss of the winter-spring bloom has been variable rather than unilinear. Oviatt *et al.* (2017) state that during colder winters with a negative North Atlantic Oscillation (NAO) index, a winter-spring bloom has at times occurred, including after the managed nutrient reductions. For instance, the 2018 phytoplankton bloom was the largest on record, defying predictions based solely on nutrient quantities (Oviatt, personal communication cited in Kuffner 2018). This is consistent with interview evidence from the NB 2019 project, in which some fishermen described an uptick in phytoplankton abundance in the year before the interviews.

With regard to changes in phytoplankton species composition, SEK monitoring backs up fishermen's statements that rust tides have become more common in recent years. Rust tides are produced by the phytoplankton *Cochlodinium polykrikoides*, a dinoflagellate that is typically present in RI coastal and estuarine waters in low numbers during the summer and early fall (DEM 2016). On occasion, *C. polykrikoides* blooms to levels of 5-10 million cells/liter, considered a bloom, turning the water rust-colored (DEM 2016). This species' first detection in the Narragansett Bay Long-Term Plankton Time Series was in 1979 (Carney 2020), and the first known rust tide bloom in Rhode Island waters occurred in Pettaquamscutt Cove in 1980 (Tomas and Smayda 2008). Documented blooms occurred again in Point Judith Pond in 1997 and in Narragansett Bay in 2016 and 2018 (DEM 2016, Carney 2020).

The increase in *C. polykrikoides* blooms has not been limited to Rhode Island, but has occurred simultaneously in many places around the globe (Griffith *et al.* 2019). For instance, in Buzzards Bay, Martha's Vineyard, Nantucket, and various estuaries on Long Island, blooms were nonexistent prior to 2004 but are now commonplace (Griffith *et al.* 2019). The mechanisms driving this increase are not fully understood. Gobler *et al.* (2012) found that nitrogen enrichment can enhance productivity of *C. polykrikoides* relative to other phytoplankton species, and that this nutritionally flexible species is able to take advantage of various types of nitrogen (glutamic acid, urea, ammonium, nitrate) and do well in a variety of nutrient regimes. Griffith *et al.* (2019) observe that blooms have intensified in areas where managed nutrient reductions have taken place, suggesting that eutrophication alone is not the primary driver of enhanced and more frequent blooms. In addition, Griffith *et al.* (2019) suggest that warming plays an important role. They demonstrate this by showing that warmer temperatures contribute to accelerated growth rates and extended growing seasons in *C. polykrikoides*.

Scientists have also detected shifts in the seasonality and species composition within the zooplankton community in Narragansett Bay. Like changes in the winter-spring diatom bloom, changes in zooplankton timing and abundance appear to be driven by climatic changes and variations, and have been evident for several decades. Although the lack of consistent long-term time series on zooplankton makes it challenging for scientists to track changes in abundance and phenology reliably over time, certain patterns emerge.

For instance, zooplankton data collected between 1972 and 1990 at the location of the Narragansett Bay Long-Term Plankton Time Series monitoring station shows that warming trends initially stimulated an increase in abundance and seasonal duration of *Acartia tonsa*, a copepod species that has traditionally been dominant in summer in Narragansett Bay (Borkman *et al.* 2018). Curiously, such a change did not take place with the winter dominant, *Acartia hudsonica* (Borkman *et al.* 2018). The net result was that in the 1980s and 1990s, the Narragansett zooplankton community shifted to a composition more characteristic of the Chesapeake Bay ecosystem (Borkman *et al.* 2018).

However, after this initial increase, *A. tonsa* abundance appears to have subsequently subsided (Sullivan *et al.* 2007), likely as a result of upward trends in the abundance and seasonal duration of another zooplankton species, *Mnemiopsis leidyi*, that preys upon *A. tonsa. M. leidyi* is summer-blooming ctenophere, for which Narragansett Bay represents the northern edge of its historic range (Sullivan *et al.* 2001). Earlier arrival and peaks in seasonal abundance of *M. leidyi* have been one of the most conspicuous changes to take place in the Narragansett Bay zooplankton community (see Beaulieu *et al.* 2013, Costello *et al.* 2006, Slesinger *et al.* 2020, Sullivan *et al.* 2001, 2008). Slesinger *et al.* (2020) found that on average, blooms occurring during the years 2001-2019 occurred four weeks earlier than blooms occurring during 1972-1997, although there was notable interannual variability within the dataset. Whereas *A. tonsa* had previously been able to take advantage of its earlier bloom time to avoid predation by *M. leidyi* in the early summer season, the earlier arrival of *M. leidyi* eliminated this opportunity (Borkman *et al.* 2018; Sullivan *et al.* 2007).

These findings underline the complexity of predicting plankton community responses to the changing climate (Sullivan *et al.* 2007). The shifting phenology of *M. leidyi* may have a variety of additional ecological repercussions. Through their predation, high numbers of *M. leidyi* can exert top-down control on the abundance of smaller zooplankton, such as copepods and ichthyoplankton (Deason and Smayda 1982). This predation has been shown in turn to reduce copepod grazing through a trophic cascade (Deason and Smayda 1982). Because of these interspecies relationships, the seasonal timing and abundance of *M. leidyi* can have ripple effects throughout the Narragansett Bay ecosystem. For instance, if fish spawning times remain static as the *M. leidyi* peaks shift to earlier in the season, then predation on planktonic eggs and larvae may increase, and fish recruitment may be affected (Sullivan *et al.* 2001). The findings of Sullivan *et al*. (2007) and Borkman *et al.* (2018) suggest that the impacts of earlier and more intense activity by *M. leidyi* on fish and shellfish species will depend on the degree to which these species' spawning phenologies adapt to changes in the climate.

The Finfish Community

Interview evidence suggests that the finfish community as a whole has experienced two discernible patterns: (1) a trend in declining abundance of resident fish, along with an increase in migratory fish, and (2) a decline in species diversity as migratory warm-water fish like scup and black sea bass have come to dominate catches.

SEK monitoring has detected community-level changes in the finfish community in Narragansett Bay as well. These include a decrease in the ratio of demersal to pelagic fish (Oviatt *et al.* 2003, Collie *et al.* 2008), a decrease in colder water species such as winter flounder (Oviatt *et al*. 2003, Collie *et al*. 2008), an increase in warmer water species such as scup (Collie *et al.* 2008), an increase in invertebrates such as lobsters, crabs, and squid (Oviatt *et al.* 2003, Collie *et al.* 2008), and a slight increase in species diversity (Collie *et al.* 2008).

Because of the passage of over a decade between when these studies were conducted and the timing of the NB 2019 interviews, it is not surprising that there are some differences between interview data and the observations summarized in Oviatt *et al.* (2003) and Collie *et al.* (2008). Specifically, instead of the slight increase in species diversity mentioned by Collie *et al.* (2008), one fisherman commented on a decrease in diversity, and instead of the increase in lobsters mentioned by Oviatt *et al.* (2003) and Collie *et al.* (2008), many fishermen mentioned a decrease in lobsters. Nonetheless, interview data and these published studies concur in their observations about a decline in winter flounder and an increase in warm-water species.

Below, we compare interview-derived accounts of finfish abundance with SEK-derived accounts of abundance for specific species in Narragansett Bay.

Black Sea Bass (*Centropristis striata*). Interview evidence suggests a sharp increase in the abundance of black sea bass in the mid-2010s, with a possible tapering off of this increase by the time of the NB 2019 interviews.

Data from the URI GSO Fish Trawl Survey (Figure H - 52) corroborates this increase and coincides with the timeline provided by most respondents. According to this data, black sea bass abundance at the sampling station in the Middle West Passage has been higher in the 2000s and 2010s than in the last two decades of the 20th century. Abundance peaked steeply in 2012 and returned to 21st-century baseline levels by 2014.

Data from the DEM Coastal Trawl Survey (Figure H - 53) also corroborate interview evidence of an increase in black sea bass, though on a slightly different timeline. In the bay-wide DEM data, an order-of-magnitude boom in black sea bass abundance occurred in 2015. The population returned to baseline levels the following year, but then began to creep upwards in 2018-2019.

Eels (*Anguilla rostrata*). Interview evidence suggests a sharp decline in eel abundance in Narragansett Bay, after a period of high abundance and landings in the 1980s. Comparing this observation with SEK is difficult because data on adult eels in Narragansett Bay is unavailable and data on glass eels (young of the year) has only been collected since 2000, at a single location (Gilbert Stuart Brook). Scientists have not been able to develop age-structured population dynamics data for eels due to their unique life histories, and landings data are often considered incomplete and can be hard to interpret because fisheries focus on different life stages for different purposes, such as aquaculture inputs, bait, and food (Haro *et al.* 2000, Shepard 2015).

Eels are catadromous and panmictic. All American eels share a common spawning area in the Sargasso Sea, and their larvae are transported to estuaries through passive drift. As a result, there is no direct relationship between the number of eels recruiting to a water body and the level of production of adult eels emigrating from that water body (Haro *et al.* 2000). However, once recruits arrive in a water body, they may be faced with a number of different anthropogenic stressors (e.g., dams, pollution, fishing) that limit their survival.

Despite these challenges, scientific interpretations of regional data coincide with fishermen's observations of a local decline beginning during or after the 1980s. For instance, Haro *et al*. (2000) evaluated available evidence from 1984-1995 and concluded that a decline in eel populations from several regions of North America was most likely occurring. The Atlantic States Marine Fisheries Commission found "some significant downward trends in surveys across the coast" (ASMFC 2017). In fact, in the early 2000s, the U.S. Fish and Wildlife Service received a petition to classify the American eel for listing under the Endangered Species Act (Shepard 2015). Landings time series show that the highest landings in their regional time series, which dates back to the 1950s, occurred from the mid-1970s to the early 1980s, after which they declined (ASMFC 2017, Shepard 2015).

Scup (*Stenotomus chrysops*). Interview data presented a mixed picture regarding trends in scup abundance in Narragansett Bay, with some fishermen saying that scup were increasing and others sharing observations of a downtick or decrease. This data was not always spatially or temporally explicit, and thus it is possible that interviewees were referring to different places or timelines.

Data from the URI GSO Fish Trawl Survey (Figure H - 55) show a long-term increase in the abundance of scup at the Fox Island Station in the Middle West Passage, but this increase has not been uniform across the time series. After reaching a high point in 2015, the time series shows a downtick during the two years immediately prior to the NB 2019 interviews.

Data from the DEM Coastal Trawl Survey (Figure H - 56) also show a general increase in the scup population in Narragansett Bay. As with black sea bass, the 2000s-2010s have exhibited a baseline population level that is higher than levels from the late 20th century. Superimposed on this baseline level, the data showed a steep peak in 2015 followed by a drop in population levels to 21-st century baseline levels from 2016-2019.

In our estimation, data from both the URI GSO Fish Trawl Survey and the DEM Coastal Trawl Survey are largely consistent with the data from fisherman interviews.

Menhaden (*Brevoortia tyrannus*). Interview data presented a mixed picture regarding trends in menhaden abundance in Narragansett Bay, with some fishermen describing an uptick in menhaden abundance in the years immediately prior to the RF 2016 and NB 2019 interviews, and others providing evidence for a decline since the mid-2010s.

Data from the URI GSO Fish Trawl Survey (Figure H - 59) show no discernible long-term trend in menhaden abundance at the Fox Island Station in the Middle West Passage. Rather, these data indicate a relatively stable abundance with occasional population booms taking place, for example in 1998, 2015, and 2018. These data are consistent with interviews, which also provided evidence for upticks around 2015 and 2018.

Data from the DEM Coastal Trawl Survey (Figure H - 60) paint a similar picture, with low and stable population levels dominating the time series and occasional population booms occurring, for example in 2007 and 2017 (different years from those shown in the URI GSO survey of the Middle West Passage).

On the whole, we find that the URI GSO Fish Trawl Survey is largely consistent with fishermen's perceptions of an uptick in menhaden abundance in the year immediately prior to the RF 2016 interviews, but not with perceptions of an uptick in the year immediately prior to the NB 2019 interviews. Both scientific monitoring datasets also align with one respondent's perception of a multi-year decrease since the mid-2010s.

Sea robins (*Prionotus evolans*). Interview evidence suggests that the abundance of striped sea robins in Narragansett Bay has increased over time.

Data from the URI GSO Fish Trawl Survey (Figure H - 63) corroborate this increase, showing a consistent increase in this species in the trawl catch since the 1990s, with a sharp spike in abundance occurring in 2017.

Data from the DEM Coastal Trawl Survey (Figure H - 64) also corroborate interviewee perceptions of an increase in this species. DEM data show two sharp increases: one in 2000 and another in 2015, two years after the increase shown in URI GSO data.

Birds

Interview evidence suggests that the cormorant population in Narragansett Bay has increased precipitously since the 1980s and 1990s. The EPA's Winter Waterfowl Survey does not indicate an obvious increase in cormorant abundance since its inception in 2004. However, the timeline of this survey began long after the fishermen interviewed began gathering their observations on cormorant abundance, and this may explain the difference. A nest survey referenced in Raposa (2009) corroborates this hypothesis, showing a sharp increase in cormorant abundance between the mid-1980s and the mid-1990s, followed by a flattening of abundance trends (see Figure H - 66).

The NB 2019 interviews also yielded observations about the relationship between cormorants and winter flounders, with a suggestion that predation of the former on the latter is an important top-down driver of population trends. In a study on this topic in the early 2000s, French McCay and Rowe (2004) estimated that cormorants consumed about 10% of winter flounder young-of-the-year, and remarked that the impact of cormorant predation on winter flounder is much less severe than the impact of human harvest. Whether or not this contradicts the observations gleaned through the NB 2019 interviews is a matter of interpretation.

Mammals

Interview evidence suggests that seals are now present in greater numbers and for longer in the season than they were when many fishermen began their careers in the 1980s and 1990s.

The Save the Bay Seal Count (Figure H - 68 through Figure H - 71) does not show any clear trends in seal abundance since 1998 at their Rome Point, Brenton Point, and Church Cove survey sites, and annual seal counts for the bay as a whole are only available from 2009-2019. However, Schroeder (2000) reported that the overall seal population in Rhode Island waters experienced a significant increase in the maximum number of seals observed in Rhode Island waters between 1973 and 1998 (Figure H - 67). During the period 1987-2000, Schroeder estimated that the number of seal haul-out sites in Rhode Island tripled and the number of harbor seals quadrupled (representing a tenfold increase since the late 1960s). Schroeder also found evidence that the seal haul-out at Rome Point (typically the largest in the bay) clearly increased between the period 1966-1973 and the 1990s. This increase is likely explained by the passage of the federal Marine Mammal Protection Act in 1972.

Abiotic Factors

Interviews provided insights on two abiotic aspects of Narragansett Bay: an increase in water clarity and a smell described as reminiscent of chlorine. There is no SEK dataset on smells in the bay, and the source of this smell may need to be investigated through conversations between fishermen, scientists, and managers. In contrast, there are several sources of water clarity data collected in Narragansett Bay which can be compared with fishermen's observations. Most of these sources were synthesized in the 2017 *State of Narragansett Bay and Its Watershed* report (NBEP 2017a).

Data from 2014 show that water clarity was greatest in the southern portions of Narragansett Bay and declined into the Upper Bay (NBEP 2017a; see Figure H - 72). Water clarity was highest during the winter, and it decreased through the spring and summer. From 1972 to 1997, water clarity increased steadily at Fox Island in the Middle West Passage, especially in the summer months, but data from 2004 to 2014 did not show any increase (NBEP 2017a; see Figure H - 73). In the bay's urbanized northern sections, water clarity data collected in recent years showed strong interannual variability with no discernible trends (NBEP 2017a; see Figure H - 74).

The picture painted in these data sets contrasts with fishermen's descriptions of a dramatic increase in water clarity. However, there is a potentially significant temporal misalignment between the timing of the data presented here (up until 2014) and the timing of fisherman interviews. Notably, fishermen only brought up this dramatic change in the RF 2016 and NB 2019 interviews (not in the SH 2014 interviews), both of which were conducted later than the data presented in Figure H – 72 to Figure H - 75. Since fishermen suggested that this increase in water clarity had occurred quite recently, it is worth examining more recent water clarity data when these data become available. Currently, NBEP is working with experts to update available data, explore new datasets, and consider how water clarity may be changing in response to managed nutrient reductions and climate change.

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APPENDIX A. INTERVIEW QUESTIONNAIRE

Part I. Interviewee Personal Information

1. Name:
2. Boat name:
3. Port(s):
4. First year and last year you fished commercially:
5. First year and last year you fished in Narragansett Bay:
6. Areas of Narragansett Bay you fish regularly (name and draw on map)
7. Areas outside Narragansett Bay you fish regularly:
8. Primary target species:
9. Secondary target species:
10. Primary gear type(s):
11. Secondary gear type(s):

Part II. Biotic Changes

I'm going to show you a list of species and lay out a bunch of cards on the table. This list and these cards contain many organisms that may be found in Narragansett Bay. I want you to look these over altogether for a minute before you say anything. Think about which of these organisms have changed in a substantial way during your time on the water.

Once you've looked them over, tell me which ones have changed during the time you've been fishing in the bay? This can be a change in time, a change in space, a change in size, or a change in behavior. For each species, I want to learn all about the changes you've observed. I'll ask you when each change occurred, and I'll ask you to draw it for me on a nautical chart if you can.

1. Has this organism changed in SPACE? Please mark up this nautical chart to illustrate changes in coverage, if appropriate. Are there certain areas where it used to be abundant and is no longer abundant? Are there certain areas where it used to be scarce and is now abundant?

2. Has this organism changed in TIME? How has it changed over the years that you've been fishing? How has its seasonality changed?

3. Has this organism changed in SIZE, SHAPE, or TEXTURE?

4. Has the organism changed in BEHAVIOR?

5. Do you see this change as being related to other changes? What makes you think there is a relationship? Things to consider:

- Wet years / dry years?

- Trend over time?
- Seasonal?
- North / South?
- Intertidal / subtidal?
- Benthic / pelagic?

5. For each change: Is this something you've personally seen, or is it something you've heard about from other people?

6. For each change: Do you consider this change to be negative, positive, or neither? Is this change an indicator of "resilience" or of "poor ecological health" of the bay, in your mind?

<u>Part III. Abiotic Changes</u>

Now let's talk about the nonliving aspects of the bay. I'm going to list several aspects of the physical environment. If you have noticed any changes in these aspects that you would consider significant, then let me know. Think with all five senses.

1. How has this aspect changed in SPACE? Please mark on the nautical chart to illustrate spatial changes, if appropriate.

2. How has this aspect changed in TIME? How has it changed over the years that you've been fishing? How has its seasonality changed?

3. Are there other dimensions that have changed? Do you see this change as being related to other changes? What makes you think there is a relationship? Things to consider:
   - Wet years / dry years?
   - Trend over time?
   - Seasonal?
   - North / South?
   - Intertidal / subtidal?
   - Benthic / pelagic?

4. For each change: Is this something you've personally seen, or is it something you've heard about from other people?

5. For each change: Do you consider this change to be negative, positive, or neither? Is this change in any way related to the "resilience" of the bay, in your mind?

<u>Part IV. Total Ecosystem Health and Resilience</u>

1. How would you define a "resilient" Narragansett Bay? A "healthy" Bay?

2. How does the Bay's current state compare to a "healthy" Bay?

3. What year(s) was the Bay at its most resilient/healthy?

4. What year(s) was the Bay at its least healthy state?

5. Are there certain parts of Narragansett Bay that are resilient now?

6. Are there certain parts of Narragansett Bay that are in poor health now?

7. Are there certain areas of the Bay that have changed more drastically than others?

8. Are there certain periods of time when the Bay changed more rapidly than others?

9. Do you have any theories about the factors causing the changes you've mentioned?

10. Have you spoken with the following groups about these changes?

__ Fishermen
__ Scientists (please specify:_______________________________)
__ Other (please specify: _______________________________)

11. What have you learned from those conversations?

List of species made available to interviewees, with photo cards where noted

Benthic Invertebrates
Lobster
Jonah crabs
Sand crabs
Spider crab
Horseshoe crabs
Green crabs
Blue crabs
Mantis shrimp
Sand shrimp
Starfish
Whelks
Moon snails
Quahogs
Blue mussels
Oysters
Deckers
Barnacles
Soft-shell clams
Scallops
Fouling invertebrates (see photo cards)
Bugula neritina
Didemnum sp.
Golden star tunicate (*Botryllus schlosseri*)
Orange tunicate (*Botrylloides violaceus*)
Hydroids (*Ectopleura sp.*)
Sea squirts (*Styela clava*)
Sea grapes (*Molgula manhattensis*)
Red beard sponge (*Clathria prolifera*)
Tricellaria inopinata
Plankton
Phytoplankton
Zooplankton
Comb jellies
Lion's mane jellyfish
Other jellyfish
Grasses/Macrophytes (see photo cards)
Eelgrass
Widgeon grass

Seaweeds/Macroalgae (see photo cards)
Agardhiella subulate
Dasysiphonia japonica
Dead man's fingers (*Codium fragile*)
Desmarestia viridis
Dulse (*Palmaria palmata*)
Ectocarpus siliculosus
Grateloupia turuturu
Grinellia americana
Irish moss (*Chondrus crispus*)
Rockweed (Order Fucales)
Sausage weed (*Scytosiphon lomentaria*)
Sea lettuce (*Ulva sp.*)
Sugar kelp (*Saccharina latissima*)
Ulva spp.
Finfish
Black sea bass
Scup
Cunner
Tautog
Summer flounder
Winter flounder
Bluefish
Striped bass
Menhaden
Herring
Sea robins
Oysterfish
Eels
"Southern" fish
Sharks
Seahorses
Birds
Mammals

APPENDIX B. DESCRIPTION OF RESPONDENTS

NB 2019 Interviews

The sample size for this interview project was 17 individuals. Sixteen individuals completed the full interview and one completed a partial interview. Table B - 1 displays biographical information on the 17 respondents who participated. In order to anonymize the data while retaining some biographical information about each respondent, a respondent code was assigned to each individual based on their primary gear type and primary port.

Table B - 1. Summary of respondents participating in the NB 2019 project interviews.

Respondent Code	Primary Gear Type	Secondary Gear Types	Port(s)	Fishing Grounds (historical and present)	Fishing History
AE1	Aquaculture	Rod and reel	East Bay	Aquaculture lease in Middle East Passage; rod and reel fishing all over Narragansett Bay	Has fished commercially since 1977 in ocean and Narragansett Bay; has had oyster farm in Middle East Passage since 2002
AE2	Aquaculture	Bull rake	East Bay	Aquaculture lease in Middle East Passage; quahogs in Upper Bay and Greenwich Bay; used to harvest wild oysters in Bristol Harbor and Upper East Passage	Has fished commercially since 1972; has quahogged in Narragansett Bay since 1981; has had an oyster farm in Middle East Passage since 2007
LK1	Lobster	Otter trawl, aquaculture	North Kingstown	Mount Hope Bay, Greenwich Bay, Upper Bay, Upper West Passage, Middle West Passage, Lower West Passage, Upper East Passage, Middle East Passage; aquaculture lease in Middle West Passage	Has fished commercially in Narragansett Bay since 1989; has oyster farm in the Lower West Passage

LN1	Lobster	Whelk pots, fish pots, rod and reel	Newport	Mount Hope Bay, Upper East Passage, Middle East Passage, Lower East Passage, Middle West Passage	Has fished commercially in Narragansett Bay since 1998
LN2	Lobster	Fish pots	Newport	Middle East Passage, Lower East Passage	Has fished commercially since 1988; has fished in Narragansett Bay since 1993
LN3	Lobster		Newport	Upper Bay, Upper East Passage, Middle East Passage, Warren River	Has fished commercially since 1980; fished in Narragansett Bay from 1980 to 2014; now fishes fulltime in Rhode Island Sound
LN4	Lobster	Fish pots, gillnet	Newport	Middle East Passage, Lower East Passage	Has fished commercially in Narragansett Bay since 1987
LN5	Lobster		Newport	Middle East Passage, Lower East Passage	Has fished commercially since 1972 in the ocean (inshore and offshore); has fished in Narragansett Bay since 1982
QE1	Quahog	Wild oysters	East Bay	Upper Bay, Upper West Passage, Middle West Passage, Warren River, Kickemuit River, Upper East Passage, Bristol Harbor	Has fished commercially in Narragansett Bay since 1979; retired recently
QE2	Quahog		East Bay	Missing	Has fished commercially in Narragansett Bay since 1959
QK1	Quahog		North Kingstown	Missing	Missing
QK2	Quahog		North Kingstown	Missing	Has fished commercially in Narragansett Bay since 1979
QK3	Quahog		North Kingstown	Missing	Has fished commercially since early 1970s; has fished in Narragansett Bay since 1980
QW1	Quahog		West Bay	Missing	Has fished commercially in Narragansett Bay since 1979

QW2	Quahog	Rod and reel, soft shell clams	West Bay	Upper Bay, Upper West Passage, Middle West Passage, Upper East Passage, Greenwich Bay	Has fished commercially in Narragansett Bay since 1982, with the exception of some time off in the 1990s.
QW3	Quahog	Lobster pots, eel pots	West Bay	Greenwich Bay, Upper Bay, Upper West Passage, Middle West Passage, Upper East Passage, Warren River	Has fished commercially in Narragansett Bay since 1981
TE1	Trawl		East Bay & Newport	Missing	Has fished commercially in Narragansett Bay and Rhode Island Sound since 1969

SH 2014 Interviews

The process of remining the 2014 Shellfish Heritage interviews found 11 interviews containing data relevant to the present project. Six of these individuals were also interviewed for the 2019 Narragansett Bay project. Biographical data for the five additional individuals is present in Table B - 2.

Table B - 2. Summary of respondents in SH 2014 project who provided data that was integrated into the present report.

Respondent Code	**Primary Gear Type**	**Secondary Gear Type**	**Port**	**Fishing History**
QK4	Quahog	Aquaculture	N. Kingstown	Has fished commercially in Narragansett Bay since 1981
QW4	Quahog		West Bay	Has fished commercially in Narragansett Bay since 1959
QK5	Quahog		N. Kingstown	Missing
QW5	Quahog		West Bay	Missing
DP1	Dredge		Point Judith	Missing

RF 2016 Interviews

The process of remining the 2016 Resilient Fisheries interviews found 8 interviews containing data relevant to the present project. Four of these individuals were also interviewed for the 2019 Narragansett Bay project. Biographical data for the four additional individuals is present in Table B - 3.

Table B - 3. Summary of respondents in RF 2016 project who provided data that was integrated into the present report.

Respondent Code	Primary Gear Type	Port	Fishing History
TK1	Trawl	N. Kingstown	Missing
TN1	Trawl	Newport	Missing
LE1	Lobster	East Bay	Fished commercially in Narragansett Bay from 1948 until retiring sometime before 2014
LN6	Lobster	Newport	Missing

APPENDIX C. KEY TO APPENDICES D-H

This appendix provides a key to reading and interpreting Appendix D through Appendix G.

Appendix D through Appendix F list observational statements made by interviewees about populations of organisms and abiotic factors in Narragansett Bay, derived from three separate research projects carried out by the same researcher, Sarah Schumann:

- A set of interviews conducted in 2019 for the "Commercial Fishermen's Observations of Ecological Change in Narragansett Bay" Pilot Project (hereafter referred to as "2019 Narragansett Bay" interviews) summarized in Appendix D;
- A subset of interviews conducted in 2014 for the book *Rhode Island's Shellfish Heritage* (hereafter referred to as the "2014 Shellfish Heritage" interviews) summarized in Appendix E; and
- A subset of interviews conducted in 2016 for the Resilient Fisheries RI project (hereafter referred to as the "2016 Resilient Fisheries" interviews) summarized in Appendix F.

Appendix G contains a table summarizing biotic observations from the 2019 Narragansett Bay project, 2014 Shellfish Heritage Project, and 2016 Resilient Fisheries project in spreadsheet form. Observations in Appendix G are cross-referenced with observations in Appendix D through Appendix F.

For each organism, the following summary information is listed at the top of the section:

- The total number of respondents commenting on this organism;
- Segments of Narragansett Bay mentioned by these individuals (defined using the Narragansett Bay Estuary Program's "BAYSEGMENTS_NBEP2017" digital map[5,6];
- Any trends in organism abundance mentioned by these individuals, defined as in Table C - 1.

For each abiotic factor, the following information is listed at the top of the section:

- the total number of respondents commenting on this organism
- segments of Narragansett Bay mentioned by these individuals (defined using the Narragansett Bay Estuary Program's "BAYSEGMENTS_NBEP2017" digital map.[5]

[5] NBEP, 2017. Bay Segments; BAYSEGMENTS_NBEP2017. Narragansett Bay Estuary Program (NBEP), URL: http://www.nbep.org, Providence, Rhode Island (publication date: 2020-01-07).
[6] In cases where spatial detail was insufficient to locate an observation by segment, a "section" was used instead: NBEP, 2017. Bay (Estuarine) Sections; BAYSECTIONS_NBEP2017. Narragansett Bay Estuary Program (NBEP), URL: http://www.nbep.org, Providence, Rhode Island (publication date: 2020-01-07).

Table C - 2. Explanation of "trend" classifications

Trend Type	Explanation
Decline	Definition: • A population has declined in abundance/frequency for two or more years; or • A population shifted from a state of greater abundance/frequency to a state of lower abundance/frequency two or more years ago. Notes: • All observational statements classified as showing a “decline” extend up to and include the present day. • When provided, the “time period” description for observations in the “decline” category will be phrased in a “since YEAR(s)” format or a “abundant in YEAR(s); scarce now” format. In the former case, the interviewee providing the observation stated either that a decline began in the YEAR(s) in question or that (s)he has not encountered the organism since the YEAR(s) in question. In the latter case, the interviewee phrased the observation in a “before/after” format, comparing the present to a point of time in the past with a higher abundance than the present.
Increase	Definition: • A population has increased in abundance/frequency for two or more years; or • A population shifted from a state of lower abundance/frequency to a state of greater abundance/frequency two or more years ago. Notes: • All observational statements classified as showing an “increase” extend up to and include the present day. • When provided, the “time period” description for observations in the “increase” category will be phrased in a “since YEAR(s)” format or a “scarce in YEAR(s); abundant now” format. In the former case, the interviewee providing the observation stated either that an increase began in the YEAR(s) in question. In the latter case, the interviewee phrased the observation in a “before/after” format, comparing the present to a point of time in the past with a lower abundance than the present.

<table>
<tr><td>Uptick</td><td>Definition:
A population experienced a minor increase, often (but not necessarily) within a longer-term countervailing trend (i.e., decline or period of constancy); or
A population experienced a minor increase within a larger pattern of variability or cyclicity, which may be part of this cyclicity/variability;
A population experienced a small increase within the last two years; or
Interviewee observed a small increase in a population within the last two years, and has no knowledge of the population prior to this time.
Notes:
All observational statements classified as showing an “uptick” extend up to and include the present day.
When provided, the “time period” description for observations in the “uptick” category will be phrased in a “since YEAR(s)” format.</td></tr>
<tr><td>Downtick</td><td>Definition:
A population experienced a minor decline, often (but not necessarily) within a longer-term countervailing trend (i.e., increase or period of constancy); or
A population experienced a minor decline within a larger pattern of variability or cyclicity, which may be part of this cyclicity/variability;
A population experienced a small decline within the last two years; or
Interviewee observed a small decline in a population within the last two years, and has no knowledge of the population prior to this time.
Notes:
All observational statements classified as showing a “downtick” extend up to and include the present day.
When provided, the “time period” description for observations in the “downtick” category will be phrased in a “since YEAR(s)” format.</td></tr>
</table>

Constant	Definition: • A population has remained stable in its abundance within the time period during which the respondent has been fishing in the area. Notes: • All observational statements classified as “constant” extend up to and include the present day. • A “time period” description is not listed for observations classified as “constant.” The timeframe is assumed to be from the start of each interviewee’s fishing career (which varies by individual) until the present.
Cyclical/ Variable	Definition: • A population has shown repeated ups and downs within the time period during which the respondent has been fishing in the area; Notes: • No distinction is made in our classification scheme between ups and downs that recur regularly and with comparable magnitude (i.e., cycles) and those that are more random and irregular (i.e., variable). • Observational statements classified as “cyclical/variable” are general statements made without regard to particular times and places. • Frequently, an interviewee may make such a statement in combination with more specific observations that serve as examples of upturns and downturns within the cycle or history of variability. These instances will be double-classified as “cyclical/variable” (without any accompanying spatial or temporal details) and as whatever trend the example represents (e.g., boom, collapse, increase; decline; uptick, downtick; with accompanying spatial or temporal details).
Boom	Definition: • A population experienced a sharp increase followed by a sharp decline at one point in time, with relatively constant abundance before and after this time; or • A population experienced a sharp increase followed by a sharp decline at one point in time, within a longer-term trend of cyclicity/variability.

	Notes: • Observational statements classified as “booms” have an end date prior to the time of the interview, and are considered historical statements. • Some “booms” are notable in their scale (i.e., an organism experienced a massive and memorable set), but this is not a precondition to be classified as a “boom”; rather, what sets a “boom” apart is that it was a time of above-average abundance with a discreet beginning and end. • When provided, the “time period” description for observations in the “boom” category will be phrased in an “in YEAR/DECADE” or “between YEAR 1 – YEAR 2” format.
Collapse	Definition: • A population experienced a sharp decline followed by a sharp increase at one point in time, with relatively constant abundance before and after this time; or • A population experienced a sharp decline followed by a sharp increase at one point in time, within a longer-term trend of cyclicity/variability. Notes: • Observational statements classified as “collapses” have an end date prior to the time of the interview, and are considered historical statements. • Some “collapses” are notable in their scale (i.e., an organism experienced a massive and memorable die-off), but this is not a precondition to be classified as a “collapse”; rather, what sets a “collapse” apart is that it was a time of below-average abundance with a discreet beginning and end. • When provided, the “time period” description for observations in the “collapse” category will be phrased in an “in YEAR/DECADE” or “between YEAR 1 – YEAR 2” format.

Observational statements are anonymously attributed to the individuals who expressed them, using the following key:

> {primary gear type*} + {port**} + {individually assigned ordinal identifying number}
>
> * "Primary gear type" is defined as: L = lobster traps; Q = quahogging; A = aquaculture; T = trawl; and D = dredge.
>
> ** "Port" is defined as: N = Newport; E = East Bay (Warren, Bristol), W = West Bay (Warwick, East Greenwich); K = North Kingstown, and P = Point Judith.

Additionally, each biotic observational statement in Appendix D through Appendix F is cross-referenced to a row in the table in Appendix G through a unique ordinal identifying number assigned to the statement itself. Both the anonymous individual attribution code and observational statement cross-referencing number are displayed in parentheses at the end of each observational statement within the text summaries in Appendix D through Appendix F. For example, "LN1-43" refers to observational statement #43 (cross reference to Appendix G), made by Newport lobsterman #1.

APPENDIX D. OBSERVATIONS EXPRESSED IN THE 2019 NARRAGANSETT BAY INTERVIEWS

Sessile Benthic Invertebrates

Biotic observations expressed by interviewees in the 2019 Narragansett Bay interviews are summarized below.

Quahogs (*Mercenaria mercenaria*)

- Number of respondents: 9
- Segments mentioned: Upper Bay, Upper West Passage, Middle West Passage, Upper East Passage, Middle East Passage, Western Greenwich Bay, Eastern Greenwich Bay, Warwick Cove, Apponaug Cove, Greenwich Cove, Dutch Harbor, Quonset Harbor, Bristol Harbor, Warren River, Potter's Cove
- Trends mentioned: decline, constant, boom, collapse

Nine quahoggers shared their observations of dynamics of the quahog population in Narragansett Bay. These observations were quite detailed, and included not only trends in abundance and distribution, but also observations related to quahog size, reproduction, and shell thickness.

Among the nine quahoggers interviewed, there was universal consensus that quahogs have become far less abundant in many parts of the bay in the last decade or so, and that this is the result of a decline in recruitment of seed quahogs. The words of one quahogger summarize the views of all of those interviewed: "There doesn't seem to be a lot of seed. Just in general. Places that typically seed up heavy (QW2)." This next several paragraphs summarize interviewee descriptions of this decline in quahog recruitment.

A quahogger and oyster grower stated, "What I've noticed is traditional areas that I fished in the '90s and early 2000s to 2010, now we go there, back to those same spots, and there's really nothing there. Maybe you'll find some chowders. But no set of clams." According to a map drawn by this individual, these areas include: a stretch of the Upper Bay from Colt State Park to Poppasquash (AE2-173); Western Greenwich Bay (AE2-174); Warwick Cove (AE2-175), Apponaug Cove (AE2-176), and Greenwich Cove (AE2-177); and an area just south of Patience Island (Upper West Passage (AE2-178). According to this individual, all of these areas stopped experiencing quahog recruitment around 2010. He adds that quahoggers don't bother working in these locations anymore. As an afterthought, he added, "In 2012 we had a set. They were tiny little seeds. You could see them. Thumbnail size. They grew up, and that carried [on] for a couple of years. That's the last set that I saw (AE2)."

A quahogger stated that several areas that were formerly quahog hotspots have stopped replenishing themselves. These areas include: a part of shellfish management areas 3W east of

Calf Pasture Point, overlapping the top of the Middle West Passage and the bottom of the Upper West Passage (QK1-179; QK1-180); Hunt's Ledge and Middle Ground in the Upper West Passage, including Magic Mountain (QK1-180); Pine Hill (Middle West Passage; QK1-179); and Western Greenwich Bay (QK1-181). In response, he adds, quahoggers have progressively shifted to now hotspots and then abandoned them when they failed to recruit:

> These normal areas, and even out in front of Quonset, in this section right here, say 15 years ago was really hot (Middle West Passage). You know, Mike McGiveney, the Marcuses, Bercaw, we were all in this area for a long time. From here, 20 years ago, we went to [Pine Hill; Middle West Passage], which was hot. Then we all went here into the hard bottom [Hunt's Ledge and Middle Ground, Upper West Passage]. And nothing's come back at all (QK1)!"

A quahogger stated that several areas that were formerly good quahog spots now only contain chowder-sized quahogs, dead shells, and deckers (*Crepidula fornicata*). These areas include: Pine Hill (Middle West Passage; QK2-182) and the High Banks and parts of Shellfish Management Area 3W (Upper West Passage; QK2-183). On the map, he also drew areas just north of Plum Point (Middle West Passage; QK-182), just south of Plum Point (Lower West Passage; QK2-184), and Dutch Harbor (QK2-185). These changes did not occur all at once, he explains; in the hard bottom, the quahogs continued to produce until more recently. He pinpoints the decline at Pine Hill and the High Banks (Upper West Passage) at about 15 years before the interview (i.e., around 2004), but did not mention when the other areas declined in relation to this (QK2).

A quahogger stated that he has seen a progressive decline in quahog abundance starting in the 1990s, with certain areas lasting longer than others. He described this progressive decline as follows:

- The shoals just north the Jamestown Bridge (Middle West Passage), just south of the Jamestown Bridge (Lower West Passage), Dutch Harbor, and Eastern Greenwich Bay declined in the 1990s (QK3-186; QK3-187; QK3-188; QK3-189).
- By 1993, a portion of the shoals east of Longmeadow (Upper Bay) was also in decline (QK3-190).
- By 2003, Rumstick Point (Upper Bay) was in decline (QK3-191).
- By 2010, Pine Hill (Middle West Passage) and the High Banks (Upper West Passage) were in decline (QK3-192; QK3-193).
- By 2015, Hunt's Ledge and Middle Ground (Upper West Passage) were in decline (QK3-194).

This quahogger estimated that the population in Greenwich Bay is about 10 percent of what it used to be, and says this change occurred within the last 5-10 years (QK3).

A quahogger stated that there is no longer much quahogging activity taking place from Warwick Lighthouse southward. In general, he commented, "Everybody's individual catches seem to be down. Everyone says the same thing. The money is maybe the same [because prices are higher]. But there aren't as many quahogs." He mentioned the following details:

- The High Banks (Upper West Passage) declined sometime after the early 2000s. It was made into a transplant area, but "It seemed like we only got back what we put in there (QW1-195)."
- The wintertime harvest area in Western Greenwich Bay stopped being productive about 8-10 years ago (e.g., about 2009-2011), after it was opened up one year during the summer (QW1-196).
- The coves of Greenwich Bay, which are only open for transplants, have also declined:

  > When we used to go into the coves to dig, it was like a holiday. You could get a lot. The most I ever did was a hundred bags. Most of the time I could get sixty, eighty, or ninety bags in four hours. The last time we had a transplant, it was in East Greenwich (Greenwich Cove), and I got thirty or thirty-three bags. It was horrible. So, what's happening with the biomass (QW1-197)?

- Ohio Ledge (Upper Bay) now contains a mix of dead shell and "good stuff" (QW1-431).

A quahogger stated that "There's a decline in the number of quahogs that we see in areas that were typically very well producing. I do know that it's a cyclical business. I've seen it where it's really good years and really bad years. I don't know if it's just the cycle of things… We're probably three good years into a decline…. Every year it's been a little less. It's not like a dramatic fall. Some places, yes, it's been a dramatic decrease. But for the most part, it's been a steady decline." He stated that quahogs have been decreasing everywhere, but the decline is more dramatic in certain locations:

- Johnson's Ledge (Middle West Passage) experienced a dramatic and sudden downtick in quahogs.

  > I fished this area a lot. And I went down there a few times, and the stuff that I was bringing up, I was bringing up full baskets, but they were all dead. They were all dead… I can bring you down there right now, and bring up a basket, and you'd go, "Oh my God, this is a great rake!" but they're all dead. They're still in the mud, but dead.... That was sudden. I want to say that was within the last year to eighteen months (i.e., 2017-2018). I made this known. Then I thought maybe it was just me, so me and Chris Hermanowski went down there. He's a good digger. And everything was dead... Two years ago, I was making a good day's pay. It was all bigs, but it was a good day's pay. And then I went down, and all of a sudden! I checked my numbers. I checked everything. I'd worked that area so much in my life. I had a bunch of old ranges. I even brought out my old book, looking at ranges. Dead. Dead. I don't know why (QW2-198)

- Dead shells are now present in several other locations: Allen's Harbor (Quonset Harbor; QW2-199), an area north of Pine Hill (Upper West Passage; QW2-200), Chepiwanoxet (Western Greenwich Bay; QW2-201) and Mary's Creek (Apponaug Cove; QW2-202). Dead shells began showing up in these areas within the 2-3 years prior to the interview (i.e., since about 2016-2017; QW2).
- Juvenile quahogs have stopped seeding up in most of Western Greenwich Bay (QW2-201), most of Eastern Greenwich Bay (QW2-427), and an area at the north end of The Gut between Patience and Prudence Islands (Upper Bay; QW2-426).

A quahogger stated that, in general, “There are a lot fewer [quahogs] than there used to be. You don’t get big sets anymore. I know there are some sets of small stuff, but we’ll see what happens this year as far as survivability.” He provided the following details:

- Areas that used to be reliable in the Middle West Passage (Pine Hill, off of Quonset, and Hope Island) have “hardly anything” nowadays (QW3-203).
- According to his drawing on the chart, this quahogger stated that in years past, juvenile quahogs set up in large swaths of Western Greenwich Bay (QW3-204) and Eastern Greenwich Bay (QW3-205), Ohio Ledge (Upper Bay; QW3-206), most of the Upper West Passage (QW3-207), and northern portion of the Middle West Passage (QW3-203). Nowadays, he only finds juvenile quahogs in certain specific spots (QW3).

A quahogger stated that Bristol Harbor, which used to be a good quahogging area, stopped producing 5 or 6 years ago (i.e., about 2013-2014). Nowadays, it is covered by a “yucky scum” or “slime” that clogs the rake, smothers the quahogs, and makes it hard to work:

> The wintertime in Bristol Harbor was always a good place. You could always make it a day in the wintertime. But now, I've poked all along the shore, up the cove, along Usher's Cove. I haven't found much. I don't even know how to describe it. It's like scum. It sticks to the rake. It makes it real hard to work. I kind of gave up on it (QE2-208)."

This quahogger stated that quahog populations in Death Valley (the channel between Hog Island and Bristol Point) have declined as well (Upper East Passage; 429).

In addition to highlighting areas where quahog recruitment has declined, these quahoggers also pinpointed areas where quahog abundance has remained stable. These areas are generally concentrated in the Upper Bay:

- A quahogger stated that Barrington Beach, the Seminary, and Rocky Point (Upper Bay) are the main areas where quahoggers work now, because they only areas with decent production of quahogs (AE2-209).
- A quahogger stated that quahog production is still good in the northern edge of Western Greenwich Bay (QK1-210) and at Rocky Point and Barrington Beach in the Upper Bay (QK1-211).
- A quahogger stated that the mouth of the Warren River (QE2-212) and Barrington Beach (Upper Bay) are still good (QE2-213).
- A quahogger stated that quahog abundance has remained steady around Rocky Point (Upper Bay; QK2-214), Friar’s Cove (Middle West Passage; QK2-215), and Mount Tom (Upper East Passage; QK2-216).
- A quahogger stated that 99% of the quahogging activity is now concentrated in Shellfish Management Areas A and B, especially Rocky Point and Barrington Beach (Upper Bay; QW1-217). He added that there’s “a little bit of stuff happening” at Homestead/Mount Tom Rock (Upper East Passage; QW1-218) and around the hard-bottom edges of Western Greenwich Bay (QW1-219).
- A quahogger listed several areas as still being good for quahogging today. In the Upper Bay, he mentioned Barrington Beach (in fact, the northern shallows have improved in

the last two years), Ohio Ledge, and Rocky Point (QK3-220). In the Upper West Passage, he mentioned Magic Mountain (QK3-221). In the Middle East Passage, he mentioned the northeast coast of Jamestown (this is a new fishing spot for him, so he does not know if this is newly abundant or has always been good; QK3-223).

- A quahogger stated that he still finds undersized quahogs (indicating active recruitment) in Friar's Cove (Middle West Passage; QW3-224), at the mouth of Greenwich Cove (QW3-225), the northern edge of Eastern Greenwich Bay (QW3-226), along the shoreline from the entrance to Potter's Cove to Mount Tom (Upper East Passage; QW3-227), and south of the Rocky Point Dock and at Barrington Beach in the Upper Bay (QW3-228). He has heard from others that there is recruitment in Warwick Cove and around Providence Point (Upper Bay). However, the recruitment that has been observed recently in these locations is diminished from years past. For example, he stated that quahog spat used to settle all over Area B, but it no longer settles in such abundance:

  > We had sets of quahogs that eclipsed anything that's happening now… We used to work out there fifteen or twenty years ago, and you could fill a rake up with half undersized. It was such a prolific set of baby quahogs, it staggered the imagination (QW3).

- A quahogger stated that Potter's Cove (QE2-229) and the shoreline between Potter's Cove and Mount Tom (Upper East Passage; QE2-230) have remained productive. Potter's Cove, in particular, "has been very good. I don't know why. I can't see what five or six months is going to do. It closes in May, Memorial Day weekend, and opens Columbus Day weekend. I don't think that's even six months. But, boom! Good again (QE2-229)."
- A quahogger stated that juvenile quahogs continue to seed up at Rocky Point and Barrington Beach (Upper Bay; W2-428).

Additionally, one individual sketched a few small areas where quahog recruitment has experienced a recent uptick. These areas are concentrated along the shoreline, where he suggested that there may be more freshwater flow. He started that they are "old areas that came back," and in some cases, they have already been depleted (QK3). These areas include:

- The shallow northern edge of Barrington Beach, for the last 2 years (i.e., since about 2017) (Upper Bay; QK3-422);
- A small area off Longmeadow (Upper Bay; QK3-422);
- Two small area south of Sandy Point (Upper West Passage; QK3-222) and north of Sandy Point inside Eastern Greenwich Bay (QK3-423);
- A small area near Calf Pasture Point (Middle West Passage; QK3-424); and
- The west side of Friar's Cove (Middle West Passage; QK3-424).

Many of today's quahoggers have several decades of quahogging under their belts, and they have seen ups and downs in the quahog population previously. The next five paragraphs summarize observations relating to historical cycles of quahog production in Narragansett Bay.

A quahogger who has been digging in Narragansett Bay since 1980 expressed a view that quahogs are cyclical (QE1-417). He explained that the 1980s were unbelievably good for quahogging (QE1-231), but in the 1990s, quahogs experienced a downward trend (QE1-232). Sometime between 2000 and 2010, quahogging got better again (QE1-233), but then it got worse, and it became harder to make a living. “I’ve lived through all those continuous events,” he says, referring to the ups and downs of the quahog population. For instance, he recalled a time when you could drift ten minutes in the mud at Pine Hill (Upper West Passage) without catching a single quahog. Then, all of a sudden, “That went from nothing to quahogs” and he started making a lot of money in that spot. In sum, he stated:

> I’ve been around long enough to know that things are cyclical. I’ve seen it when there were no quahogs. I’ve talked to old-timers who are way older than me, when I was young. They remember having to go to Jamestown because there was nothing. They would have to go to the north end of Jamestown in a skiff with a ten-horse because they needed to make money. There was nothing, nothing. They would come out of Warren. There was nothing. Then I’ve seen quahogs where you put in the rake and [count] “one, two, three, four” and you pick it up and they’re falling out like crazy. Two hundred littlenecks in the rake. And then go back to nothing again (QE1-417).

A quahoggger who has been digging in Narragansett Bay since 1958 stated:

> It's up and down. I know when I first started it was lousy. It was hard to make a living. The prices were low. Everybody seems to think that they were just plastered all over the place. I think a lot of it was we didn't have the equipment we got now. The poles would break. If you got a good pole, you'd treasure it. You'd cry when it breaks. I think the rakes weren't that good. I started in '58. But then things got better. Places started getting better. There were different times. The bay was closed for about five or six years. The Upper Bay, Barrington Beach. Even Ohio Ledge was closed. Part of Rocky Point was closed. Because of pollution, I guess. I've forgotten just why. And then they opened it up. Oh, my word! Barrington Beach! I took my daughter the first day, picking for me. We filled the boat up. We had about 1,500 pounds. It was hard to stop. We went home, went up to Wheatie’s for lunch and dropped my stuff off. She was pooped, so I dropped her off at home, and I went back out and got another 700 pounds. I had over a ton of quahogs that day. I wasn't high man by any means. I think three of four guys sank. All that weight. But it’s never done like that since. That was ’81. At the end of the year, the price went down. They wouldn't buy stuff. In the end, it was no better, because it messed the market up (QE2-234, QE2-418).

A quahogger who has been digging in Narragansett Bay since 1980 stated that the 1990s and early 2000s were good for quahogging, and part of the reason may have been that technology was improving. The areas that were best during that era, he explained, were in deeper waters. According to this individual, these areas were not only good because quahogs were plentiful in them, but also because the industry was adopting new technology such as GPS, suitcase rakes, and mechanized rake haulers. He also thinks that technological advances may have a relationship to the more recent decline:

> There were millions of pounds of quahogs all stretched through these areas that we didn't harvest, because you couldn't make any money harvesting it. But we were able to start fishing out there, because of the better equipment, and also simultaneously we had a good set of small ones that mixed in with them. You could make money on the small ones and the big ones. That biomass of larger and mixed clams that were out in those deeper areas got harvested. We took a huge percentage of the total biomass of the West Bay out in 10 years. There were plenty of areas over here where you could just barely make $20 an hour, and all of a sudden, we could make $50 an hour. Everybody came in. That was kind of peak in the digging in the Lower Bay. I occasionally thought that had something to do with the loss of recruitment in the West Bay, is that we wiped it out. That was also the same in some of these areas up here that I showed you. Those areas were marginal when you had to haul by hand. When you had a suitcase rake and you could catch twice as much as you could previously, that was pretty destructive to the biomass (QK3).

A quahogger who began digging in Narragansett Bay in the 1980s shared a view that quahogging is cyclical (QW2-419), and he has seen it change throughout his career. The 1980s, he said, were a high point "because the bay sustained that kind of numbers on a consistent basis for quite a few years… There were 1,000 or 2,000 guys out there every single day (QW2-235)." In contrast, the 1990s were a low point, and this individual quit quahogging for several years during that decade because he could not support his family on his quahogging income (QW2-236). Another high point occurred starting in 2005: "The best fishing I've seen was after the pogy [menhaden] kill. Two years after that, we had a super [quahog] set that came in (QW2-237)." At present (i.e., 2019), he said, quahogging is the worst he's ever seen it during his four-decade career (QW2).

A quahogger who began digging in Narragansett Bay in 1982 stated:

> There was a time when some of the old-timers talk about, when there were no quahogs at all in the bay. Then they started coming back in the Sakonnet River or something. But what caused that? Is it just a natural cycle? I know one thing that's wiped out quahogs in the past has been starfish. Like any predator, like a coyote, after they eat all the rabbits, they go away. After they go away, the rabbits come back, and then the coyotes come back. It's such a complex web. But one thing that's for sure, if you kill the nurseries, you ain't going to get anything.

When asked what time period in his career he would call the worst, he says "It appears to be now (QW3)."

Despite widespread agreement among interviewees that the quahog population has always been cyclical—whether due to recruitment variability, predation, or fishing pressure—two interviewees expressed a feeling that the changes they are witnessing today (progressive declines in recruitment in many areas that were previously quahog hotspots) are qualitatively different from downward trends of the past.

For instance, a quahogger who has been digging in Narragansett Bay since 1980 stated that recruitment is now more variable than in the past: "It was always variable in that you could make more money one place or another. But if you left areas, they came back. The recruitment stopped (QK3)."

In addition, a quahogger who has been fishing since the 1980s described today's low recruitment as "different," saying that:

> I blame that on overfishing, back then [in the 1990s]. We had thousands of guys, so there wasn't anything around. Now we're seeing dead stuff. There's not as many guys. And frankly, I don't think the bay would support the numbers [of quahoggers] that we had years ago. I know a lot of guys want to open up licensing, but based on what I see, the grounds aren't coming back. This one worries me the most [Johnson Ledge in the Middle West Passage], because you can surmise things that could have happened up here [in Western Greenwich Bay and Western Greenwich Bay]. There's old housing. You don't know what's coming in. But down here, I can't understand why. And the thing is, they're not laying on top. You bring the basket up and they look beautiful. They're still black with the white. They look gorgeous. But the more you shake them, it's a basket of dead shells. What happened? [In all the other spots] I can kind of figure maybe something happened environmentally. But there? That baffles me. That baffles me completely (QW2).

In addition to the observations summarized so far in this section, which are based on quahog abundance, several quahoggers also shared observations based on other quahog characteristics, such as their spawning behavior and their shell thickness. These observations are summarized below.

A quahogger shared evidence for a theory that quahogs are producing less spat than in the past, potentially explaining their low recruitment in recent years:

> A few years ago, I found that during the spawning season, I didn't feel that they were producing the amount of spat that they used to. I brought this up with one of the Sea Grant things and they kind of looked at me like I was out of my mind. Typically, in the summer, years ago, if you put water in a pail, the top of the pail would get slimy white. I mean, you could almost not even see the quahogs in the pail. I'm going to go out on a limb, but I'm going to say conservatively, the last five years, the water's as clean as you just poured it in the bucket. They don't seem to be producing the spat (QW2).

Three quahoggers shared an impression that quahog shells have become thinner and more brittle at times. This characteristic seems to vary over time and space.

A quahogger shared recollections of an upward trend in the frequency of brittle shells that occurred about 10 years before the interview (i.e., around 2009) and eventually tapered off: For a number of years, the quahog shells were very thin, but they seem to have adapted to that. Their shells seem to be hard again. They're not breaking like they were. I think it was about 10 years ago, it was like that… We went through a stage where they were was so brittle in a lot of places, that you get into the shop, and in some shops, even though it's really not the right thing to do, they were putting the bags in buckets of water that they would run into the water, so they wouldn't break so bad.

According to this quahogger, shells were more brittle in some locations than in others; the Upper Bay had the largest concentration of brittle shells (QK2).

A quahogger stated that he has been observing an upward trend in the frequency of brittle shells for the last 7 to 8 years (i.e., since about 2011-2012):

> The seed, the smaller ones—thin shelled, very fragile… They're thinner… It's becoming common now. I don't believe it ever really was [before]. When they get right around the size of where they're legal, you'll be racking them and there will be all sorts of cracks in them. You'll shake the rack and they'll break. I don't remember that so much [before].

This quahogger has encountered thin-shelled quahogs in a number of Upper Bay locations: Ohio Ledge, Magic Mountain, the north end of The Gut between Patience and Prudence Islands, Rocky Point, and the ledge near Seminary Point. He first noticed thin-shelled quahogs at Magic Mountain, and then at other locations (QW2).

A quahogger stated that quahog shells have been thinner and more fragile: "It's easier to break them. You can drop them on the floor of the boat and they're more likely to break." He adds that shells tend to be thinner in spots where quahogs are more crowded or where they don't get as much nutrition, causing them to grow more slowly. He also theorized that shell brittleness might be a symptom of lower pH/ocean acidification. According to this individual, shell brittleness can be found all over the bay, not only in specific locations. He stated that this has been a gradual change taking over the course of his career (QW3).

Bay Scallops (*Argopecten irradians*)

- Number of respondents: 5
- Segments mentioned: Upper Bay, Potter's Cove, Middle East Passage, Middle West Passage
- Trends mentioned: cyclical/variable, boom

Five individuals shared observations of bay scallops. All noted that bay scallops are highly variable in both space and time, popping up one year in one location and another year in another location (QE1-12, AE2-13, QK2-14, AE1-15, QK3-16). They described finding bay scallops in the following times and places:

- Potter's Cove in the 1980s (QE1-17)
- Aquaculture lease in the Middle East Passage in 2008: "we were averaging about 30 or 40 [per oyster bag]" (AE2-18)
- Scofield Ledge (off Rumstick Point in the Upper Bay) in 2014: "maybe a dozen in the course of a day" (QE1-19)

- Plum Point (Middle West Passage) at the time of the interview (2019): "enough to feed the seagulls" (QK2-20)
- Aquaculture lease in the Middle East Passage 4-5 years before interview (i.e., 2014-2015): "Four or five years ago was definitely the strongest I've ever seen. Before six or seven years ago, I never saw them (AE1-21)."
- Rocky Point (Upper Bay) in the year of the interview (2018-2019; QK3-22)
- Friar's Cove (Middle West Passage) in the year of the interview (2018-2019; QK3-23)
- Off Jamestown (segment unclear) in the year of the interview (2018-2019; QK3-24)

One observer drew a contrast between the scallops he observed when he started fishing in the 1970s and the scallops he finds now, saying that early in his career, scallops were more abundant and "huge." The scallops of recent years, he says, are like "runt scallops" (QK3).

Mussels (*Mytilus edulis*)

- Number of respondents: 7
- Segments mentioned: Upper Bay, Upper West Passage, Middle West Passage; Lower East Passage, Newport Harbor, Mouth of Narragansett Bay
- Trends mentioned: cyclical/variable, constant, increase, decline, boom

Four individuals stated that mussels have traditionally followed a cyclical pattern of population abundance in Narragansett Bay:

- A quahogger stated that mussel populations are cyclical (QK3-140).
- A quahogger stated that mussel populations are naturally cyclical (QW3-141).
- A quahogger stated "I have seen blue mussels come and go within two years (QE1-142)."
- A lobsterman stated that mussel populations are cyclical (LN4).

A lobsterman elaborated on the population cycles of mussels, stating that mussel populations seem to boom in inverse proportion to starfish populations, in a predator-prey loop:

> The starfish and the mussels are opposite… It was like a five- or six-year cycle: one year of mussels; the next year there'd be mussels and a couple stars; the third year there'd be less mussels and a few stars. Starting the fourth year, there's be primarily starfish, because they'd wipe out ninety percent of the mussels. Then the fifth year or the sixth year, they would start the whole cycle all over again, where the mussels would get a toehold.

This lobsterman also stated that in locations that are too turbulent for starfish, such as the House on the Rocks (Lower East Passage), mussel populations remain consistent rather than cycling (LN4-133). Additionally, he stated that mussel populations have stopped cycling in recent years due to the disappearance of starfish in Narragansett Bay (LN4).

Two individuals shared examples of memorable mussel sets from years past. Both described these sets as temporary occurrences with discreet beginnings and ends:

- A quahogger stated that the biggest mussel set he remembers took place about 15 years before the interview (e.g., around 2004) in the Upper West Passage and the Upper Bay: "It got paved with mussels on the east side of the channel bank from Poppasquash all the way to Nayatt. The same thing has happened in the lower bay[7] at times. You'd get a massive set of mussels and they'd smother in their own excrement... When those mussels smothered and died, the shells broke down a bit and we'd get phenomenal set of necks. But we haven't had any sets of mussels like that [in a while] (QW3-145; QW3-146)."
- A quahogger stated that a big mussel set occurred around Middle Ground in the Upper West Passage in the 1990s. According to this individual, this population increased for a year or two until mussels were so thick that it was hard to rake quahogs there. Then the mussels "disappeared as fast as they arrived," and now, there's "not even a shell" in these locations (QE1-147).

Two individuals shared examples of locations where mussels have declined. These individuals did not specify a time before mussels were abundant in these locations, so it is not clear whether these were temporary booms or whether there was a shift from a mussel-dominated state to a non-mussel-dominated state:

- A lobsterman mentioned a few locations where mussels used to be abundant, but have since declined: Brenton Point (between the Lower East Passage and the Mouth of Narragansett Bay; abundant in 1980s); Long Wharf (Newport Harbor; abundant as recently as three years before the interview; i.e., 2016); and southwest corner of Goat Island (Lower East Passage; LN2-148; LN2-149).
- A lobsterman mentioned a few locations where mussels used to be abundant, but have since declined (Lower East Passage): Fort Adams to Castle Hill; along the edge of the shoals near Rose Island; and near the Naval War College (LN4-150).

Two individuals mentioned areas where mussels have been consistent over the years, up through the present:

- A lobsterman stated that mussels continue to be present near the House on the Rocks (Lower East Passage; LN4-143).
- A lobsterman stated that mussels continue to be present at several locations in the Lower East Passage: Fort Adams; the west side of Rose Island in the shoals; Coddington Point; and the northwest corner of Goat Island (LN2-151).

Four individuals reported a recent increase in mussel populations in some locations in Narragansett Bay:

[7] Quahoggers often refer to areas south of Warwick Point as the "Lower Bay." In the NBEP designations used in this report, the area in question is considered the "Upper West Passage."

- An oyster grower stated that he had seen an increase in mussels clinging to the lines of his oyster cages recently (Middle East Passage; AE1-152).
- A quahogger stated that he had seen an increase in mussels in deeper water (over 30 feet), where they typically haven't set in the past. He theorizes this may be due to conch fishermen moving their traps around. Currently, he sees mussels at the Boiler Wash and the Hump (Middle West Passage). The mussel set located at the Hump just appeared recently, during the year of the interview (Middle West Passage; QK2-153).
- A quahogger stated that in the year prior to the interview (i.e., since about 2018), he had seen an increase in mussels around Middle Ground in the Upper West Passage (QW2-154).
- A lobsterman stated that he noticed a mussel set in front of the Naval War College (Lower East Passage) for the first time four years before the interview (i.e., about 2015; LN2).

Oysters (*Crassostrea virginica*)

- Number of respondents: 6
- Segments mentioned: Nannaquaket Pond, Mill Gut, Warren River, Barrington River, Kickemuit River, Bristol Harbor, Warwick Cove, Upper Bay, Upper East Passage,
- Trends mentioned: boom

Five individuals recollected an oyster boom that took place sometime between the late 1980s and the early 2000s. There was not universal agreement on when this boom took place, but it was a memorable (and profitable) event for those who participated in harvesting those oysters.

A quahogger who has been working in Narragansett Bay since the 1950s recalled the following:

- "When I first started doing this, you didn't see many. Just great big ones that had been there for 100 years. Once in a while you'd get two or three. That was about it (QE2)."
- Then, in the early 1990s, oysters showed up in Nannakuaket Pond (QE2-156).
- "Then, all of a sudden! I don't think anybody knows why they came back. Oh man, was that fun! The limit, you could get three bushels a day (QE2).[8]"
- "I remember Saturday afternoon, stopping at Mill Gut, when the tide was right, and grab three bushels. At the time was I think it was $25 for 50 pounds, if they were nice. You'd get them in no time (QE2-157)."
- "I remember in the Warren River, there were so many oysters on the beach, that you cut your boots up. They were standing up, all stuck together. Loads of them. They were kind of misformed, they were so close together. They were kind of ugly, but the meats were good (QE2-158)."
- "They were everywhere. They were even out in the middle (QE2)."

[8] RIDEM's daily limit for the commercial harvest of oysters is three bushels per day.

- "They were on Hog Island (Upper East Passage; QE2-159) and Ohio Ledge (Upper Bay; QE2-160)."
- "They were here for maybe eight or ten years…. Then they started to dwindle. You'd see little ones, but they didn't seem to grow (QE2)."

Another quahogger stated that during the oyster boom, he used to make three trips a day to the Barrington River to collect oysters, getting his 3-bushel limit each time (QE1-161). He stated that Bristol Narrows (Kickemuit River; QE1-162) was "paved" and that in Mill Gut, he "made a lot of money (QE1-163." He pins the timing of the boom somewhere in the early 2000s:

> That was all in the early 2000s. There were so many oysters. The more mature ones were in the water, the ones that got exposed at low tide were smaller because they didn't get fed as much. I saw a guy drive his truck down to the water, right over all the small oysters. They got the idea that, "This is never going away. This is always going to be here." … It was literally paved with oysters. They were driving on them! There were so many (QE1).

Three other quahoggers also shared recollections of this once-in-a-lifetime oyster boom:

- A quahogger stated that "We had a big oyster boom a few years back… I was tonging for them. It would take you half an hour to fill your boat and two hours to pick them down. It was insane (QW2-164).
- A quahogger stated that the "weird cycle" of oysters occurred in the 1990s (QK3-165).
- A trawl fisherman stated that "We had oysters come in. Boy, it was phenomenal! We had spat all over this bay with oysters. I'm going to say late '80s, around '85. We were getting sets of them everywhere. It was phenomenal. Then they [oysters] all got… a virus. That virus connected and went all over. (TE1-166)."

Several individuals stated that oyster populations have never again surged in this way. They maintained that at present, wild oysters are by and large absent from Narragansett Bay, although there were reports of oyster sets occurring sporadically in specific locations:

- A quahogger stated, "Nowadays, you don't see any; it seems like the spat doesn't settle anymore (QE2)."
- A quahogger stated, "You can't even find an oyster shell today (QE1)."
- A trawl fisherman stated, "Now we don't have any oysters (TE1)."
- An oyster grower stated, "We haven't had a good natural set in fifteen or more years." However, he added that good oyster sets occasionally occur in the Kickemuit River, Bristol Harbor, and Barrington River (AE1).

Two individuals shared a perception that much of Narragansett Bay's habitat is no longer favorable for oyster recruitment and growth:

- Observing the rise of oyster farming and the restoration programs that are in place for oysters, a trawl fisherman commented, "Look at all the oysters they're putting out there, and there's no sets. You would think that something would come out of it (TE1)."

- A quahogger who helps coordinate the Rhode Island Shellfishermen's Association's oyster restoration project stated:

  > The Shellfish Association keeps putting oysters out, trying to help them grow, and we get spots that they sustain, but they don't mass-produce. If you put oysters in a certain area and they have what they need, they explode. But we're not seeing it. I planted them, so I go back and check them. You might find one here, a couple there. But where I'm putting them, I'm putting them in notoriously famous oystering beds, and they're not coming back…. I'm putting them where the booms were…. I know, because I planted them, and they're not there…. I'm not going to say they're dying; they're just not doing anything. Even out of that survival rate, I'm going to say we lost a quarter to predation. But the ones in the upweller in <u>[Warwick] Cove</u>, they exploded (QW2).

  Regarding possible habitat differences that might explain the success of the oysters in the Association's upweller in <u>Warwick Cove</u>, this quahogger suggested that there is more food available in the water column for them there: "They got stuff to eat (QW2)."

<u>Deckers (*Crepidula fornicata*)</u>

- Number of respondents: 5
- Segments mentioned: Upper West Passage, Middle West Passage
- Trends mentioned: increase, cyclical/variable

A number of quahoggers mentioned recent increases in the population of "deckers" (also known as slipper limpets or slipper shells) in Narragansett Bay. Some of these observations were tied to specific locations:

- A quahogger stated that there has been a sharp increase in deckers at Magic Mountain (<u>Upper West Passage;</u> QK1-43) and Pine Hill (<u>Middle West Passage</u>; QK1-44).
- A quahogger stated that there are now "an enormous amount of deckers" at Pine Hill, High Banks, and 3W (<u>Middle West Passage</u>; QK2-45).
- A quahogger stated that "six or seven years ago (i.e., around 2012-2013), I started to see them more and more." He drew 10 current decker hotspots on the map: Barrington Beach, Rocky Point, and Ohio Ledge (<u>Upper Bay</u>; QW2-46); two areas in <u>Eastern Greenwich Bay</u> (QW2-47); Middle Ground in the <u>Upper West Passage</u> (QW2-48); off Quonset, and Pine Hill (<u>Middle West</u> Passage; QW2- 430) and the northeastern edge of Prudence Island and Mount Tom (<u>Upper East Passage</u>; QW2-49)."

Two individuals provided information indicating that decker populations are cyclical and have increased similarly in the past:

- A quahogger stated that deckers "come and go (QE1-50)."
- A quahogger stated that deckers are cyclical, and they have been thicker in some places in years past but they generally die off after a while (QK2-51).

The observed increase in abundance of deckers may have significant implications for quahogging in Narragansett Bay, by interfering with fishing activities. One quahogger stated, "You can kind of get underneath them, but you usually don't catch anything. You catch a few chowders. You catch some dead shell (QK2)."

Another quahogger stated:

> To be honest, it's put guys out of work, because there are certain guys who just cannot get through them. They just can't get underneath them. There are some guys, like myself, who we get around them. But there are some guys who just cannot get underneath them, so they've left the business. There were guys who were telling me, "I can't go to work, because it's blowing too hard and I can't get underneath the deckers. The deckers! The deckers (QW2)!"

Several individuals posited that the increase in deckers may also have negative impacts on the quahog population in Narragansett Bay. For instance, two quahoggers noted a tie between increases in decker populations and decreases in quahog populations in certain locations:

- One quahogger stated, "They seem to be so thick that I just don't think it's easy for quahogs to even set in a lot of places (QK2)."
- One quahogger stated, "They've started to fill in places that seemed to be heavily fished, and all of a sudden you'd go back and it was just full of those decker shells (QW2)."

Another quahogger mentioned that he previously held the opinion that deckers facilitated reseeding by quahogs by giving them shelter from predators; however, based on patterns he's observed in recent years (an increase in deckers combined with a decrease in quahogs), he is longer so sure about this positive relationship, and believes now that the impact of deckers on quahogs may be more negative (QK3).

Additionally, one quahogger and conch fisherman suggested that the increase in abundance of deckers may be tied to a dramatic decrease in the abundance of starfish, which prey on deckers. This quahogger says that these two changes coincided in time, and explains that deckers:

> … have always been around. What used to happen is they would kind of die off or they'd get eaten. There were so many starfish. I mean, there was a time when you could put your pots in a place where there were too many starfish, and you could barely pull your pot up overnight. It'd be like, instead of your pot weighing 30 or 40 pounds, it would weigh close to 100, because the thing would be completely covered in starfish. It really kind of coincided. Then all of a sudden, the starfish all died. What used to happen a lot is that places would get covered up with deckers or mussels. Then they would die off or get eaten, and it would be really good [for quahogs]. But it was like a much shorter time, like a year or two (QK2).

Soft Shell Clams (*Mya arenaria*)

- Number of respondents: 5
- Segments mentioned: Upper Bay, Western Greenwich Bay, Eastern Greenwich Bay, Barrington River, Palmer River
- Trends mentioned: boom, decline

A quahogger stated that, in general, there is a lack of soft shell clams nowadays (QE2), and the other 4 individuals mentioning soft shell clams tended to agree with him. They contrasted this with a soft shell clam boom that took place at Conimicut Point (Upper Bay).

One quahogger stated that this boom took place between around 2003-2004, and described it the following way (QW1-281):

> It was unbelievably great… The spat was like a carpet. Thick. It was like you had to part it so you could get at the adults. And of course, you didn't want to hurt the babies. That happened for two or three years, where we got carpets of them. I was like, "Holy smokes. This is going to be enough for forever (QW1.)

However, he went on to say, the boom ended shortly thereafter:

> All of a sudden, the water got warm. The water really comes flying over that sandbar. That's back when we had a half inch [of rain] to close [Shellfish Management] Area A. At that time, it was closing a lot on us. Then we had to wait a week or ten days to get up there again. We went up there and the water was hot. It was flying over that sandbar. There's a lot of movement. We come back after the closure, and all of a sudden, their necks are hanging out in the water. Kind of stressed out or something. We dug a whole pile of them, and I just wanted to sell them as fast as I could. They don't have a good shelf life as it is. We had two or three days of that, and then it rained and we weren't up there for a week or ten days. We get up there, and all the shells are empty. They had died and emptied out. I kept thinking, did some chemicals come down and go over that sand bar (QW1)?

This individual stated an area off Longmeadow, south of the main location of the boom, lasted for another year after that (QW1-282).

Two other individuals also shared recollections of the Conimicut Point (Upper Bay) soft shell clam boom:

- A quahogger stated that there was a temporary boom at Conimicut Point but there are no steamers there anymore (QW2-283).
- A quahogger stated that the Conimicut soft shell clam boom took place around the change of millennium. Then something came, he said, and it busted (QK3-284).

Aside from Conimicut Point, two individuals mentioned other locations where soft shell clams have been present in the past:

- A quahogger stated that soft shell clams were a "mainstay" for years at several locations where they used to set up year after year: from Cedar Tree Point to the mouth of

Warwick Cove (Western Greenwich Bay and Eastern Greenwich Bay); Chepiwanoxet and west of Sally Rock Point (Western Greenwich Bay); and the shoreline south of Pojac Point (Upper West Passage). He stated that soft shell clams disappeared from these locations in the late 1990s and never returned (QW2-285; QW2-286; QW2-287).

- A quahogger stated that soft shell clams were once abundant in Hundred Acre Cove Barrington River) and the Palmer River. These areas are productive because they are very shallow and they warm up fast, he explained. However, these areas have been closed to shellfishing due to pollution for years, so he does not know whether there are still soft shell clams there (QE1).

Mobile Benthic Invertebrates

Lobsters (*Homarus americanus*)

- Number of respondents: 6
- Segments mentioned: Upper Bay, Middle West Passage, Lower West Passage, Upper East Passage, Middle East Passage, Lower East Passage, Newport Harbor
- Trends mentioned: decline, boom, uptick

Five lobstermen and a quahogger who used to set lobster traps shared a widespread consensus that lobsters have been declining in Narragansett Bay. Many of these observations were quite detailed in space and time.

One lobsterman observed that "We've had less and less lobsters." In his fishing grounds in the Lower West Passage and Middle West Passage, he says, this decline took place in three phases:

- During the first phase, lobsters showed up consistently each season. The respondent could not remember when this phase ended, but he stated that after a while, lobsters stopped showing up consistently each year. He circled an area on the map in the Middle West Passage west of Great Ledge as being emblematic of this decline (LK1-81).
- During the second phase, which occurred between 2004-2008, there was a "pop" of lobsters. They were highly abundant and could be caught in various different water depths. Suddenly, in the fall of 2008, the lobsters failed to show up for their fall run: "No one showed up that fall. No one. We were hauling 300 pots for 10-12 lobsters. I lost my fucking mind that year. Blew the transmission on the boat. No money. House foreclosed on. We're not allowed to quit, so we kept plugging (LK1)." He circled an area north of Jamestown (Middle West Passage) and several areas in the Lower West Passage (LK1-82; LK1-83).
- During the third phase, which occurred between 2012-2013, there was a pop of lobsters concentrated at the bottom of the Lower West Passage: "You couldn't get them from Dutch Island north. Nothing. Empty, empty, empty. Then you get below that and we're doing nine-potters for 40-counts of nice, beautiful, rock hard lobsters… That was fun.

Everybody's bitching, 'Oh, I can't catch,' and I just had a 45 out of nine pots. I'm like "I ain't catching anything either! It's terrible." The respondent believes that these lobsters were different from the populations that usually frequent Narragansett Bay: "Those lobsters were not from here. Those lobsters were walkabout. I can't tell you where they came from, but they weren't living here. They're coming from over from Noman's. They're rock hard. The color of them, you can look at them and you can tell: 'Where the hell are you from (LK1-84)?'"

- Since that time, the respondent stated, there has not been a strong lobster run in the Middle West Passage or Lower West Passage (LK1).

A second lobsterman described a similar step-wise, north-to-south pattern of decline in the Upper Bay and Upper East Passage. "When I first started lobstering, it was in 1990," he recalled. At the time, lobsters were incredibly abundant. "I can remember being on a radio and hearing the guys right up in the bay working and saying, 'Do you have any bands? I can't even buy bands anywhere.' There were no lobster bands. 'You got a case I can borrow?' No local dealers even had bands. That's how much stuff was being caught right in this bay. It was crazy." However, according to this respondent, lobstering got progressively worse, and in 2014, he left the bay to fish full-time in the ocean, due to lack of lobsters in the bay. He explained that the decline of lobsters happened gradually and progressed along a north-south gradient, "a few miles every year." He said, "It just progressively, year after year, got worse, as we went down the bay. That was strange. It definitely came from the north and worked its way south (LN3-85; LN3-86)."

A third lobsterman shared similar observations garnered from fishing in the Middle East Passage, Lower East Passage, and Newport Harbor. According to this respondent, former lobster hotspots, including a large area between Gould Island, Prudence Island, Jamestown, and Aquidneck Islands (Middle East Passage; LN4-421) and Newport Harbor (LN4-88) have been relatively empty for at least 6-7 years (i.e., since about 2012-2013). A smaller area west of Goat Island where the cruise ship anchorage is located, began declining before that time, he added (Lower East Passage; LN4-87). Other areas still have some lobsters left, but not as many as they previously did. These areas are generally concentrated from Bishop's Rock southward; they include the coast of Jamestown from Kettle Bottom to Taylor Point, the southwest coast of Newport from Castle Hill to the bridge, and the area west of Rose Island, and the Navy breakwall (Lower East Passage; LN4-89). The respondent also stated that he can still find a few lobsters (but nothing like it used to be) at the old mussel farm near Melville and in a few deep holes in the channel between Prudence and Aquidneck Islands (Middle East Passage; LN4-90). In general, however, "every year for the last ten, the fall has been progressively worse (LN4)."

A fourth lobsterman described the biomass of lobsters in Narragansett Bay in the 1990s as "astronomical" and higher than ever before. He stated that this biomass decreased along a north-south gradient since that time. In particular, he noted that in areas in the Upper Bay, such as around Colt State Park and Rumstick Point, lobsters are "nonexistent (LN5-91)." Biomass around Gould Island (Lower East Passage), in contrast, is "very diminished" but not altogether gone (LN5-92).

A fifth lobsterman stated that there has been a sharp decline in lobsters in several locations: the coastline between the Naval Base and the Naval War College and along the west of Goat Island (Lower East Passage; LN2-93) and in Newport Harbor (LN2-94). According to the respondent, lobster abundance declined in some Lower East Passage areas 5-6 years ago (i.e., about 2013-2014) and 8-9 years ago (i.e., about 2010-2011) in others (LN2-93); it declined in Newport Harbor later than other spots (LN2).

Finally, a quahogger who used to set 60 lobster traps around the edges of Patience and Prudence Islands stated that he quit lobstering when it went downhill (QW3).

In spite of widespread agreement about a decline in lobster populations in Narragansett Bay over the last two decades, several individuals stated that there are still areas in the bay with persistent lobster populations. All areas mentioned as having persistent presence of lobsters were located in the Lower East Passage and Newport Harbor. They also highlighted that 2018 was the best year in many years for lobstering in these locations:

- A lobsterman stated that he still catches lobsters along the coastline from Fort Adams to Castle Hill and the area around Rose Island (Lower East Passage) and occasionally in the area by Ida Lewis Yacht Club (Newport Harbor). In fact, the year before the interview (i.e., 2018) was one of his best years lobstering: “This year was so much better than it has been. But I don’t know if that’s just a cycle. Saw a lot of little lobsters too. Eggers, too. I don’t remember seeing so many eggers as I saw this year (LN2-95; LN2-96).”
- A lobsterman stated that the summer before the interview (i.e., 2018) was surprisingly good for lobstering: “We had one of the better summers we’ve had in quite some time. The fall was horrible, and it seems each fall gets worse. I don’t know if that’s an indication. This last summer may have been a one-off (LN4-97).”
- A lobsterman who no longer fishes in the bay shared second-hand knowledge that lobstermen fishing between the Newport Bridge and Castle Hill (Lower East Passage) did quite well the year before the interview (i.e., 2018; LN3). The lobstermen referenced in this comment may have been the other two individuals cited in this paragraph.

One lobsterman, who only fishes in Narragansett Bay, shared observations of changes in lobster phenology in the bay, saying “When I first started, I used to try and be in by the last week of April. Then it got to be May, and now it’s got to be June (LN2).”

Another lobsterman, who used to fish in the bay and now fishes exclusively in the ocean, stated that this change in seasonality has taken place across inshore waters, not only in Narragansett Bay. In the ocean locations where he currently fishes, the fall peak in lobster catches now takes place in late December, which used to be the time when the fall run was dying down. This lobsterman posited a relationship between fisheries management actions and changes in the seasonal molting and migration of lobsters:

> "[Lobster] seasons have definitely changed. Sizes have changed because we've had a number of gauge increases. There's a couple of things going on. Lobsters, when they're small, shed more often, so the bigger the minimum size, I think we're at the point now

where they don't really shed [as much]. Years ago, we had two sheds. We'd catch them in the spring. We'd have a spring shed, the summer shed, and then you get a shed in the fall, because the minimum size was smaller, to where they were still shedding twice a year. Now I think we've gotten the minimum size to the point where a lot of them only shed once a year. Because when they're real small, they'll shed five, six times a year. As they get bigger, they shed less and less, and when they get really big, they might shed once every two years. We don't get that fall shed (LN3)."

Additionally, a lobsterman shared an interesting comment about spatial patterns and sex ratios of lobsters in Narragansett Bay. Although this lobsterman no longer fishes in the bay due to lack of lobsters, he stated that when lobsters were plentiful in Narragansett Bay, males and females used to "segregate" themselves:

> There'd be a line up here. This is a true story that not a lot of people know. It was from Sandy Point across. All of it was predominantly male lobsters. The further south you went, there was more females. The V-notchers[9] would come up with me. We would have 500 pounds of male lobsters, and they'd do 50 females. They'd do 50 notches. They just couldn't believe it. It was always predominantly male. All big claws, big beautiful lobsters. And then as you got south, as you got south of Sandy Point, there would be a mix. There would be males and females in this little area. And then it was predominantly female all down (LN3).

Two individuals shared their recollections of how lobster shell disease (*Aquamarina sp.*) first manifested in lobsters and crabs in Narragansett Bay, and how they saw this disease progress over the years. These observations are summarized below.

A lobsterman recalls first seeing shell disease in crabs before he saw it in lobsters. This observation took place around the time that he first started fishing, between 1987 and 1990, and he first saw it between Castle Hill and Fort Adams (Lower East Passage). At first, he only saw shell disease on crabs: "little black holes on the shell." Then, "over the years, it progressively got worse." He first saw shell disease on lobsters for the first time after the North Cape oil spill of 1996: "The [lobster] shell rot has been with us since just about the time they transplanted all those lobsters in here after the oil spill." This lobsterman interprets the appearance of shell disease as a harbinger of the decline in the lobster population that has taken place since then (see section on lobsters, above): "the first thing I ever saw that indicated any downfall coming was the sand crabs and the rock crabs had shell rot in them (LN4-279)."

A lobsterman stated that he saw shell disease for the first time after the North Cape oil spill, and that it seemed to get progressively worse from there:

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[9] The V-notch program was an observer program funded by the North Cape American Lobster Restoration Project from 2000-2006. Observers went aboard commercial lobster boats, clipped a "V-notch" in the tail fins of female lobsters that were caught by the boat, and returned them to the water so that other fishermen could not legally catch them.

The first year I saw it was the year after the oil spill. The oil spill was in '96. I saw it in '97. We always said, "This has got something to do with the oil spill." But if that was the case, I think it would have come and gone. That's the first year. I know the oil spill was '96 and '97 was the first year we were catching, and we were like, "What is this?" We don't even know what we were looking at, at the time. It wasn't terrible. We'd just see it on some lobsters. Then there were times when I was down in the lower bay, over in this channel [between the southern tip of Prudence Island and Aquidneck Island in the Middle East Passage]… I think we had like 280 or 300 pots, and we had like 3,200 lobsters for the day. When I graded them out and saw how many had shell disease, there was like almost 80% of the stuff I threw back. They were all female eggers. Every one of them had shell disease (LN3-280)."

Starfish (*Asterias forbesi*)

- Number of respondents: 12
- Segments mentioned: Upper Bay, Upper West Passage, Lower East Passage, Newport Harbor, Mouth of Narragansett Bay
- Trends mentioned: decline, cyclical/variable, boom

Twelve interviewees shared evidence of a dramatic decline in starfish populations in Narragansett Bay. This is perhaps one of the most sweeping species-level changes that was catalogued through these interviews.

- An oyster farmer with a lease in the Middle East Passage stated:

  We haven't had a big starfish problem on the lease in ten or twelve years. When we first started, I would take probably four or five five-gallon pails a day off the lease [of starfish]. I'd either put freshwater or bleach and let them sit a couple days and put them back over the side. But we haven't had starfish like that in 6 or 7 years, at least (i.e., since about 2012-2013; AE1-294)."
- An oyster farmer and quahogger stated:

  They've been non-existent. I'll give you an example from back when I started – 2007, 2008, those years. We'd plant our [oyster] seed right on this dock, and we put it out into the bay. It's usually about June when we plant them. I don't know how the starfish must have smelled that seed, but they knew. They didn't bother the regular oysters, but I counted 85 starfish in a cage [of seed oysters]. They would stick their stomachs through the mesh and get the oysters. They didn't have to be in. They just would sit on top of the bags. I pulled 85 [starfish] and stopped counting. It was probably over 100 on one cage. They were all big ones. There were that many starfish around. Then something happened, and they couldn't reproduce anymore. They kind of disappeared, and they almost went extinct. Last year (i.e., 2018), I probably counted about a half dozen (AE2-295).
- A quahogger stated that starfish are gone. He didn't recollect when that change happened, just that he hasn't seen any in a while (QE2-296).

- A quahogger stated that he doesn't see many starfish anymore. In years past, he said, starfish were be prevalent at Rocky Point and northeast of Providence Point (both in the Upper Bay) and High Banks and The Gut between Prudence and Patience Islands (both in the Upper West Passage). But that has changed, he said: "It was weird—there were so many around, and then they were gone. I don't know where they went. It's been a while. Five, six, seven, eight, nine years ago maybe (i.e., 2010-2013), where you'd pull a bunch of them up in a basket (QW2-297; QW2-298)."
- A quahogger stated that "starfish have disappeared." He said that this was a gradual change that happened within the last ten years (i.e., since about 2009; QW3-299).
- A lobsterman recalled working on his dad's lobster boat in the late 1990s and early 2000s and seeing the traps loaded with starfish. Now, he said, sees a few, but not in the numbers that he used to (LN1-300).
- A lobsterman stated that starfish were once abundant, but they disappeared about 8 years before the interview (i.e., about 2011). "Starfish were everywhere... They're gone, though... They were there one year, and they weren't there the following year… [Now] there aren't any starfish. I might see four or five starfish in the course of a season (LN2-301)."
- A lobsterman stated that starfish stopped being around in the mid-2000s (LN3-302). In the 1980s and 1990s, he said, starfish hotspots used to include Rocky Point and Ohio Ledge (Upper Bay), especially in the shoal water. He describes how thick they used to be in those areas:

  > They would come through in a pack. It would be like a mat over the bottom. We used to dread seeing them because they were eating the clams. There was such a pack of them in [t]here. It was the wintertime and the [lobster] pots were dirty. I used to take them and set a trawl at a time. I would set them in on the starfish and let them sit for a week, because the starfish would eat them. It would help clean them. Let the starfish do some cleaning (LN3-302)."

- A lobsterman stated, "We used to catch starfish in such numbers that they were a nuisance. We used to actually bring home barrels of them to dry them out and kill them…. We haven't seen starfish in years." Former starfish hotspots mentioned by this individual include Newport Harbor and areas east and northeast of Rose Island and west of Goat Island in the Lower East Passage. He said that he hasn't seen starfish in about 8 years (i.e., since about 2011; LN4-303; LN4-304).
- A lobsterman stated that starfish disappeared suddenly from the bay in the winter of 2013-2014. According to this individual, the disappearance of starfish coincided with a disappearance of hydroids (which he referred to as "rosebuds") and barnacles. He stated that starfish were formerly abundant, both in the Narragansett Bay and Rhode Island Sound, but there were generally higher numbers of them in the bay than the sound. He added that Newport Bridge was a hotspot (Lower East Passage). When starfish disappeared in 2013-2014, he stated, they disappeared first from the bay first and later from Rhode Island Sound. Today, he said, starfish are "nonexistent" in both locations.

> In 2014, the winter of 2014, ’13 to ’14, there were some drastic changes that took [place] in the bay that were astonishing to observe. I’d never seen changes like this before. For one, all the starfish in the bay disappeared overnight that winter. The winter prior to that [2013-2014], the starfish were still the same biomass as it’s been for years and years. Millions and millions of starfish we used to catch in our traps, especially in the wintertime. In fact, I used to set my traps around the columns of the Newport Bridge so that starfish would eat the barnacles off the traps—and they did. In 2014, they [starfish] disappeared. I was actually doing some collaborative work at URI at the time, and one of the professors wanted me to bring in starfish. They were doing testing on them. I spent the whole day in Narragansett Bay accumulating starfish for this professor. One day I caught twelve, and those were down at the mouth of the bay (<u>Mouth of Narragansett Bay</u>). The next time, I caught six, down by Beavertail and Castle Hill (<u>Lower East Passage</u>). Nothing in the middle and upper bay, not one. And then I couldn’t catch any. They just disappeared entirely. Until today, I’m lucky if I see one starfish all day long, from here to the three-mile limit. If we see one now, it’s a big thing. We say “Look, a starfish! There’s one left in the world (LN5-305)!”

- A trawl fisherman stated that 10-15 years ago (i.e., about 2004-2009), “The starfish disappeared! There would be so much starfish sometimes, and they would roll in overnight. Someone told me that they’ll get together and they’ll actually roll with the tide.” According to this individual, the channel east of Middle Ground in the <u>Upper West Passage</u> was a starfish hotspot. At present, there is “no amount of them. Used to be sometimes you couldn’t get away from them (TE1-306).”

Some fishermen remarked that starfish abundance has typically been cyclical:

- A quahogger stated that starfish populations follow cycles (QE1-307. When he was a kid, he explains, starfish were abundant. When he started quahogging commercially in the early 1980s, there were hardly any. Then around the early 2000s, starfish populations exploded (QE1-308). After that, it tapered off, he said, but you could still hit a pile of them. This individual is no longer fishing, but he has heard from his fellow fishermen that there are no more starfish in the bay (QE1).
- A quahogger stated that he has seen cycles (QW2-309), but in some of these cycles, he suspects the hand of man; quahoggers used to deliberately cull starfish to keep their populations in check when they became too abundant:

> I think they’re cyclical. I remember as a kid I used to pin them. There were loads when I was a kid. But then not so much. Then they were in the lower bay pretty heavy, back in the ‘80s. But there were so many of us and we used to put them in pails. I think we put a hurt on them, the quahoggers. Back in the ‘80s, that’s where we stayed, was in the lower bay. [Shellfish Management] Area A was shut down most of the time, so we were all pinned down there. I think we did a number on them back then. It’s hard to say. But I haven’t seen anything in massive numbers lately (QW2).

However, one individual remarked that although starfish have conventionally cycled in Narragansett Bay (LN4-310), he does not view their current absence as part of a natural cycle (LN4).

A number of individuals commented on ecological relationships in which starfish act as predators or competitors with other organisms in Narragansett Bay.

Observations describing the predatory role of starfish included the following:

- A quahogger described starfish as predators of quahogs (*Mercenaria mercenaria*): "In some quahogging spots, sometimes the starfish would come in, and they'd decimate a bed of quahogs. They were right there, and they would hone in on them. Then you'd try raking, and it would be just dead shells, because the starfish got them (AE2)."
- A lobsterman described starfish as predators of mussels (*Mytilus edulis*), saying that starfish predation is an important factor in determining mussel abundance:

  > The starfish and the mussels are opposite… It was like a five- or six-year cycle: one year of mussels; the next year there'd be mussels and a couple stars; the third year there'd be less mussels and a few stars. Starting the fourth year, there's be primarily starfish, because they'd wipe out ninety percent of the mussels. Then the fifth year or the sixth year, they would start the whole cycle all over again, where the mussels would get a toehold (LN4).

Observations describing a competitive dynamic between starfish and other organisms included the following:

- An oyster grower suggested that starfish compete with whelks (*Busycotypus canaliculatus, Busycon carica*) and moon snails (*Lunatia heros*), and stated that he has observed an inverse relationship between the abundance of starfish and the abundance of whelks and moon snails:

  > The whelks have come back like gangbusters, and starfish and whelks, you get one or the other. You don't get them both. Once there's a lot of whelks, then the starfish will come back. Then there will be a lot of starfish and not a lot of whelks. Moon snails are the same (AE1)."

- A quahogger stated that he has observed an inverse relationship between starfish and spider crabs (*Libinia emarginata*): "Seems like when the starfish moved out, the spiders came in (QW2)."

Blue Crabs (*Callinectes sapidus*)

- Number of respondents: 5
- Segments mentioned: Upper Bay, Western Greenwich Bay, Wickford Harbor, Mount Hope Bay
- Trends mentioned: increase, decline, variable

Interviewees' impressions of trends in blue crab abundance seemed to differ based on how long they had been fishing:

- A younger lobsterman suggested there has been an increase in blue crabs, stating that he has seen more in the last four years (i.e., since about 2015) than before: not a "crazy number," but more than there used to be (LN1-33).
- A quahogger who has been fishing in Narragansett Bay since the 1950s stated that blue crabs were more prevalent when he was a kid. Then they declined, and now they are more abundant again, but not as abundant as when he as a kid. He views this as a decadal cycle: "Some things just come and go (QE1-34)."
- A trawl fisherman who has been fishing since at least the 1970s stated that blue crab abundance is "hardly anything like it used to be (TE1-35)."

In terms of the distribution of blue crabs, interviewees offered the following observations:

- A lobsterman stated that blue crabs are more abundant in shallow waters than deeper waters (LN1).
- A lobsterman stated that he saw a few blue crabs around the pilings in Wickford Harbor in 2018 (QK2).
- A quahogger described a bloom of blue crabs about 2 years ago (i.e., around 2017) at Barrington Beach and Rocky Point (Upper Bay) and Western Greenwich Bay (QW2-35, QW2-36).
- A trawl fisherman specified that he has seen a decline in blue crabs in Mount Hope Bay, where they were once abundant (TE1-37).

Taken together, these observations suggest a pattern of both long-term and short-term variability in blue crab abundance. For example, the two comments below can either be read as contradictory, or as evidence of a long-term decline combined with a more recent uptick:

> Blue-shell crabs! I don't know what happened to them! They were thicker than fleas. We used to go in the wintertime up in Mount Hope Bay in the deeper water, all winter long in the mud. Bushels of them. Bushels of them. Now, there's none. You might have four or five in the course of a day. In the fall, they would come up along these estuaries. Oh my gosh, you wouldn't believe the run. It'd last for sometimes a month, and they'd be so thick it was unbelievable. Now, it's hardly anything like it used to be (TE1-37).
>
> Two years ago (i.e., around 2017), there were blue crabs, millions of them, at Barrington. Greenwich was loaded, and even out at Rocky Point in the mud. Loaded with blue crabs… I mean millions of them. You'd see them all on top of the water. And then they were gone. Something got at them or they didn't have enough to eat… They were little. They were young ones. A couple of jumbos too. We were actually going to start potting them and getting them going. And then it just went away. It went almost as fast as it came. It was almost like massive, and then gone. Two years they lasted, and then no more. I mean, we always have a few, but this was insane. Especially at Barrington. I

didn't know what I was looking at. I drove my skiff right into it and took my scoop net, and it was all tiny crabs (<u>Western Greenwich Bay, Upper Bay;</u> QW2 -35, QW2-36).

<u>Horseshoe crabs (*Limulus polyphemus*)</u>

- Number of respondents: 3
- Segments mentioned: Upper Bay, Western Greenwich Bay, Eastern Greenwich Bay, Upper West Passage, Mount Hope Bay
- Trends mentioned: decline

Four individuals mentioned horseshoe crabs. Three mentioned a notable decline:

- A quahogger stated that "I've seen an immense decline in horseshoe crabs. In the 1980s, every third rake, you'd hit a horseshoe crab. You'd have to pick up the rake, swear, start again. Then it got to the point where we caught none. I went from catching one every third rake to catching none (QE1-68)."
- A quahogger stated that he has seen a gradual decline in the number of horseshoe crabs that get caught in his rake while he quahogs. He pinpoints this decline as occurring at Conimicut Point and Rocky Point (<u>Upper Bay</u>), the northern half of <u>Western Greenwich Bay</u>, the western side of the mouth of Greenwich Bay (<u>Eastern Greenwich Bay),</u> and the shoreline south of Pojac Point in the <u>Upper West Passage</u> (QW2-69; QW2-70; QW2-71; QW2-72).
- A trawl fishermen states that he formerly saw horseshoe crabs "thick as fleas," along with blue crabs and spider crabs, in the channel that runs through <u>Mount Hope Bay</u>. "Now, not so much," he adds. The last time he remembers seeing these crabs in abundance was 10-15 years ago (i.e., about 2004-2009; TE1-73).

Two individuals provided evidence that horseshoe crabs are not altogether absent:

- A quahogger stated that he "got a few of them in my rake recently (QE1)."
- A quahogger stated that he catches them in his rake still, but not in the numbers that he used to (QW2).

<u>Spider Crabs (*Libinia emarginata*)</u>

- Number of respondents: 7
- Segments mentioned: Upper Bay, Warwick Cove, Mount Hope Bay
- Trends mentioned: increase, decline, constant, cyclical/variable

Six individuals commented on spider crab abundance in their interviews. Few provided any spatial or temporal details on these observations, and their comments were not consistent with one another in terms of painting any clear trends in spider crab abundance:

- A quahogger stated that spider crabs seem to be *more* abundant than before: "Loads of them. They move in a biomass, there are just mounds of them all over the place. You can go to places where you'll just fill a rake with them." Specifically, he mentioned spider crab hotspots on Barren Ledge, the deeper ledge going towards the shipping channel, the 18 mark (all in the Upper Bay), and Warwick Cove. In these locations, he stated, spider crabs are sometimes so thick that he can't get a rake into the bottom: "It feels like you hit a cotton ball (QW2-288; QW2-289)."
- A trawl fisherman stated that spider crabs seem to be *less* abundant than before: "The other species that was really, really thick—phenomenally, unbelievably thick—was the spider crabs. I don't see so many of them now." He mentioned that the channel that runs through Mount Hope Bay used to be a hotspot (TE1-290).
- A quahogger stated that spider crabs *might be less* abundant than before. There are still plenty of them, he explained, but possibly less than there used to be: "I used to fill the rake up with them in certain places (QW3-291)."
- An oyster farmer and quahogger stated that spider crabs have been "pretty consistent (AE2-292)."
- A quahogger stated simply that "they're around (QE1)."
- A quahogger stated that "Spider crabs go up and down in the bay. They always have (QK3-293)."

In addition to these comments on spider crab presence and abundance, two individuals shared observations on the ecological relationships between spider crabs and other species:

- A quahogger stated that spider crabs have a negative impact on quahog populations: "I know one thing: they're predators, pure and simple. If they get to a certain place, they can wipe out a bed. They're vicious (QW2)."
- A lobsterman stated that spider crabs and lobsters "trade off bottom": "Normally what happens is the spider crabs will show up, and then the lobsters come. Then, when the lobsters leave, the spiders come back in again (LN2)."

Urchins (*Arbacia punctulata*)

- Number of respondents: 2
- Segments mentioned: Lower East Passage, Newport Harbor
- Trends mentioned: decline, uptick

Two individuals commented on the scarcity of sea urchins in Narragansett Bay, saying that although they have always been fairly rare in the bay, they have been notably absent altogether for about a decade:

- A lobsterman stated that no one he knows has seen an urchin in 10 years (i.e., since about 2009; LN2-320).

- A lobsterman stated that he used to see urchins near Goat Island (Newport Harbor) and Rose Island (Lower East Passage), but he stopped seeing them 10-12 years before the interview (i.e., around 2007-2009; LN4-321; LN4-322).

However, during the year of the interview (i.e., 2018-2019), one of these individuals suddenly caught ten or twelve urchins, a notable uptick: “Until this year,” he observed, “I haven’t seen an urchin in at least ten years (LN4-323).”

Green Crabs (*Carcinus maenas*)

- Number of respondents: 2
- Segments mentioned: Lower East Passage, Newport Harbor, Wickford Harbor
- Trends mentioned: decline

Two individuals shared observations about green crabs, and both stated that they have seen a decrease in this species recently:

- A lobsterman stated that green crabs have been less prevalent in his traps for the last 4-5 years (i.e., since about 2014-2015). This fisherman fishes predominantely in the Lower East Passage and Newport Harbor. Three years ago (i.e., about 2016), he set some green traps near Fort Adams (Lower East Passage), but the traps caught nothing but spider crabs. However, he said he has heard that another fisherman does well setting green crab traps around Rose Island (Lower East Passage; LN2-65; LN2-66).
- A quahogger stated that there are fewer green crabs around than there used to be. He used to set green crab traps around Wickford Harbor, but the crabs stopped showing up (QK2-67).

Whelks (*Busycotypus canaliculatus, Busycon carica*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: constant, downtick

Two individuals commented on the abundance of whelks in Narragansett Bay. The two accounts do not paint a clear picture of trends:

- A quahogger stated that whelks typically follow a “boom-bust” population pattern (QW2-324). This individual pulls whelks up as incidental catch in his bull rake sometimes (including juveniles). In the year before the interview (i.e., 2018), he said that he did not catch very many. In the past, he added, he used to be able to grab five or six whelks a day and sell them. The year before the interview (i.e., 2018), in contrast, he only sold one whelk all season. However, he heard the pot fishermen did really well that fall (QW2-325).

- A quahogger stated that whelk abundance is stable. He added that he sees plenty of them and had heard that the pot fishermen are getting "tons" (QW3-326).

Miscellaneous Mobile Benthic Invertebrates

Flame-colored Box Crab (*Calappa flammea*). A quahogger reported that he caught several of these by the Rocky Point Dock (Upper Bay) ten years before the interview (i.e., about 2009). After that, he never saw one again (QW3).

Jonah Crabs (*Cancer borealis*). A quahogger stated that Jonah crabs (and all kinds of crabs) have experienced a gradual decline since he started fishing in 1982 (QW3-106).

Lady Crabs (*Ovalipes ocellatus*). A quahogger stated that lady crabs (and all kinds of crabs) have experienced a gradual decline since he started fishing in 1982 (QW3-107).

Moon Snails (*Lunatia heros*). A quahogger stated that moon snails increased in the 3 years preceding the interview (i.e., since about 2016), especially at Barrington Beach, Ohio Ledge, Rocky Point (all Upper Bay), and near Sandy Point (Western Greenwich Bay; QW2-108; QW2-109).

Oyster Drills (*Eupleura caudate, Urosalpinx cinerea*). An oyster grower saw a substantial set of oyster drills on his bags and cages during the year before the interview (i.e., 2018; AE1).

Sea Mouse (*Aphrodita aculeata*). A quahogger stated that he used to dig up sea mice when raking on banks; places where, "because of the hydrodynamic flow, there's a stretch of that bank which is transitional from mud to hard bottom. That's where those sea mice like to live and that's where the quahogs like to live. But I don't see as many of those [sea mice] around… I haven't seen one in a long time (QW3-114)."

Unknown (possibly octopus). A quahogger mentioned that quahog shells with a bite out of them have been coming up in his rake. He suspects that these bitemarks may be signs of octopus preying on quahogs. He stated that he typically finds these shells around Davisville and Allen's Harbor (Quonset Harbor) as well as in Ninigret Pond. He started noticing them frequently between 2000-2005. At first he suspected that the predator in question was a box crab, but after a period of time, he stopped seeing box crabs but continued raking up shells with bitemarks; thus, he now believes that there may be an increase in octopus predation on quahogs in Narragansett Bay (QK3).

Fouling Invertebrates

Barnacles (Cirripedia: Thoracica)

- Number of respondents: 4
- Segments mentioned: Middle East Passage, Lower East Passage, Mouth of Narragansett Bay
- Trends mentioned: decline, constant

Four individuals discussed the abundance of barnacles. Two were lobstermen from Newport and two were oyster farmers with leases on the Middle East Passage.

Both Newport lobstermen shared observations indicating a decline in the abundance of mature barnacles in certain locations:

- Pilings in Newport Harbor (LN2-4)
- From the Newport Bridge northward (the northern limit of this individual's fishing grounds is Gould Island; Lower East Passage; Middle East Passage; LN5-6, LN5-6)

In terms of the timeframe of this observed decline in abundance, one individual stated that the change in Newport Harbor occurred about 20 years ago (i.e., around 1999; LN2-4) while the other individuals said that the change occurred suddenly in the Lower and Middle East Passage in 2014 (LN5-5, LN5-6).

These two individuals' observations differed with regard to the abundance of barnacles in the Mouth of Narragansett Bay. One individual shared observations of a decline in barnacle abundance along Ocean Drive, Land's End, and Ruggles (LN-7). However, the other individual stated that barnacles continue to be highly abundant at the Mouth of Narragansett Bay out into ocean waters:

> No barnacles grew on our traps from the Newport Bridge north, starting in 2014… The traps out front towards the ocean and the mouth of the bay still had a full set of barnacles on them. Full growth of adult barnacles. From the Newport Bridge north, not one barnacle grew on the traps, starting that year (LN5-8).

This individual also noted a temporal correlation between the observed disappearance of barnacles in 2014 and a sudden decline in hydroids and starfish in the Middle and Lower East Passage (LN5-8).

The observed decline in mature barnacles contrasts with observations of abundance barnacle spat. According to three individuals, barnacle spat appears each year around February on many surfaces: lobster traps, oyster bags and cages, and oysters and lobsters themselves (LN2-9, AE1-10, AE2-11). All three individuals stated that the appearance of spat has been consistent each year in terms of its occurrence; however, one noted that it has been occurring earlier in recent years:

> This year, there's more spat than I've seen in a long time… My pots that I pulled out in January, they had spat on them already. I've always pulled my gear out at the end of

February, and I usually beat when the spat started to show up. The last couple of years, I've seen it a little earlier every year. This year, in particular. I keep lobsters in a car. Those lobsters have got spat all over them, pretty thick (LN2-9).

All three individuals stated that little of the spat survives to adulthood. For instance, one individual said:

> We already had our first barnacle set [this year]. It's all over everything. Most of it will die off. We may get a second set in another month or two. Sometimes we do. Sometimes we don't. We always get our first big set at the end of February [into] March. All of a sudden, instead of being a million over everything, you'll go out there in three months and there'll be a few big ones. And the majority of them—95 percent of them—will be gone. I don't know what kills them…. But if you sit tight, most of them will go away (AE1-10; similar comment by AE2-11).

One oyster grower observed that some barnacles do make it to adulthood, but whether or not this happens seems to vary on a very small scale. He offered a photograph of an oyster covered in mature barnacles, saying:

> That trawl that I was going through [when I took the photo], they were really heavy in some spots, but as I worked my way north, there were less and less [barnacles]. It's in certain sections. For some reason, they just set on certain cages (AE2).

<u>Sea Grapes (*Molgula manhattensis*)</u>

- Number of respondents: 2
- Segments mentioned: Newport Harbor, Middle East Passage, Lower East Passage, Mouth of Narragansett Bay
- Trends mentioned: decline, constant

Two individuals mentioned a decline in the abundance of sea grapes on their lobster traps in recent years:

- A lobsterman stated that sea grapes used to be prevalent in <u>Newport Harbor</u>, but starting 10-12 years ago (i.e., about 2007-2009), they stopped appearing on his traps, even when he left his traps unattended in the water for several months (LN4-256).
- A lobsterman stated that sea grapes suddenly stopped appearing on his traps inside Narragansett Bay in the winter of 2013-2014 (LN5-257; LN5-258). In contrast, he explains, sea grapes continue to be prevalent outside the bay, especially by the RACON Buoy[10] (<u>Mouth of Narragansett Bay</u>; LN5-259), and at Kettle Bottom (<u>Lower East Passage</u>; LN5-260). The 2013-2014 disappearance of sea grapes coincided with a disappearance of hydroids (which he calls "rosebuds"), starfish, and barnacles in the same areas. He recalled:

[10] Narragansett Bay Entrance Lighted Whistle Buoy NB, N 41° 23' 00.000", W 071° 23' 21.470

> We call them grapes, or snotties. They're like grapes. They were so bad at times from the bridge up to Gould Island (Lower East Passage and Middle East Passage) that you couldn't even land the traps in the spring. They grew so bad over the winter that you could barely get the traps on the boat, they'd be so heavy with these grapes. [Then they] disappeared completely. Yet I still see rosebuds and grapes growing on my gear from the mouth of the bay (Mouth of Narragansett Bay) to the three-mile limit (LN5-257; LN5-258; LN5-259."

Sea Squirts (*Styela clava*)

- Number of respondents: 2
- Segments mentioned: Newport Harbor, Lower East Passage
- Trends mentioned: decline, increase

Two individuals shared a perception that sea squirts have decreased. Both named Newport Harbor as a location where this decline had occurred:

- A lobsterman stated that sea squirts used to be abundant in Newport Harbor, but starting 10-12 years ago (i.e., about 2007-2009), they stopped appearing on his traps, even when he left is traps unattended for several months (LN4-274).
- A lobsterman stated that sea squirts used to be prevalent in Newport Harbor, showing up in the summer at the same time and places as *Didemnum sp*. He added that both species were "very prevalent for a number of years. I'm going to say the past five or six years (i.e., since about 2013-2014), it disappeared (LN2-275)."

Conversely, a lobsterman noted that sea squirts started appearing for the first time east of Rose Island (Lower East Passage) in the two years prior to the interview (i.e., since 2017; LN2-276).

Miscellaneous Fouling Invertebrates

Didemnum sp. A lobsterman stated that *Didemnum sp.* was formerly common in Newport Harbor and along the west side of Goat Island (Lower East Passage), showing up in the summer at the same time and places as sea squirts. About 5-6 years before the interview (i.e., around 2013-2014), "it disappeared," the lobsterman said (LN2-115; LN2-116). He also noted that *Didemnum sp.* began appearing east of Rose Island (Lower East Passage) in the year before the interview (i.e., around 2018; LN2-117).

Red Beard Sponge (*Microciona prolifera*). A quahogger picked up the photo ID card for red beard sponge, and stated that he had recently seen this species appear suddenly, only a week before the interview. The location of this appearance was in Western Greenwich Bay (QW2).

Hydroids (Hydrozoa). A lobsterman reported that an organism that he and other lobstermen refer to as "rosebuds" suddenly stopped growing on their lines and traps during the winter of

2013-2014. This fisherman fishes in the Lower East Passage and Middle East Passage up to Gould Island (LN5-110; LN5-111). When shown the photo ID card of hydroids, he affirmed that it was the same organism. He stated that rosebuds have not returned since that time, but that they have been consistently present outside the bay, and at the Mouth of Narragansett Bay, especially at the RACON Buoy,[11] and up to Kettle Bottom (Lower East Passage; LN5-112; LN5-113). He added that the disappearance of rosebuds during the winter of 2013-2014 coincided with a disappearance of sea grapes and barnacles in the same areas (LN5).

Seaweed/Macroalgae

Rockweed (Order Fucales)

- Number of respondents: 6
- Segments mentioned: Mount Hope Bay, Bristol Harbor, Middle East Passage, Lower East Passage, Mouth of Narragansett Bay
- Trends mentioned: decline, constant, uptick

Six individuals commented on the abundance of *Ascophyllum nodosum* and one individual commented on *Fucus spp*. All were lobstermen who fish out of Newport (one formerly fished out of Bristol) and one was a trawl fisherman who fishes out of both Newport and Bristol.

Several individuals noted that *Ascophyllum* is now absent from many areas where it used to be prevalent (TE1, LN2, LN3, QE1, QE2). Four respondents mention that they used to harvest *Ascophyllum* for use in clambakes when they were younger (TE1, LN2, QE1, QE2).

Respondents offered the following examples of locations where *Ascophyllum* used to be common but is now absent:

- Seal Rock (Mount Hope Bay; TE1-238)
- East side of Bristol Harbor near Sip-N- (TE1-239)
- Rose Island (Lower East Passage; LN2-240)
- Bishop's Rock (Lower East Passage; LN2-240)
- Eastern shore of Jamestown (Lower East Passage, Middle East Passage; LN5-241; LN5-242)
- Western shore of Aquidneck Island, all the way north to Melville (Lower East Passage, Middle East Passage; LN5-242)
- Gould Island (Middle East Passage, LN5-242)
- Kickemuit River (LN3-243)
- Rumstick Point (Upper Bay; LN3-244)

[11] Narragansett Bay Entrance Lighted Whistle Buoy NB, N 41° 23' 00.000", W 071° 23' 21.470

- Poppasquash (Upper Bay; LN3-244)
- Warren River (LN3-432)
- Bristol Harbor (LN3-245)

In terms of the timeframe of this observed decline in abundance, one individual mentioned that *Ascophyllum* was abundant going back to the 1970s and is no longer present (TE1). Another mentioned that *Ascophyllum* was abundant in the 1990s and is no longer present (LN5). A third said that *Ascophyllum* was abundant going back to the 1960s, but had become scarce by 2005-2007. None mentioned a specific timeframe during which they noticed the change, suggesting that the decline of *Ascophyllum* has been gradual, perhaps occurring on a decadal scale.

Two individuals commented that *Ascophyllum* has remained present in several oceanfront areas at the mouth of the Bay, including the following locations:

- Brenton Point (Mouth of Narragansett Bay; LN2-246)
- Land's End (Mouth of Narragansett Bay; LN2-246)
- Ocean Drive (Mouth of Narragansett Bay; LN5-247)
- Beavertail Point (Mouth of Narragansett Bay; LN5-247)
- Skindiver Cove (Lower East Passage; LN5-248)
- East Skindiver Cove (Lower East Passage; LN5-248)

Another individual commented that *Ascophyllum* experienced a small uptick in abundance in several locations in the year preceding the interview (2018-2019):

- Taylor's Point (Lower East Passage; LN5-248)
- Van Zandt Pier (Lower East Passage; LN5-248)
- Rose Island (Lower East Passage; LN5-248)

Another individual reported that he observed *Ascophyllum* returning to the location in Bristol Harbor near the Lobster Pot restaurant, and along Washington St, south of the east end of the Newport Bridge (Lower East Passage) within the year preceding the interview (2018-2019; LN3-249; LN3-250).

According to one individual, some areas formerly populated by *Ascophyllum nodosum* are now populated by *Fucus spp*. These include the east side of Bristol Harbor near Sip-N-Dip (TE1-133) and around Seal Rock (Mount Hope Bay; TE1-134).

One individual provided the following statement contrasting *Ascophyllum* abundance in the Lower East Passage (where he has observed a decrease in *Ascophyllum*) and the Mouth of Narragansett Bay (where he still observes *Ascophyllum*):

> There's no rockweed growing in the basin around Fort Wetherhill, where they tie up the John H. Chafee, the research vessel. But yet, when you go right around the corner, to the first cove going to the west of Fort Wetherhill—we call it Skindiver Cove and East Skindiver Cove; there's two of them, east and west--[there are] multiple layers of rockweed growing on the shore there. None growing in the basin by Fort Wetherhill

where the DEM boat is… The rockweed wasn't growing there, but you go around the corner to the open ocean, where you get away from the bay, and it's prevalent… The rockweed also, on Ocean Drive and Beavertail Point is prevalent. There's tons of it growing there. If you go from the bridge going up, there's no more rockweed growing (LN5).

Sea Lettuce (*Ulva sp.*)

- Number of respondents: 5
- Segments mentioned: Upper Bay, Greenwich Cove, Upper West Passage, Lower East Passage
- Trends mentioned: uptick, decline, constant

Three individuals highlighted times and places where sea lettuce has demonstrated a recent uptick:

- A quahogger stated that sea lettuce (along with *Grinnellia americana*) increased at Barrington Beach (Upper Bay) the summer before the interview (i.e., summer 2019). He shared that he and his fellow quahoggers would joke, "Oh, I'm going to go fight the lettuce today (QW1-264)."
- A quahogger stated that sea lettuce has increased in several locations: Barrington Beach and Longmeadow in the Upper Bay, and Greenwich Cove. He observed that it was a particular nuisance at Barrington Beach in the summer before the interview (i.e., summer 2019); quahoggers could not get their rakes through it (QK3-265; QK3-266).
- A quahogger stated that sea lettuce increased in abundance in the areas north and south of The Gut between Patience and Prudence Islands (Upper Bay and Upper West Passage, respectively), during the year before the interview (i.e., summer 2018; QW2-267; QW2-268).

Another individual described a decline in sea lettuce. This lobsterman stated that he regularly encountered sea lettuce at Bishop's Rock (Lower East Passage) until about 15-20 years ago (i.e., about 1999-2005), along with *Codium fragile, Dasysiphonia japonica,*[12] *Grateloupia turuturu,* and *Ectocarpus sp.*, as well as an unidentified "brown slime" (LN2-269). He sees all of these species to the present day around Rose Island (Lower East Passage; LN2-270).

Lastly, a lobsterman voiced a view that sea lettuce has been fairly consistent in its abundance in the Lower East Passage. There has been interannual variability, he said, but no major change

[12] Although this fisherman selected *Dasysiphonia japonica* from among the photo ID cards provided in the interview, regional scientific monitoring data holds that this species did not appear in New England until around 2010. Since *Dasysiphonia* closely resembles a number of other seaweed species to the naked eye, the species that this fisherman referred to may not have actually been *Dasysiphonia,* but another species that visually resembles it.

upward or downward. He stated that he often sees it on the shoals around Rose Island (Lower East Passage) in the springtime (LN5-171).

Kelp (*Saccharina latissima*)

- Number of respondents: 5
- Segments mentioned: Lower East Passage, Middle East Passage
- Trends mentioned: decline, uptick

Four Newport-based individuals voiced a strong view that kelp has declined in abundance in the last decade or two. All four provided specific locations and timeframe estimates for this decline:

- A trawl fisherman who used to catch free-floating kelp in his net as it drifted around stated, “We used to get so much kelp it was ridiculous. Now I don’t see no more kelp.” On the map, he drew the area where he used to catch it the most: in the Lower East Passage between Beavertail and Fort Wetherhill on the Jamestown side and Fort Adams and Castle Hill on the Aquidneck Island side. He added that kelp usually appeared in the spring and remained abundant until fall. According to this individual, kelp abundance peaked around 1984, and by 1995, it had started to decline (TE1-74).
- A lobsterman stated that kelp, once abundant, disappeared from Kettle Bottom and the area between Castle Hill and Brenton Point (Lower East Passage) about 10 years before the interview (i.e., around 2009): “Kelp was thick here. When I was young, you pulled kelp off of Kettle Bottom. The kelp disappeared ten years ago (LN2-75).”
- A lobsterman stated that in the 1990s, kelp was common, but it disappeared in the early 2000s. Hotspots where it formerly collected in lobster traps include the #12 buoy near Rose Island, the #11 buoy near Fort Wetherhill, the #4 buoy near Kettle Bottom, and the deep hole near Castle Hill (Lower East Passage; LN5-76).
- A lobsterman and gillnetter stated that in the past, while lobstering, he “hauled up pots that would come up bigger than the table and chairs. Almost as big as the skiff I used to have. It would take you an hour to get a trawl up. But I don’t see it like that anymore.” While gillnetting near Fort Adams (Lower East Passage), sometimes “the net was so heavy you’d have trouble getting the net back. It would lay it right down and in a couple of hours, it would fill right up. But the kelp, there’s just not the abundance there was." He states that he hasn’t seen kelp in its former abundance in 8-10 years (i.e., since about 2009-2011; LN4-77).

In addition, a lobsterman who has not fished in Narragansett Bay since 2014 stated that for a few years before he left, he caught kelp in his traps that appeared to have been degraded by “something acidic” which he compared to the appearance of lobster shell disease. This degraded kelp was prevalent around Gould Island (Middle East Passage; LN3).

In addition to the commonly held perception of a long-term decline in abundance of kelp in Narragansett Bay, two individuals shared a view that kelp has experienced a slight uptick in abundance over the last 2 years compared to the previous 10 or 20 years:

- A lobsterman stated that kelp reappeared in the area between Castle Hill and Brenton Point and near Kettle Bottom (Lower East Passage) starting 2 years before the interview (i.e., since around 2017; LN2-78).
- A lobsterman stated that kelp reappeared at Castle Hill and the #12 buoy near Rose Island (Lower East Passage) during the year and the year prior to the interview (i.e., 2018-2019). Prior to this, he said, he had not seen "a strand" for years. "We actually saw more this year than I've seen in decades. So there was a change that took place this year (LN5-79)."

Miscellaneous Seaweeds

- Number of respondents: 10
- Segments mentioned: Upper Bay, West Greenwich Bay, Middle West Passage, Lower West Passage, Quonset Harbor, Dutch Harbor, Upper East Passage, Bristol Harbor, Lower East Passage, Mouth of Narragansett Bay
- Trends mentioned: increase, decline, uptick, downtick, constant

Seaweeds in general were the subject of many observations. This may be related to a comment made by one lobsterman, who said that, in general, "We see more seaweed than we ever used to. Not all the same seaweed we used to see. We'd see a lot of kelp." Now, instead of kelp he sees other species instead (LN4).

Many interviewees did not know the common or scientific names for the types of seaweed that they have encountered in recent years. Some were able to find images of the seaweed types they had seen among the photo ID cards presented to them during the interview, but many were not. This does not necessarily mean that the species was not present among the cards; that is because seaweed species can look different on paper than they do on deck or in the water. When interviewees did not find a match among the photo cards, they provided a verbal description of the seaweed(s) they have observed.

Early in the research project, a lobsterman provided a screenshot of a photo he had taken of some large balls of a seaweed type that he calls "slime weed" coming up in his lobster traps (see below; LN5). This photo was integrated into future interviews as a tool to ascertain whether other interviewees were referring to seaweed with the same visual appearance as the seaweed in the photo.

This section includes observations of the following;

- Seaweed types that were identified only by a verbal description or colloquial name (e.g., “slime weed,” “brown slime,” “brown stuff,” “yucky scum,” “mermaid hair,” or “green hair”;
- Seaweed types that were identified using a photo card, for which no prior name was known by the interviewee;
- Seaweed types for which a name was known, but which bear similarities to the other types of seaweed described in this section via only a verbal description or colloquial name; and
- Seaweed types for which only one individual offered an observation.

Two individuals selected the photo ID card of *Agardhiella subulata,* and said that this species was present in Western Greenwich Bay. One individual believes *Agardhiella* has always been this abundant in this location (QK3-1), while the other believes it has long been present in moderate abundance but has become more abundant there recently (QW2-2).

One individual stated that *Agardhiella* appeared for the first time recently around Providence Point (Upper Bay; QW2-3).

Two individuals mentioned observations related to Irish moss (*Chondrus crispus*). Neither named it by name; rather, both identified it using the photo ID cards that were provided during the interview. One individual refers to this species as "kale."

A lobsterman described patterns in the distribution of Irish moss in this way:

> This time of year, we have this stuff that we call "kale." I don't know what it's called, but that's more plentiful right now too. We just had it last week, believe it or not. Our traps were covered by it. This stuff washes around also. I don't think it's attached to the bottom… It fills the traps right up to the doors, and nothing can get into the traps. If it happens when you're first setting the traps, the traps won't fish. It's a real, real nuisance (LN5).

This lobsterman states that "kale" appears in the springtime and coincides with the appearance of other seaweeds that have come and gone over the years, which he calls "horsehair" and "slime." He adds that he sees more "kale" in his deep-water sets around Castle Hill (Mouth of Narragansett Bay) than in other locations. He did not mention any interannual trends in the abundance or distribution of "kale" (LN5).

A quahogger noted that a bloom of Irish moss occurred around the north end of The Gut between Prudence and Patience Islands (Upper Bay), during the year before the interview (i.e., 2018-2019). He states that its presence coincided with a bloom of *Desmarestia* in the same area and that the two species were so thick that he couldn't bullrake there. He states that the bloom took place during the spring, then subsided, and then returned in the summer (QW2-40).

Two individuals referenced *Desmarestia viridis* in their recollections. One trawl fisherman, who has long been familiar with *Desmarestia* and has done some reading on this species, recounted that he first observed this seaweed in an area just north of the Jamestown Bridge (Middle West Passage) in 1969 or 1970 (TE1-118). From there, he saw it spread to a large portion of the Lower West Passage (TE1-119) and Middle West Passage (TE1-118), and eventually to the Lower East Passage (TE1-120). It is densest, he said, in Dutch Harbor (TE1-121). The identifying characteristics of *Desmarestia* are that it "burns your arms and eyes because it has sulfuric acid in it." When shown the photo of "slimeweed" provided by a lobsterman, he confirmed that *Desmarestia* matches the appearance of this photo. He added that *Desmarestia* grows in areas down to 40 feet in depth, and prefers sandy and gravelly bottoms. This habitat, he said, is found in Dutch Harbor and is also preferred by winter flounder. He recounted that *Desmarestia* begins growing in December, with their holdfasts anchored to gravel pebbles. By May, *Desmarestia* plants have become "really big sails" and they detach and flush out with the tide. This interviewee stated that he catches *Desmarestia* in his net once it has already detached, often around Castle Hill (Lower East Passage; TE1-120), around April or May.

This trawl fisherman shared observations of several ecological impacts associated with *Demarestia*:

- "I'll be catching good fish, and as soon as that stuff comes by, everything disappears. Everything chases away from it. Crabs, everything. It all gets burnt. If you leave it in the pile too long, you can see the scales burnt right off the fish. It's all white (TE1)."
- "It will start in May in here, then by July it's out there. It's rolling. And no matter where you go, wherever it's been, it's devoid of life. No fish! They smell it, they're gone… I think it's herding everything. That seaweed's actually pushing them. You'll say 'Wow, I can't wait to go out the next day!' The next day, you get the seaweed, and after that, you don't see nothing (TE1)."
- "It's like clear-cutting the forest. Everything that it lays against. Because we used to get some nice big kelp. It was loaded with kelp in here. Now, once that stuff started traveling through here and getting caught on the roots structures and laying there, it burned it right off. It clears everything right off. Sulfuric acid. And for some reason, when it breaks loose, that's when it really starts to give off its acid (TE1)."

A quahogger picked the *Desmarestia viridis* card from the identification card pile, and stated that in the year prior to the interview (i.e., around 2018), this seaweed had appeared on the north end of Prudence Island (Upper Bay) along with *Chondrus crispus*. He had never seen it there before. He recalled that he and two other quahoggers had encountered it through the spring and summer, and then it disappeared. Then, it returned later in the summer, and became so thick that it was difficult to bull rake in the area (QW2-122).

The lobsterman who provided the photograph of "slime weed" on his lobster trap lines (taken in 2014) provided details on the so-called "slime weed" as well as another type of seaweed, which he calls "horsehair." He did not find a match to either of these seaweeds in the identification cards provided during the interview (LN5).

This lobsterman described "slime weed" as follows. It started appearing in Narragansett Bay about 10 years ago (i.e., about 2008) and continues to show up to the present day (LN5-123. It appears in the spring and sticks around until the early summer. The spring before the interview (i.e., 2018; LN5-124), he observed some slime weed, but it wasn't as thick as the spring prior to that (i.e., 2017). That spring, slime weed was most abundant in shoal water places like Hull Cove, Mackerel Cove, and the shoals at Rose Island (Lower East Passage; LN5).

This lobsterman states that "horsehair" appeared on the scene about 4-5 years after kelp disappeared around the early 2000s. He stated that horsehair was prevalent between 2004 to 2010; it was then supplanted by slime weed. Like slime weed, he added, horsehair typically appears in the spring. In addition, he stated that:

> I believe that this kind of seaweed is free-floating. It doesn't actually attach to the bottom, like kelp and rockweed does. My best guess is that it was probably wiping off any seed on the bottom for kelp and rockweed. It didn't actually get a chance to hold. Just a thought. On the moon tides, it was ridiculous, the amount that would wrap up on

> our lobster gear, like the kelp used to. We had that horsehair for a few years—four or five years—and that sort of disappeared, and we got the stuff that people call slime weed (LN5-125).

Eight other individuals shared observations of seaweeds that bear resemblance in their physical descriptions, seasonality, and distribution to *Desmarestia viridis*, slime weed, or horsehair. These descriptions are summarized in the paragraphs below. According to these interviewees, none of the seaweed types described below were present among the identification cards shown to them during their interviews. However, some of the interviewees describing these seaweeds did identify a match with the photograph of "slime weed" offered by a lobsterman, shown above.

An oyster grower described some "brown stuff" that gets "on the motors, it's on the cages, it's on the lines" in his lease (Middle East Passage) during the springtime:

> Right now, there's a wicked set of brown stuff. It's all going to be gone in another two weeks. It's kind of like the food for everything at the beginning of the spring. As soon as stuff comes out of hibernation, there's this brown stuff all over everything on the bottom. In another three or four weeks, that'll be gone. I don't know where it goes—if it's eaten or drifts away or dies.

He stated that it is not acidic. When presented with the photo of "slime weed" above, he responded, "Yup! That's it (AE1)."

An oyster grower described a "stringy brown hair" that appears on his lease (Middle East Passage) in winter-springtime, then disappears:

> I've seen it just about every year, this time of year. It's very heavy. It doesn't really affect much. Gets on the bags. It can foul out the bags a little bit. But if you rinse it in the water, it just falls right off. It's not like it sticks to anything. It just gets clumped on the ropes. Like if you're pulling up a cage, that's when you'll get a big ball of it, on the top of a cage… By the summertime, this stuff will die off. You won't see it. It'll be [replaced by] something else.

He stated that it is not acidic. When presented with the photo of "slime weed" above, he responded, "That's it (AE2)."

A lobsterman described a seaweed that he calls "slime weed." This lobsterman stopped fishing in Narragansett Bay in 2014 and now only fishes in the ocean. When he fished in the bay, he recalls, slime weed showed up in the springtime. "This stuff is slimy, nasty. It comes up in big balls," he recounted. "One year we hit that. It was east of Prudence Island. It took two and a half hours of hauling to clear that stuff. That's how long it was." He does not encounter a lot of slime weed now that he fishes in the ocean; the only place he sees it, he says, is right around Brenton Reef (Mouth of Narragansett Bay), so he thinks it washes out of the bay there. He stated that what he calls "slime weed" is the same type of seaweed called "slime weed" by the lobsterman who provided the photo; he verified a match by looking at the photo (LN3).

A lobsterman described a “brown hairy weed” that “will actually change the color of my deck plates… There’s some type of an acid in there.” He recalled that this seaweed started appearing 5-8 years ago (i.e., between 2011-2014). He stated that it shows up in spring and sticks around into summer. The summer before the interview (i.e., 2018), it stuck around late into the season; the year of the interview (i.e., 2019), it showed up early this year:

> Last summer, it stuck around most of the summer. You used to see a little bit of weed come through early in the spring, and it would flush out of the bay. But the stuff we’ve had the last however many years never seems to leave. In the wintertime, you don’t see it as much, but I did just see it yesterday or the day before yesterday (interview was conducted on March 15, 2019), when I was bringing the last of my gear home. We would usually see it in another month or so, when we’re setting our gear and first hauling.

He added that this “brown hairy weed” tends to be prevalent west of the Naval War College, east of Rose Island, around Fort Wetherhill, and from Fort Adams to Castle Hill (Lower East Passage). For example, he said, “Right along the edge of the fort, I used to set gillnets in here, and the net was so heavy you’d have trouble getting the net back. It would lay it right down and in a couple of hours, it would fill right up." When presented with the photo of “slime weed” above, he responded that it appeared to be the same type of seaweed that he described as “brown hairy weed (LN4-126).”

A lobsterman described a “brown slime” or “slimy crap” that he used to encounter at Bishop’s Rock (Lower East Passage), until about 15-20 years ago (i.e., about 1999-2005), along with *Codium fragile, Ulva sp., Dasysiphonia japonica,*[12] *Grateloupia turuturu,* and *Ectocarpus sp*. After that time, all of these seaweeds suddenly disappeared from that location. He sees all of them to the present day around Rose Island (Lower East Passage). When presented with the photo of “slime weed” above, he concluded that it matched his recollection of “brown slime,” but also appeared to have another seaweed mixed in, which he called “green hair (LN2-127).”

A quahogger described a “yucky scum” that appeared “a few years back” and began to smother the quahogs in Bristol Harbor. More recently, he has begun to see it between the entrance to Potter’s Cove and Mount Tom (Upper East Passage), in smaller quantities. He stated that it is “like a slime”: “I don't even know how to describe it. It's like scum. It sticks to the rake. It makes it real hard to work. I kind of gave up on it." This individual was not presented with the photo of “slime weed” above (QE2-128; QE2-129).

A quahogger and conch fisherman described a “brown weed” or “mermaid hair” that he saw in the springtime during the year of the interview (2019). He described it as brown, really heavy, and “nasty,” but added that it doesn’t stick around very long. In some places, he said, it was “out of control”: “This stuff was so dense. You’d see it and catch a little bit of it, and it would be gone. It moved fast. If you had pots out too soon, you would get hammered with it. You’d get these giant balls that would stick to your pots.” This individual was not presented with the photo of “slime weed” above (QK2-130).

A quahogger described a seaweed that he called "dead man's hair," which is reddish brown, mats the bottom, and smothers everything. According to this individual, dead man's hair used to show up in the springtime at Allen's Harbor (Quonset Harbor) and Friar's Cove and Quonset (Middle West Passage). It was problematic about ten years ago (i.e., about 2009), but since then, it disappeared. This individual was not presented with the photo of "slime weed" above (QW3-131; QW3-132).

In addition to the seaweed observations listed up to this point in this section, which—with the exception of *Desmarestia viridis*—did not correspond to any of the seaweed identification cards presented during the interviews, interviewees also shared assorted observations of seaweeds which they were able to match to identification cards. The paragraphs below list species for which only one interviewee shared an observation. Species for which two or more interviewees shared observations are summarized within their own sections, listed alphabetically by species.

Grinnellia americana. A quahogger stated that he has encountered *Grinnellia* mixed in with *Ulva sp.* at Barrington Beach (Upper Bay). He added that it increased in abundance substantially in the year leading up to the interview (i.e., 2018-2019; QW1-135).

Codium fragile. A lobsterman stated that he used to encounter *Codium fragile* at Bishop's Rock (Lower East Passage) until about 15-20 years ago (i.e., about 1999-2005), along with *Ulva sp., Dasysiphonia japonica,*[12] *Grateloupia turuturu,* and *Ectocarpus sp.*, as well as the "brown slime" described previously in this section. He sees all of these species to the present day around Rose Island (Lower East Passage; LN2-136).

Dasysiphonia japonica. A lobsterman stated that he used to encounter *Dasysiphonia japonica* at Bishop's Rock (Lower East Passage) until about 15-20 years ago (i.e., about 1999-2005),[12] along with *Ulva sp., Codium fragile, Grateloupia turuturu,* and *Ectocarpus sp.*, as well as the "brown slime" described previously in this section. He sees all of these species to the present day around Rose Island (Lower East Passage; LN2-137).

Grateloupia turuturu. A lobsterman stated that he used to encounter *Grateloupia turuturu* at Bishop's Rock (Lower East Passage) until about 15-20 years ago (i.e., about 1999-2005), along with *Ulva sp., Codium fragile, Dasysiphonia japonica,*[12] and *Ectocarpus sp.*, as well as the "brown slime" described previously in this section. He sees all of these species to the present day around Rose Island (Lower East Passage; LN2-138).

Ectocarpus sp. A lobsterman stated that he used to encounter *Ectocarpus sp.* at Bishop's Rock (Lower East Passage) until about 15-20 years ago (i.e., about 1999-2005), along with *Ulva sp., Codium fragile, Dasysiphonia japonica,*[12] and *Grateloupia turuturu*, as well as the "brown slime" described previously in this section. He sees all of these species to the present day around Rose Island (Lower East Passage; LN2-139).

Plankton

<u>Phytoplankton and Zooplankton</u>

- Number of respondents: 4
- Segments mentioned: Mouth of Narragansett Bay, Middle East Passage, Lower East Passage
- Trends mentioned: decline, constant, uptick

Two individuals voiced a perception that the density of plankton in the waters of Narragansett Bay has diminished considerably in recent years.

- A lobsterman stated:

  > You could dip a bucket over the side and there'd be stuff moving in the bucket. It's not like that anymore. That little stuff, a lot of the finer stuff in the water, doesn't seem to be there, or at least not in the numbers that it was. Going back probably 7 or 8 years (i.e., around 2012-2013), I remember looking over the side at times, and the water was just covered with critters. Most of it was baby crabs and lobsters that hadn't hardened up enough to settle to the bottom yet, but they were there. We don't see that now… Not anywhere near that extent (LN4-167).

- A lobsterman stated:

  > These days, probably in the last ten years or so (i.e., since about 2009), we've seen the phytoplankton and the zooplankton in Narragansett Bay, from the [Newport] bridge going north, basically disappear. You scoop up a bucket in the summertime, and it's supposed to be full of life. It's clear water, similar to a swimming pool (LN5).

This lobsterman fishes in the <u>Lower East Passage</u> and the <u>Middle East Passage</u> up to Gould Island (LN5-168; LN5-169).

A lobsterman contrasted the concentration of plankton in the water column in Narragansett Bay to the concentration in the waters of Rhode Island Sound:

> When you go down to the mouth of the bay (<u>Mouth of Narragansett Bay</u>), you can scoop up a bucket of water, and you still see zooplankton in it. Or out front even, out to the three-mile limit, same thing… That's the larvae for crabs, lobsters, all kinds of fish, everything. From the [Newport] bridge up, it's nonexistent anymore. You go out to the mouth of the bay (<u>Mouth of Narragansett Bay</u>), and it's amazing. The water column is just full of zooplankton, late spring, early summer (LN5-170; LN5-171).

The Newport Bridge, he emphasized, "seems to be the dividing line for it all, amazingly. It washes one way or another, but generally around the bridge is where things change. If you had to choose a dividing point in the bay, I'd say it's the bridge (LN5)."

This lobsterman also contrasted the concentration of plankton in the water column in Narragansett Bay today to the concentration that was present in the 1990s:

> In the summertime, you'd scoop up a bucket of water in the bay and it would be full of life. It was amazing to see the little animals swimming around—millions of them—in a bucket of water. You could do that in the mouth of the bay (Mouth of Narragansett Bay), and you could do that north of the bridge, and all the way up by Prudence Island (Lower East Passage and Middle East Passage). This was back in the '90s (LN5).

However, this lobsterman noted that in the year prior to the interview (i.e., 2018), he witnessed an increase in phytoplankton concentration in the water column:

> Last winter, we saw a big bloom of phytoplankton. The water in winter is very clear. When it rains, it gets cloudy, murky. But this wasn't murky, it was a green color because of the chlorophyll (LN5).

He added that this uptick coincided with a reappearance of kelp and rockweed in locations where they had been absent for some time (LN5).

Two individuals commented on the occurrence of rust tides and harmful algal blooms in recent years:

- A quahogger alluded to the blooms of *Pseudo-nitzschia* that took place in 2016 and 2017, shutting down shellfishing for a period of time: "I never saw the bay close because of red tide. Never. And then a whole month? That's when I saw the writing on the wall and I sold my commercial license (QE1)."
- A quahogger stated:

  > I see more tides like the rust tide. I see more algae blooms than I remember in past years, when the water maybe wasn't as clean. I see more of these things happening. I think again, when you're playing with chemistry, one thing affects another thing. Maybe some of these things that they're taking out of the water makes it so these other things thrive. I don't know… It's really weird, because you'll be driving in through that crystal-clear water, and all of a sudden, you'll see it, because it's like a line (QW2)."

Lion's Mane Jellyfish (*Cyanea capillata*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: uptick

Two individuals mentioned lion's mane jellyfish. One commented on changes in its seasonality, while the other commented on changes in the abundance of this species.

A quahogger stated that lion's mane jellyfish appeared earlier in the season than usual during the year of the interview (2019). Specifically, the jellyfish appeared in February, while their usual arrival takes place in March. He added that they were also abundant that year (QW2).

A lobsterman stated that lion's mane jellyfish had been declining previously, but that during the "last couple years" before the time of the interview (i.e., around 2017-2018), this species began to increase again in abundance: "Lion's manes, I want to say the last couple years they've made a comeback. They were always around. You saw them everywhere. The whole bay. Everywhere you wanted to look, you saw them. And then they kind of went away. But then, the last couple of years, I've been seeing them (LN2-80)."

<u>Miscellaneous plankton</u>

"Hard, clear jelly fish with short tentacles" (Moon jellyfish? *Aurelia aurita*?). A quahogger recalled seeing these as a kid, and says they used to be everywhere, to the point where it was impossible to swim. He stated that he no longer encounters these (QE1-105).

Finfish

<u>Black Sea Bass (*Centropristis striata*)</u>

- Number of respondents: 7
- Segments mentioned: Lower West Passage; Middle West Passage; Mount Hope Bay
- Trends mentioned: increase; downtick

Interviewees conveyed a general consensus that black sea bass are increasing in Narragansett Bay and elsewhere. Opinions differed as to when this increase began and whether it occurred suddenly or gradually. The following individuals described this increase, without regard to any particular location:

- An oyster farmer and rod and reel fishermen stated that "Sea bass are very abundant right now. I don't know why that is. Where there used to be none, there's tons (AE1-25)."
- A quahogger stated that black sea bass have been "everywhere" for about two years (i.e., since about 2017). He has been pulling them up in dead quahog shells (QW1-26).
- A lobsterman stated that from when he started fishing as a kid with this father (he started in 1998) up to now (2019), there has been a gradual increase in black sea bass, "to the point where you see them in every trap (LN1-27)."
- A lobsterman stated that starting in 2010, local waters have been "overrun" by black sea bass: "When I first started [fishing, several decades ago], we caught five or six in a day, or eight a day. Eight was a lot a real lot. Now it's just were overrun (LN3-28)."
- A lobsterman stated that fishermen have been "inundated" by black sea bass starting 5-6 years ago (i.e., about 2013-2014; LN5-29).

This comment by a Newport lobsterman highlights the scale of this increase:

> Back a few years ago, I'm guessing five or six years ago (i.e., 2012-2013), we got inundated with black sea bass. It was a real inundation. I mean, we were used to catching a few black sea bass, but all of a sudden, we were catching thousands of them as a byproduct in our traps—in our lobster traps, our crab traps, our fish traps. When I say thousands, I mean like there could be days when you're catching between ten and twenty in each trap you hauled, all day long. Not just we see that. Every fisherman in this area is seeing it (LN5-30).

Two individuals linked black sea bass abundance to specific areas:

- A quahogger stated that the increase of black sea bass has been concentrated in the <u>Lower West Passage</u> and <u>Middle West Passage</u>, compared with other areas in the more northern portions of the bay: "There's been a definite increase in black sea bass, but more in the southern part of the bay, like towards Dutch, Fox Island (QW2-30, QW2-31)."
- A trawl fisherman did not mention whether or not black sea bass had increased, but stated that the channel that runs northwest-southeast through <u>Mount Hope Bay</u> has more sea bass than the shallower areas. He added that this area is not as good as it once was for catching fish, but is still producing seabass, as well as fluke, scup, and butterfish (TE1).

A lobsterman who fishes both inside Narragansett Bay and in state waters outside of the bay stated that the increase in black sea bass has taken place uniformly in both areas (LN5).

According to one lobsterman, the increase in black sea bass that has taken place over the last several years has already begun to taper off:

> In the last few years (i.e., leading up to 2019), that's tapered off some. We don't see the massive biomass that we saw five years ago (i.e., around 2014). We still see them, but this year here (i.e., 2019), it just wasn't as intense as it has been in the last few years (LN5-32).

<u>Eels (*Anguilla rostrata*)</u>

- Number of respondents: 4
- Segments mentioned: Greenwich Cove, Apponaug Cove, Buttonwoods Cove, Warwick Cove, Potowomut River, Middle Providence River
- Trends mentioned: decline

Several individuals shared a view that eels have declined in abundance in Narragansett Bay, seemingly on a decadal scale. Many provided spatial observations relating to places where eels were once common but can no longer be found:

- A quahogger stated that eels used to be popular, but they've taken a hit (QE1).

- A quahogger stated that eels were plentiful in the 1980s in all the coves around Greenwich Bay (Greenwich Cove, Apponaug Cove, Buttonwoods Cove, Warwick Cove, Potowomut River), but by the 2000s, the population was declining (QW2-56; QW2-57; QW2-58; QW2-59).
- A quahogger recalls that eels were highly abundant for a short time in the 1980s, in all the coves around Greenwich Bay (Greenwich Cove, Apponaug Cove, Buttonwoods Cove, Warwick Cove, Potowomut River), but they "petered out (QW3-60; QW3-61; QW3-62; QW3-63; QW3-64)."

Some participants once harvested eels commercially, but all have since stopped setting eel pots due to the decline of the eel population (QK3, QW2, QW3). One individual reported eeling in the 1980s and again after taking some time off the water in the 1990s; he quit about 6 years ago (i.e., around 2013; QW2). Another reported that he started eeling in the early to mid-1980s, and stopped when the eels disappeared (no time given; QW3).

One individual shared the following recollections of the former abundance of the eel population in Narragansett Bay:
I put one eel pot down where I kept my boat, next to the old East Greenwich co-op. I went down the next morning and you couldn't fit another eel in it. It had like thirty pounds of eels in it. And I never had another haul like that. I caught a few, but they petered out (Greenwich Cove; QW3).

The same individual described his belief that overharvest of elvers (also known as glass eels) is responsible for the decline of the eel population:
There used to be a has company, I think it was Gulf. There was a river. The herrings would go up there, and the eels would go up there too. A friend of mine that I had known forever told me that the glass eels showed up when the shadberry bushes bloomed, so we went up there and got a mess of them to eat. In subsequent years, they started selling for a hundred dollars a pound. People started grabbing them up by the Pawtuxet River, up by the Pawtuxet Village there (Middle Providence River), and every other place they would swim. That killed it. A hundred dollars a pound, people are going to kill for that (QW3).

Scup (*Stenotomus chrysops*)

- Number of respondents: 4
- Segments mentioned: Mount Hope Bay, Middle West Passage, Lower West Passage, Lower East Passage
- Trends mentioned: increase, decline, constant

Four individuals discussed observations related to recent changes in scup populations. There was very little agreement across statements.

A quahogger stated that a sudden increase in scup occurred, mostly in the southern part of the bay, such as around Fox and Dutch Islands (Middle West Passage and Lower West Passage, respectively; QW2-251; QW2-252).

An oyster farmer and rod and reel fisherman stated that he has seen an increase in scup, particularly *large* scup, but has not seen many smaller scup at all:

> Scup are very abundant right now. Large scup. The average size seems to be a lot bigger than it was just a few years ago... In the last few years, the size of scup has gone from what we call smalls or mediums to large and jumbos. I haven't seen a medium or small scup in the bay in a couple of years (AE1-253).

A lobsterman who also sets fish traps stated that 7-8 years ago (i.e., around 2011-2012), he stopped catching scup in an area that used to be good in the shoals by Bishop's Rock (Lower East Passage; LN4-254). He added that this is right near a wastewater outflow. He said that he still catches scup at Fort Adams, Rose Island, and the House on the Rocks (Lower East Passage), specifying that the House on the Rocks is good habitat for scup because it has a lot of mussels (LN4-255).

A trawl fisherman did not discuss whether or not scup had increased, but he did mention that he catches more scup in the channel that runs through Mount Hope Bay than he does in the shallower areas around it. This channel is not as good as it once was, he stated, but is still producing scup, along with sea bass, fluke, and butterfish (TE1).

Winter Flounder (*Pseudopleuronectes americanus*)

- Number of respondents: 3
- Segments mentioned: Mount Hope Bay, Taunton River, Lees River, Kickemuit River
- Trends mentioned: decline

Three individuals commented on the abundance of winter flounder in Narragansett Bay. All agreed that this species has precipitously declined in the bay over the last several decades:

- A quahogger stated that he used to catch flounders "by the bucket" in the 1980s: "Another one, another one, another one." Now, he said, he sees none. He theorized that an increase in cormorant (*Phalacrocorax auritus*) abundance has played a role in the demise of winter flounder (QE1-327).
- A quahogger stated that winter flounder fishing was really good in the bay in the 1990s; then, all of a sudden, it was gone. He described it as a "boom-bust" pattern in which the population got too large to sustain itself (QK3-328).
- A trawl fisherman stated that winter flounder fishing was really good in the 1970s and early 1980s. The best location was Mount Hope Bay, and he attributes this to the influx of freshwater from the Taunton River, Lees River, and Kickemuit River. This abruptly changed in 1986, he said: "In '86, we got '86'ed." After that, he recounted, the resource

collapsed. Nowadays, due to conservation measures, he is not allowed to keep winter flounder, so he no longer targets them and does not have a good sense of their abundance (TE1-329).

Menhaden (*Brevoortia tyrannus*)

- Number of respondents: 4
- Segments mentioned: none
- Trends mentioned: decline, uptick

Three individuals described declines in the population of menhaden (pogies) populations in Narragansett Bay:

- An oyster grower and rod and reel fisherman stated that menhaden have tapered off (AE1-98).
- A quahogger stated that baitfish in general have been less abundant in the 3-5 years before the interview (i.e., since about 2014-2016): "We used to have the pogy boats, because there were so many pogies. Then we saw a decline in that. Now, I don't know if they're getting them before they come into the bay to spawn, but last year, there weren't the populations that we used to have. We used to see schools. Then the bluefish would follow. But if there's nothing to eat, they're not here, so they haven't been coming up... Pogies, I didn't see many. I didn't see them like we used to (QW2-99)."
- A quahogger recalled large menhaden runs in the 1970s and 1990s. He stated that in the last 5 years leading up to the interview (i.e., since 2014), *large* menhaden were rare in Narragansett Bay (QK3).

One individual speculated on the reasons for this observed decline, suggesting that there may be a shortage of forage for menhaden in the bay: "They eat plankton. They're not meat-eaters. So if there's nothing here for them, there's no reason to be here (QW2)."

However, some respondents reported a short-term increase in menhaden abundance in the years of and just prior to the interview (i.e., 2018 and 2019).

- A quahogger observed "tons of pogies" in the fall before the interview (i.e., fall 2018; QK2)
- A quahogger stated that there had been a notable increase in peanut bunker (small menhaden) in the fall when he was interviewed (i.e.; 2019; QK3).

Striped bass (*Morone saxitilis*)

- Number of respondents: 3

- Segments mentioned: Upper Bay, Upper West Passage, Upper East Passage, Wickford Harbor
- Trends mentioned: decline, uptick

Three individuals commented on striped bass populations. Their comments present a mixed picture in terms of trends in abundance.

Two individuals remarked that striped bass seem to be increasing:

- An oyster grower and rod and reel fisherman stated that he has seen an uptick striped bass, just recently. He had formed an impression that they were declining about five years prior to the interview (i.e., starting around 2014; AE1-311), but says that the year before the interview (i.e., 2018), he had a great year catching striped bass (AE1-312).
- A quahogger stated that he saw large numbers of striped bass in the year of the interview (i.e., 2019) in Wickford Harbor (QK2-313).

In contrast, a quahogger and rod and reel fisherman stated that, at least for larger striped bass, he has seen a decline: "It does seem like right now, the larger bass population is down… That's getting harder, to get my five fish. It used to be a lot easier. Now I have to put a lot more time in." On the chart, he outlined that striped bass have remained more consistent in the Upper Bay (QW1-314) and Upper East Passage (QW1-315) compared to the Upper West Passage (QW1-316). The shorelines of Patience and Prudence Islands in the Upper West Passage used to be good fishing spots for stiped bass, but these areas have dropped off, this individual said (QW1-316).

Bluefish (*Pomatomus saltatrix*)

- Number of respondents: 3
- Segments mentioned: Wickford Harbor
- Trends mentioned: decline, uptick

Three individuals mentioned bluefish. Their comments do not reveal a clear trend, but would be consistent with a long-term decline followed by a shorter, more recent uptick:

- An oyster grower and rod and reel fisherman stated that bluefish abundance has been "definitely tapering off" starting 8-10 years ago (i.e., since about 2009-2011; AE1-416).
- A quahogger stated that there was a noticeable increase in bluefish abundance the summer before the interview (i.e., 2019) in Wickford Harbor (QK2-38).
- A quahogger stated that bluefish tend to "come and go" interannually, and described this as a coastwide phenomenon (not just in Narragansett Bay; QK1-39).

Seahorses (*Hippocampus erectus* and possibly other spp.)

- Number of respondents: 2
- Segments mentioned: Lower East Passage, Newport Harbor
- Trends mentioned: decline

Two individuals mentioned that they have observed a decline in their incidental catch of seahorses in recent years:

- A lobsterman stated that he used to catch seahorses occasionally along Coddington Point, the east side of Rose Island, and from Fort Adams to Castle Hill (Lower East Passage). However, he said that it's been 8 or 9 years (i.e., since about 2010-2011) since the last time he saw one (LN2-261).
- A lobsterman estimated that he used to catch about two sea horses per week during the fall months. He recalls catching a variety of different species: "The dwarfs all the way to the giants. I had one that had antlers coming off its head like a deer. I had another big one that had turquoise cheeks. There were three different seahorse varieties that we would have in the bay." He stated that his incidental catches of seahorses were concentrated in Newport Harbor and three areas roughly bounded by Coddington Point, Rose Island, and Goat Island (Lower East Passage). He stated that he has not seen sea horses in 10-12 years (i.e., since 2007-2009): "We don't get any of them [now]. None. I haven't heard of anybody saying they caught a seahorse… I know they still seem them outside [the bay] here and there, but not in the bay (LN4-262; LN4-263)."

Tautog (*Tautoga onitis*)

- Number of respondents: 3
- Segments mentioned: Warren River, Mount Hope Bay
- Trends mentioned: decline

Three individuals remarked that there has been a decline in the abundance of tautogs in Narragansett Bay. According to two of these accounts, this has been a long-term, gradual decline; the third did not specify a timeline.

- A lobsterman described how he used to set tautog pots in the 1990s in the Warren River, and did quite well at it. He saw their abundance decrease before he moved to Newport in 2001-2002 and stopped fishing near Warren (LN3-317).
- A quahogger stated that tautogs have decreased over a "long period of time" (longer than most of the changes he discussed in his interview; QW2-318).
- A trawl fisherman stated that tautog abundance dropped off in Mount Hope Bay: "In this area, every fish there was dropped. Sand dabs. Everything. The blackfish, the tautogs, this was the main spawning area. They got hit. Everything got hit (TE1-319)."

Sea Robins (*Prionotus evolans*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: increase

Two individuals shared a perception that sea robins have recently become more abundant in Narragansett Bay:

- An oyster grower stated that robins are suddenly more abundant (AE1-272).
- A quahogger stated, "The sea robins are way more. When we're digging up along those shallow islands, I see them swimming by in the spring (QK3-273)."

Fluke (*Paralichthys dentatus*)

- Number of respondents: 2
- Segments mentioned: Mount Hope Bay
- Trends mentioned: constant

Two individuals mentioned fluke, but neither gave much detail or indicated a trend:

- An oyster farmer and rod and reel fisherman stated that fluke have been around since he was a kid decades ago (AE1).
- A trawl fisherman stated that he catches fluke in the channel in the middle of Mount Hope Bay, along with scup, butterfish, and sea bass. He added that this area may not be as good as it once was, but it's still more productive than surrounding shallower areas (TE1).

Miscellaneous Finfish

- Number of respondents: 5
- Segments mentioned: Upper Bay, Mount Hope Bay
- Trends mentioned: increase, decline, constant

"Miscellaneous finfish" are defined as finfish species for which only one individual offered an observation.

Cunners (*Tautogolabrus adspersus*). According to a lobsterman, "The cunners have disappeared. There used to be millions of them, and large sizes of them—adult sizes (LN5-101)."

False Albacore (*Euthynnus alletteratus*). According to an oyster grower and rod and reel fisherman, there were "tons of them" in the bay during the fall for several years prior to the

2019 interview, especially around Barrington Beach (Upper Bay). This individual does not recall seeing false albacore in the bay prior to this in his lifetime: “I’ve fished there for a long time, and except for the last three or four years (i.e., since about 2015-2016), I don’t remember seeing stuff like that (AE1-102).”

Sand Dabs (*Scopthalmus aquosus*). According to a trawl fisherman, sand dab abundance has dropped off in Mount Hope Bay and elsewhere (TE1-103).

Squeteague (*Cynoscion regalis*). According to an oyster grower and rod and reel fisherman, there were “huge schools” of squeteague in Narragansett Bay when he was a kid. He stated that he has not seen squeteague in those numbers since the 1970s (AE1-104).

Butterfish (*Peprilus triacanthus*). A trawl fisherman stated that the channel that runs through Mount Hope Bay contains more butterfish than the shallower areas around it. He added that this area is not as productive as it once was, but it is still a good place to catch butterfish (TE1).

Submerged Aquatic Vegetation

Eelgrass (*Zostera marina*)

- Number of respondents: 4
- Segments mentioned: Upper West Passage, Middle East Passage
- Trends mentioned: increase, constant

Four individuals commented on eelgrass in Narragansett Bay. All shared site-specific observations.

Two individuals stated that they have seen an increase or first-time appearance of eelgrass in certain locations:

- An oyster farmed stated that he “never used to see eelgrass,” but he has seen it for the last 2 years (i.e., since about 2017 to 2019) on the southeast shore of Prudence Island, in 5-6 feet of water (Middle East Passage; AE1-52).
- A quahogger stated that there is more eelgrass generally. He mentioned a restoration site along the western side of Prudence Island south of The Gut between Prudence and Patience Islands, where eelgrass seems to be doing well (Upper West Passage; QW1-53).

Two individuals mentioned eelgrass along the northeast shore of Jamestown; there is no evidence that this is a new occurrence:

- A quahogger shared recent observations of eelgrass along the northeast shore of Jamestown in less than 10 feet of water, but stated that he had not spent time in that area until recently and did not know how long eelgrass had been present there (Middle East Passage; QK3).

- A quahogger stated that to his knowledge, there has always been eelgrass along the northeast shore of Jamestown (Middle East Passage; QK2-54).

Birds

Cormorants (*Phalacrocorax auritus*)

- Number of respondents: 2
- Segments mentioned: Lower East Passage
- Trends mentioned: increase

Two individuals mentioned observations related to cormorants. Both felt strongly that there has been an increase in cormorant abundance since they started fishing:

- A quahogger stated that when he started fishing in 1980, he "didn't see any cormorants," but now they are plentiful (QE1-41).
- A lobsterman stated that he has seen changes in the number of cormorants showing up in the summer and fall, adding that he now sees "thousands of them" on the House on the Rocks, Mackerel Cove, and Hull Cove (Lower East Passage; LN5-42).

A lobsterman provided the following detail:

> One of the other big changes we've seen is the amount of cormorants that invade our bay during the warmer months. They leave in the wintertime. They migrate south. They show up through the summertime, the early fall. There's a rock over by Fort Wetherhill, the House on the Rocks by the Dumplings. For years, you'd see a few cormorants show up there. Now it's so inundated, there are so many of them by that rock, that now they've spread to other rocks, like Mackerel Cove and Hull Cove. They sit on the rocks and dry themselves off. They nest there. There's thousands of them. We used to have a few, a dozen here and there (LN5-42).

Both individuals associated the increase in cormorants with a decline in winter flounder populations in Narragansett Bay, stating that cormorants were initially drawn to the bay to prey upon winter flounder, but that they have since decimated the winter flounder population. One lobsterman stated:

> Hundreds of them at a time are diving down to the bottom, and almost every single time they come up, they have a juvenile fish in their mouth. If we're hauling a trawl, they'll follow us, and as we're dragging the traps across the bottom, the muddy bottom, they're picking away the little fish that get disturbed, that start swimming around. They just grab them. I think that's taken a toll on a lot of these species of fish in Narragansett Bay, including the winter flounders, the summer flounders, the cunners. All these bottom-dwelling fish are being eaten every single day by thousands of cormorants (LN5).

Mammals

Seals (*Phoca vitulina*)

- Number of respondents: 2
- Segments mentioned: Lower East Passage
- Trends mentioned: increase

Two individuals commented on an increase in the seal population in Narragansett Bay:

- A lobsterman stated that the increase in seals is one of the biggest changes he's witnessed during his career as a fisherman, started around 1998. In the early part of his career, he explained, he would typically see one or two seals a week. Now, he sees multiple seals every single day. He states that this increase in seals has taken place both inside Narragansett Bay and in the ocean outside the bay (LN1-277).
- A lobsterman stated:

> The seal population has grown in Narragansett Bay over the last thirty years (ie., since about 1989). There's more seals now that come out and sun themselves on places like Rose Island (Lower East Passage). There's way more than there used to be. We used to see a few seals here and there. Now you see them all over the bay. I mean, everywhere you go on a nice calm day, you can be hauling trawls all day long and everywhere you look, you see a seal. They're taking their toll on the fish species, there's no question about it (LN5-278)."

In addition, a lobsterman noted that seals are present in Narragansett Bay longer throughout the year than they used to be. He previously never saw seals in the summertime, but now he sees them all through the year, adding that some of them never seem to leave the bay (LN1).

Other mammals

- Number of respondents: 1
- Segments mentioned: Middle East Passage
- Trends mentioned: none

An oyster grower stated that he saw a pod of 40-50 "harbor porpoises" near his lease, off the west coast of Aquidneck Island (Middle East Passage) in October or November 2018. He added that he had never seen this species before in this area. Around the same time, he saw a lot of false albacore in the area, and he wondered whether there may have been a correlation between the two species' atypical abundances in this area (AE1). Although this fisherman used the term "harbor porpoise," we suggest that he may have actually been referring to dolphins, which are often called porpoises by fishermen. Harbor porpoises (*Phocoena phocoena*) are not social and do not travel in pods, while the common dolphin (*Delphinus delphis*) does (Kenney, personal communication).

Abiotic Observations

Abiotic observations expressed by interviewees in the 2019 Narragansett Bay interviews are summarized below.

Clarity / Turbidity

- Number of respondents: 9
- Segments mentioned: Warren River, Upper East Passage, Lower East Passage, Newport Harbor

Eight individuals expressed a perception that the water column in Narragansett Bay has become remarkably clearer in recent times. Embedded in many of these comments was an associated perception that the clear water typical of wintertime in Narragansett Bay has become typical of summer as well (in contrast to years past, when summertime waters were murky).

For instance, a lobsterman stated that certain locations in the Lower East Passage (e.g., around Rose Island) and Newport Harbor (e.g., the docks at Long Wharf) have experienced a decline in turbidity starting about three years before the interview (i.e., since around 2016). Moreover, he stated that lower turbidity levels have been persisting longer into the spring season than they used to:

> On the side of the dock here, you never saw the water crystal clear, except in February. Now you can come down here at the end of the summer and see clear. Rose Island is a perfect [example]…. That clarity was there too. I mean, there's spots in twenty, twenty-five feet of water where I had never seen the bottom. In the past few years, I'm looking at the bottom for a good third of the season… Especially in the spring, you see that clarity is coming around here. Unbelievable clarity. I've only seen the bottom here and here in February. And now, you can see it (LN2).

A quahogger stated that the Warren River has experienced a decline in turbidity since about 2012:

> I look at it now. It rained really hard, and the water is still clearish. I've never seen that before. I saw the progression, where it got clear and then it got dirty again. Then it got clearer, clearer, clearer. This year, it's like really clean.... There are areas I work in the Warren River, where it's 14 feet deep and I could see the rake. That only happened after 2012. I could see the freaking rake in the water, in 14 feet. Holy shit! I hadn't seen that before. It didn't exist before that (QE1).

A lobsterman stated that he has seen a dramatic decline in turbidity, with summer months now having the same clarity that only winter months used to have before. He finds this to be a cause for concern:

> I noticed that the water was getting clearer and clearer and clearer… To me, an estuary or any place like that, especially as you go into the upper reaches of the bay, the water wasn't dirty but it wasn't crystal clear. But if you scooped up a bucket of it, you'd see something in the water. At the time, you'd see like a cloudiness to the water. That was plankton and zooplankton. I didn't even know where I was looking at back then. Now after we've thought about this and read about it, that was life. Well, now, as of a few years ago, there was nothing. It was crystal clear. We'd come in, even in here in the lower part of the bay, in the middle of summer, in August, September, I could see 16, 17 feet down. I'd see the bottom of it. You could never, ever, ever see that in the middle of summer. The only time we ever saw water like that was when I used to go up the Warren River in a quahogging skiff. It would be the end of February, March, when the water was absolutely the coldest it would be. It would be crystal clear. To me, it was because it was so cold nothing was growing. But that was natural. That's the way the cycle went. Then I started seeing that happening like that down the lower part [of the bay], because that's where I'm working now. I'd see the water like that in the middle of summer, and I'm saying, "There's something wrong. There's no life in the water (LN3).

A quahogger stated that the water is much clearer than it used to be (QE2).

A quahogger stated that the water is much clearer than it used to be: "The water seems ridiculously clean… Even up in Mount Tom (Upper East Passage), there are days up there that I can see bottom in 17 or 18 feet of water. Just crazy. Just really seems too clean. Almost like pool water (QK2)."

A quahogger stated that in the earlier part of his fishing career in the 1970s and 1980s, the water was turbid all year long, "like muddy river water." Now, in contrast, he stated that the water is clear (QK3).

A quahogger stated that the water is much clearer than it used to be: "I see that some days, it's really, really clear—like Caribbean clear. On some days, you can see 10 or 12 feet down. You can see the rake. Whereas years ago, you couldn't see it. In some ways, I think it's cleaner than it was (QW2)."

A lobsterman stated that the water is much clearer than it used to be during the summertime:

> In the summertime, between July and August, the water in Narragansett Bay would be brown. Actually brown, where you couldn't see one foot through the water column from the surface down. Now, in the summertime, when that water's supposed to be brown, it's clear. The water is clear. There's nothing in it. You can see 10, 15 feet down through the water column from the surface in the middle of July and August. Clear water. No life in it. That's a drastic change from how it used to be (LN5).

Making a spatial comparison, one individual (a lobsterman) stated that the turbidity inside Narragansett Bay has become more similar to that of the water outside the bay, in Rhode Island Sound. He described a "tidal line" that used to appear across the Lower East Passage in the vicinity of Castle Hill in years past. This line, he explained, would fluctuate northward and southward with the tide. The water on the northern side of the line would be more turbid and the water on the southern side would be clearer. However, this lobsterman stated that the "tidal line" gradually disappeared. He had not seen the line for about ten years before the time of the interview (i.e., since about 2009):

> Years ago, there used to be a line at Castle Hill, with the tide fluxing in and out. You could see the line where the phytoplankton and the zooplankton change at Castle Hill. The water would be brown. You would see the line go right across the bay. I observed this for years. A line going right across the bay, right here, and it would fluctuate with the tides. It might go up to here, might come down to here. From here up would be brown. All this water would be brownish color. And from here out would be clear. I don't see that anymore. That line, that brownish water, that area up here, has disappeared. That bay has disappeared… You could see the line go right across the bay. You could be hauling a trawl in brown water and end up hauling the rest of the trawl in clear water. It was amazing to see it. All gone. Doesn't happen anymore (LN5).

One individual (an oyster grower and rod and reel fisherman) stated that he has not perceived any change in clarity/turbidity:

> I haven't seen any changes outside of what I think of as normal. As far as clarity and stuff like that, it's very clear right now. It's very clear in the winter, when everything is cold and nothing is growing. Then as soon as the food gets in the water for the shellfish, it gets cloudy. The cloudier it gets, the better it is for the shellfish. That's a good thing, in my opinion. Most people like the clear water, but I don't have any problem with it being cloudy, because I know my oysters are loving it… As far as significantly more in the last few years than before, I can't honestly say that I've seen anything (AE1).

One individual commented on a correlation between the decline he has observed in water column turbidity and other ecological changes in Narragansett Bay. This lobsterman stated that the change in turbidity occurred "around or just after" rockweed (*Ascophyllum nodosum*) started to decline in abundance in the bay (LN3).

As hinted by many of the comments in this section, many interviewees feel alarmed about the remarkable increase in water clarity that they have witnessed in the bay. Echoing the sentiments of many, one lobsterman said:

> At the time, I thought it was a good thing, because obviously the water is getting clearer. I was around back in the days when they used to just open up [the combined sewer overflows]. They get a big rain fall up in Providence, and they literally just open the valve and let the stuff go. You would have everything in the world floating down. Everything you could imagine, like solids. It was gross. I mean it was everything. You name it, we saw it. All that disappeared when they put those underground tunnels in.

> They were able to capture all the solids. Then when they started those underground tunnels, it's all sudden--like the time frame, to me, was like, "Wow, they're starting to really treat this stuff, and not just letting it go." And I'm saying, "The water is getting really clean, like ridiculously clean." And I'm saying, "Are they like over-treating the water? Is there collateral damage?" That's the way I thought about it. I know it was unintentional. They weren't trying to do that. But I'm saying, "There's something drastically wrong with [the bay] …" I hear people, they think it's a good thing. To the laymen, "Geez, the bay water is crystal clear. It's perfect. We're doing such a great job." It's hard to get them to think, "Well no, this is food that we're eliminating here. The bay shouldn't be like the ocean or shouldn't be like the Caribbean or like a swimming pool (LN3)."

However, not all interviewees who had noticed a change in clarity were alarmed by it. One quahogger shared an assumption that the increased clarity is a good thing, although he also noted that he is not a biologist (QE2).

<u>"Chlorine" Smell</u>

- Number of respondents: 5
- Segments mentioned: East Greenwich Bay, Upper Bay, Upper West Passage, Middle East Passage, Lower East Passage, Mount Hope Bay

Five individuals described a "chlorine" smell that they have perceived occasionally while working on Narragansett Bay. They put forth various theories as to the source of this smell, ranging from wastewater treatment plants to gas stabilizer used by boats with gas-powered outboards, and also shared some theories as to its potential association with ecological change.

Interviewees offered the following descriptions of the smell:

- A quahogger commented, "I swear I smell chlorine sometimes, but everybody else tells me that's impossible (QW3)."
- A quahogger commented that in certain places, "The water smells like a pool. It smells like bleach… Really pungent. It's like bleach. That's the best way to describe it (QW2)."

Interviewees associated this smell with the following locations:

- A quahogger stated that he detects the smell frequently off Warwick Lighthouse (between <u>East Greenwich Bay</u>, <u>Upper West Passage</u>, and <u>Upper Bay</u>), where the water is deep and it "swirls up, goes down to the bottom of that trench and sweeps up and curls around. It's a very violent place." His theory is that the mixing of the water makes the smell more noticeable in that location (QW3).
- A quahogger stated that the smell is pungent at Barrington Beach and Longmeadow (<u>Upper Bay</u>; QW2).

- A lobsterman stated that he detects the chlorine smell along the West Coast of Aquidneck Island from the Navy Breakwater to Goat Island (Middle East Passage and Lower East Passage; LN4).
- A trawl fisherman stated that he detects the smell on the west side of Aquidneck Island near Newport (Lower East Passage; TE1).
- This trawl fisherman also detects the smell on the Fall River side of Mount Hope Bay, near a sewer plant (TE1).

Interviewees described the following timelines and trends associated with this smell:

- A quahogger stated that he noticed this smell starting 2-3 years before the interview (i.e., since 2016-2017) in the Upper Bay: “It’s new. It’s maybe two or three years old (QW2).”
- A lobsterman stated that he now detects this smell in the Middle East Passage and Lower East Passage, but less frequently than before (LN4).
- A trawl fisherman stated that he has detected the smell in the Lower East Passage since 1971. He stated that the smell has decreased in frequency over the last 5-6 years leading up to the interview (i.e., since about 2013-2014; TE1).
- This trawl fisherman also stated that the smell used to be more frequent in Mount Hope Bay: “It used to be really serious”. He still detects the smell in this location, but he stated that it has declined in frequency (TE1).

Interviewees described the following seasonal aspects associated with this smell:

- A lobsterman stated that he smells it most frequently in spring and summer. However, he notes that this is when he is fishing most frequently, so this observation may be an artefact of his greater presence on the water during those months (LN4).
- A quahogger stated that he smells it most frequently in the summer (QW1).

Some interviewees associated the smell with specific conditions. Two individuals associated the smell with calm mornings. Two individuals associated the smell with nearby boat traffic. One associated the smell with peaks in emissions from wastewater treatment plants.

- A quahogger stated that he tends to smell it when recreational boats go by: “I don’t know if it’s a stabilizer that they’re putting in, but when a boat goes by, it smells just like chlorine bleach (QW1).”
- A quahogger stated that he tends to smell it most often when large boats pass: “You know when you can really smell it? When a big boat goes by. Sometimes in the summertime when the boats have that spray and it’s a little windy, you get that spray, and it reeks (QW2).”
- A lobsterman stated that he tends to smell it most often around “six o’clock, five o’clock in the morning on a nice, flat day. No breeze at all. It was like a mirror. If you had a breeze, it would just blow the stink away (LN4).”
- A trawl fisherman stated that he tends to smell it “early in the morning, when there’s not as much of a wind blowing things around (TE1).”

- This trawl fisherman also stated that in the Lower East Passage, the smell is particularly noticeable after a busy tourist weekend in Newport, when "everyone's flushing toilets (TE1)."

Interviewees put forth two hypotheses regarding the source of this smell. Several assumed that the chlorine smell emanates from wastewater effluent, specifically that it is caused by the chlorine used in wastewater treatment processes (TE1, QW3). One individual put forth an alternative hypothesis: "I was also wondering, a lot of people put something in their gas that smells like bleach. I don't put anything in my gas, but a lot of recreational boats, when they go by, it smells like bleach…. Something people put in their gasoline (QW1)."

Several interviewees expressed concern about this smell, wondering whether it indicates chemical activity in the water column that could have negative ecological impacts on Narragansett Bay's biotic communities:

- A quahogger commented that he noticed a temporal correlation between the time that this smell became noticeable (since about 2016-2017, according to this individual) and the time that quahog recruitment dropped off: "It seemed to me—and again, I'm not a scientist—but I'm just telling you, when the quahogs stopped spawning, I started smelling it. Right hand of God. It seemed like that started—and not just me, it's everybody. There's a decrease in the littlenecks. We got that stink. It's not septic either. It's like bleach, like chlorine. I don't know. I know we're trying to make the bay really clean. But on the other side, these are organisms, these little animals, they grow up on stuff that's not so clean (QW2)."
- A quahogger expressed concern about the interactions between ocean and coastal acidification and chlorine use in wastewater treatment processes, hypothesizing that a lowering of pH in the water column may make chlorine-based contaminants more available to interact with biotic components of the ecosystem (QW3).
- A trawl fisherman stated a belief that chlorine use in wastewater has had negative effects on Narragansett Bay's biotic communities: "Before that, they were just dumping raw sewerage. And you want to see this place thrive with fish! Oh! It was phenomenal. Because that's good nitrogen, because that's what they feed off of. One thing leads to the next. It's natural. Now, here we are: it's poison. Gee, there's none of this, none of that. You fed them poison (TE1)!"

Miscellaneous Abiotic Observations

- Number of respondents: 4
- Segments mentioned: Middle West Passage, Lower East Passage, Mouth of Narragansett Bay

This section contains four observations of abiotic factors that were shared by only one individual apiece. Three of these relate to smells, and one relates to changes in predominant wind directions and storm frequency.

“Ocean” Smell. A lobsterman described an “ocean smell” that hangs in the air from Castle Hill southward (Lower East Passage and Mouth of Narragansett Bay). He said that the ocean smell starts being noticeable in the spring time, and it has been consistent over the decades he’s been fishing (LN5).

“Plankton” Smell. A trawl fisherman described a distinctive “plankton smell” that used to regularly occur around Castle Hill, especially in the spring and summer. He said that this smell stopped occurring about ten years ago (i.e., since about 2009): “I have a good sense of smell, and I used to always smell, in the morning, that fresh, fresh plankton smell, like the smell of vegetation. You don’t smell that no more…. Real organic, like really healthy… It’s like dead air now (TE1).”

“Burning Rubber” Smell. A quahogger stated that he detects a smell somewhat like that of burning rubber while fishing around Quonset (Middle West Passage): “Occasionally, I did get a smell of something. I thought it was I thought it was just something coming from Quonset, because the smells down there are really terrible. I don't know how guys even worked there, like in Friar's Cove. There's all kinds of construction and everything going on. It almost smells like burning rubber over there. It's just an awful, toxic smell. It's noisy over there too (QK2)."

Wind Direction and Storminess. A quahogger stated that in his first 20 years of quahogging (1980s and 1990s), the summertime wind emanated predominantly from the NW and SE, and never came from the NE except for a few minutes while it was coming around from NW to SE. Now, he stated, he notices more wind coming from the NE in the summertime. He has also noticed more storms. He theorized that these changes may be associated with climate change (QE1).

APPENDIX E. OBSERVATIONS EXPRESSED IN THE 2014 SHELLFISH HERITAGE INTERVIEWS

Sessile Benthic Invertebrates

Quahogs (*Mercenaria mercenaria*)

- Number of respondents: 8
- Segments mentioned: Upper Bay, Lower West Passage, Dutch Harbor, Quonset Harbor, Middle West Passage, Greenwich Bay (section)
- Trends mentioned: boom, collapse, increase, decline, constant

Four individuals mentioned that the 1980s were a booming time for quahogging in Narragansett Bay. It is hard to disentangle fishermen's biological recollections about this time from their economic recollections. It is clear from fishermen's memories that in the 1980s, Narragansett Bay supported a far greater number of quahoggers, collectively harvesting a far greater number of quahogs, than ever before or since. However, many of these fishermen attribute the high level of landings during this period to the opening of many previously closed shellfishing areas, thanks to improving water quality. Whether it was due to the improvements in water quality, the pollution itself, the de-facto protection of large areas as spawner sanctuaries, or something else, the 1980s were a time of a high abundance of quahogs and one-time bonanza for quahoggers.

Of the boom, a quahogger recalled, "I've seen the openings. When I first started, [Shellfish Management] Area A (Upper Bay) had just opened up. It had been closed for many years. There were a lot of people doing it back then, in the early '80s. You could see 600 boats up there. Those were the days! Quahogs were everywhere (QK4-351)."

Another quahogger recalled two important openings: the Upper Bay as far north as Rumstick Point in 1981, and Barrington Beach (Upper Bay) in 1982. The 1980s, he said,

> …were a bonanza. The license was $15. Everybody got in. Prior to that, very few people shellfished. Then they opened Barrington Beach. That's when so many people got in. There were people quahogging out of canoes. There were thousands of boats. They only opened it one day a week, on Tuesday. You had to make all your money in one day because the price went down so much. Then they changed it to three days a week. You didn't go anywhere else because you didn't want to deplete your usual areas, and the price went down so low. We were actually making a good living in the 1980s (QE1-352)."

A third quahogger recalled:

> Coming back from Barrington [Beach] (Upper Bay) with the boat loaded. The boat had so much weight in it that water was coming over the sides. I pulled the plug and put the plug in my mouth and I'm driving, and the water's coming in the boat, over the floor, and out the hole. The boat was full of quahogs. Full. The boat was barely moving. It took

> me like an hour to get home from Barrington Beach. That was fun times. You used to come in, sell off, and go back out. Because you knew it was going to end, so get it now. It was great. I went and bought an outboard, cash. I had a custom-built boat made, cash. Everything I did was cash (QW2-352).

The boom lasted until the 1990s, and then the population crashed, several quahoggers explained. One quahogger stated that he quit fishing in Narragansett Bay and resumed fishing in Ninigret Pond from 1993 to 1995, as he had done before the bay's quahog boom (QK3-354).

According to two individuals, many of those who started quahogging during the boom of the 1980s quit quahogging in the 1990s. For example, one quahogger recalled:

> That all fell apart when it got overfished [in the 1990s]. When it got overfished, we lost our market share. That's when everybody made a mass exodus out of the business. Because they couldn't pay their mortgages, they couldn't pay their rent, they couldn't live. I remember, my right hand to God, I remember one March when I made $30. I went every day and I could not break a $30 bill. And I was a pretty good quahogger back then. I was starting a family, and had a young wife. I had to go to Red Cross and get a box of food. I was like a month or two behind on the rent, and I was getting pressure from the family. I had to get out (QW2-355).

Another quahogger recalled, "Eventually [Barrington Beach] (Upper Bay) became just like any other areas, just a regular place to go. A lot of people got out of the business, because it was no longer a bonanza. Then we had some lean years, in the 1990s (QE1-356)." After a few years, he added, prices improved, so that quahoggers were able to make due with lower landings. However, the terrorist attacks of September 11, 2001 brought prices back down again, and more quahoggers quit. This was followed by a moratorium on the issuance of new licenses, which has kept the numbers of quahoggers low ever since (QE1).

Descriptions of the boom of the 1980s and collapse of the 1990s tend to emphasize the Upper Bay, and it is not clear from fishermen's observations whether there was abnormally high quahog abundance in other segments of the bay, or whether quahog abundance in the Upper Bay was simply so high that it alone sustained the massive influx of quahoggers that took place in the 1980s.

Three quahoggers provided additional statements that help paint a picture of how quahog abundance has fluctuated in the western parts of the bay.

A quahogger stated that some areas in the West Passage have declined since he started quahogging in 1981:

> As far as things I've seen in the bay, when I started there was a lot more production in the lower west bay down below the bridges (Lower West Passage), down into Dutch Harbor. When the old bridge was there, there are two shoals there, and when I first started, there was always guys raking. Then it slowly, it got a big set of mussels on top of

it, and that was the end of that. It's never come back. There were scattered areas below Wickford and along Jamestown where you could make a day's pay quahogging, and they've slowly gone away. I don't know if that's due to salinity, whether it's global warming, who knows, whether it's a change in the seed patterns (QK4).

Areas like in front of Allen's Harbor (Quonset Harbor), there were good areas from like 15 years ago to 5 years ago (i.e., from around 1999 to around 2009), there was fairly good digging there, and even out in deeper water like in front of Allen's Harbor (Quonset Harbor) and Hope Island (Middle West Passage). There's still quahogs there, it's just not enough to make a living (QK4-359).

In contrast, this quahogger stated that quahog abundance has increased in Friar's Cove (Middle West Passage): "One of the areas that was good, that's come back, is the area we call Friars Cove (Middle West Passage). It's the area between the Davisville car piers and the Quonset airport. That has come back quite well (QK4-360)."

Another quahogger echoed this statement about Friar's Cove (Middle West Passage):

I've spent days working in Friar's Cove (Middle West Passage). I hadn't worked in Friar's Cove in probably twenty years (i.e., since about 1994). It's right near Quonset. There's not an enormous amount of stuff everywhere, but what there is, there's little ones, everywhere in there. Pretty much everywhere you go, there's small ones, undersize. It's obvious that the bay is healthy (QK2-361).

Two quahoggers also provided evidence that quahog abundance in the Upper Bay increased in the years immediately prior to the interview:

- A quahogger stated, "The Upper Bay, which was just mediocre 10, 15 years ago (i.e., around 1999-2004) has come back bigtime (QK4-362)."
- A quahogger stated. "The thing about quahogging is that places that were good years ago, sometimes they come back around again, and get good. The Upper Bay was incredible last summer, 2012. 2012 was one of the best years I've had. It was just crazy good. You could go catch every single day. Full rakes of clams… A couple of years ago (i.e., around 2010-2011), it was all chunky stuff. Bag after bag of all this chunky stuff. Bigger necks, cherry stones, and chowders. There were so few small ones (QK2-363)."

Two individuals expressed differing interpretations on the recruitment of quahogs in Greenwich Bay (Greenwich Bay section):

- A quahogger stated, "A couple of years ago (i.e., around 2010-2011)… there were so few small ones, except in Greenwich Bay, where there were always small ones (QK2-364)."
- A quahogger expressed concern about a decline, stating that Greenwich Bay is "almost the worst I've ever seen it." That area has been "going downhill," he explained, ever since DEM made a decision to open it to shellfishing one summer (this area is typically only opened on a controlled schedule during the wintertime; QW3-365).

In general, however, at the time of the interviews, shellfishermen seemed to think that the quahog population in Narragansett Bay was doing well:

- A quahogger stated, "Now there's sets everywhere. Pretty much everywhere you go, there's small ones, undersize. It's obvious that the bay is healthy (QK2-366)."
- A quahogger stated, "The bay is looking good. There's lots of undersize around. It's nice to see (QE2-367)."
- A quahogger who had been fishing since 1959 stated: "I go around now to places that I used to catch quahogs before, and I still catch them. Some of the guys say there's nothing around. It's just not on the beach no more, as a rule. They're in deeper water (QW4-368)."

In addition to commenting on trends in abundance and distribution of quahogs, some interviewees brought up observations about quahogs' relationships with other species and their shell thickness.

A quahogger reflected on ecological relationships between mussels (*Mytilus edulis*) and quahogs, and offered a theory as to why he does not see as many quahogs as before:

> One of the reasons that there aren't more quahogs out there is the wild mussels that set. The process is that you get a big set of wild mussels. They protect the quahog spat from the crabs and other predators, and after about 5 years they die and they just smother in their own excrement. The shells break down, and you have a massive set of quahogs there. You get a nice black mud bottom. Well, with these guys scooping up the mussel sets because they can sell them, because the mussels don't have crabs in them anymore, at least for now, they're able to dredge those mussels, massive amounts of them, boatload after boatload after boatload, and the areas where the mussels were, there aren't the sets of quahogs that used to happen. I've seen that happen historically over the course of thirty years, over and over and over again. Now with the dredging of mussels, we've lost those sets (QW3).

A quahogger stated that some quahogs' shells seemed to be more fragile than they used to be: "Quahogs in areas with strong current are very fragile. For example, in the trench south of Warwick Neck (<u>Upper West Passage</u>). That stuff is so brittle that it breaks when it goes down the count machine. That seems to be characteristic of quahogs in any area that has really strong current (QW3)."

<u>Bay Scallops (*Argopecten irradians*)</u>

- Number of respondents: 4
- Segments mentioned: Potter's Cove, Mount Hope Bay, The Cove, Nannakuaket, Upper Bay
- Trends mentioned: boom, uptick

Several interviewees shared recollections of a time when bay scallops were much more plentiful in Narragansett Bay than they are today—plentiful enough for fishermen and their families to dedicate a season each year to catching and shucking them for market.

One quahogger, who grew up on Prudence Island in the 1940s and 1950s, recalled that when he was a teen:

> Most every shellfisherman had scallop dredges… I remember having so many scallops. We were trying to shuck them because you get more money that way, but we just couldn't keep up. Working at night, and I was only about Evan's age – so we started selling them in bushels. It's too bad they went away. It's nice to see a few around. I hope they come back (QE2).

This quahogger recalled several areas that had exceptionally good sets, back in his early years:

- "Potter's Cove was plastered with scallops. There was everything from little dories with ten-horse outboards on them, Manchester's boats were in there, there were some pleasure boats, cabin cruisers, 25-, 40-footers. Everybody was hauling a dredge. It looked like a circus out there. I don't remember how many days it lasted (QE2-330)."
- "I remember going over to the oil docks in Tiverton, across from Common Fence Point (Mount Hope Bay). They're not there anymore. Off that [shoreline] was loaded with scallops (QE2-331)."
- Spectacle Cove (The Cove; QE2-332)
- Nannakuaket (QE2-333)

Another quahogger recalled of his older relatives, "They used to go over the Tiverton scalloping. After the '38 hurricane, they were up at Rocky Point (Upper Bay). They made a lot of money. In the 1920s, he bought a model A pickup truck and a car and he paid cash. He lived for scalloping (QW5-334)."

A quahogger who began fishing commercially in 1959, recalled, "In the fall, we'd go scalloping. There was a lot of scallops in the bay, years ago. Now most of the scallops are down in the salt ponds, and they're only every once in a while, too (QW4-335)."

Two quahoggers commented on recent scallop sets. However, they commented that the volumes in these sets are much diminished from what they would have been years ago:

- "There were a few scallops around last year (i.e., 2013-2014)," said one quahogger (QW4-336).

A quahogger stated that there was a set of scallops near Rocky Point (Upper Bay) the year before the interview (i.e., 2013-2014): "Right here, at the end of my street, we had scallops show up for the first time since I've been fishing. We had a ton of them in the summer. When you catch them in your bull rake when you're bullraking for quahogs, that means there are a lot there. I'd get maybe 20 a day. That's enough where you could tow a dredge through there and get a limit. But they pretty much died out. I haven't seen any down there in months, not since the end of the summer (QW3-337)."

Mussels (*Mytilus edulis*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: cyclical/variable

Two individuals spoke about mussel populations in Narragansett Bay.

A quahogger whose father was known as the "mussel king" of Narragansett Bay in the 1940s and 1950s explained that mussel sets are sporadic and they seem to follow their own rhythm:

> When they set, they set so many. You don't need a regulation because there's so many. And when they don't set, all the regulations in the world aren't going to help you, because the set didn't take…. They set so thick, and once they start dying, they contaminate themselves. Because once they start dying, you could have been getting twenty bushels to a dredge, but the next week you'd fill it up and it would be all shells, and the belly would be hanging off of them. It's Mother Nature that makes them come and go. When conditions are wrong, they're going to die, and that's that (QK5-340).

This quahogger described the mussel cycles in Narragansett Bay. "Mussels died off in bay in the 1960s (QK5-341)," he recalled. "Musselling came back, but my father had lost his connection. There was someone in Bristol selling them. Mussels were being sold locally a bit. The whole operation had changed. Then they died off completely. Then they came back, about five years ago (i.e., around 2009), and quahog boats were towing little dredges for mussels and selling them to American Mussel (QK5-342)."

The captain of a Point Judith scallop dredge boat who dabbled in mussel dredging in the bay stated, "There are various places around the bay that they set up. I tend to work the southern end of the bay because it's closer to Point Judith, and I wasn't big on going anywhere further… Then the beds died out. We had a big starfish invasion after a big storm, and the beds got silted over and it died out, and I didn't want to push further up the bay (DP1)."

Oysters (*Crassostrea virginica*)

- Number of respondents:
- Segments mentioned:
- Trends mentioned: boom

Five individuals described in detail a phenomenal oyster boom that took place in Narragansett Bay in the 1990s or 2000s. The timeline of this boom is somewhat inconsistent across interviewees.

According to one quahogger, this memorable oyster set took place in…

> …2003-ish. And they lasted. There were still some after 7 years. But they were huge and there wasn't a lot of them. They lasted for about 3 years (i.e., until around 2006) where people could make money on them. We were getting 80 cents a pound. The whole harbor right here in Wickford (Wickford Harbor) got covered with them. On winter day's you could go out and make a quick $120, right there. It took 45 minutes (QK4-343).

A quahogger recalled:

> I oystered for a couple of years, between 15 and 20 years ago (i.e., 1994-1999) when the oysters just kind of showed up. There was a sand bar in Wickford (Wickford Harbor) where there were millions of them there. They were all kind of bunched up, and so you used to have to split them. We all used to go. I'm guessing like between 25 and 30 guys used to go over there every day in the wintertime at the low tide and pick oysters. There were tons of them. It was unbelievable how many of them were there. The whole place was just filled with them. They were everywhere (QK2-344).

According to this quahogger, the oysters stopped recruiting to that location, and eventually the bed disappeared:

> But then the oysters disappeared from there. The easy ones at least. But I kept going off and on after that. There were still some places around the bay where you could get them. There was Rumstick, on the other side. There were some beautiful ones there (Upper Bay; QK2-345). There were some nice oysters right off of Davisville, where the car pier is (Middle West Passage; QK2-346).

Another quahogger stated that the boom occurred around the late 1990s:

> It only lasted a couple of years. The guy that found them was Georgie Fecteau, it was off of Greene's River (Upper West Passage). He was getting them for a while and keeping it a secret, sneaking them out of his boat. When the guys found it, it was just so thick it was incredible (QW3-347). Guys were getting their limit in about an hour, or less. Then it turned out there were other places. They were all over the bay. But there aren't too many around now. It goes in cycles (QW3-348).

Another quahogger said that the oysters…

> … just came up and then went back down. There were oysters everywhere. I remember cutting boots on them in Smith's Cove in Warren (Warren River). They were just all over the place. My brother had a shop, he was buying them and shucking them. He didn't care about their size and shape because he was shucking them. That was great – quahogging at the same time. I get all excited thinking about it (QE2)!

A fifth quahogger stated that the oyster boom took place around 1997-1999. He recalled:

> When the oysters came in, that was very good for us. It took the pressure of quahogging. We did very well oystering. You can see oysters, so everyone just picks them up. They're extremely vulnerable. They were everywhere, in the estuary areas, any small coves. It's a cyclical thing. Some people credit Luther Blount's experimental oyster farm, but I don't know… Things are cyclical in this business (QE1-350; QE1-420).

Deckers (*Crepidula fornicata*)

- Number of respondents: 1
- Segments mentioned: Middle West Passage, Upper Bay
- Trends mentioned: decline

One individual also stated that, at the time of the interview (2014), deckers were abundant in Friar's Cove (Middle West Passage; QW4)." He added that they were formerly abundant at Barrington Beach (Upper Bay; QW4-338).

This individual also made the following observation about the relationship between deckers and quahogs: "Quahogs do well in decker shells, because they can breath through the layer of shells and they protect them. Unless they're too thick; if you get two feet of decker shells on top of the quahogs, forget it (QW4)."

Soft Shell Clams (*Mya arenaria*)

- Number of respondents: 2
- Segments mentioned: Upper Bay
- Trends mentioned: cyclical/variable, boom, decline

An individual who has been shellfishing since 1959 recalled that soft shell clam sets occurred more frequently in his early days than they do now, although these sets still do occur occasionally:

> You'd dig some clams, steamer clams. There was a lot of them then. In the late '50s, you could catch 15 or 30 bushel a day. As far back as I can remember, there were steamers around. There were people catching steamers. That kind of tapered off a lot through the 1960s and 1970s (QW4-369). You couldn't catch as many. Just about 5 years ago (i.e. around 2009), there was a good set. But it's gone now (QW4-370).

The recent set that this individual was referring to in the last paragraph was probably a well-known soft shell clam boom that occurred at Conimicut Point in the early 2000s. Two other individuals also alluded to this famous soft shell clam boom. One quahogger briefly described participating in "the clam bonanza at Conimicut (Upper Bay; QE1)," while another provided a more descriptive account:

> Steamers opened up, off of Conimicut (Upper Bay). There were some off of Longmeadow (Upper Bay). But the ones off of Conimicut, that was a horror show. I got pictures. It almost looked like a bunch of zombies coming off the beach when the tide was low. All these people coming out with pitch forks and bull rakes, toilet plungers. It was like something out of a scary movie. There would be 300 people within 20 acres! That's everybody right on top of each other. That was different. Big stripers would be swimming around you the whole time, schools of them…. (QK4-371).

He explained that this set of soft shell clams had occurred while this area was closed, due to pollution. When the area was opened, there was an influx of shellfishermen, and no effort was made to conserve the incredible set for the long term. As a result, this boom was temporary:

> [Steamers] come in cycles (QK4-372). They were there before, and then the area was closed off. They moved the pollution line. And it reset. It was the second or third year of the set that they opened it up. Unfortunately, they wanted to change the size limit to 2" from 1 ½". Unfortunately, 80% of the steamers that were up there were 1¾" or less. And they didn't change the bushel limit. It was just wide open: 12 bushels. So you've got all these people digging 12 bushels, and here were all these smaller ones. People were stepping on them, just crunching them. And there was a big set of baby starfish, billions of them. When all those steamers came out of the bottom, they didn't even have a chance to get back into the bottom, because either people stepped on them, or sea gulls got them, or the starfish ate them. Within a year and a half, there was nothing left. No babies, nothing. Then another set took, they looked like little rice. I don't know what happened to them. Something came down the river and killed every one of them. Last time I was up there, a year and a half ago, I didn't find a single steamer (QK4).

Mobile Benthic Invertebrates

Whelks/Conchs (*Busycotypus canaliculatus, Busycon carica*)

- Number of respondents: 1
- Segments mentioned: none
- Trends mentioned: none

A quahogger who also sets whelk pots stated, "The snailing used to be good. Not so much the last few years. A year ago (i.e., around 2013) in the fall was awesome… I couldn't believe how good it was. But now it's pretty much over. I hear that it's better for guys on the other side (QK2)."

Miscellaneous Mobile Benthic Invertebrates

One quahogger commented, “We’re getting a lot of crabs. Even ones I’ve never seen before. I just saw some this winter that I’ve never seen before. I think the ships bring them in in their bilges (QK4-339).

APPENDIX F. OBSERVATIONS EXPRESSED IN THE 2016 RESILIENT FISHERIES INTERVIEWS

General Observations

General observations on community-level change expressed by interviewees in the 2016 Resilient Fisheries interviews are summarized below.

- Number of respondents: 5
- Segments mentioned: none

Several respondents shared a strong sentiment that the bay was losing its vigor as a habitat for marine life. A retired lobsterman expressed this feeling by saying that recent changes at the level of the whole ecosystem have been "drastic. It's been like the past, maybe ten years, the real drastic changes." When asked if he thought these changes might go back the other way, he responded, "I wonder. I really wonder. I'd like to think it could, because there was a stretch there 90 years back when the lobstering kind of disappeared here. It did the same thing up in Maine. Everything runs in cycles, whether you're a farmer or a fisherman. But this one, I don't know. This is scary (LE1)."

Three individuals referred to certain parts of Narragansett Bay as having "died":

- A lobsterman stated: "You know what we named the upper bay, above the [Newport] bridge? Chernobyl. Chernobyl. We equated that to the Chernobyl meltdown. We've been seeing that for the last couple of years (LN5)."
- A fisherman who lobsters, trawls, and grows oysters stated that there are several dead zones in Narragansett Bay. He mentioned three areas:
    - "Above Common Fence Point, it's a dead zone. Massive dead zone. …. It's the whole <u>Mount Hope Bay</u> (LK1)."
    - "They've got [a dead zone] now over by the donut, which is where EB is (<u>Middle West Passage</u>). There's a treatment plant there now. You used to have to power wash your pots every week over there; now you can throw a lobster pot in in April and haul it back in November and there's nothing growing on it. What the fuck is that?... Why is there nothing growing on the rocks down there? Why is there nothing growing on the pilings (LK1)?"
    - "That whole area from the north of Jamestown all the way up (<u>Middle West Passage</u>), I've caught thousands and thousands of lobsters up there. I haven't caught a lobster up there in 5 years. None. Zero. I put my lobster pots overboard and the brown silt, mud that's in the water, the dead animals that die and make that mud, that's on your pots. Normally there's crabs, there's starfish, there's lobsters, and they're walking on it and they knock that shit off with their feet, all around the pot, because a pot's habitat. Everything goes to a pot, there's bait in there. The bait attracts little minnows, the crabs go for that, everything goes

there – it's its own little stimulus package. Each trap is its own little city. [But that doesn't seem to be happening anymore; LK1]."

Additionally, a trawl fisherman described a specific die-off event that occurred recently:

> There was one time right in front of Newport (Lower East Passage) where everything just died…. Yeah, something happened out there. Everything just died. There was no fish, no nothing. One day I caught 10,000 scup there, and some mixed stuff, some fluke. It looked regular. It looked normal. The next day I was out there – nothing. Everything I caught was dead. Dead skates, dead. Those guys called me and we were like "What's going on? Was there a spill? Maybe from one of these tugs or ships?... [That was] a couple years ago, or a year ago (TN1).

Several individuals commented on changes in the species composition of the finfish community in Narragansett Bay, including a shift from resident species to migratory species:

- A lobsterman stated, "The migratory fish come in, do a lap around the bay, and they're done. All our residents – lobsters, quahogs, scallops, oysters, blackfish, blackback flounders – all the permanent residents of Narragansett Bay are in trouble. There's not one case that anyone can list today of a resident of Narragansett Bay that isn't in trouble. And why? Because they have to live in that cesspool all day long (LN6)."
- A trawl fisherman said that there are now "more species that come and go. But actually, that's a tough one to say, because last year the blackfish, there was a ton of them. It's blackfish, flounders, lobsters – those are like Rhode Island species. Close to year-round residents in our waters. Those were disappearing. But last year's blackfish population was really good (TN1)."
- Additionally, this trawl fisherman described today's finfish community as less diverse than it was in the past: "The fish populations were the same, if not better. Actually, there wasn't as many of things as there is now, but there was more variety. I would catch the same weight, but it would be a little bit of everything. Instead of all scup, all sea bass. That's what we're doing now (TN1)."

One respondent (a trawl fisherman) also commented on seasonality, saying that "My season has gotten shorter on the spring end… I actually started fishing the last week of March, the first year I fished in the bay, and caught fish. Now, up until now, I fished from the last week of April. Now it was the first week of May (TN1)."

Respondents also commented on changes in the human component of Narragansett Bay's ecosystem, saying that there are far fewer fishermen than there once were:

- A Wickford fisherman recalled, "The town dock, you couldn't get close to tying up down there. There were 30 trucks at any time down there: guys quahogging, lobstering, the dragging fleet. There was guys tied up on the other side of the shipyard. There was a community. Now? Now it's nice, there's nobody to bother me (LK1)."
- A retired Warren fisherman recalled, "At one time out of Warren, there were probably 10 boats fishing for lobsters and crabs. I don't think there's one now. There's one guy

who's got pots in the water that I know of, but other than that, everyone's gone, because you just can't afford to do it anymore… In the bay, it's out of the question to try to make a living now. For generations, people fished for crabs and lobsters in the bay. They supported a lot of families, bought a lot of shoes for the kids. But that's done (LE1)."

Sessile Benthic Invertebrates

Mussels (*Mytilus edulis*)

- Number of respondents: 1
- Segments mentioned:
- Trends mentioned: cyclical/variable, increase

One individual mentioned ups and downs in the mussel population in Narragansett Bay, and its ties to starfish populations:

> There were mussels in a lot of places, and then they disappeared. We would always catch starfish. You could fill one of those crates half full of starfish if you just set it down. But then the mussels disappeared, and the starfish disappeared. And a couple years ago, three or four years ago (i.e., since 2012-2014), the mussels all of a sudden came back again. But you never saw the starfish in the same numbers as before (LN2-400; LN2-401).

Mobile Benthic Invertebrates

Lobsters (*Homarus americanus*)

- Number of respondents: 7
- Segments mentioned: Lower East Passage
- Trends mentioned: decline, constant, uptick, downtick

One individual, who recently retired from a 68-year-long lobstering career, explained that, years ago,

> … I caught a lot of lobsters within sight of my house (in Warren). And I had friends with the East Providence Fire Department who were divers, and they'd dive up around the Washington Bridge (Seekonk River), and they'd say, "You can't believe the lobsters up there." I know I fished quite a ways up. In Buddy Cianci's picture window (LE1-387).

However, due to a progressive decline in the lobster population that worked its way from the upper bay to the lower bay, this individual decided to retire from lobstering:

> It just keeps going down the bay. It got to the point where I just couldn't afford to go lobstering anymore, so I had to sell out and retire. But guys I talk to, like Denny and the rest of the crew down in Newport, it's like it's going down the bay like this every year. Worse and worse all the way down…. It's done. It's gone. They say it runs in a cycle (LE1-387).

A trawl fisherman stated:

> This whole lobster collapse, it was like a light switch. Same thing as the flounders. We catch lobsters dragging. We would go up in the bay and get 100 lobsters in a couple of tows. The next year, we'd go up there and catch 8 pounds…. [That happened] like three or four years ago (i.e., 2010-2011; LN1-388).

A lobsterman who fishes close to Newport explained that the areas where he fishes are not as good as they used to be, but he's still able to carve out a living in certain pockets:

> From my viewpoint of here, down in the bay, there were four guys fishing in one area, and I'm the only one left in there… The four of us did fairly well in there. Now I'm the only one. I'm not catching lobsters in there. I set trawls in there and I don't catch anything (LN2-389)… If I'm on a spot, like over on Rose Island (Lower East Passage), there's a good tidal flow there, so they do appear there. I don't go in and get that mass out of the areas I go into anymore. I've set myself up in shallow water, but I'm on the traveling route for them (LN2-390).

However, the year before the interview (i.e., 2015), he had "a banner year," he explained:

> Last year, I had the best summer that I've had since ten or twelve years…. I didn't understand what was going on in terms of my catch from last year. I've caught fourfold my catch from the last few years (LN2-391).

Interviewees also reflected on correlations between the decline in lobster populations and other changes they have witnessed in the bay and nearby ocean waters. They then drew on these observed correlations to put forth three theories to explain the declining lobster populations in Narragansett Bay.

The first of these theories is that the observed decline in lobsters is tied to changes in wastewater inputs into the bay. One lobsterman explained this theory as follows:

> True story: some of the best places I caught lobsters were in the sewer treatment runoff pipe outflows. The fish were eating what was coming out of the pipes. The Navy base, when the ships were there—that's before my time, but the old guys will tell you—they never caught lobsters like they caught underneath them boats. It wasn't because there was shade there. It was because there was absolutely no recycling or effort or decontamination made. It just got pumped overboard. That was some of the best lobsters they caught (LN4).

This lobsterman went on to explain how these inputs have changed:

> On the other side of the coin, there's a place at Bishop Rock (Lower East Passage) where I used to set, when I had the skiff, in between some rocks. There's a waste treatment

pipe that discharges there. I was catching crazy numbers of lobsters. When I bought the bigger boat, I told [LN2], "I can't get in there anymore. That's a place that there's lobsters" So he went in there, and the first year or so that he was in there, he caught a few. Never caught what I caught. And now, you can't even catch a lobster. There's nothing (LN4).

The lobsterman referenced in the paragraph above (LN2) had a "banner year" in 2015 followed by a mediocre year in 2016. Lending additional evidence for the theory that changes in wastewater inputs play a localized role in lobster abundance, he explained that in 2015, "That's what I did. I went up to the area where the outfall from the plant is, on the south side of that (Lower East Passage). I've done well (LN2-391)." In 2016, however, he tried the same strategy without success: "Then this year, even on that south side, there was nothing (LN2-392)." As in the last paragraph, this comment hints that both lobstermen feel there may have been a change in the composition of wastewater effluent entering the bay in this area.

This lobsterman also put forth a regional explanation for lobster declines, suggesting that ups and downs in lobster population have been linked to changes in water temperature:

> Last year we had a real winter, a hard winter. There you go, there's your answer. This year, we didn't have a hard winter, so I don't expect much... The warming water, I think that's a big player in the lobster industry. Because as localized as this is, even offshore, there's something missing out there too (LN2).

Three other individuals alluded to predation as a cause of population decline among lobsters:

- A retired lobsterman observed, "The predation is horrible – the sea bass. Whatever they're trying to protect is eating lobsters (LE1)."
- A trawl fisherman said, "There are so many [sea bass]. If you put them in a tank, they regurgitate their food. And guess what's in there. Tiny lobsters (TK1)."
- A trawl fisherman said, "The last couple of years, it's been like 2,000 pounds a tow [of black sea bass], and all we can have is 50 pounds… So you think there's no lobsters there for a reason (TN1)?"
- A lobsterman stated, "There are so many scup there all summer long that that percentage of the breeding stock, which is a big percentage of it, when they're dropping their eggs, they don't even make it to the surface, let alone live up there for a week and think they're going to make it back down through (LK1)."

One individual commented on an anomaly that occurred in the early 2000s, not long after the Long Island Sound lobster die-off of 1999:

> Around 2001 or 2003, we caught lobsters here, inshore guys… we went through a two- or three-week period when, I would come in with lobsters that were perfectly healthy and they were dead by the time I got in to the dock. Everyone can tell you about that. And that's when you heard that New York had gone belly up. It was like something was going through the whole industry (LN2).

One individual commented on changes in seasonal migrations, saying:

> You used to start the end of April… Then it shifted to May. It's June now. You pretty much ain't missing nothing if you get in the water by the first of June. That lasts pretty much until September. But now that fall one, the best time used to be between Thanksgiving and Christmas. Now it's almost like "I hope they show up by Thanksgiving." It has changed a lot…. [The season is] much shorter in duration, and kind of later. That's telling me that the mass isn't there (LN2).

This individual also noted a change in the size at reproductive maturity, saying, "Another part of it is eggers. Used to be a lobster would have to be 5 or 6 years old before it would egg out. Now I see lobster this big that are egged out…. Is that them trying to save themselves (LN2)?"

Two individuals, who participated in a joint interview, expressed a view that the regional occurrence of lobster shell disease is concentrated in Narragansett Bay, perhaps even emanating from the bay outward. One individual stated:

> You see shell disease in our lobsters here. You talk to everybody up and down the coast, they see miniscule amounts of shell disease. Less than one percent. In Narragansett Bay, shell disease is rampant, and it's getting worse. In the last few years, you go offshore 40, 50 fathom, and you don't see any shell disease. Even at Cox's [Ledge], you start to see just a little bit. The closer you get to Narragansett Bay, the shell disease gets worse. It's almost like it's starting here (LN5).

Both individuals shared a view that shell disease in lobsters is becoming worse, and is now spreading to juvenile lobsters and crabs.

> Up until the last year, the baby juvenile lobsters, between 30 and say 60 millimeters, up until last year, they never had shell disease. Now, shell disease is rampant in those small lobsters. I know this for a fact because I do research for the [Commercial Fisheries Research] Foundation. Every day I go out, I'm measuring lobsters (LN5-393).

When asked how many crabs have shell disease, the other individual answered, "All of them. They're black. But it's always inshore, where we are (LN6-394)."

Both individuals also suggested evidence for a tie between shell disease and water quality. One said:

> You want to hear something real weird? Cut a band off a lobster that's covered in shell disease. It looks brand new under there. Like shiny new paint. So is it a disease? Or is it a water quality problem? We've said this to a million people, and they don't want to acknowledge it (LN6).

The other individual added, "We've done that hundreds of times. You cut the bands off a lobster, and there's no shell disease underneath (LN5)."

Starfish (*Asterias forbesi*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: decline

Two individuals shared a perception that starfish "disappeared" in Narragansett Bay. One stated, "There were millions of starfish in the bay. In the middle of the wintertime, you'd haul a trap, and there'd be 200 starfish in one trap. Three years ago (i.e., around 2013), they disappeared (LN5-410)."

Another individual placed the disappearance of starfish with a chronology relating it to cycles in mussel (*Mytilus edulis*) populations, but added that even though mussels have returned in their usual locations, starfish have not:

> There were mussels in a lot of places, and then they disappeared. We would always catch starfish. You could fill one of those crates half full of starfish if you just set it down. But then the mussels disappeared, and the starfish disappeared. And a couple years ago, three or four years ago, the mussels all of a sudden came back again. But you never saw the starfish in the same numbers as before (LN2).

Blue Crabs (*Callinectes sapidus*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: cyclical/variable, boom

Two individuals made reference to the variable or cyclical nature of blue crab populations.

- A trawl fisherman said, "Five or six years ago (i.e., 2010-2011), I was bringing in blue crabs. Tons of blue crabs. Last year, none. This year, some. Things change a lot (TN1-379; TN1-380)."
- A retired lobsterman said:
  They come and go like the wind. Some 8 or 9 years ago (i.e., around 2007-2008), blue shells were everywhere. We figured, "Oh, here we go. They're talking climate change." We figured we're going to be full of them, like the Chesapeake. But they came that one year, and we were catching half a dozen [or] 10 pairs in the lobster pots, because they found a hiding spot. All of a sudden, they just went "poof." The guys that I know who go after them with a dip net, this year's great, the next year is not so hot, then it stinks, then it's good (LE1-381; LE1-382).

Miscellaneous Mobile Benthic Invertebrates

One individual, a retired lobsterman, observed that sand crabs (*Cancer irroratus*; also called rock crabs) have declined in Narragansett Bay. He stated, "Come springtime, after the first of the year, right out here at Colts Drive (Upper Bay), you could just catch as many as you wanted to. They're gone (LE1-398)."

Fouling Invertebrates

Barnacles (Cirripedia: Thoracica)

- Number of respondents: 2
- Segments mentioned: Newport Harbor
- Trends mentioned: decline

Two individuals, who participated in a joint interview, shared an observation that barnacles have declined precipitously in Narragansett Bay since 2014. One individual said, "barnacles are not living, period. They're not even growing (LN5)," while the other individual said, "I know a fisherman who left his gear out there last winter. It was covered with barnacles. We got a rain event, and it killed all the barnacles (LN6)." This individual added that he recently hired a diver to check on something under his boat (kept in Newport Harbor), and the diver reported that there wasn't a single barnacle growing on the hull, even after two years in the water since it's last bottom paint job (LN6).

One of the individuals in this interview displayed a photograph of a lobster trap that had been in Narragansett Bay for an entire year. It did not have a single barnacle or other organism growing on it (LN5). In contrast, said the other individual, lobster traps placed in ocean waters still become covered with barnacles (LN6). "And it used to be worse in the bay!" added the other individual (LN5).

Sea Grapes (*Molgula manhattensis*)

- Number of respondents: 1
- Segments mentioned: none
- Trends mentioned: decline

Sea grapes were one of several species mentioned by a lobsterman when explaining a lack of fouling organisms growing on lobster traps since about 2014:

> I've been on the bay my whole life, and there's nothing growing there anymore. Think of a lobster trap. When I used to fish in the bay, I used to put my lobster traps in and

> within two weeks they'd be dirty. And there was plant life, flowering, like rose buds, sea grapes, all kinds of stuff going on. I can show you pictures. There's nothing growing on these traps anymore. You can leave them in for a whole year, and they look like you just took them off the truck (LN6-409).

<u>Hydroids (*Hydrozoa spp.*)</u>

- Number of respondents: 1
- Segments mentioned: none
- Trends mentioned: decline

Hydroids (called "rosebuds") were one of several species mentioned by a lobsterman when explaining a lack of fouling organisms growing on lobster traps since about 2014:

> I've been on the bay my whole life, and there's nothing growing there anymore. Think of a lobster trap. When I used to fish in the bay, I used to put my lobster traps in and within two weeks they'd be dirty. There was plant life, flowering, like rose buds, sea grapes, all kinds of stuff going on. I can show you pictures. There's nothing growing on these traps anymore. You can leave them in for a whole year, and they look like you just took them off the truck (LN6-385).

Seaweed/Macroalgae

<u>Rockweed (Order Fucales)</u>

- Number of respondents: 2
- Segments mentioned: Bristol Harbor, Middle East Passage, Mouth of Narragansett Bay
- Trends mentioned: decline

Two individuals discussed a steep decline of rockweed in Narragansett Bay.

One individual stated:

> All over our shores used to be prolific with rockweed. Now it's gone…. It used to be all over Jamestown shore, Middletown shore (<u>Middle East Passage</u>). All the way up. Everywhere. You go out front, around Ocean Drive, and rockweed is prolific out there (<u>Mouth of Narragansett Bay</u>). There's none left in the bay (LN5-402; LN5-403).

Another individual, who used to collect rockweed commercially in his teens, near the start of his 68-year commercial fishing career, stated:

> There is no more rockweed. There's little bits of it here and there, but the shores used to be covered in it. There's all these different clubs. I belong to the German Club. Every year we have two clambakes. You know that stretch of shore along the Topside in Bristol (Bristol Harbor)? That stretch used to supply all the clubs and the firehouses. I don't know how many clambakes. Now you have to go to Sakonnet (LE1-404).

Kelp (*Saccharina latissima*)

- Number of respondents: 1
- Segments mentioned: none
- Trends mentioned: decline

One individual stated that kelp has declined considerably in Narragansett Bay since the 1990s:

> We used to have huge kelp fields in Narragansett Bay. I've done some reading on it. Those kelp fields, those kelp farms, were the estuary areas for juvenile lobsters. Without them, they can't survive. All the kelp areas in Narragansett Bay are gone…. In the '90s, when the lobstering was really prolific in Narragansett Bay, the best lobster fishing in the whole East Coast was right here in Narragansett Bay. Then kelp was so bad that we'd be hauling our traps, and there'd be balls of kelp the size of pick-up trucks on every trap in the channel. I fished there for decades and I used to deal with all that kelp. [Now there's] zero. Zero kelp. You can't even find a strand of kelp (LN5-386).

Miscellaneous Seaweed

One individual described a "horsehair red weed" that has become commonplace in Narragansett Bay. This seaweed, he explained, can at times become a serious nuisance for fishing:

> How about the red weed? Has anyone talked to you about that? Like a horsehair red weed…. Unbelievable in our bay. Mats of it on certain tides. It's just un-fricking-bearable. It's year round. It's almost every moon now. It used to be spring and fall – real bad in the spring, and bad in the fall. Now it's every big moon. I have to look at my tide book and the tide speed before I even go in the bay, because of that red weed. That's how bad it is. I make decisions based on red weed (TN1-399).

Finfish

Black Sea Bass (*Centropristis striata*)

- Number of respondents: 3

- Segments mentioned: Middle East Passage, Lower East Passage
- Trends mentioned: increase

Interviews documented a consensus view among fishermen that the numbers of black sea bass in local waters are increasing rapidly. This view was expressed not only by those fishing in Narragansett Bay, but also by those who fish in ocean waters, both inshore and offshore. All interviewees expressed a frustration with the fact that fisheries science management has not yet caught up to this changing reality, and as a result, fishermen must obey retention limits that are far lower than the volumes of sea bass that they are catching today.

Below, three Narragansett Bay fishermen share their views.

- A trawl fisherman stated:

  > Sea bass, right now, is just out of control. Everybody's told you that. [It's been that way for] 2 years (i.e., since about 2014). Well, I saw it coming. For the last 15 years, we would catch 100 pound a tow in May in the bay. For 15 years, 20 years (i.e., from about 1994-1999 through 2014). Then the last couple of years (i.e., 2014-2016), it's been like 2,000 pounds a tow. And all we can have is 50 pounds… The schools have to be huge. Numerous schools of black sea bass coming in and out of our bay (TN1-375).

- A lobster and trawl fisherman stated:

  > I had one day in like 5 years when we caught 300 lbs, when we actually caught some, and it was a big deal. It was like "Oooh!" to see them. Now, it's like "Awww." I could feed a town every day with three tows. It's sick… Get rid of these limits. Take all the big ones. The stuff that's already bred two or three times. By the third time they breed, you need room for the little ones. The big ones are taking up as much room as 200 little ones take up. They're wicked aggressive and they chase the fish out. You think you're doing something good by saving these fish, but you're not. It's working exactly opposite (LK1-376).

- A trawl fisherman stated:

  > Last year, if you set the net in at Newport Bridge and you towed to the north end of Jamestown (<u>Lower East Passage</u> and <u>Middle East Passage</u>), [you'd catch] 2,000 large and jo (jumbo) seabass in the net… They don't even want to come up in the bay. They're chasing food, they're so hungry. They're looking for something to eat so they'll extend themselves up into places like the bay. Because there are so many of them (TK1-377; TK1-378).

Two Narragansett Bay fishermen also expressed concern over the ecological impacts of this black sea bass boom (e.g., predation on lobsters; a concern shared by many of their peers who fish on the ocean as well):

- "Guess what's in there. Tiny lobsters. Every lobster out there is being consumed (TK1)."
- "You think there's no lobsters there for a reason? You think there's not squid there for a reason? Of course not (TN1)."

Scup (*Stenotomus chrysops*)

- Number of respondents:
- Segments mentioned:
- Trends mentioned: increase, downtick

Three individuals mentioned scup. All three implied that scup populations experienced a strong increase at some point in the recent past. One seemed to feel that this increase was ongoing, saying, "A 3,000-pound tow is not uncommon by any means… There are certain times when it's just so thick" and "All along the coast, there are so many scup there all summer long (LK1-405)."

However, two individuals stated that this increase has subsided slightly in more recent years, probably as a result of competition imposed by surging black sea bass (*Centropristis striata*) populations:

- One stated, "Scup have been scarcer the last 2-3 years (i.e., since about 2013-2014)… Around here, it has [been replaced by sea bass]…. Whether the sea bass came in and booted out the scup? Or have we, with our 10,000-pound limit, caught up the scup, and the sea bass have moved into their niche? Who knows (LN2-406)?"
- Another said, "I've seen it with scup in the bay too. I think the scup population right now is where it belongs. I don't think it's out of control. I think it's in the middle. I also think that scup and sea bass compete. You're not going to see big fluctuations with scup until the sea bass settle down…. [Scup have] gone down to where they should be. Because they were high like the sea bass… Huge fluctuations. It wasn't like that when I first started (TN1-407; TN1-408).

One individual expressed concern about the effects of scup predation on lobster and shellfish populations:

> That percentage of the [lobster] breeding stock, which is a big percentage of it, when they're dropping their eggs, they don't even make it to the surface, let alone live up there for a week and think they're going to make it back down through. The scup are everywhere, from that big to that big, and the ones that are that big are eating everything. The little oysters swimming around in the water column. The little quahogs. They're eating everything (LK1).

Winter Flounder (*Pseudopleuronectes americanus*)

- Number of respondents:
- Segments mentioned:
- Trends mentioned:

Four interviewees commented on the historic decline of winter flounder in Narragansett Bay.

- A lobsterman stated, "I was fishing in upper Narragansett Bay in the mid-'90s, the mid-'80s, and there were so many flounder up there it was unbelievable… The populations of fish stocks started to decline (LN6-412)."
- A lobsterman stated:

  > When I was a kid, we used to just drift back and forth between Goat Island and the corner of Wellington over there (Newport Harbor). Just drift back and forth or stand here, in our teens, and catch the winter flounder. We used to go up to Tiverton and fish up there for them. It's illegal to even take them now (LN2-413).
- A trawl fisherman stated:

  > When I first started, you could go up in the bay and catch 1,000 pounds of winter flounder in a day… It was like a freaking light switch. Absolutely nothing in the bay. But you'd go out like 3 or 4 miles and you'd catch winter flounder. You'd go off of Block Island, and you'd catch the same amount you'd always caught (TN1-414).
- A trawl fisherman stated, "Winter flounder, for example, represented 30 to 40 percent of our catch at one time. Now, it represents zero (TK1-415)."

Menhaden (*Brevoortia tyrannus*)

- Number of respondents: 2
- Segments mentioned: none
- Trends mentioned: boom, uptick

Two individuals stated that the years of the interview and immediately prior to the interview (i.e., 2015-2016) were big years for menhaden in Narragansett Bay—bigger than they had seen in a number of years.

A trawl fisherman said, "Menhaden, big time. Last year there were lots of menhaden, late into the season. Arc Bait were millionaires, and they will be again this year. I thought about bringing the boat up menhaden fishing this year, that's how many I think are coming, from what I saw last fall (TN1-395)."

A lobsterman said, "All of a sudden the menhaden have shown up." He recalled that there have been ups and downs in the menhaden population throughout his fishing career:

> When I was real young, there was nobody really taking them. Then, when I was in my twenties (in the mid to late 1970s), there would be big almost factory boats coming up from Jersey with spotter planes. At that time, I was building houses on the other side of the island, on the Sakonnet River. You could see a school of pogies come up the Sakonnet River. A couple days later, you'd see those boats come, and here would come the plane, and those pogies were gone (LN2-396)…. You used to be able to go around here in the fall, when the pogies were coming down the bay. You'd snag them, and

you'd snag some bluefish with them. You'd use them live. Until this year, we hadn't seen that in probably 25 years (LN2-397).

Submerged Aquatic Vegetation

Eelgrass (*Zostera marina*)

- Number of respondents: 2
- Segments mentioned:
- Trends mentioned: decline

Two individuals briefly alluded to a decline in eelgrass during their interviews.

- One stated, "Eelgrass. Where's all the eelgrass? It's gone (LN5-383)."
- Another stated that the changes he's seen in the bay have been drastic: not only lobsters and rockweed, but also, "It's the scallops, the eelgrass (LE1-384)."

Abiotic Observations

Abiotic observations expressed by interviewees in the 2016 Resilient Fisheries interviews are summarized below.

Clarity/Turbidity

The abiotic observation most frequently mentioned by interviewees was the increasing clarity of the water column in Narragansett Bay. Many interviewees interpreted this change as a cause of concern, an indicator of a decline in the bay's capacity to support life and fisheries:

- A trawl fisherman said, "I grew up in East Providence. We'd go to Barrington Beach [and] catch scup, bluefish, quahogs, you name it. Now, you go to the same areas, and you can see the bottom 20 feet deep, clear as a bell (TN1)."
- A trawl fisherman said, "Let me tell you something. Fifteen years ago, it looked like murky water. That was because it had animals living in it, little microscopic things. And the bay was booming. Now the bay is booming still in certain aspects, but in other aspects it's not (TK1). "
- A lobsterman said, "If you come down to my boat and look over the side right now, you can see the different colored bands on the lobsters in my [holding] car. It never used to be like that… It's like a swimming pool (LN6)."
- A retired lobsterman said:

  > You're not supposed to be able to see down the water column 10 or 15 feet in the middle of the summer. There's supposed to be stuff living in the water. [But] you

look down there, and it's like a swimming pool…. There's nothing living in the water column. That's the thing. I don't want to sound like an idiot, but years ago, when everybody's sewage went into the bay—[it's like on] the farms: you grow things on crap. Everything was fine. And all of a sudden, they started cleaning up Narragansett Bay. They got rid of all the crap and they started pumping chemicals into it. The rest of history (LE1)."

- A lobsterman said:

> In the summertime up by Gould Island in Narragansett Bay (<u>Middle East Passage</u>), check the water column. In August, it would be brown. It would be full of phytoplankton. Then the zooplankton would bloom, and it would feel on the phytoplankton. You could scoop up a bucket of water, and you'd see little things swimming in the bucket like you wouldn't believe. Well, right now, this year, this summer, you go up to Gould Island and you scoop up a bucket of water and you look at it. Nothing in it swimming. You go out front, past Castle Hill, where it's open to the ocean, and you scoop up a bucket, there's millions of little things swimming in it. For some reason, it's not in the bay anymore (LN5).

- A lobsterman said: "Save the Bay says the bay is so damn clean. Well, so is my swimming pool. And nothing lives in there either. So, are we experiencing cleaner waters? Or have we sterilized them (LN4)?"

<u>Miscellaneous Abiotic Factors</u>

A lobsterman stated that he has perceived a smell reminiscent of bleach, starting fifteen years before the interview (i.e., since about 1999). He added that the smell is more detectable on flat, calm days: "I can take you out one early spring morning, when the bay is flat calm at 5:30 in the morning. I'll take you out in the middle of the bay, and you'll smell chlorine. It'll smell like you're in a backyard swimming pool." He had detected this smell in many locations covering the whole area he fishes, including Melville (<u>Middle East Passage</u>) and south and east of Rose Island (<u>Lower East Passage</u>; LN4).

A trawl fisherman stated that he has observed a change in the color, texture, and smell of bottom sediments in Narragansett Bay. He suggested that this change may be tied to a decrease in the number of trawl boats turning over the bottom:

> There used to be about 15 draggers in the bay. The bottom was a lot different – the texture of the bottom, the smell of the bottom…. When you get north of the Jamestown Bridge, into any water shallower than 60 feet in our bay, the bottom is muck. Dead. There's fish that go up in there. The scup, the sea bass, they'll still go up in there. But I don't know what it is, but when we haul back, it's black muck on your net that stinks bad, like unbelievable stink. If you go to an area where boats have been fishing, you don't get that. You get that in our bay, way up north. Sakonnet River is a good example.

There used to be five or six dayboats that would work in the Sakonnet River… People fished there, dragged there. You'd go there and catch varieties of species. Good fishing. Clean fishing. Not weed, not muck. There's no one who fishes now. One little old guy who goes out part-time. I can't even go over there now. If I went over there now, I'd probably lose my net on muck, weed, garbage, shoes, clothes, you name it. You pull back, it stinks, it smells, and you catch nothing (TN1).

APPENDIX G. BIOTIC OBSERVATIONS FROM THE NB 2019, SH 2014, AND RF 2016 PROJECTS

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
126	LN4	NB 2019	"brown hairy weed"		Lower East Passage	west of the Naval War College; east of Rose Island; around Fort Wetherhill; from Fort Adams to Castle Hill	increase	since 2011-2014
127	LN2	NB 2019	"brown slime"		Lower East Passage	Bishop's Rock	decline	since 1999-2005
130	QK2	NB 2019	"brown weed/mermaid's hair"				uptick	since 2019
132	QW3	NB 2019	"dead man's hair"		Middle West Passage		decline	since 2009
131	QW3	NB 2019	"dead man's hair"		Quonset Harbor		decline	since 2009
105	QE1	NB 2019	"Hard, clear jelly fish"	*Aurelia aurita?*			decline	abundant when he was a kid; scarce now
125	LN5	NB 2019	"Horse hair"				boom	between 2004-2010
399	TN1	RF 2016	"Horsehair red weed"				increase	
110	LN5	NB 2019	"Rosebuds"	Hydrozoa	Lower East Passage	north of Kettle Bottom	decline	since 2013-2014
111	LN5	NB 2019	"Rosebuds"	Hydrozoa	Middle East Passage		decline	since 2013-2014
112	LN5	NB 2019	"Rosebuds"	Hydrozoa	Lower East Passage	south of Kettle Bottom	constant	
113	LN5	NB 2019	"Rosebuds"	Hydrozoa	Mouth of Narragansett Bay	especially at Racon Buoy	constant	
385	LN6	RF 2016	"Rosebuds"	Hydrozoa			decline	
123	LN5	NB 2019	"Slime weed"				increase	since 2008
124	LN5	NB 2019	"Slime weed"				downtick	since 2018
128	QE2	NB 2019	"Yucky scum"		Bristol Harbor		increase	
129	QE2	NB 2019	"Yucky scum"		Upper East Passage	between the entrance to Potter's Cove and Mount Tom	increase	
3	QW2	NB 2019	*Agardhiella subulata*	*Agardhiella subulata*	Upper Bay	Providence Point	increase	
1	QK3	NB 2019	*Agardhiella subulata*	*Agardhiella subulata*	Western Greenwich Bay		constant	
2	QW2	NB 2019	*Agardhiella subulata*	*Agardhiella subulata*	Western Greenwich Bay		increase	
4	LN2	NB 2019	Barnacles (mature)	Cirripedia: Thoracica	Newport Harbor		decline	since 1999
5	LN5	NB 2019	Barnacles (mature)	Cirripedia: Thoracica	Lower East Passage	from Newport Bridge northward	decline	since 2013-2014
6	LN5	NB 2019	Barnacles (mature)	Cirripedia: Thoracica	Middle East Passage		decline	since 2013-2014
374	LN6	RF 2016	Barnacles (mature)	Cirripedia: Thoracica	Newport Harbor	Long Wharf	decline	since 2014
373	LN5	RF 2016	Barnacles (mature)	Cirripedia: Thoracica			decline	since 2014
7	LN2	NB 2019	Barnacles (mature)	Cirripedia: Thoracica	Mouth of Narragansett Bay	Ruggles; Land's End; Ocean Drive	decline	

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
8	LN5	NB 2019	Barnacles (mature)	Cirripedia: Thoracica	Mouth of Narragansett Bay		decline	
9	LN2	NB 2019	Barnacles (spat)	Cirripedia: Thoracica			constant	
10	AE1	NB 2019	Barnacles (spat)	Cirripedia: Thoracica			constant	
11	AE2	NB 2019	Barnacles (spat)	Cirripedia: Thoracica			constant	
18	AE2	NB 2019	Bay scallops	*Argopecten irradians*	Middle East Passage	aquaculture lease	boom	in 2008
19	QE1	NB 2019	Bay scallops	*Argopecten irradians*	Upper Bay	Scofield Ledge (off Rumstick Point)	boom	in 2014
21	AE1	NB 2019	Bay scallops	*Argopecten irradians*	Middle East Passage	aquaculture lease	boom	in 2014-2015
23	QK3	NB 2019	Bay scallops	*Argopecten irradians*	Middle West Passage		uptick	in 2018-2019
22	QK3	NB 2019	Bay scallops	*Argopecten irradians*	Upper Bay		uptick	in 2018-2019
24	QK3	NB 2019	Bay scallops	*Argopecten irradians*	unclear	off Jamestown	uptick	in 2018-2019
20	QK2	NB 2019	Bay scallops	*Argopecten irradians*	Middle West Passage		uptick	in 2019
17	QE1	NB 2019	Bay scallops	*Argopecten irradians*	Potter's Cove		boom	in the 1980s
334	QW5	SH 2014	Bay Scallops	*Argopecten irradians*	Upper Bay	Rocky Point	boom	in the late 1930s
331	QE2	SH 2014	Bay Scallops	*Argopecten irradians*	Mount Hope Bay	across from Common Fence Point	boom	in the mid 20th century
333	QE2	SH 2014	Bay Scallops	*Argopecten irradians*	Nannakuaket Pond		boom	in the mid 20th century
330	QE2	SH 2014	Bay Scallops	*Argopecten irradians*	Potter's Cove		boom	in the mid 20th century
332	QE2	SH 2014	Bay Scallops	*Argopecten irradians*	The Cove	Spectacle Cove	boom	in the mid 20th century
337	QW3	SH 2014	Bay Scallops	*Argopecten irradians*	Upper Bay	Rocky Point	uptick	since 2013-2014
336	QW4	SH 2014	Bay Scallops	*Argopecten irradians*			uptick	since 2013-2014
12	QE1	NB 2019	Bay scallops	*Argopecten irradians*			cyclical/ variable	
13	AE2	NB 2019	Bay scallops	*Argopecten irradians*			cyclical/ variable	
14	QK2	NB 2019	Bay scallops	*Argopecten irradians*			cyclical/ variable	
15	AE1	NB 2019	Bay scallops	*Argopecten irradians*			cyclical/ variable	
16	QK3	NB 2019	Bay scallops	*Argopecten irradians*			cyclical/ variable	
335	QW4	SH 2014	Bay Scallops	*Argopecten irradians*			decline	
27	LN1	NB 2019	Black sea bass	*Centropristis striata*			increase	since 1998
28	LN3	NB 2019	Black sea bass	*Centropristis striata*			increase	since 2010
29	LN5	NB 2019	Black sea bass	*Centropristis striata*			increase	since 2013-2014
375	TN1	RF 2016	Black Sea Bass	*Centropristis striata*			increase	since 2014
26	QW1	NB 2019	Black sea bass	*Centropristis striata*			increase	since 2017
32	LN5	NB 2019	Black sea bass	*Centropristis striata*			downtick	since 2019
377	TK1	RF 2016	Black Sea Bass	*Centropristis striata*	Lower East Passage		increase	
30	QW2	NB 2019	Black sea bass	*Centropristis striata*	Lower West Passage		increase	
378	TK1	RF 2016	Black Sea Bass	*Centropristis striata*	Middle East Passage		increase	
31	QW2	NB 2019	Black sea bass	*Centropristis striata*	Middle West Passage		increase	
25	AE1	NB 2019	Black sea bass	*Centropristis striata*			increase	
376	LK1	RF 2016	Black Sea Bass	*Centropristis striata*			increase	

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
381	LE1	RF 2016	Blue Crabs	*Callinectes sapidus*			boom	in 2007-2009
379	TN1	RF 2016	Blue Crabs	*Callinectes sapidus*			boom	in 2010-2011
35	QW2	NB 2019	Blue crabs	*Callinectes sapidus*	Upper Bay		boom	in 2017
36	QW2	NB 2019	Blue crabs	*Callinectes sapidus*	Western Greenwich Bay		boom	in 2017
37	TE1	NB 2019	Blue crabs	*Callinectes sapidus*	Mount Hope Bay		decline	since 1970s
33	LN1	NB 2019	Blue crabs	*Callinectes sapidus*			increase	since 1998
34	QE1	NB 2019	Blue crabs	*Callinectes sapidus*			cyclical/ variable	
380	TN1	RF 2016	Blue Crabs	*Callinectes sapidus*			cyclical/ variable	
382	LE1	RF 2016	Blue Crabs	*Callinectes sapidus*			cyclical/ variable	
416	AE1	NB 2019	Bluefish	*Pomatomus saltatrix*			decline	since 2009-2011
38	QK2	NB 2019	Bluefish	*Pomatomus saltatrix*	Wickford Harbor		uptick	since 2019
39	QK1	NB 2019	Bluefish	*Pomatomus saltatrix*			cyclical/ variable	
136	LN2	NB 2019	Codium fragile	*Codium fragile*	Lower East Passage	Bishop's Rock	decline	since 1999-2005
116	LN2	NB 2019	Colonial Tunicate	*Didemnum sp*	Lower East Passage	west side of Goat Island	decline	since 2012-2013
115	LN2	NB 2019	Colonial Tunicate	*Didemnum sp*	Newport Harbor		decline	since 2012-2013
117	LN2	NB 2019	Colonial Tunicate	*Didemnum sp*	Lower East Passage	Rose Island	uptick	since 2018
41	QE1	NB 2019	Cormorants	*Phalacrocorax auritus*			increase	since 1980
42	LN5	NB 2019	Cormorants	*Phalacrocorax auritus*	Lower East Passage	House on the Rocks; Mackerel Cove; Hull Cove	increase	
101	LN5	NB 2019	Cunner	*Tautogolabrus adspersus*			decline	
137	LN2	NB 2019	Dasysiphonia japonica	*Dasysiphonia japonica*	Lower East Passage	Bishop's Rock	decline	since 1999-2005[12]
47	QW2	NB 2019	Deckers	*Crepidula fornicata*	Eastern Greenwich Bay		increase	
44	QK1	NB 2019	Deckers	*Crepidula fornicata*	Middle West Passage	Pine Hill	increase	
45	QK2	NB 2019	Deckers	*Crepidula fornicata*	Middle West Passage	Pine Hill; High Banks; Shellfish Management Area 3W	increase	
430	QW2	NB 2019	Deckers	*Crepidula fornicata*	Middle West Passage	off Quonset; Pine Hill	increase	
338	QW4	SH 2014	Deckers	*Crepidula fornicata*	Upper Bay	Barrington Beach	decline	
46	QW2	NB 2019	Deckers	*Crepidula fornicata*	Upper Bay	Barrington Beach; Rocky Point; Ohio Ledge	increase	
49	QW2	NB 2019	Deckers	*Crepidula fornicata*	Upper East Passage	northeastern edge of Prudence Island; Mount Tom	increase	
43	QK1	NB 2019	Deckers	*Crepidula fornicata*	Upper West Passage	Magic Mountain	increase	
48	QW2	NB 2019	Deckers	*Crepidula fornicata*	Upper West Passage	Middle Ground	increase	
50	QE1	NB 2019	Deckers	*Crepidula fornicata*			cyclical/ variable	
51	QK2	NB 2019	Deckers	*Crepidula fornicata*			cyclical/ variable	

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
118	TE1	NB 2019	Desmarestia viridis	*Desmarestia viridis*	Middle West Passage	first saw it just north of the Jamestown Bridge; saw it spread from there	increase	since 1969-1970
119	TE1	NB 2019	Desmarestia viridis	*Desmarestia viridis*	Lower West Passage		increase	since 1969-1971
120	TE1	NB 2019	Desmarestia viridis	*Desmarestia viridis*	Lower East Passage	catches a lot of it (detached) near Castle Hill	increase	since 1969-1972
121	TE1	NB 2019	Desmarestia viridis	*Desmarestia viridis*	Dutch Harbor		increase	since 1969-1973
122	QW2	NB 2019	Desmarestia viridis	*Desmarestia viridis*	Upper Bay	north end of Prudence Island	uptick	since 2018
139	LN2	NB 2019	Ectocarpus sp.	*Ectocarpus sp*	Lower East Passage	Bishop's Rock	decline	since 1999-2005
52	AE1	NB 2019	Eelgrass	*Zostera marina*	Middle East Passage	aquaculture lease	increase	since 2017
54	QW2	NB 2019	Eelgrass	*Zostera marina*	Middle East Passage	northeastern shore of Jamestown	constant	
53	QW1	NB 2019	Eelgrass	*Zostera marina*	Upper West Passage	The Gut	increase	
383	LN5	RF 2016	Eelgrass	*Zostera marina*			decline	
384	LE1	RF 2016	Eelgrass	*Zostera marina*			decline	
56	QW2	NB 2019	Eels	*Anguilla rostrata*	Apponaug Cove		decline	abundant in the 1980s; declining since 2000s
57	QW2	NB 2019	Eels	*Anguilla rostrata*	Buttonwoods Cove		decline	abundant in the 1980s; declining since 2000s
59	QW2	NB 2019	Eels	*Anguilla rostrata*	Potowomut River		decline	abundant in the 1980s; declining since 2000s
58	QW2	NB 2019	Eels	*Anguilla rostrata*	Warwick Cove		decline	abundant in the 1980s; declining since 2000s
61	QW3	NB 2019	Eels	*Anguilla rostrata*	Apponaug Cove		decline	abundant in the 1980s; now scarce
62	QW3	NB 2019	Eels	*Anguilla rostrata*	Buttonwoods Cove		decline	abundant in the 1980s; now scarce
60	QW3	NB 2019	Eels	*Anguilla rostrata*	Greenwich Cove		decline	abundant in the 1980s; now scarce
64	QW3	NB 2019	Eels	*Anguilla rostrata*	Potowomut River		decline	abundant in the 1980s; now scarce
63	QW3	NB 2019	Eels	*Anguilla rostrata*	Warwick Cove		decline	abundant in the 1980s; now scarce
55	QE1	NB 2019	Eels	*Anguilla rostrata*	Greenwich Cove		decline	
102	AE1	NB 2019	False Albacore	*Euthynnus alletteratus*	Upper Bay	Barrington Beach	increase	since 2015-2016
138	LN2	NB 2019	Grateloupia turuturu	*Grateloupia turuturu*	Lower East Passage	Bishop's Rock	decline	since 1999-2005
65	LN2	NB 2019	Green Crabs	*Carcinus maenas*	Lower East Passage	Fort Adams	decline	since 2014-2015
66	LN2	NB 2019	Green Crabs	*Carcinus maenas*	Newport Harbor		decline	since 2014-2015
67	QK2	NB 2019	Green Crabs	*Carcinus maenas*	Wickford Harbor		decline	
135	QW1	NB 2019	Grinnellia americana	*Grinnellia americana*	Upper Bay	Barrington Beach	increase	since 2018-2019
68	QE1	NB 2019	Horseshoe Crabs	*Limulus polyphemus*			decline	abundant in the 1980s; now scarce

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
73	TE1	NB 2019	Horseshoe Crabs	*Limulus polyphemus*	Mount Hope Bay	channel running through the middle	decline	abundant until 2004-2009; now scarce
71	QW2	NB 2019	Horseshoe Crabs	*Limulus polyphemus*	Eastern Greenwich Bay	western side of mouth of Greenwich Bay	decline	
69	QW2	NB 2019	Horseshoe Crabs	*Limulus polyphemus*	Upper Bay	Conimicut Point; Rocky Point	decline	
72	QW2	NB 2019	Horseshoe Crabs	*Limulus polyphemus*	Upper West Passage	shoreline south of Pojac Point	decline	
70	QW2	NB 2019	Horseshoe Crabs	*Limulus polyphemus*	Western Greenwich Bay	northern portion	decline	
339	QK4	SH 2014	Invasive Crabs				increase	
40	QW2	NB 2019	Irish Moss	*Chondrus crispus*	Upper Bay	north end of The Gut	uptick	since 2018-2019
106	QW3	NB 2019	Jonah Crabs	*Cancer borealis*			decline	since 1982
386	LN5	RF 2016	Kelp	*Saccharina latissima*			decline	abundant in the 1990s; now scarce
74	TE1	NB 2019	Kelp	*Saccharina latissima*	Lower East Passage	between Beavertail and Fort Wetherhill on the Jamestown side and Fort Adams and Castle Hill on the Aquidneck Island side (free-floating)	decline	since 1995
75	LN2	NB 2019	Kelp	*Saccharina latissima*	Lower East Passage	Kettle Bottom; the area between Castle Hill and Brenton Point	decline	since 2009
77	LN4	NB 2019	Kelp	*Saccharina latissima*	Lower East Passage	Fort Adams	decline	since 2009-2011
78	LN2	NB 2019	Kelp	*Saccharina latissima*	Lower East Passage	Kettle Bottom; area between Castle Hill and Brenton Point	uptick	since 2017
79	LN5	NB 2019	Kelp	*Saccharina latissima*	Lower East Passage	Castle Hill; #12 buoy near Rose Hill	uptick	since 2018-2019
76	LN5	NB 2019	Kelp	*Saccharina latissima*	Lower East Passage	#12 buoy near Rose Island; #11 buoy near Fort Wetherhill; #4 buoy near Kettle Bottom; deep hole near Castle Hill	decline	since early 2000s
107	QW3	NB 2019	Lady Crabs	*Ovalipes ocellatus*			decline	since 1982
80	LN2	NB 2019	Lion's Mane Jellyfish	*Cyanea capillata*			uptick	since 2017-2018
92	LN5	NB 2019	Lobsters	*Homarus americanus*	Middle East Passage	Gould Island	decline	abundant in 1990s; now scarce
91	LN5	NB 2019	Lobsters	*Homarus americanus*	Upper Bay	Colt State Park; Rumstick Point	decline	abundant in 1990s; now scarce
85	LN3	NB 2019	Lobsters	*Homarus americanus*	Upper Bay		decline	abundant in 1990s; scarce by 2014
86	LN3	NB 2019	Lobsters	*Homarus americanus*	Upper East Passage		decline	abundant in 1990s; scarce by 2014
83	LK1	NB 2019	Lobsters	*Homarus americanus*	Lower West Passage	several areas in Lower East Passage	boom	between 2004-2008
82	LK1	NB 2019	Lobsters	*Homarus americanus*	Middle West Passage	north of Jamestown	boom	between 2004-2008
84	LK1	NB 2019	Lobsters	*Homarus americanus*	Lower West Passage	southern end of Lower East Passage west of Beavertail	boom	between 2012-2013
93	LN2	NB 2019	Lobsters	*Homarus americanus*	Lower East Passage		decline	since 2010-2011
388	LN1	RF 2016	Lobsters	*Homarus americanus*			decline	since 2010-2011

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
421	LN4	NB 2019	Lobsters	*Homarus americanus*	Middle East Passage	between Prudence Island, Gould Island, Jamestown, and Aquidneck Island	decline	since 2012-2013
88	LN4	NB 2019	Lobsters	*Homarus americanus*	Newport Harbor		decline	since 2012-2013
391	LN2	RF 2016	Lobsters	*Homarus americanus*	Lower East Passage	Bishop's Rock	uptick	since 2015
392	LN2	RF 2016	Lobsters	*Homarus americanus*	Lower East Passage	Bishop's Rock	downtick	since 2016
95	LN2	NB 2019	Lobsters	*Homarus americanus*	Lower East Passage		uptick	since 2018
96	LN2	NB 2019	Lobsters	*Homarus americanus*	Newport Harbor		uptick	since 2018
97	LN4	NB 2019	Lobsters	*Homarus americanus*			uptick	since 2018
87	LN4	NB 2019	Lobsters	*Homarus americanus*	Lower East Passage	cruise ship anchorage west of Goat Island	decline	since before 2012-2013
89	LN4	NB 2019	Lobsters	*Homarus americanus*	Lower East Passage	coast of Jamestown from Kettle Bottom to Taylor Point; southwest coast of Newport from Castle Hill to the bridge; area west of Rose Island, and the Navy breakwall	constant	
390	LN2	RF 2016	Lobsters	*Homarus americanus*	Lower East Passage	Rose Island	constant	
90	LN4	NB 2019	Lobsters	*Homarus americanus*	Middle East Passage	old mussel farm near Melville; a few deep holes in the channel between Prudence and Aquidneck Islands	constant	
81	LK1	NB 2019	Lobsters	*Homarus americanus*	Middle East Passage	west of Great Ledge	decline	
94	LN2	NB 2019	Lobsters	*Homarus americanus*	Newport Harbor		decline	
387	LE1	RF 2016	Lobsters	*Homarus americanus*			decline	
389	LN2	RF 2016	Lobsters	*Homarus americanus*			decline	
396	LN2	RF 2016	Menhaden	*Brevoortia tyrannus*			boom	in the mid to late 1970s
99	QW2	NB 2019	Menhaden	*Brevoortia tyrannus*			decline	since 2014-2016
395	TN1	RF 2016	Menhaden	*Brevoortia tyrannus*			uptick	since 2015
397	LN2	RF 2016	Menhaden	*Brevoortia tyrannus*			uptick	since 2015
100	QK2	NB 2019	Menhaden	*Brevoortia tyrannus*			uptick	since 2018
98	AE1	NB 2019	Menhaden	*Brevoortia tyrannus*			decline	
108	QW2	NB 2019	Moon Snails	*Lunatia heros*	Upper Bay	Barrington Beach; Rocky Point; Ohio Ledge	increase	since 2016
109	QW2	NB 2019	Moon Snails	*Lunatia heros*	Western Greenwich Bay	Sandy Point	increase	since 2016
146	QW3	NB 2019	Mussels	*Mytilus edulis*	Upper Bay	Poppasquash to Nayatt	boom	in 2004
145	QW3	NB 2019	Mussels	*Mytilus edulis*	Upper West Passage		boom	in 2004
342	QK5	SH 2014	Mussels	*Mytilus edulis*			boom	in 2009
341	QK5	SH 2014	Mussels	*Mytilus edulis*			collapse	in the 1960s
147	QE1	NB 2019	Mussels	*Mytilus edulis*	Upper West Passage		boom	in the 1990s
401	LN2	RF 2016	Mussels	*Mytilus edulis*			increase	since 2012-2014
155	LN2	NB 2019	Mussels	*Mytilus edulis*	Lower East Passage	along the south side of the Naval War College	increase	since 2015
149	LN2	NB 2019	Mussels	*Mytilus edulis*	Newport Harbor	Long Wharf	decline	since 2016
154	QW2	NB 2019	Mussels	*Mytilus edulis*	Upper West Passage		uptick	since 2018
153	QK2	NB 2019	Mussels	*Mytilus edulis*	Middle West Passage	The Hump	uptick	since 2019

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148	LN2	NB 2019	Mussels	*Mytilus edulis*	Lower East Passage	Brenton Point; southwest corner of Goat Island	decline	since the 1980s
144	LN4	NB 2019	Mussels	*Mytilus edulis*	Lower East Passage	House on the Rocks	constant	
151	LN2	NB 2019	Mussels	*Mytilus edulis*	Lower East Passage	Fort Adams; the west side of Rose Island in the shoals; Coddington Point; the northwest corner of Goat Island	constant	
150	LN4	NB 2019	Mussels	*Mytilus edulis*	Lower East Passage	Fort Adams to Castle Hill; along the edge of the shoals near Rose Island; along the west side of the Naval War College	decline	
152	AE1	NB 2019	Mussels	*Mytilus edulis*	Middle East Passage	aquaculture lease	increase	
140	QK3	NB 2019	Mussels	*Mytilus edulis*			cyclical/ variable	
141	QW3	NB 2019	Mussels	*Mytilus edulis*			cyclical/ variable	
142	QE1	NB 2019	Mussels	*Mytilus edulis*			cyclical/ variable	
143	LN4	NB 2019	Mussels	*Mytilus edulis*			cyclical/ variable	
340	QK5	SH 2014	Mussels	*Mytilus edulis*			cyclical/ variable	
400	LN2	RF 2016	Mussels	*Mytilus edulis*			cyclical/ variable	
346	QK2	SH 2014	Oysters	*Crassostrea virginica*	Middle West Passage	off Davisville	boom	between 1994-1999
345	QK2	SH 2014	Oysters	*Crassostrea virginica*	Upper Bay	Rumstick Point	boom	between 1994-1999
344	QK2	SH 2014	Oysters	*Crassostrea virginica*	Wickford Harbor	the sand bar	boom	between 1994-1999
350	QE1	SH 2014	Oysters	*Crassostrea virginica*			boom	between 1997-1999
343	QK4	SH 2014	Oysters	*Crassostrea virginica*	Wickford Harbor		boom	between 2003-2006
157	QE2	NB 2019	Oysters	*Crassostrea virginica*	Mill Gut		boom	in the 1990s
156	QE2	NB 2019	Oysters	*Crassostrea virginica*	Nannakuaket Pond		boom	in the 1990s
160	QE2	NB 2019	Oysters	*Crassostrea virginica*	Upper Bay	Ohio Ledge	boom	in the 1990s
159	QE2	NB 2019	Oysters	*Crassostrea virginica*	Upper East Passage	Hog Island	boom	in the 1990s
158	QE2	NB 2019	Oysters	*Crassostrea virginica*	Warren River		boom	in the 1990s
165	QK3	NB 2019	Oysters	*Crassostrea virginica*			boom	in the 1990s
161	QE1	NB 2019	Oysters	*Crassostrea virginica*	Barrington River		boom	in the early 2000s
162	QE1	NB 2019	Oysters	*Crassostrea virginica*	Kickemuit River		boom	in the early 2000s
163	QE1	NB 2019	Oysters	*Crassostrea virginica*	Mill Gut		boom	in the early 2000s
166	TE1	NB 2019	Oysters	*Crassostrea virginica*			boom	in the late 1980s
347	QW3	SH 2014	Oysters	*Crassostrea virginica*	Upper West Passage	Greene's River	boom	in the late 1990s
349	QE2	SH 2014	Oysters	*Crassostrea virginica*	Warren River	Smith's Cove	boom	
164	QW2	NB 2019	Oysters	*Crassostrea virginica*			boom	
348	QW3	SH 2014	Oysters	*Crassostrea virginica*			cyclical/ variable	

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420	QE1	SH 2014	Oysters	*Crassostrea virginica*			cyclical/ variable	
167	LN4	NB 2019	Plankton				decline	abundant 2012-2013; now scarce
168	LN5	NB 2019	Plankton		Lower East Passage	north of the Newport Bridge	decline	since 2009
169	LN5	NB 2019	Plankton		Middle East Passage		decline	since 2009
172	LN5	NB 2019	Plankton				uptick	since 2018
170	LN5	NB 2019	Plankton		Lower East Passage	south of Newport Bridge	constant	
171	LN5	NB 2019	Plankton		Mouth of Narragansett Bay		constant	
359	QK4	SH 2014	Quahogs	*Mercenaria mercenaria*	Middle West Passage	in front of Allen's Harbor (Quonset Harbor) and around Hope Island	decline	abundant from 1999 to 2009; less now
358	QK4	SH 2014	Quahogs	*Mercenaria mercenaria*	Dutch Harbor		decline	abundant in 1981; scarce now
357	QK4	SH 2014	Quahogs	*Mercenaria mercenaria*	Lower West Passage		decline	abundant in 1981; scarce now
354	QK3	SH 2014	Quahogs	*Mercenaria mercenaria*			collapse	between 1993-1995
237	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*			boom	in 2005
234	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Barrington Beach	boom	in the 1980s
231	QE1	NB 2019	Quahogs	*Mercenaria mercenaria*			boom	in the 1980s
235	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*			boom	in the 1980s
232	QE1	NB 2019	Quahogs	*Mercenaria mercenaria*			collapse	in the 1990s
236	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*			collapse	in the 1990s
355	QW2	SH 2014	Quahogs	*Mercenaria mercenaria*			collapse	in the 1990s
356	QE1	SH 2014	Quahogs	*Mercenaria mercenaria*			collapse	in the 1990s
233	QE1	NB 2019	Quahogs	*Mercenaria mercenaria*			boom	in the 2000s
351	QK4	SH 2014	Quahogs	*Mercenaria mercenaria*	Upper Bay	Shellfish Management Area A	boom	in the early 1980s
352	QE1	SH 2014	Quahogs	*Mercenaria mercenaria*	Upper Bay	Barrington Beach	boom	in the early 1980s
188	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Dutch Harbor		decline	since 1990s
189	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Eastern Greenwich Bay		decline	since 1990s

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186	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Lower West Passage	shoals just south of Jamestown Bridge	decline	since 1990s
187	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	just north of Jamestown Bridge	decline	since 1990s
190	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	shoals east of Longmeadow	decline	since 1993
362	QK4	SH 2014	Quahogs	*Mercenaria mercenaria*	Upper Bay		increase	since 1999-2004
191	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Rumstick Point	decline	since 2003
183	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	High Banks; parts of Shellfish Management Areas 3W	decline	since 2004 (High Banks)
182	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Pine Hill; an area north of Plum Point	decline	since 2004 (Pine Hill)
196	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay		decline	since 2009-2011
176	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Apponaug Cove		decline	since 2010
177	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Greenwich Cove		decline	since 2010
192	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Pine Hill	decline	since 2010
173	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Colt State Park to Poppasquash	decline	since 2010
178	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	area just south of Patience Island	decline	since 2010
193	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	High Banks	decline	since 2010
175	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Warwick Cove		decline	since 2010
174	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay		decline	since 2010
363	QK2	SH 2014	Quahogs	*Mercenaria mercenaria*	Upper Bay		increase	since 2010-2011
208	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Bristol Harbor	western side	decline	since 2013-2014
194	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	Hunt's Ledge and Middle Ground	decline	since 2015
202	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Apponaug Cove	Mary's Creek	decline	since 2016-2017
199	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Quonset Harbor	Allen's Harbor	decline	since 2016-2017
200	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	an area north of Pine Hill	decline	since 2016-2017

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201	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay		decline	since 2016-2017
424	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	western side of Friar's Cove; area near Calf Pasture Point	uptick	since 2017
422	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	edge of shoreline in Barrington Beach; small area in Longmeadow	uptick	since 2017
198	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Johnson's Ledge	downtick	since 2017-2018
195	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	High Banks	decline	since early 2000s
185	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Dutch Harbor		decline	
226	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Eastern Greenwich Bay	northern edge	constant	
205	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Eastern Greenwich Bay		decline	
427	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Eastern Greenwich Bay		decline	
423	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Eastern Greenwich Bay	small area north of Sandy Point	uptick	
364	QK2	SH 2014	Quahogs	*Mercenaria mercenaria*	Greenwich Bay (section)		constant	
365	QW3	SH 2014	Quahogs	*Mercenaria mercenaria*	Greenwich Bay (section)		decline	
225	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Greenwich Cove	mouth of Greenwich Cove	constant	
197	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Greenwich Cove		decline	
184	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Lower West Passage		decline	
223	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle East Passage	northeast coast of Jamestown	constant	
215	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	western Friar's Cove	constant	
224	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Friar's Cove	constant	
179	QK1	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	near northern edge; Pine Hill	decline	
203	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Pine Hill; off Quonset; Hope Island	decline	
360	QK4	SH 2014	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Friar's Cove	increase	
361	QK2	SH 2014	Quahogs	*Mercenaria mercenaria*	Middle West Passage	Friar's Cove	increase	

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229	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Potter's Cove		constant	
353	QW2	SH 2014	Quahogs	*Mercenaria mercenaria*	Upper Bay	Barrington Beach	boom	
209	AE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Barrington Beach; the Seminary; Rocky Point	constant	
211	QK1	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Rocky Point; Barrington Beach	constant	
213	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Barrington Beach	constant	
214	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Rocky Point	constant	
217	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Rocky Point; Barrington Beach	constant	
220	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Barrington Beach; Ohio Ledge; Rocky Point	constant	
228	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	south of Rocky Point dock; Barrington Beach	constant	
428	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Rocky Point; Barrington Beach	constant	
206	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Ohio Ledge	decline	
426	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	north end of The Gut between Patience and Prudence Islands	decline	
431	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper Bay	Ohio Ledge (seeing more dead shells mixed in)	decline	
216	QK2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper East Passage	Mount Tom	constant	
218	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper East Passage	Homestead (Mount Tom)	constant	
227	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper East Passage	between the entrance to Potter's Cove and Mount Tom	constant	
230	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper East Passage	between the entrance to Potter's Cove and Mount Tom	constant	
429	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper East Passage	Death Valley (between Hog Island and Bristol Point)	decline	
221	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	Magic Mountain	constant	
180	QK1	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	near southern edge; Hunt's Ledge; Middle Ground; Magic Mountain	decline	
207	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage		decline	
222	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Upper West Passage	small area south of Sandy Point	uptick	

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212	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*	Warren River	mouth of Warren River	constant	
210	QK1	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay	northern edge	constant	
219	QW1	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay	nothern edge	constant	
425	QK3	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay	northern edge	constant	
181	QK1	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay		decline	
204	QW3	NB 2019	Quahogs	*Mercenaria mercenaria*	Western Greenwich Bay		decline	
368	QW4	SH 2014	Quahogs	*Mercenaria mercenaria*			constant	
417	QE1	NB 2019	Quahogs	*Mercenaria mercenaria*			cyclical/ variable	
418	QE2	NB 2019	Quahogs	*Mercenaria mercenaria*			cyclical/ variable	
419	QW2	NB 2019	Quahogs	*Mercenaria mercenaria*			cyclical/ variable	
366	QK2	SH 2014	Quahogs	*Mercenaria mercenaria*			increase	
367	QE2	SH 2014	Quahogs	*Mercenaria mercenaria*			increase	
133	TE1	NB 2019	Rockweeds	*Fucus spp.*	Bristol Harbor	near Sip-N-Dip	increase	
134	TE1	NB 2019	Rockweeds	*Fucus spp.*	Mount Hope Bay	around Seal Rock	increase	
245	LN3	NB 2019	Rockweeds	*Ascophyllum nodosum*	Bristol Harbor		decline	abundant going back to 1960s; scarce since 2005-2007
243	LN3	NB 2019	Rockweeds	*Ascophyllum nodosum*	Kickemuit River		decline	abundant going back to 1960s; scarce since 2005-2007
244	LN3	NB 2019	Rockweeds	*Ascophyllum nodosum*	Upper Bay	Rumstick Point; Poppasquash	decline	abundant going back to 1960s; scarce since 2005-2007
432	LN3	NB 2019	Rockweeds	*Ascophyllum nodosum*	Warren River		decline	abundant going back to 1960s; scarce since 2005-2007
239	TE1	NB 2019	Rockweeds	*Ascophyllum nodosum*	Bristol Harbor	near Sip-N-Dip	decline	abundant going back to 1970s; scarce now
238	TE1	NB 2019	Rockweeds	*Ascophyllum nodosum*	Mount Hope Bay		decline	abundant going back to 1970s; scarce now
241	LN5	NB 2019	Rockweeds	*Ascophyllum nodosum*	Lower East Passage	eastern shore of Jamestown; western shore of Aquidneck Island	decline	abundant in 1990s; scarce now

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242	LN5	NB 2019	Rockweeds	*Ascophyllum nodosum*	Middle East Passage	eastern shore of Jamestown; western shore of Aquidneck Island all the way up to Melville; Gould Island	decline	abundant in 1990s; scarce now
249	LN3	NB 2019	Rockweeds	*Ascophyllum nodosum*	Bristol Harbor	near Sip-N-Dip	uptick	since 2018-2019
248	LN5	NB 2019	Rockweeds	*Ascophyllum nodosum*	Lower East Passage	Taylor's Point; Van Zandt Pier; Rose Island	uptick	since 2018-2019
250	LN3	NB 2019	Rockweeds	*Ascophyllum nodosum*	Lower East Passage	along Washington St (south of bridge)	uptick	since 2018-2019
404	LE1	RF 2016	Rockweeds	*Order Fucales*	Bristol Harbor		decline	
240	LN2	NB 2019	Rockweeds	*Ascophyllum nodosum*	Lower East Passage	Rose Island; Bishop's Rock	decline	
402	LN5	RF 2016	Rockweeds	*Order Fucales*	Middle East Passage		decline	
246	LN2	NB 2019	Rockweeds	*Ascophyllum nodosum*	Mouth of Narragansett Bay	Brenton Point; Land's End	constant	
247	LN5	NB 2019	Rockweeds	*Ascophyllum nodosum*	Mouth of Narragansett Bay	Ocean Drive; Beavertail Point; Skindiver Cove; East Skindiver Cove	constant	
403	LN5	RF 2016	Rockweeds	*Ascophyllum nodosum*	Mouth of Narragansett Bay		constant	
398	LE1	RF 2016	Sand Crabs	*Cancer irroratus*	Upper Bay		decline	
103	TE1	NB 2019	Sand Dabs	*Scopthalmus aquosus*	Mount Hope Bay		decline	
254	LN4	NB 2019	Scup	*Stenotomus chrysops*	Lower East Passage	Bishop's Rock	decline	since 2011-2012
406	LN2	RF 2016	Scup	*Stenotomus chrysops*			downtick	since 2013-2014
255	LN4	NB 2019	Scup	*Stenotomus chrysops*	Lower East Passage	Fort Adams; Rose Island; House on the Rocks	constant	
252	QW2	NB 2019	Scup	*Stenotomus chrysops*	Lower West Passage		increase	
251	QW2	NB 2019	Scup	*Stenotomus chrysops*	Middle West Passage		increase	
408	TN1	RF 2016	Scup	*Stenotomus chrysops*			downtick	
253	AE1	NB 2019	Scup	*Stenotomus chrysops*			increase	
405	LK1	RF 2016	Scup	*Stenotomus chrysops*			increase	
407	TN1	RF 2016	Scup	*Stenotomus chrysops*			increase	
256	LN4	NB 2019	Sea Grapes	*Molgula manhattensis*	Newport Harbor		decline	since 2007-2009
257	LN5	NB 2019	Sea Grapes	*Molgula manhattensis*	Lower East Passage	north of Newport Bridge	decline	since 2013-2014
258	LN5	NB 2019	Sea Grapes	*Molgula manhattensis*	Middle East Passage	up to Gould Island	decline	since 2013-2014
260	LN5	NB 2019	Sea Grapes	*Molgula manhattensis*	Lower East Passage	Kettle Bottom	constant	
259	LN5	NB 2019	Sea Grapes	*Molgula manhattensis*	Mouth of Narragansett Bay	especially at Racon Buoy	constant	
409	LN6	RF 2016	Sea Grapes	*Molgula manhattensis*			decline	

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
269	LN2	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Lower East Passage	Bishop's Rock	decline	since 1999-2005
267	QW2	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Upper Bay	The Gut between Patience and Prudence Islands	uptick	since 2018
268	QW2	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Upper West Passage	The Gut between Patience and Prudence Islands	uptick	since 2018
266	QK3	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Greenwich Cove		uptick	since 2019
264	QW1	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Upper Bay	Barrington Beach	uptick	since 2019
265	QK3	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Upper Bay	Barrington Beach; Longmeadow	uptick	since 2019
270	LN2	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Lower East Passage	Rose Island	constant	
271	LN5	NB 2019	Sea Lettuce	Blade-forming *Ulva spp.*	Lower East Passage	especially Rose Island	constant	
114	QW3	NB 2019	Sea Mouse	*Aphrodita aculeata*			decline	
272	AE1	NB 2019	Sea Robins	*Prionotus carolinus*			increase	
273	QK3	NB 2019	Sea Robins	*Prionotus carolinus*			increase	
274	LN4	NB 2019	Sea Squirts	*Styela clava*	Newport Harbor		decline	since 2007-2009
275	LN2	NB 2019	Sea Squirts	*Styela clava*	Newport Harbor		decline	since 2013-2014
276	LN2	NB 2019	Sea Squirts	*Styela clava*	Lower East Passage	Rose Island	increase	since 2017
263	LN4	NB 2019	Seahorses	*Hippocampus erectus, etc*	Lower East Passage	three areas roughly bounded by Coddington Point, Rose Island, and Goat Island	decline	since 2007-2009
262	LN4	NB 2019	Seahorses	*Hippocampus erectus, etc*	Newport Harbor		decline	since 2007-2009
261	LN2	NB 2019	Seahorses	*Hippocampus erectus, etc*	Lower East Passage	Coddington Point; east side of Rose Island; from Fort Adams to Castle Hill	decline	since 2010-2011
277	LN1	NB 2019	Seals	*Phoca vitulina*			increase	scarce in 1998; abuntant now
278	LN5	NB 2019	Seals	*Phoca vitulina*			increase	since 1989
279	LN4	NB 2019	Shell Disease	*Aquamarina sp*			increase	since 1987-1990 in crabs; since 1996 in lobsters
280	LN3	NB 2019	Shell Disease	*Aquamarina sp*			increase	since 1996-1997
393	LN5	RF 2016	Shell Disease	*Aquamarina sp.*			increase	
394	LN6	RF 2016	Shell Disease	*Aquamarina sp.*			increase	
281	QW1	NB 2019	Soft Shell Clams	*Mya arenaria*	Upper Bay	Conimicut Point	boom	between 2003-2004
282	QW1	NB 2019	Soft Shell Clams	*Mya arenaria*	Upper Bay	Longmeadow	boom	between 2003-2005
284	QK3	NB 2019	Soft Shell Clams	*Mya arenaria*	Upper Bay	Conimicut Point	boom	in 2000
370	QW4	SH 2014	Soft Shell Clams	*Mya arenaria*			boom	in 2009
369	QW4	SH 2014	Soft Shell Clams	*Mya arenaria*			decline	since 1960s-1970a
286	QW2	NB 2019	Soft Shell Clams	*Mya arenaria*	Eastern Greenwich Bay	mouth of Warwick Cove westward	decline	since late 1990s

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
287	QW2	NB 2019	Soft Shell Clams	*Mya arenaria*	Upper West Passage	shoreline south of Pojac Point	decline	since late 1990s
285	QW2	NB 2019	Soft Shell Clams	*Mya arenaria*	Western Greenwich Bay	Cedar Tree Point eastward; Chepiwanoxet; west of Sally Rock Point	decline	since late 1990s
283	QW2	NB 2019	Soft Shell Clams	*Mya arenaria*	Upper Bay	Conimicut Point	boom	
371	QK4	SH 2014	Soft Shell Clams	*Mya arenaria*	Upper Bay	Conimicut Point; Longmeadow	boom	
372	QK4	SH 2014	Soft Shell Clams	*Mya arenaria*			cyclical/ variable	
290	TE1	NB 2019	Spider Crabs	*Libinia emarginata*	Mount Hope Bay		decline	
288	QW2	NB 2019	Spider Crabs	*Libinia emarginata*	Upper Bay	Barren Ledge; the deeper ledge going towards the shipping channel' the 18 mark	increase	
289	QW2	NB 2019	Spider Crabs	*Libinia emarginata*	Warwick Cove		increase	
292	AE2	NB 2019	Spider Crabs	*Libinia emarginata*			constant	
293	QK3	NB 2019	Spider Crabs	*Libinia emarginata*			cyclical/ variable	
291	QW3	NB 2019	Spider Crabs	*Libinia emarginata*			decline	
104	AE1	NB 2019	Squeteague	*Cynoscion regalis*			decline	since the 1970s
300	LN1	NB 2019	Starfish	*Asterias forbesi*			decline	abundant in late 1990s and early 2000s; scarce now
308	QE1	NB 2019	Starfish	*Asterias forbesi*			boom	in the early 2000s
306	TE1	NB 2019	Starfish	*Asterias forbesi*	Upper West Passage		decline	since 2004-2009
299	QW3	NB 2019	Starfish	*Asterias forbesi*			decline	since 2009
297	QW2	NB 2019	Starfish	*Asterias forbesi*	Upper Bay	Rocky Point; northeast of Providence Point	decline	since 2010-2013
298	QW2	NB 2019	Starfish	*Asterias forbesi*	Upper West Passage	High Banks; The Gut between Prudence and Patience Islands	decline	since 2010-2013
304	LN4	NB 2019	Starfish	*Asterias forbesi*	Lower East Passage	areas east and northeast of Rose Island and west of Goat Island	decline	since 2011
303	LN4	NB 2019	Starfish	*Asterias forbesi*	Newport Harbor		decline	since 2011
301	LN2	NB 2019	Starfish	*Asterias forbesi*			decline	since 2011
294	AE1	NB 2019	Starfish	*Asterias forbesi*	Middle East Passage	aquaculture lease	decline	since 2012-2013
410	LN5	RF 2016	Starfish	*Asterias forbesi*			decline	since 2013
305	LN5	NB 2019	Starfish	*Asterias forbesi*	Lower East Passage		decline	since 2013-2014
302	LN3	NB 2019	Starfish	*Asterias forbesi*	Upper Bay	Rocky Point; Ohio Ledge	decline	since mid-2000s
295	AE2	NB 2019	Starfish	*Asterias forbesi*	Middle East Passage	aquaculture lease	decline	
307	QE1	NB 2019	Starfish	*Asterias forbesi*			cyclical/ variable	
309	QW2	NB 2019	Starfish	*Asterias forbesi*			cyclical/ variable	
310	LN4	NB 2019	Starfish	*Asterias forbesi*			cyclical/ variable	
296	QE2	NB 2019	Starfish	*Asterias forbesi*			decline	
411	LN2	RF 2016	Starfish	*Asterias forbesi*			decline	

Observation ID	Respondent Code	Project	Common Name	Scientific Name	Bay Segment	Location(s)	Trend Type	Time Description
311	AE1	NB 2019	Striped Bass	*Morone saxitilis*			decline	since 2014
312	AE1	NB 2019	Striped Bass	*Morone saxitilis*			uptick	since 2018
313	QK2	NB 2019	Striped Bass	*Morone saxitilis*			uptick	since 2018-2019
314	QW1	NB 2019	Striped Bass	*Morone saxitilis*	Upper Bay		decline	
315	QW1	NB 2019	Striped Bass	*Morone saxitilis*	Upper East Passage		constant	
316	QW1	NB 2019	Striped Bass	*Morone saxitilis*	Upper West Passage		constant	
317	LN3	NB 2019	Tautog	*Tautoga onitis*	Warren River		decline	since late 1990s
319	TE1	NB 2019	Tautog	*Tautoga onitis*	Mount Hope Bay		decline	
318	QW2	NB 2019	Tautog	*Tautoga onitis*			decline	
322	LN4	NB 2019	Urchins	*Arbacia punctulata*	Lower East Passage	Rose Island	decline	since 2007-2009
321	LN4	NB 2019	Urchins	*Arbacia punctulata*	Newport Harbor	Goat Island	decline	since 2007-2009
320	LN2	NB 2019	Urchins	*Arbacia punctulata*			decline	since 2009
323	LN4	NB 2019	Urchins	*Arbacia punctulata*			uptick	since 2018-2019
325	QW2	NB 2019	Whelks	*Busycotypus canaliculatus, Busycon carica*			downtick	since 2018
326	QW3	NB 2019	Whelks	*Busycotypus canaliculatus, Busycon carica*			constant	
324	QW2	NB 2019	Whelks	*Busycotypus canaliculatus, Busycon carica*			cyclical/ variable	
412	LN6	RF 2016	Winter Flounder	*Pseudopleuronectes americanus*			decline	abundant in 1980s-1990s; scarce now
327	QE1	NB 2019	Winter Flounder	*Pseudopleuronectes americanus*			decline	abundant in 1980s; scarce now
329	TE1	NB 2019	Winter Flounder	*Pseudopleuronectes americanus*	Mount Hope Bay		decline	since 1986
328	QK3	NB 2019	Winter Flounder	*Pseudopleuronectes americanus*			decline	since 1990s
413	LN2	RF 2016	Winter Flounder	*Pseudopleuronectes americanus*	Newport Harbor		decline	
414	TN1	RF 2016	Winter Flounder	*Pseudopleuronectes americanus*			decline	
415	TK1	RF 2016	Winter Flounder	*Pseudopleuronectes americanus*			decline	

APPENDIX H. VISUALIZATIONS OF ECOLOGICAL TRENDS BASED ON SCIENTIFIC MONITORING DATASETS

This appendix presents graphic visualizations of SEK-derived abundance trends, wherever they are available, for species and abiotic characteristics mentioned in fishermen interviews.

Sessile Benthic Invertebrates

Quahogs (*Mercenaria mercenaria*)

We obtained long-term data on quahog abundance from two sources. Fishery-independent measures of quahog density (legal and sublegal individuals) were obtained from the DEM Shellfish Dredge Survey. We grouped sampling stations in clusters so that they aligned with important areas described by fishermen during their interviews, and then plotted annual mean density per tow for each area. Figure H - 1 to Figure H - 13 show the average annual density per tow of legal and sublegal quahogs in each area, and Table H - 1 summarizes the number of tows per year in each area represented in the figures. Fishery-dependent measures of commercial harvest were obtained from the DEM landings dataset and visualized by tagging area. Landings data are shown in Figure H - 14 through Figure H - 16.

Figure H - 1. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) at Barrington Beach (Upper Bay), 1994-2019. Source: DEM Shellfish Dredge Survey, Stratum 2: Stations 1-14, 17-20.

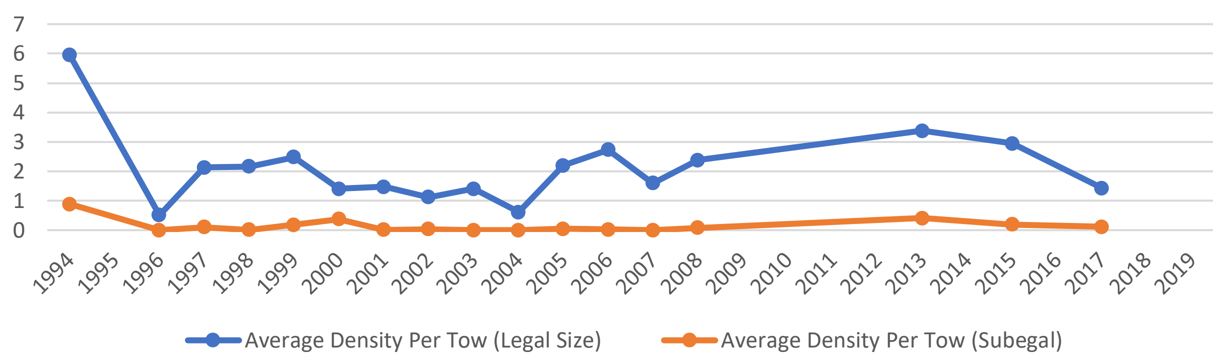


Figure H - 2. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) from Conimicut Point to Rocky Point (Upper Bay), 1994-2019. Source: DEM Shellfish Dredge Survey, Stratum 1: Stations 1-18.

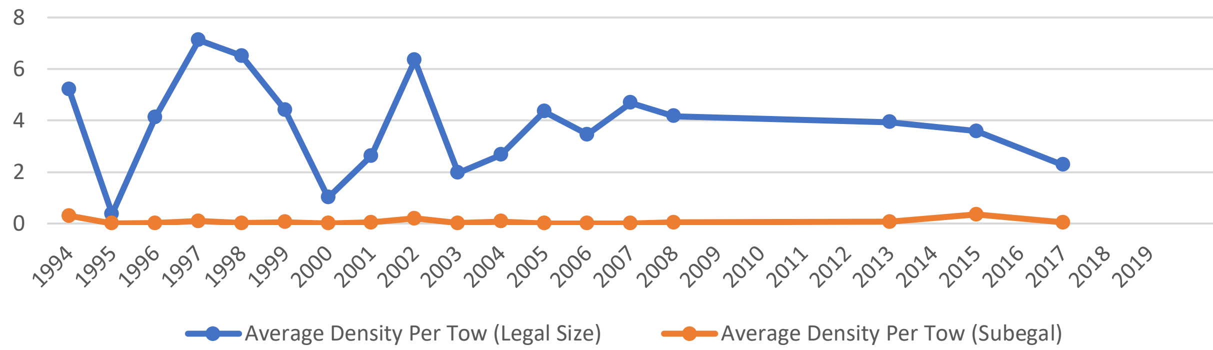


Figure H - 3. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) at Ohio Ledge (Upper Bay), 1994-2019. Source: DEM Shellfish Dredge Survey, stratum 3.

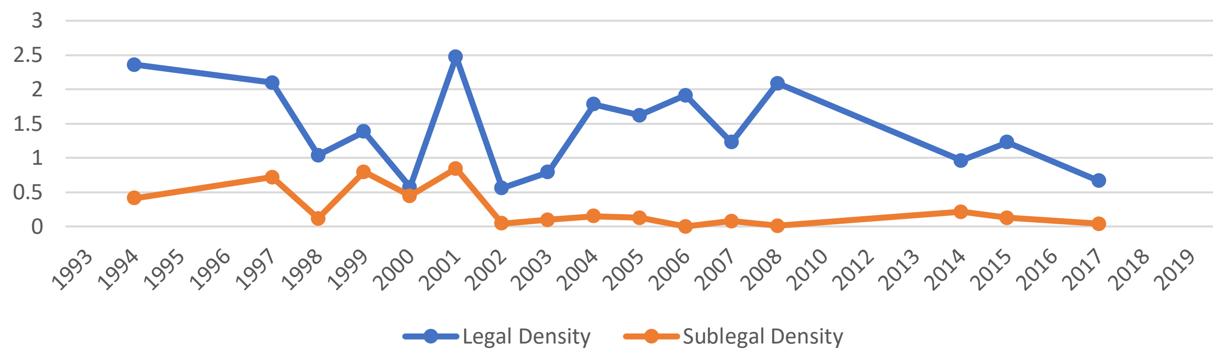


Figure H - 4. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) in Western Greenwich Bay, 1993-2019. Source: DEM Shellfish Dredge Survey: stratum 16, stations 1-12.

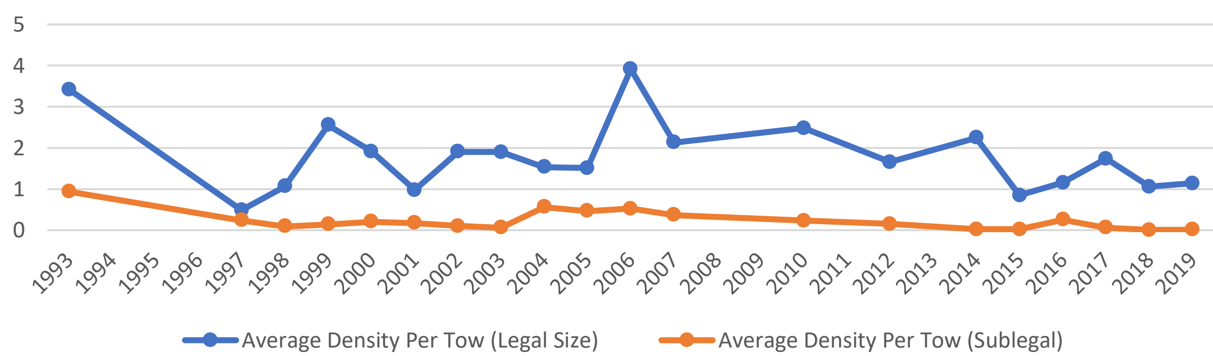


Figure H - 5. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) in Eastern Greenwich Bay, 1993-2019. Source: DEM Shellfish Dredge Survey: stratum 16, stations 13-27.

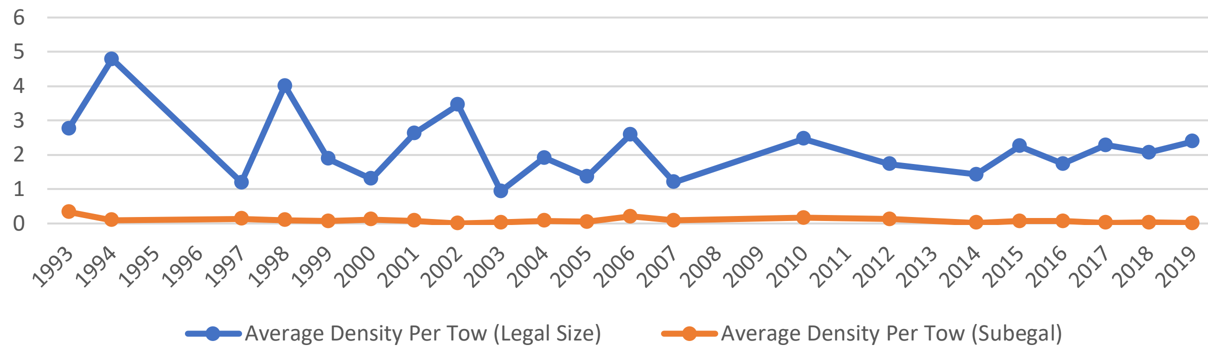


Figure H - 6. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) High Banks (Upper West Passage), 1994-2019. Source: DEM Shellfish Dredge Survey: stratum 5: stations 11-12, 15-16, 18-21.

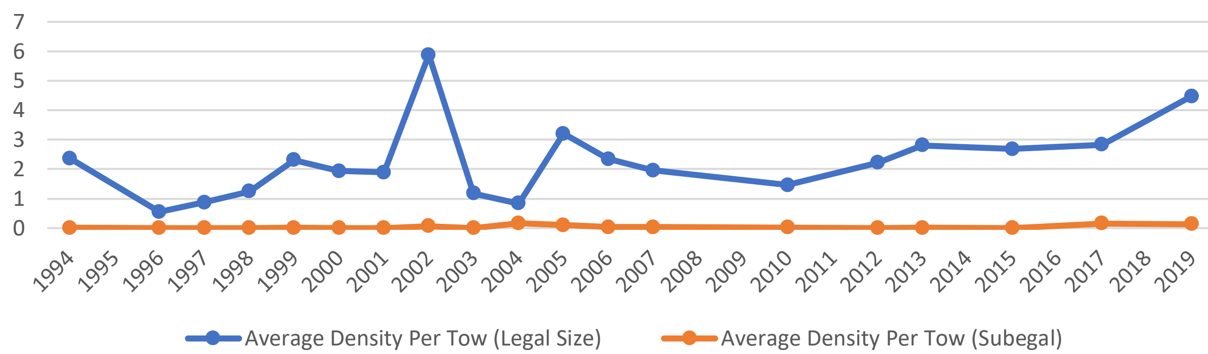


Figure H - 7. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) at Hunt's Ledge, Middle Ground, and Magic Mountain (Upper West Passage), 1994-2019. Source: DEM Shellfish Dredge Survey: stratum 5: stations 10-17, 18-30.

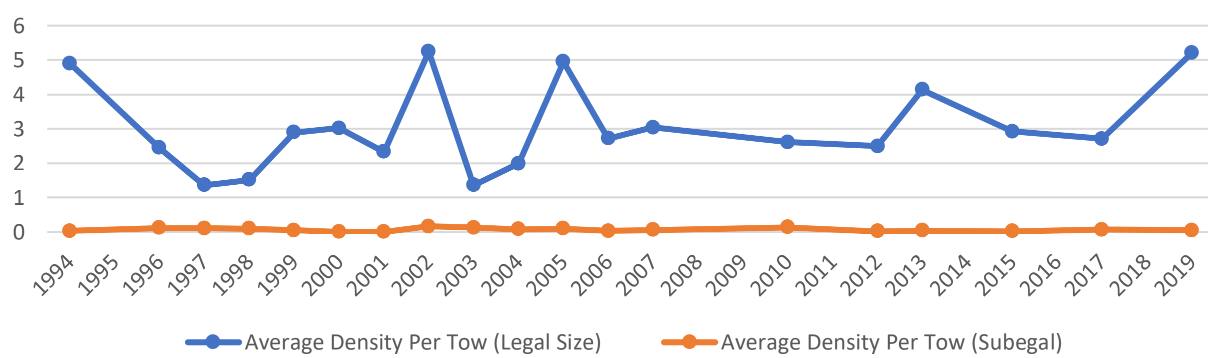


Figure H - 8. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) at Pine Hill (Middle West Passage), 1994-2019. Source: DEM Shellfish Dredge Survey: Stratum 4: Stations 16-18; Stratum 9: Stations 7, 11, 15-18.

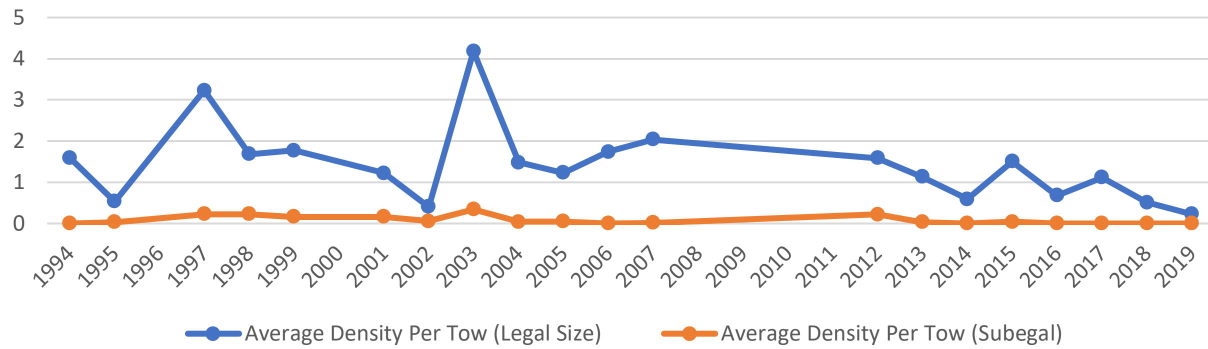


Figure H - 9. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) from Potter's Cove to Mount Tom (Upper East Passage), 1995-2019. Source: DEM Shellfish Dredge Survey: stratum 1, stations 5-11.

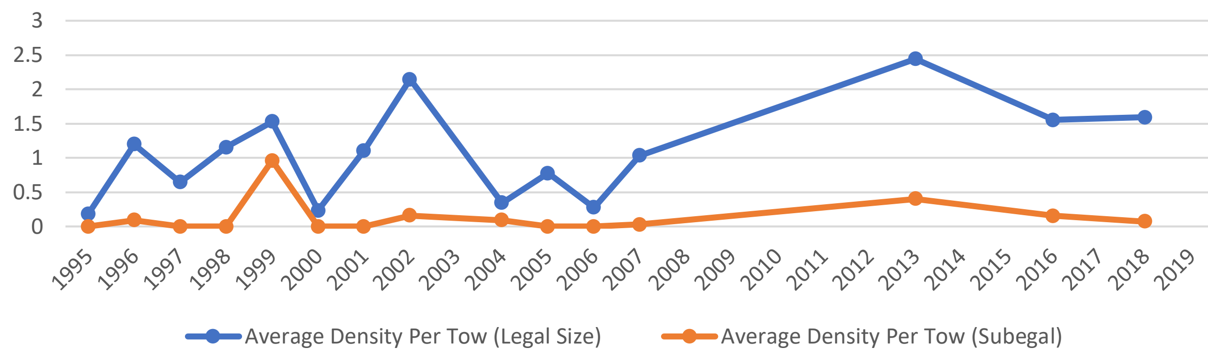


Figure H - 10. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) in western Bristol Harbor, 1999-2019. Source: DEM Shellfish Dredge Survey: stratum 6, stations 1-5, 7-8, 11-13.

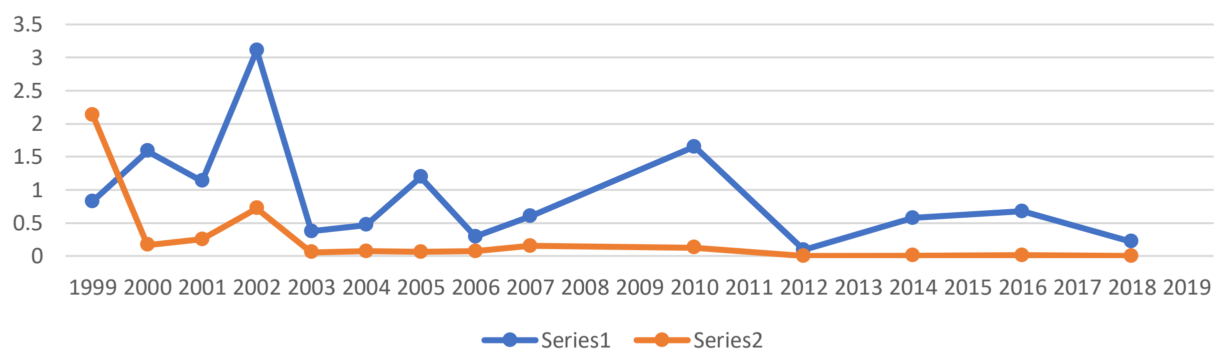


Figure H - 11. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) in Friar's Cove (Middle West Passage), 1995-2019. Source: DEM Shellfish Dredge Survey: stratum 6.

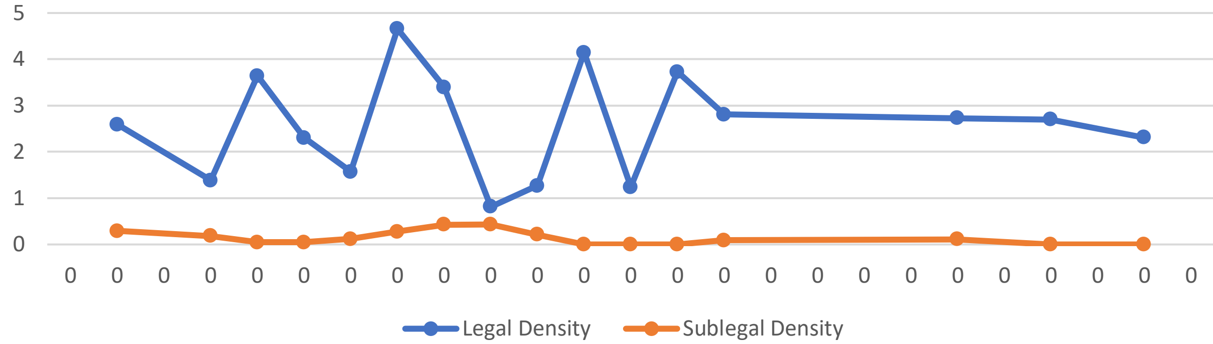


Figure H - 12. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) from Rome Point to Plum Point (Middle West Passage), 1995-2019. Source: DEM Shellfish Dredge Survey: stratum 11, stations 23-24; Stratum 12, stations 4-5.

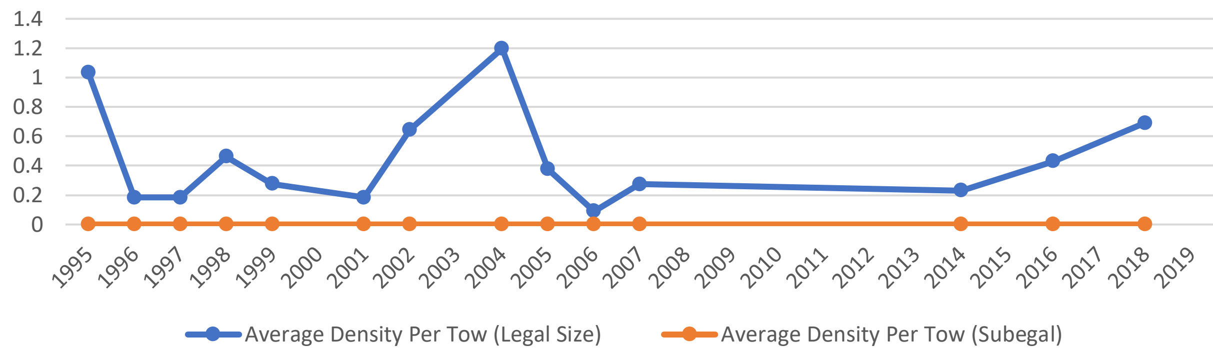


Figure H - 13. Density (individuals/m^2) of legal (hinge width >1") and sublegal (hinge width <1") quahogs (*Mercenaria mercenaria*) in Dutch Island Harbor, 1995-2019. Source: DEM Shellfish Dredge Survey: stratum 15.

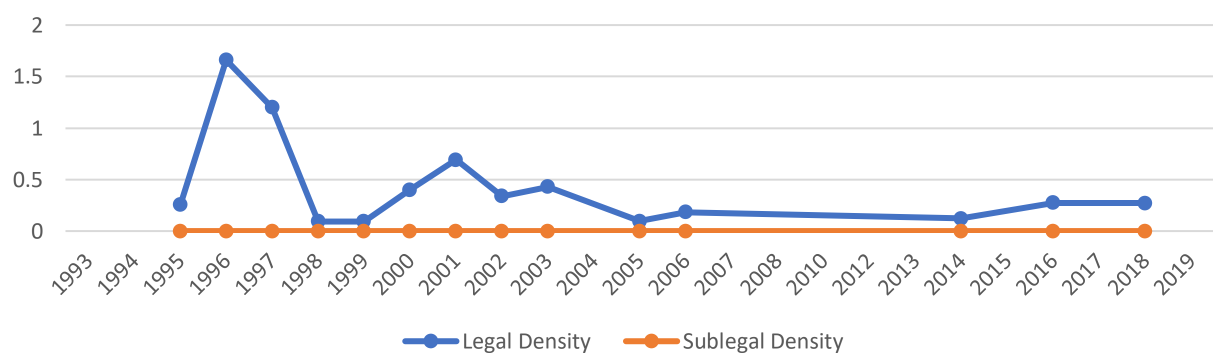


Table H - 1. Number of tows per year in Narragansett Bay in DEM's Shellfish Dredge Survey for 13 geographic areas of interest.

Year	Figure H-1 Barrington Beach	Figure H-2 Conimicut to Rocky Point	Figure H-3 Ohio Ledge	Figure H-4 Western Greenwich Bay	Figure H-5 Eastern Greenwich Bay	Figure H-6 High Banks	Figure H-7 Hunts Ledge, Middle Ground	Figure H-8 Pine Hill	Figure H-9 Potters Cove to Mt. Tom	Figure H-10 Western Bristol Harbor	Figure H-11 Friars Cove	Figure H-12 Rome Point to Plum Point	Figure H-13 Dutch Island Harbor
1993				113	170								
1994	14	17	7		1	11	26	4			5		
1995		1						6	2			5	4
1996	4	5				2	4		1		1	1	1
1997	6	8	4	7	8	6	8	2	1		2	1	1
1998	7	7	4	6	7	2	8	4	2		2	1	1
1999	12	15	5	11	12	7	7	1	3	2	4	1	1
2000	7	3	4	6	8	1	7		2	2	2		3
2001	6	4	3	4	8	2	4	2	2	2	2	1	2
2002	6	8	2	4	7	4	8	2	3	2	2	1	3
2003	9	11	2	13	18	7	11	1		4	2		3
2004	5	5	2	10	18	3	9	2	3	4	1	3	
2005	4	6	2	6	10	1	6	2	1	3	1	1	1
2006	4	3	2	11	20	3	3	2	1	1	1	1	1
2007	4	5	2	8	12	2	3	6	3	1	1	1	
2008	17	18	10										
2009													
2010				39	32	17	22			12			
2011													
2012				12	22	8	17	2		1			
2013	18	18				7	16	5	7				
2014			10	13	20			5		10	5	4	3
2015	17	18	10	11	18	8	17	4					
2016				11	19			5	7	8	4	4	3
2017	16	18	10	12	20	7	16	4					
2018	14			11	17			6	7	8	4	2	3
2019				10	19	2	6	2					

Figure H - 14. Quahog (*Mercenaria mercenaria*) landings by count, <u>Upper Bay</u> (shellfish tagging areas 1A and 1B), 2012-2019. Source: DEM Landings Statistics.

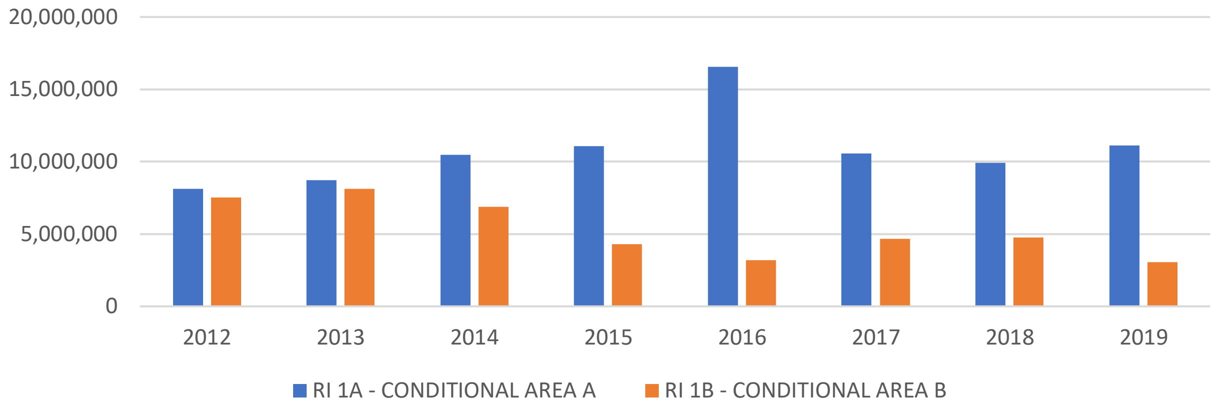


Figure H - 15. Quahog (*Mercenaria mercenaria*) landings by count, Greenwich Bay (shellfish tagging areas 2A, 2B, and 2C), 2013-2019. Source: DEM Landings Statistics.

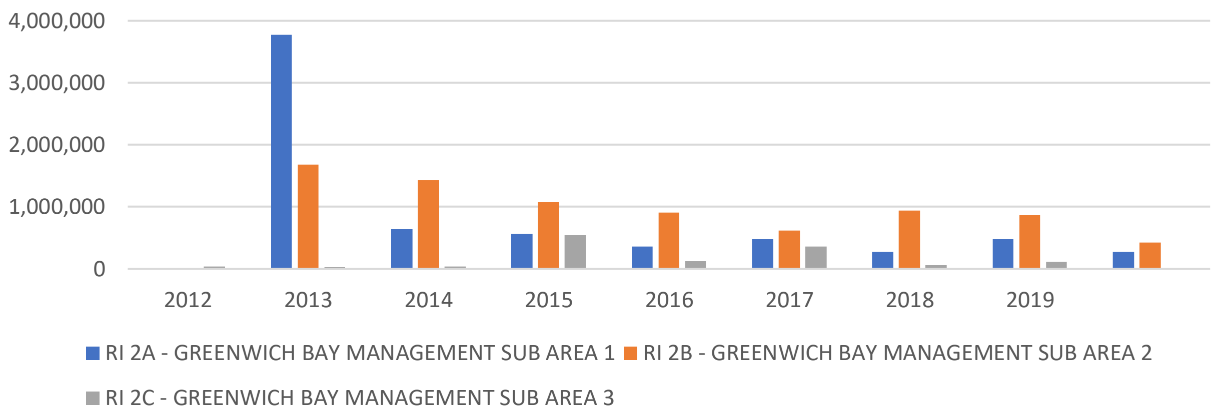


Figure H - 16. Quahog (*Mercenaria mercenaria*) landings by count, West Passage (shellfish tagging areas 3H and 3W), 2012-2019. Source: DEM Landings Statistics.

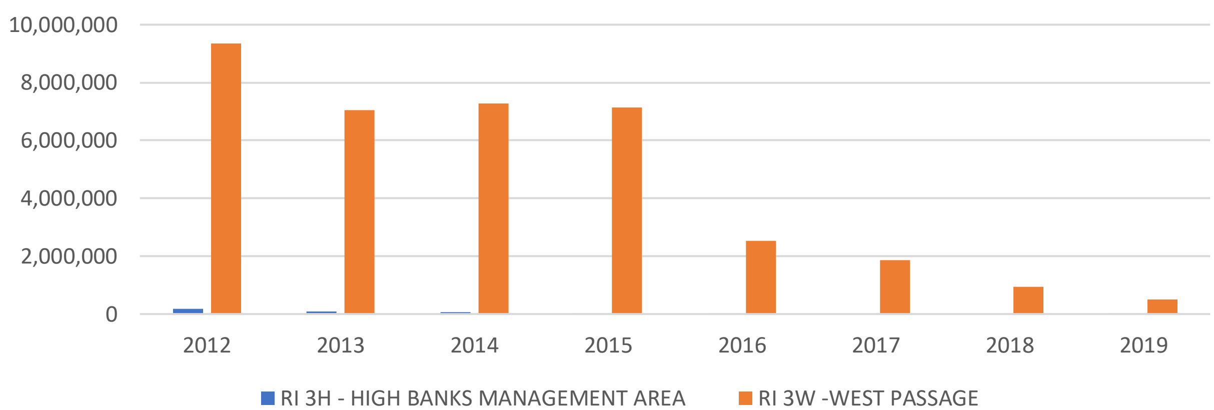
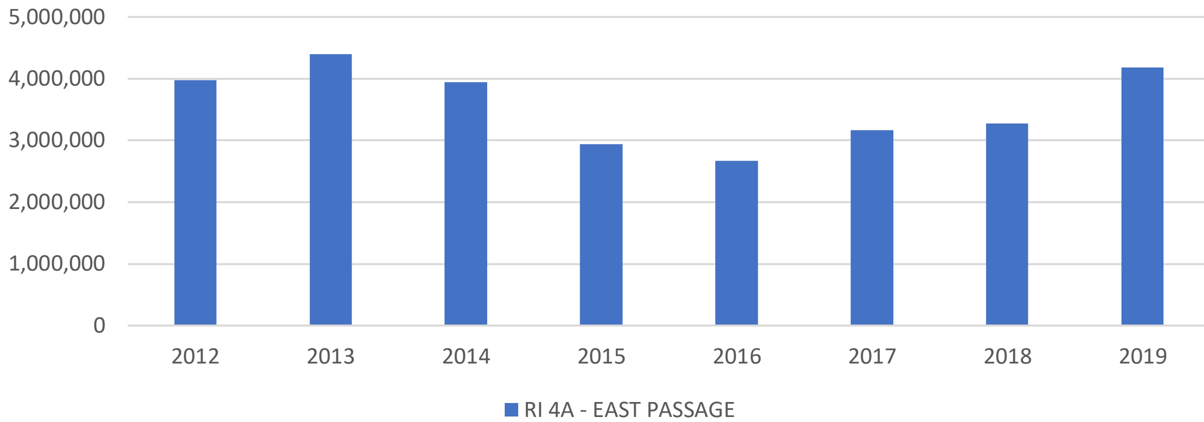


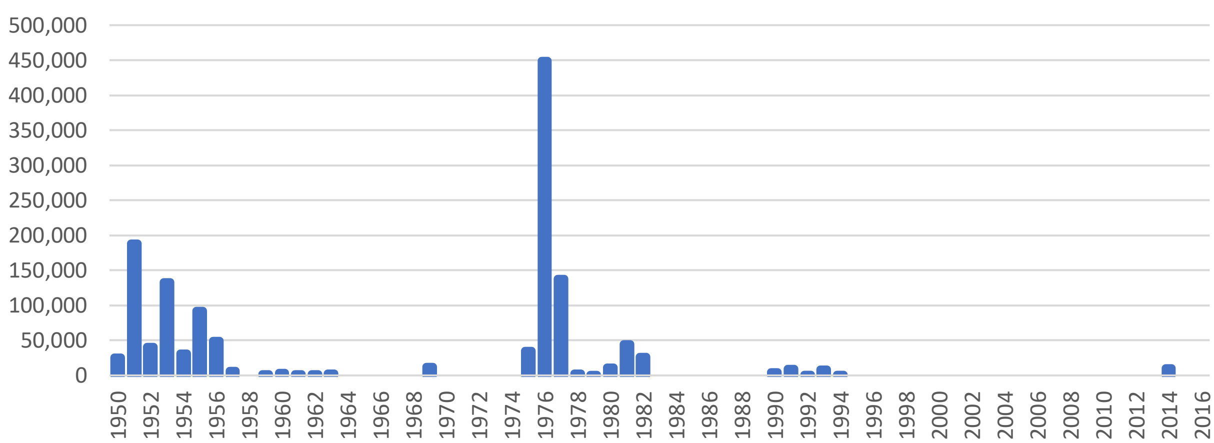
Figure H - 17. Quahog (*Mercenaria mercenaria*) landings by count, from East Passage (shellfish tagging area 4A), 2012-2019. Source: DEM Landings Statistics.



Bay scallops (*Argopecten irradians*)

To our knowledge, there has been no long-term fishery-independent monitoring of the abundance of bay scallops in Narragansett Bay. Fishery-dependent landings data are available for Rhode Island as a whole from NOAA Fishery Landings Statistics (see Figure H - 18). However, these landings figures do not disaggregate Narragansett Bay from other areas where bay scallops may be caught, such as the Sakonnet River and coastal salt ponds. DEM has collected tagging area-specific shellfish landings since 2006, but there are no records of bay scallops in these landings data – either because there have been no landings, or because these data are subject to the "rule of three" to protect harvester confidentiality.

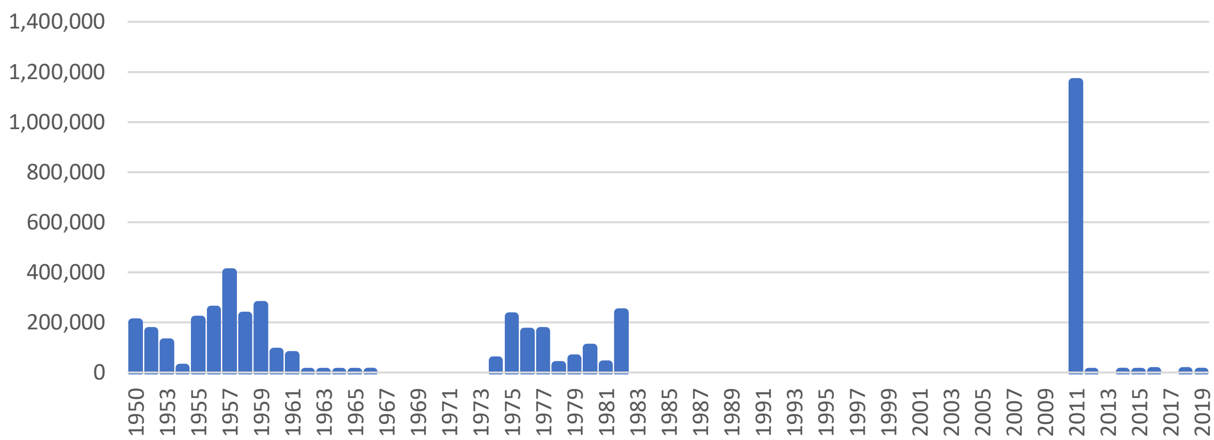
Figure H - 18. Commercial landings of bay scallops (*Argopecten irradians*) by weight (pounds) in Rhode Island, 1950-2019. Source: NOAA Commercial Fisheries Landings Statistics.



Mussels (*Mytilus edulis*)

To our knowledge, there has been no long-term fishery-independent monitoring of the abundance of blue mussels in Narragansett Bay. Fishery-dependent landings data is available for Rhode Island as a whole from NOAA Fishery Landings Statistics (see Figure H - 19). However, these landings figures do not disaggregate Narragansett Bay from other areas where mussels may be caught. DEM has collected tagging area-specific mussel landings since 2006, but these data are very intermittent, due to the "rule of three," which protects harvester confidentiality by blocking access to data for any year in which three or fewer individuals harvested a species.

Figure H - 19. Commercial landings of blue mussels (*Mytilus edulis*) by weight (pounds) in Rhode Island, 1950-2019. Source: NOAA Commercial Fisheries Landings Statistics.



Oysters (*Crassostrea virginica*)

To our knowledge, there has been no long-term fishery-independent monitoring of the abundance of oysters in Narragansett Bay. However, fishery-dependent landings data are available for Narragansett Bay since 2006 from DEM Landings Statistics (see Figure H - 20) and for Rhode Island as a whole since 1950 from NOAA Fishery Landings Statistics (see Figure H - 21). NOAA landings figures do not disaggregate Narragansett Bay from other areas where oysters may be caught, such as the Sakonnet River and coastal salt ponds, and do not distinguish between wild and farmed oysters.

Figure H - 20. Commercial landings of wild oysters (*Crassostrea virginica*) by weight (pounds) harvested in Narragansett Bay, 2006-2019. Source: DEM Landings Statistics.

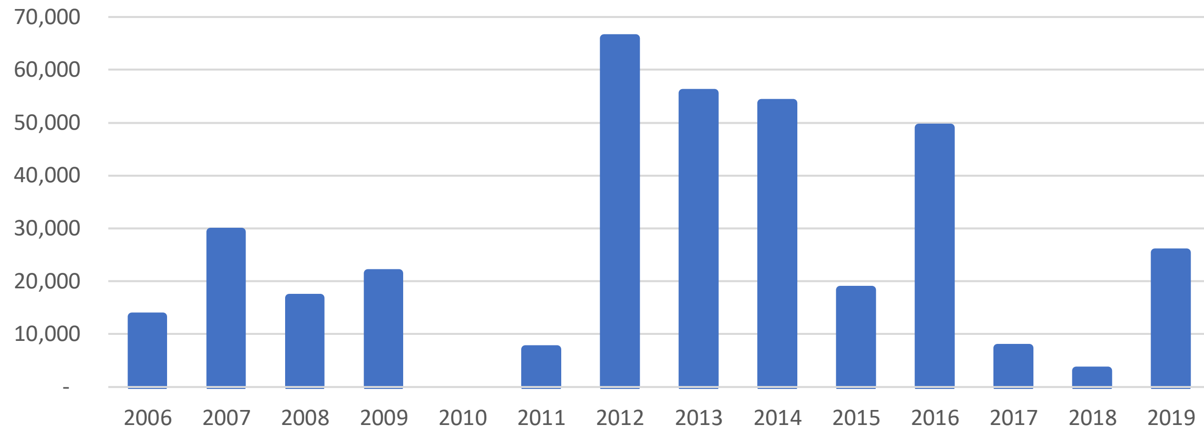
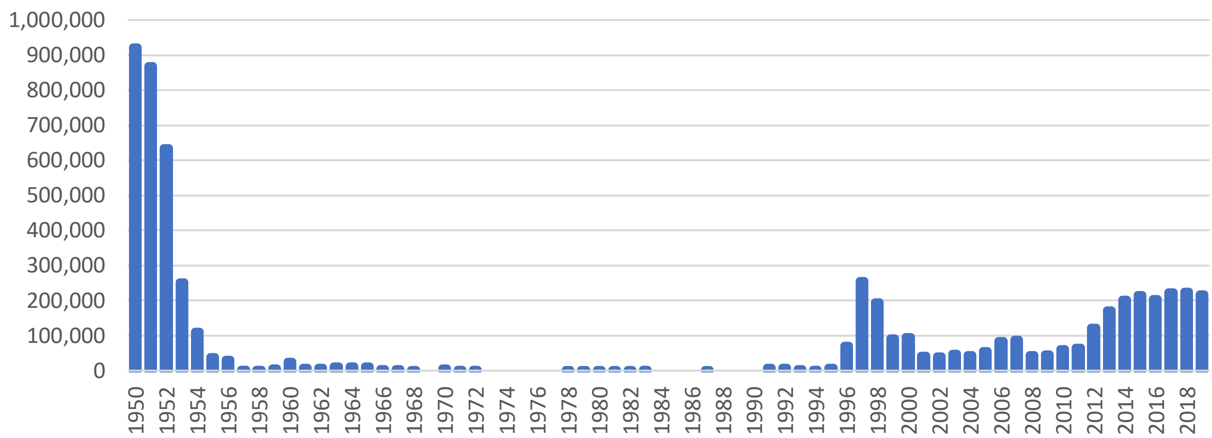


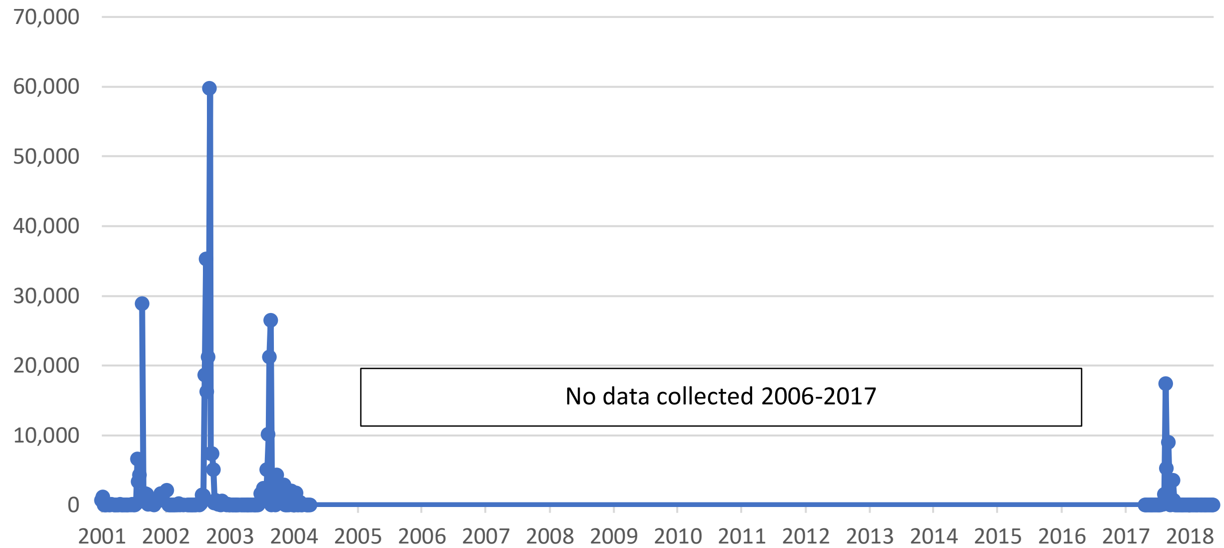
Figure H - 21. Commercial landings of oysters (*Crassostrea virginica*) by weight (pounds) in Rhode Island, 1950-2019. Source: NOAA Commercial Fisheries Landings Statistics.



<u>Deckers (*Crepidula fornicata*)</u>

To our knowledge, there has been no long-term scientific monitoring of deckers in Narragansett Bay. The only data source that we could locate pertaining to this species was the URI GSO Long-Term Plankton Time Series, which counted decker larvae from 2001-2005 and 2018-2019 at its site in the Middle West Passage.

Figure H - 22. Decker (*Crepidula fornicata*) larvae (individuals/m^3) at a location in the Middle West Passage, 2001-2005 and 2018-2019. Source: URI GSO Long-Term Plankton Time Series.



Soft shell clams (*Mya arenaria*)

To our knowledge, there has been no long-term fishery-independent monitoring of the abundance of soft shell clams in Narragansett Bay. However, fishery-dependent landings data are available for Narragansett Bay since 2006 from DEM Landings Statistics (see Figure H - 23) and for Rhode Island as a whole since 1950 from NOAA Fishery Landings Statistics (see Figure H - 24). NOAA landings figures do not disaggregate Narragansett Bay from other areas where soft shell clams may be caught, such as the coastal salt ponds.

Figure H - 23. Commercial landings of soft shell clams (*Mya arenaria*) in pounds, Narragansett Bay, 2006-2019. Source: DEM Landings Statistics.

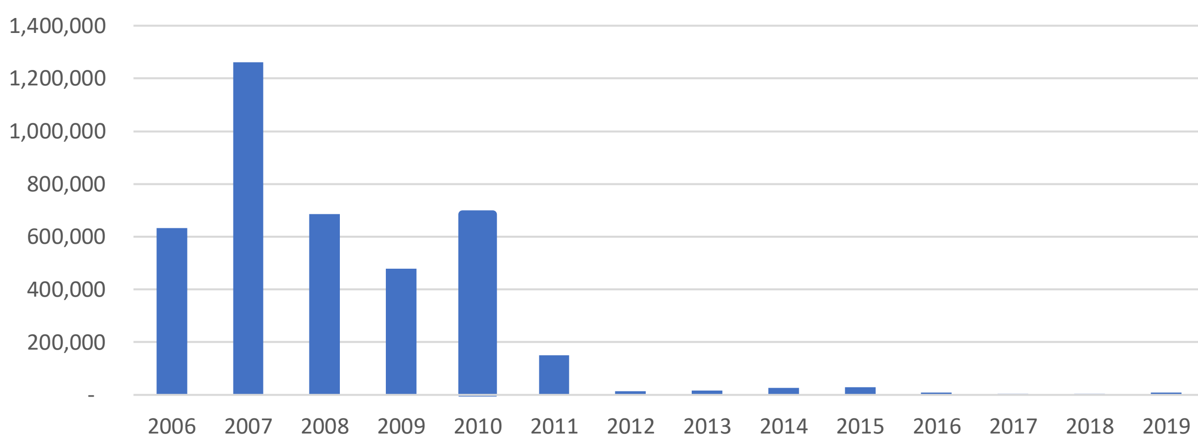
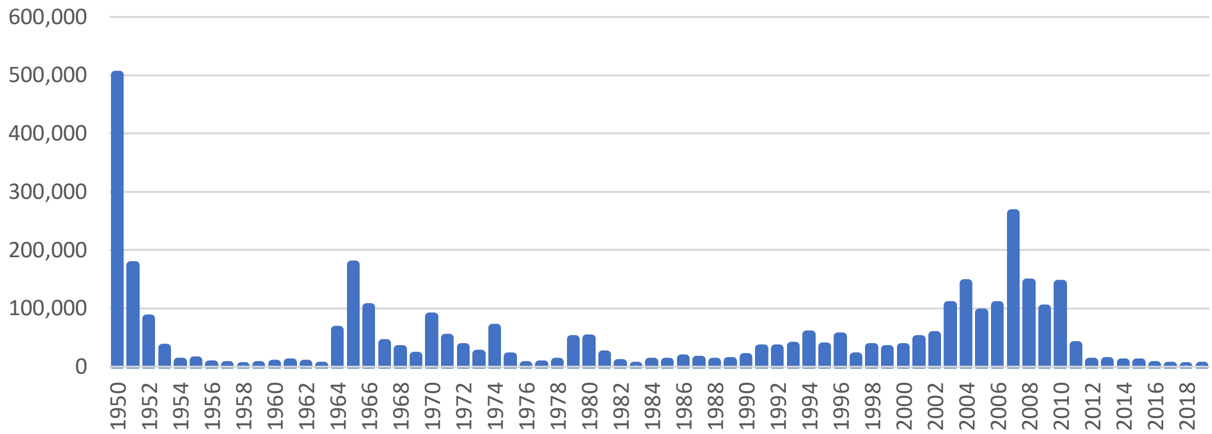


Figure H - 24. Commercial landings of soft shell clams (*Mya arenaria*) by weight (pounds) in Rhode Island, 1950-2019. Source: NOAA Fishery Landings Statistics.



Mobile Invertebrates

<u>Lobsters (*Homarus americanus*)</u>

Long-term data on lobster abundance were obtained from four sources. Trawl survey-based indicators of lobster abundance were obtained from the URI GSO Fish Trawl Survey for the Fox Island Station in the Middle West Passage and from the DEM Coastal Trawl Survey for 9 stations in the <u>Upper Bay</u>, <u>Mount Hope Bay</u>, <u>Middle West Passage</u>, <u>Middle East Passage</u>, <u>Lower West Passage</u>, and <u>Lower East Passage</u>. Data from the DEM Ventless Lobster Trap survey were obtained for legal and sublegal lobsters for the <u>Upper Bay</u>, <u>Upper East Passage</u>, <u>Middle West Passage</u>, <u>Middle East Passage</u>, <u>Lower West Passage</u>, and <u>Lower East Passage.</u>

Figure H - 25. Mean annual number of lobsters (*Homarus americanus*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

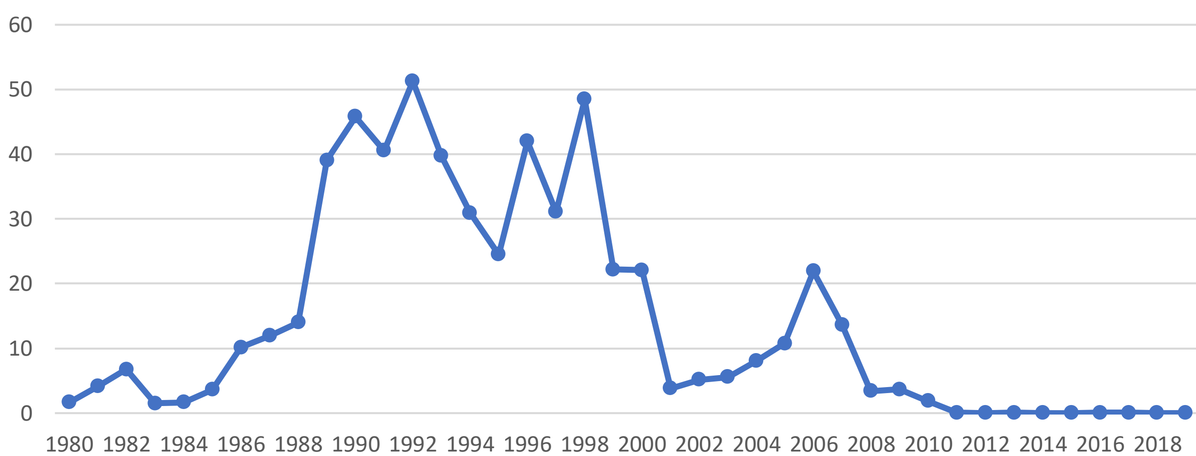


Figure H - 26. Mean annual number of lobsters (*Homarus americanus*) per tow by region of Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.

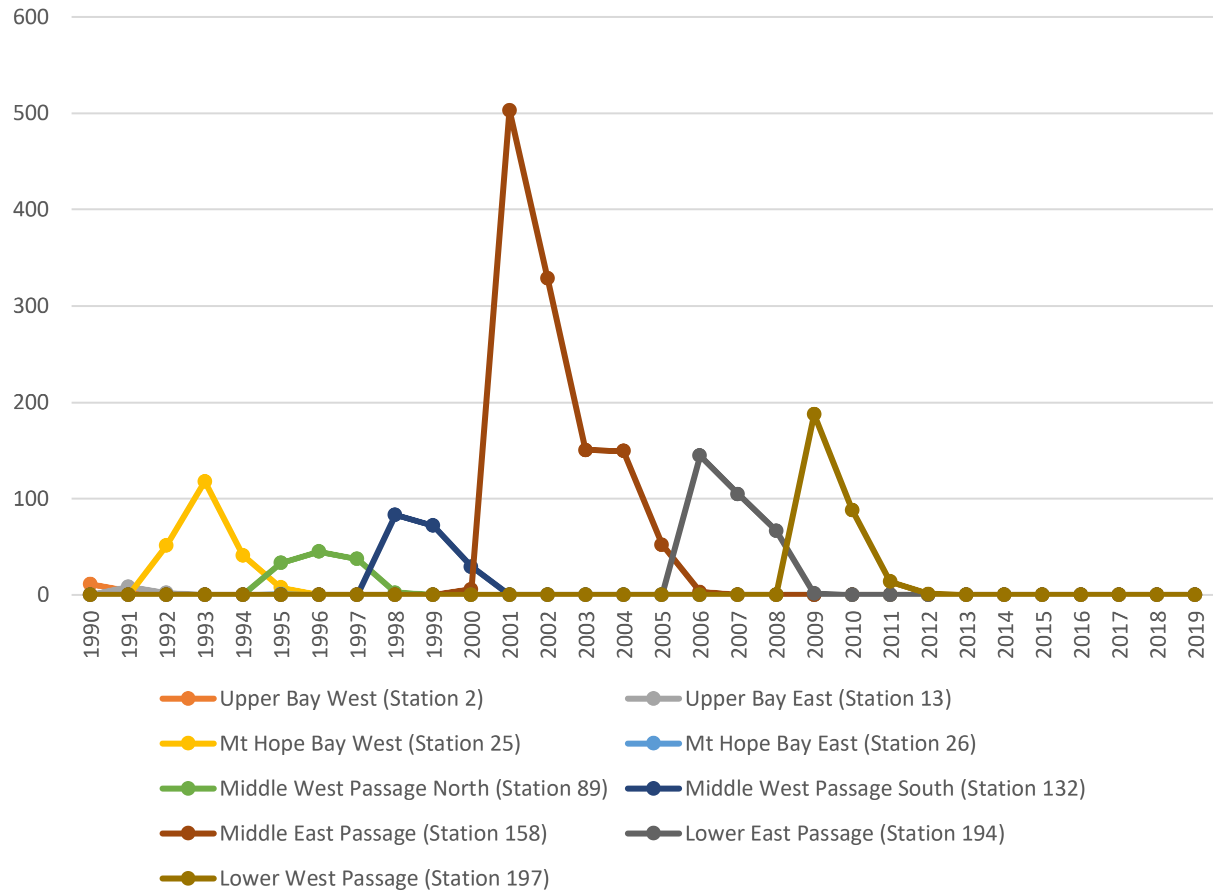


Figure H - 27. Mean annual number of legal and sublegal lobsters (*Homarus americanus*) per trap, 2006-2019, in the Upper Bay and East and West Passages, aggregated. Source: DEM Ventless Trap Survey.

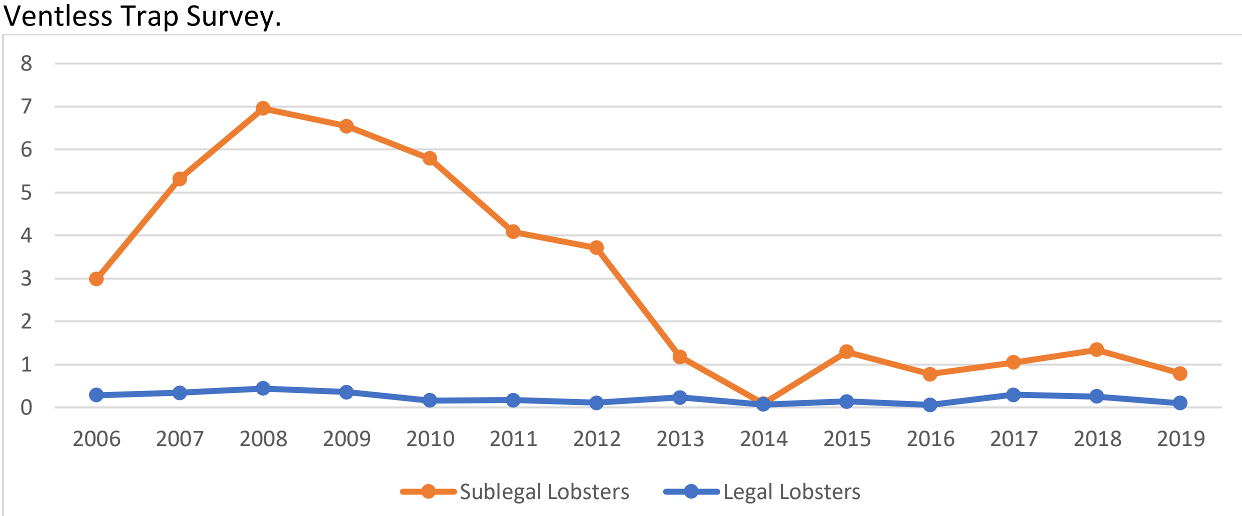
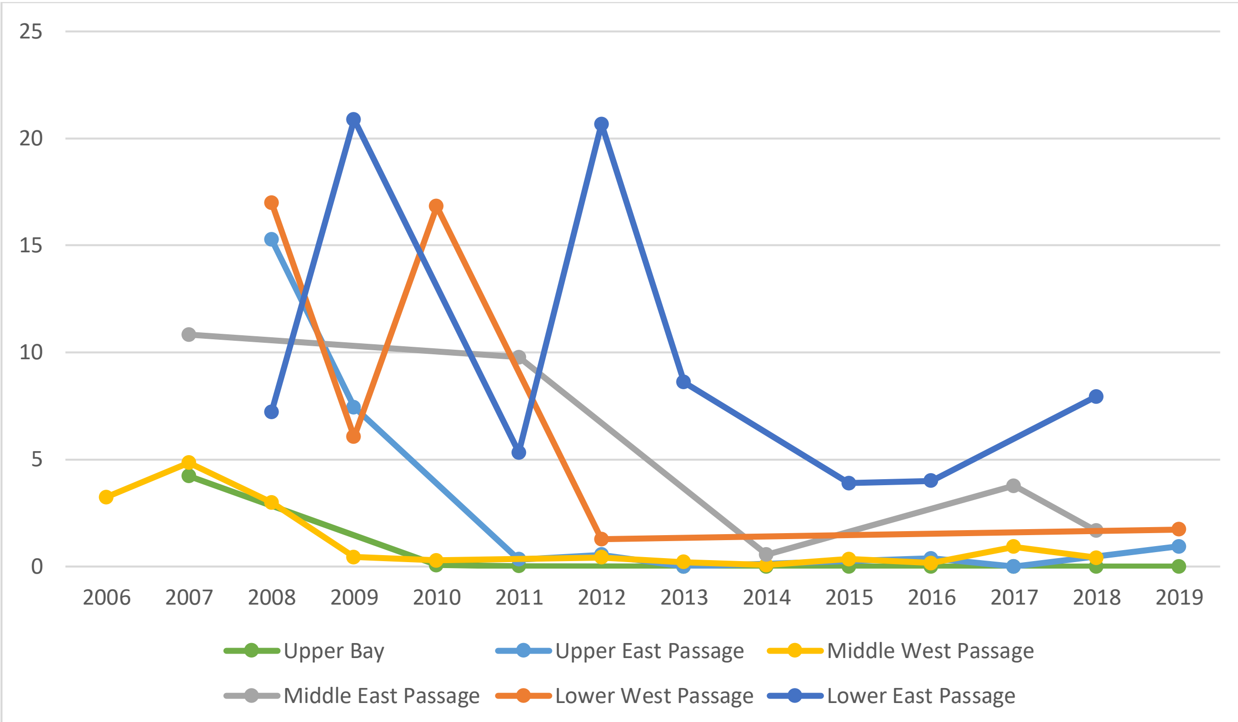


Figure H - 28. Mean annual number of lobsters (*Homarus americanus*) per trap (legal and sublegal combined), 2006-2019, by bay segment. Source: DEM Ventless Trap Survey.



Starfish (*Asterias forbesi*)

There has been little long-term scientific monitoring on the abundance of starfish in Narragansett Bay. Starfish are incidentally caught in both of the long-term trawl surveys (URI GSO Fish Trawl Survey and DEM Coastal Trawl Survey), but are only counted and recorded in the URI GSO survey; the DEM survey does not count them because they are an incidental catch that is not subject to a management plan or commercial or recreational harvest. Starfish have also been counted in the DEM Ventless Trap Survey since 2006.

Figure H - 29. Mean annual number of starfish (*Asterias forbesi*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

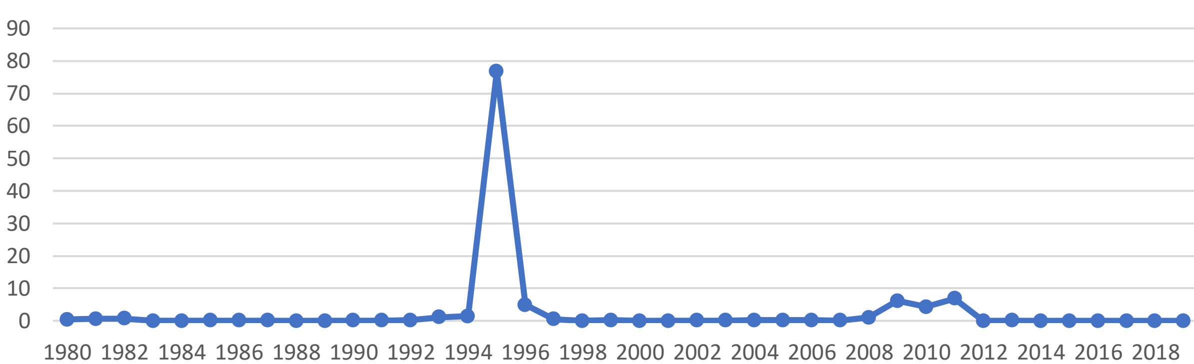
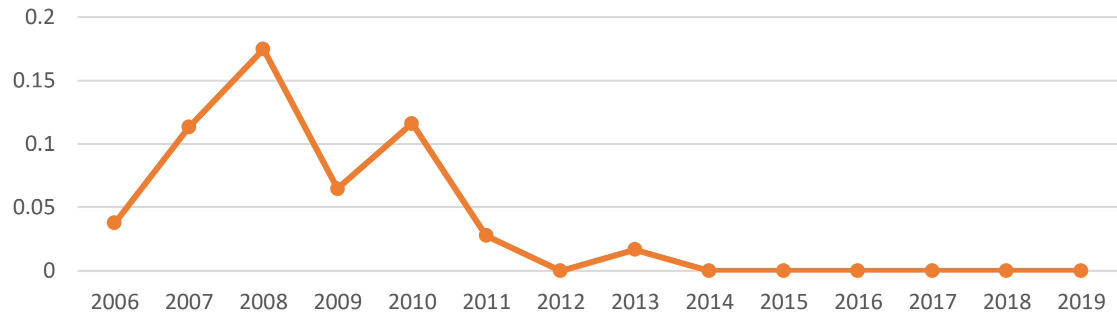


Figure H - 30. Mean annual number of starfish (*Asterias forbesi*) per trap, 2006-2019, in the Upper Bay and East and West Passages, aggregated. Source: DEM Ventless Trap Survey.



Blue crabs (*Callinectes sapidus*)

Long-term data on blue crab abundance were obtained from the URI GSO Fish Trawl Survey for the Fox Island Station in the Middle West Passage and from the DEM Coastal Trawl Survey for Narragansett Bay as a whole.

Figure H - 31. Mean annual number of blue crabs (*Callinectes sapidus*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

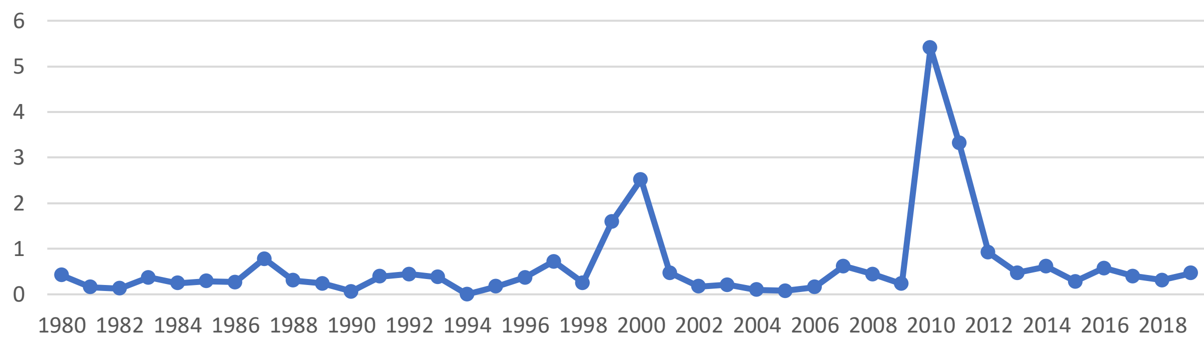


Figure H - 32. Mean annual number of blue crabs (*Callinectes sapidus*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.

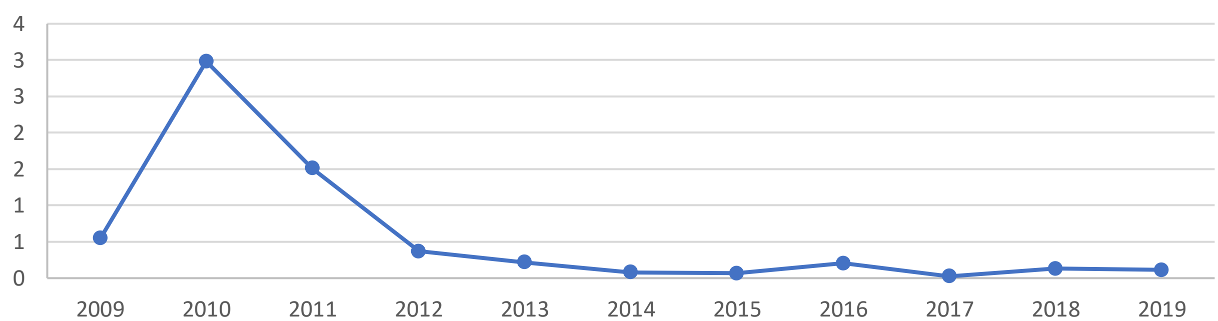
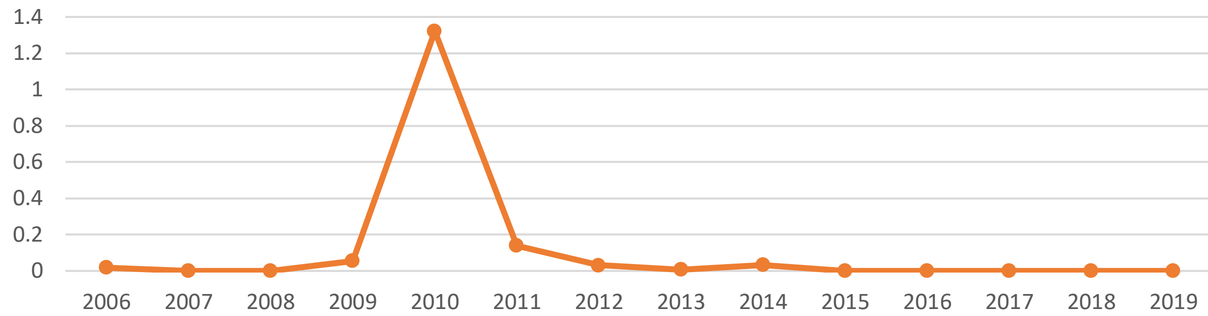


Figure H - 33. Mean annual number of blue crabs (*Callinectes sapidus*) per trap, 2006-2019, in the Upper Bay and East and West Passages, aggregated. Source: DEM Ventless Trap Survey.



Horseshoe crabs (*Limulus polyphemus*)

Long-term data on horseshoe crab abundance were obtained from three sources. Trawl survey-based data were obtained from the URI GSO Fish Trawl Survey for the Fox Island Station in the Middle West Passage and from the DEM Coastal Trawl Survey for Narragansett Bay as a whole. Data from 2000-2019 were also obtained from the DEM Horseshoe Crab Spawning Survey, a visual hand count that takes place twice a year during full and new moon phases in May at Conimicut Point in the Providence River/Upper Bay.

Figure H - 34. Mean annual number of horseshoe crabs (*Limulus polyphemus*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

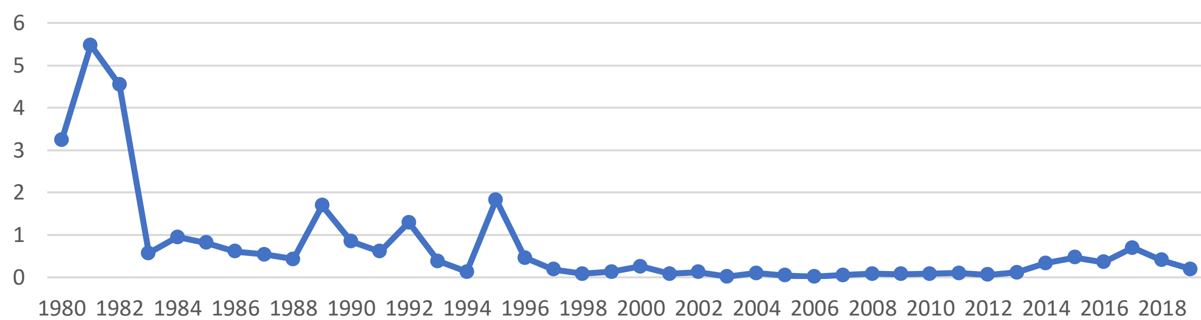


Figure H - 35. Mean annual number of horseshoe crabs (*Limulus polyphemus*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.

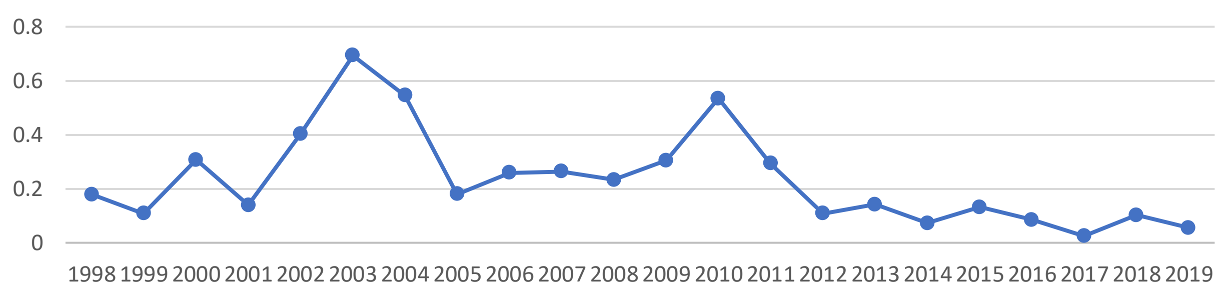
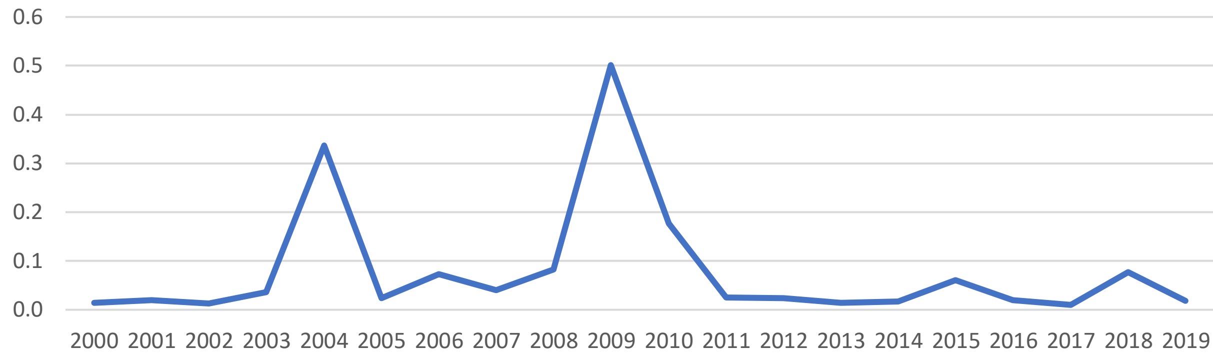


Figure H - 36. Maximum density (crabs/m^2) of horseshoe crabs (*Limulus polyphemus*) counted at Conimicut Point, 2000-2019. Source: DEM Horseshoe Crab Spawning Survey.



Spider Crabs (*Libinia emarginata*)

Long-term data on spider crab abundance were obtained from the URI GSO Fish Trawl Survey for the Fox Island Station in the Middle West Passage and from the DEM Juvenile Fish Seine Survey, which is conducted at 15 stations in Narragansett Bay, including Mount Hope Bay and Greenwich Bay. Since spider crabs are an incidental species in the seine survey, they are not enumerated, but rather are assigned a relative score of "few," "many," or "abundance," based on the subjective estimation of the research crew. In addition, we obtained spider crab abundance data from 2006-2019 from the DEM Ventless Trap Survey.

Figure H - 37. Mean annual number of spider crabs (*Libinia emarginata*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

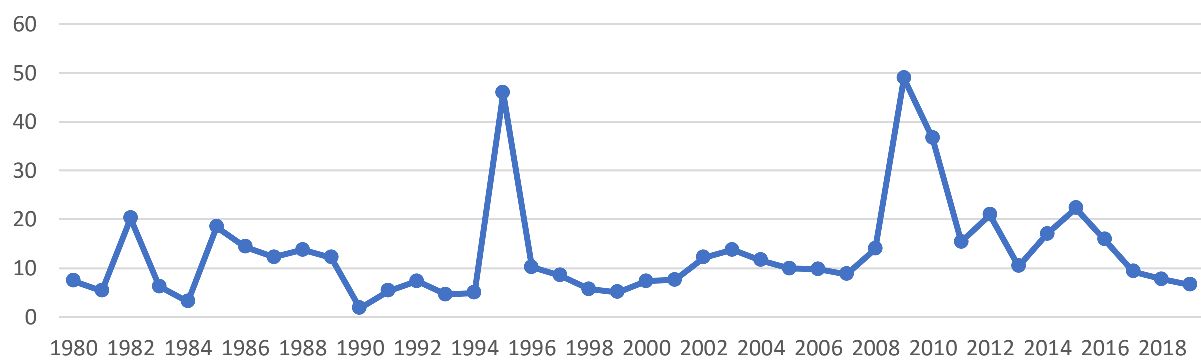


Figure H - 38. Relative estimations of spider crab (*Libinia emarginata*) abundance from the DEM Juvenile Fish Seine Survey. Spider crabs are assigned a subjective score of "few," "many," or "abundance," based on the estimation of the research crew.

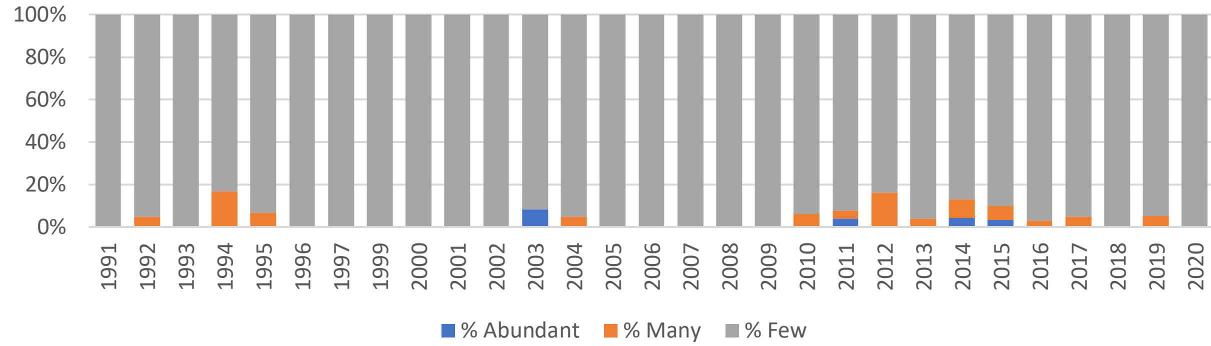
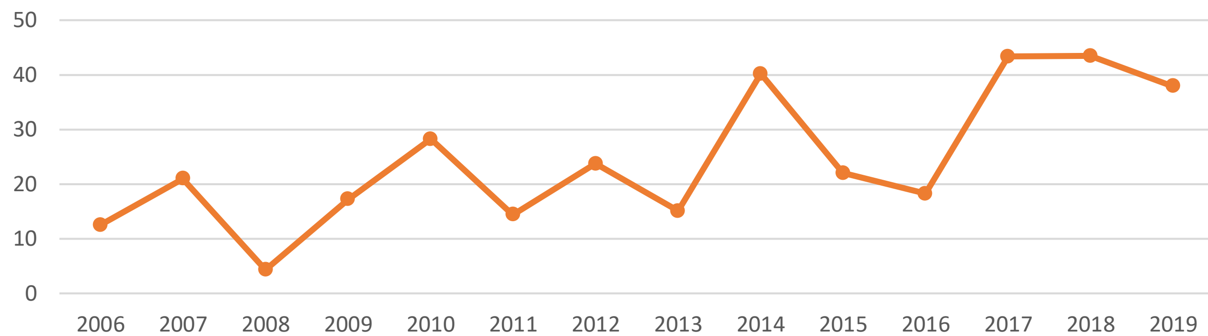


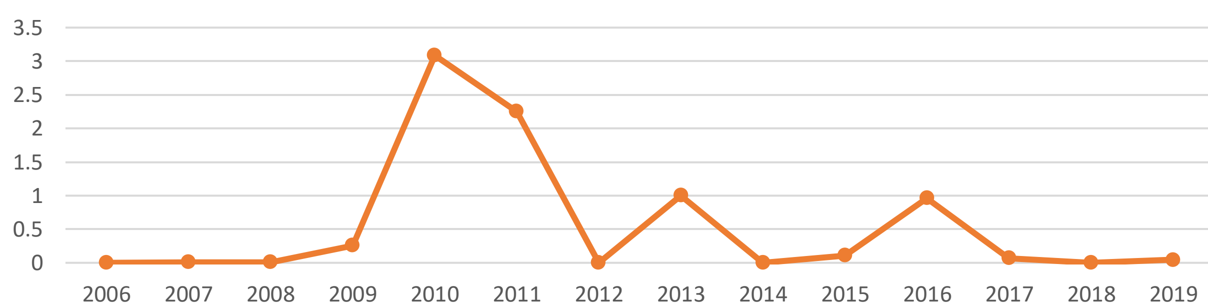
Figure H - 39. Mean annual number of spider crabs (*Libinia emarginata*) per trap, 2006-2019, in the Upper Bay and East and West Passages, aggregated. Source: DEM Ventless Trap Survey.



Green Crabs (*Carcinus maenas*)

Data on the abundance of green crabs in Narragansett Bay were obtained from the DEM Ventless Trap Survey and are presented in Figure H-40.

Figure H - 40. Mean annual number of green crabs (*Carcinus maenas*) per trap, 2006-2019, in the Upper Bay and East and West Passages, aggregated. Source: DEM Ventless Trap Survey.



Whelks: Channeled and Knobbed (*Busycotypus canaliculatus, Busycon carica*)

Long-term data on the abundance of channeled and knobbed whelks is available from the URI GSO Fish Trawl Survey, the DEM Coastal Trawl Survey, and the DEM Shellfish Survey. Mean annual number and weight per tow in these three surveys are plotted in the figures below, reproduced from Angell (2020).

Figure H - 41. Mean annual number and weight of combined whelk (channeled whelk and knobby whelk), 2009-2019. Source: DEM Seasonal Trawl Survey. Reproduced from Angell (2020).

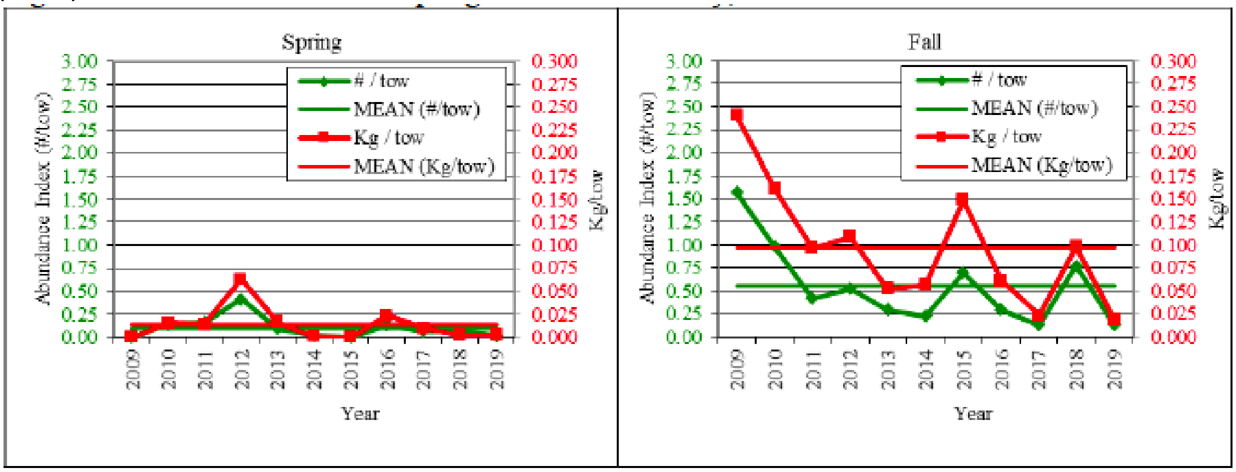


Figure H - 42. Mean annual number and weight of combined whelk (channeled whelk and knobby whelk), 2009-2019. Source: DEM Monthly Trawl Survey. Reproduced from Angell (2020).

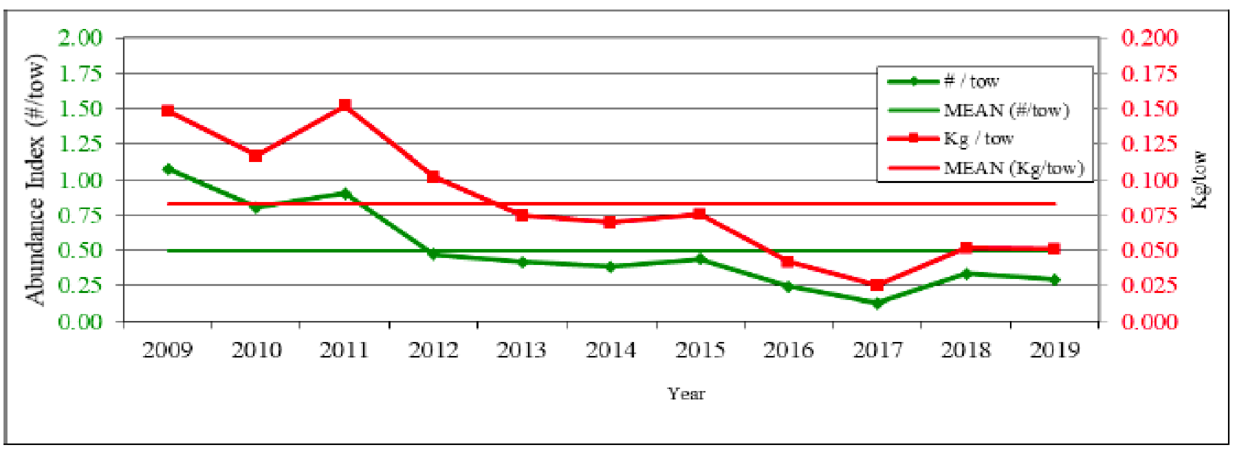


Figure H - 43. Mean annual number and weight of combined whelk (channeled whelk and knobby whelk), 1980-2019. Source: URI GSO Fish Trawl Survey. Reproduced from Angell (2020).

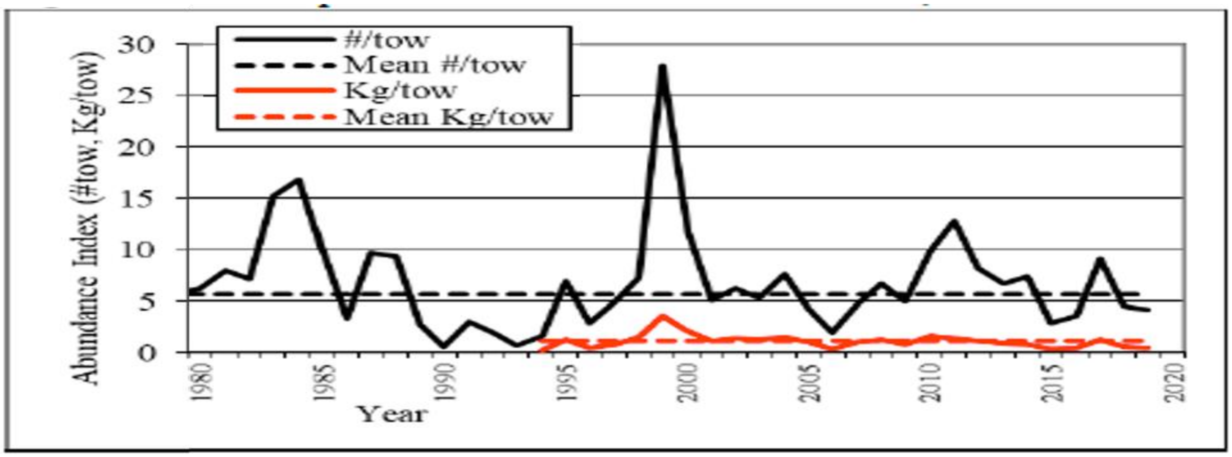
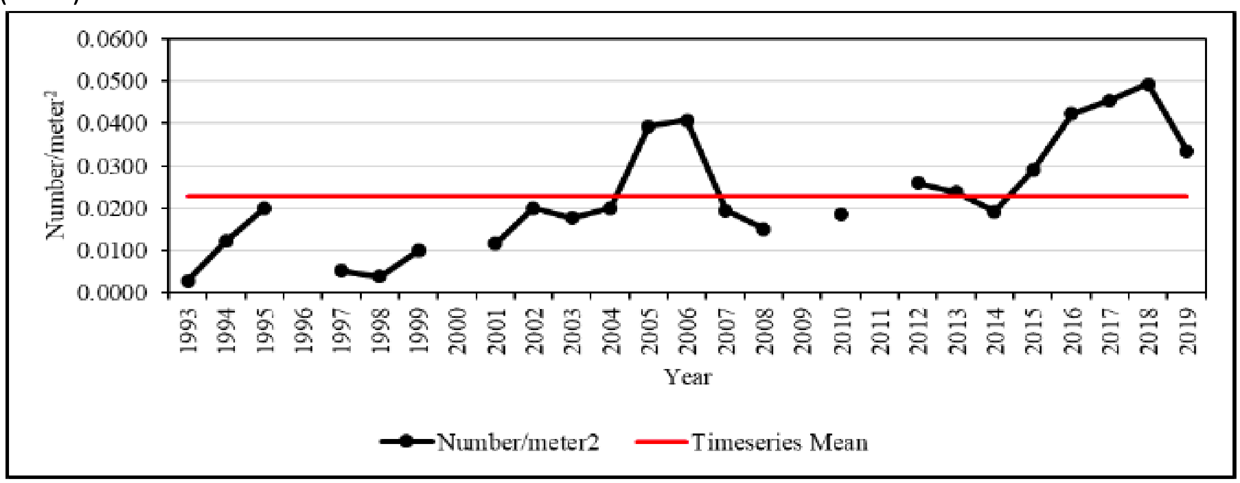


Figure H - 44. Density of combined whelk (channeled whelk and knobby whelk) in Narragansett Bay (all strata combined), 1993-2019. Source: DEM Shellfish Survey. Reproduced from Angell (2020).

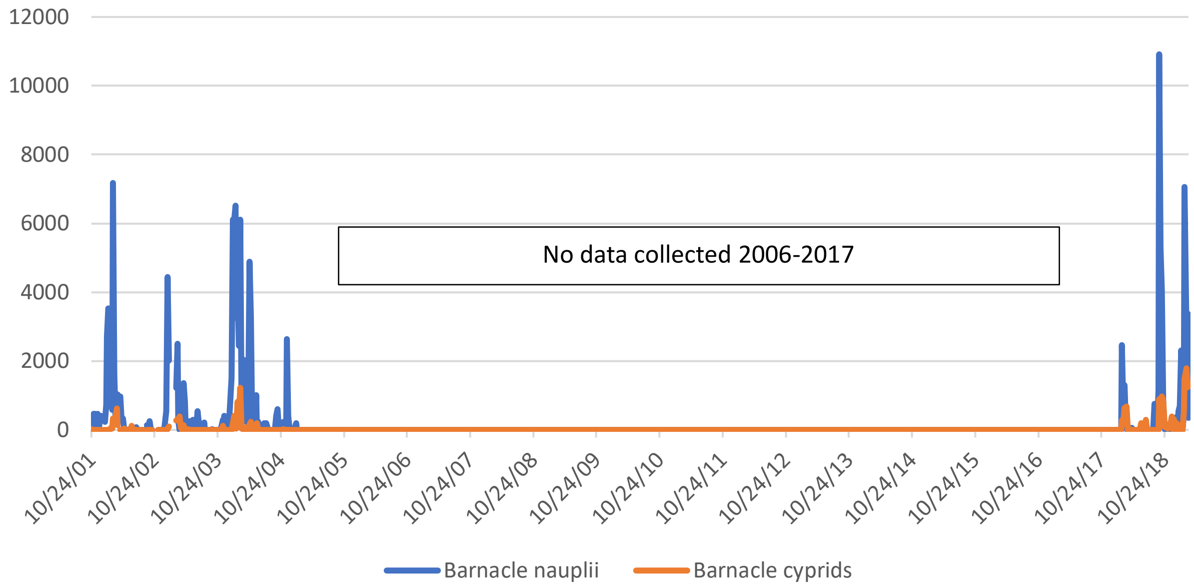


Fouling Invertebrates

Barnacles (Cirripedia: Thoracica)

To our knowledge, there is no long-term scientific monitoring of adult barnacle populations in Narragansett Bay. Several short-term studies were performed by the Mark Bertness and collaborators at Brown University in the 1980s and 1990s, but the only recent data on barnacles comes from the URI GSO Long-Term Plankton Time Series, which counted barnacle larvae in the water column from 2001-2005 and 2018-2019. There have been no scientific studies of adult barnacle abundance or distribution in Narragansett Bay since the 1990s.

Figure H - 45. Barnacle (Cirripedia: Thoracica) larvae (individuals/m^3) at a location in the Middle West Passage, 2001-2005 and 2018-2019. Source: URI GSO Long-Term Plankton Time Series.



Tunicates

Most tunicates found in Narragansett Bay are non-indigenous or cryptogenic species, and thus they are picked up in CRMC Aquatic Invasive Species Monitoring programs at floating docks and on settlement plates. These data are reported out in the regional Bioinvasive Species Rapid Assessment Surveys that have published at three- to six-year intervals since 2000. Table H - 2 presents a summary of species presence from the three most recent Bioinvasive Species Rapid Assessment Surveys. As a native species, sea grapes (*Molgula manhattensis*) are not included in these surveys.

Hydroids

Many hydroid species found in Narragansett Bay are non-indigenous or cryptogenic species, and thus they are picked up in the Bioinvasive Species Rapid Assessment Surveys that have been conducted at irregular intervals since 2000. Table H - 3 presents a summary of presence data on non-indigenous and cryptogenic hydroid species from the three most recent Bioinvasive Species Rapid Assessment Surveys.

Table H - 2. Presence of non-indigenous and cryptogenic tunicate species in the 2010, 2013, and 2019 Bioinvasive Species Rapid Assessment Surveys. 2010 data are from McIntyre et al. 2013, 2013 data are from Wells et al. 2013, and 2019 data are from Pederson et al. 2021.

Species	**2010**				**2013**			**2019**	
	Port Edgewood Marina	**Allen Harbor**	**Fort Adams**	**Kings Beach**	**Port Edgewood Marina**	**Allen Harbor**	**Fort Adams**	**Save the Bay**	**Allen Harbor**
Ascidiella aspersa (European tunicate)			X				X		
Botrylloides violaceus (sheath tunicate)	X	X	X	X		X	X		
Botryllus schlosseri (star tunicate)	X	X	X	X		X	X		
Botryllus sp. (colonial tunicate)						X			
Ciona intesintalis (sea vase)			X						
Didemnum vexillum (pancake batter tunicate or colonial tunicate)			X	X			X		
Diplosoma listerianum (gelatinous tunicate or compound tunicate)			X	X		X	X	X	
Styela canopus (rough tunicate)							X	X	X
Styela clava (club tunicate)		X	X			X	X		

Table H - 3. Presence of non-indigenous and cryptogenic hydroid species in the 2010, 2013, and 2019 Bioinvasive Species Rapid Assessment Surveys. 2010 data are from McIntyre *et al*. 2013, 2013 data are from Wells *et al*. 2013, and 2019 data are from Pederson *et al*. 2021.

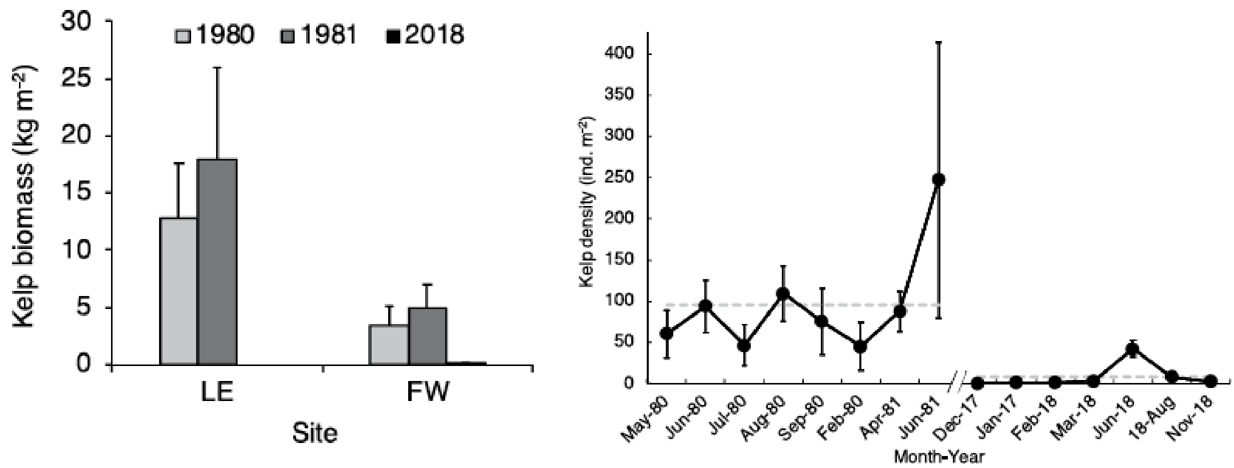
Species	**2010**				**2013**			**2019**	
	Port Edgewood Marina	**Allen Harbor**	**Fort Adams**	**Kings Beach**	**Port Edgewood Marina**	**Allen Harbor**	**Fort Adams**	**Save the Bay**	**Allen Harbor**
Clytia linearis					X	X	X		
Dynamena pumila (sea oak hydroid)				X					
Obelia dichotoma (sea thread hydroid)	X		X					X	
Obelia geniculata (knotted thread hydroid)			X						
Obelia longissimia (bushy wineglass hydroid)		X	X						

Macroalgae

Kelp (*Saccharina latissima*)

To our knowledge, there is no consistent multi-decadal scientific monitoring of kelp populations in Narragansett Bay. However, intermittent monitoring has occurred at locations in the Lower East Passage (Fort Wetherhill) and the Mouth of Narragansett Bay (Land's End). This work was conducted by Brady-Campbell *et al.* (1984) and Feehan *et al*. (2019).

Figure H - 46. Left: Mean kelp biomass (kg/m^2) at Land's End (LE) and Fort Wetherill (FW) in 1980-1981 and 2018. Right: Mean kelp density (individuals/m^2) at Fort Wetherill (FW) from 1980–81 and 2017–18. The gray horizontal dashed lines indicate mean densities from 1980 to 1981 and 2017 to 2018. Sources: Brady-Campbell et al. (1984), Feehan et al. (2019).



Invasive and cryptogenic seaweeds

Many macroalgal species found in Narragansett Bay are non-indigenous or cryptogenic species, and thus they are picked up in the Bioinvasive Species Rapid Assessment Surveys that have been conducted at irregular intervals since 2000. Table H - 4 presents a summary of data on the presence of non-indigenous or cryptogenic macroalgal species from the three most recent Bioinvasive Species Rapid Assessment Surveys.

Table H - 4. Presence of non-indigenous and cryptogenic macroalgae species in the 2010, 2013, and 2019 Bioinvasive Species Rapid Assessment Surveys. 2010 data are from McIntyre et al. 2013, 2013 data are from Wells et al. 2013, and 2019 data are from Pederson et al. 2021.

Species	2010				2013			2019	
	Edgewood Marina	Allen Harbor	Fort Adams	Kings Beach	Edgewood Marina	Allen Harbor	Fort Adams	Save The Bay	Allen Harbor
Bryopsis plumosa						X	X		X
Codium fragile (dead man's fingers or green fleece)			X						
Cladophora sericea								X	
Gracilaria vermiculophylla (wormleaf)				X	X	X			
Grateloupia turuturu (Devil's tongue weed / Asian red seaweed)		X	X	X		X	X		
Dasysiphonia japonica (siphoned feather weed)			X				X		
Lomentaria clavellosa (club bead-weed)							X		
Neosiphonia harveyi (doughball weed)	X	X	X	X	X	X	X		
Pyropia yezoensis (open sea nori)									
Ulva compressa								X	X

Plankton

The phytoplankton community in Narragansett Bay is well studied. The URI GSO Long-Term Plankton Time Series has collected phytoplankton samples and chlorophyll data at a station near Wickford (Middle West Passage) continuously since 1957. The Narragansett Bay Commission (NBC) has collected phytoplankton samples near Bullock's Reach (Providence River) since 2012. Since 2004, a coalition of partners including DEM, URI, and NBC, has operated a network of monitoring buoys that collect data on chlorophyll concentrations in the water column. This network currently has 15 buoys operating in the bay.

Compared with the phytoplankton community, long-term data on the zooplankton community is more sporadic. The URI GSO Long-Term Plankton Time Series has collected zooplankton weekly since 2001, but only samples from 2001-2005 and 2018-present have been identified and enumerated in the lab. A previous zooplankton count using slightly different methods ied out by URI GSO between 1972–1997.

Figure H - 47. Summer surface chlorophyll (a) before, (b) during, and (c) after nutrient reduction at stations in the Providence River (PR), upper bay (UB), mid bay (MB), and lower bay (LB) ± standard deviation. Reproduced from Oviatt et al. (2017).

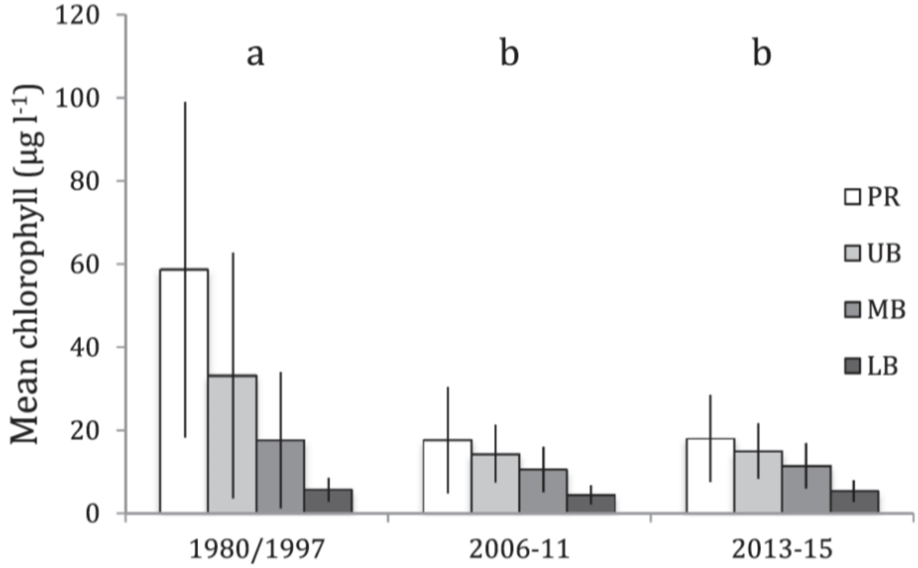


Figure H - 48. Annual average surface chlorophyll a, with one standard deviation above and below the mean, from the URI GSO plankton survey collection station in the Middle West Passage. Source: URI GSO Narragansett Bay Long-Term Plankton Time Series; data plot by Tricia Thibodeau, URI GSO.

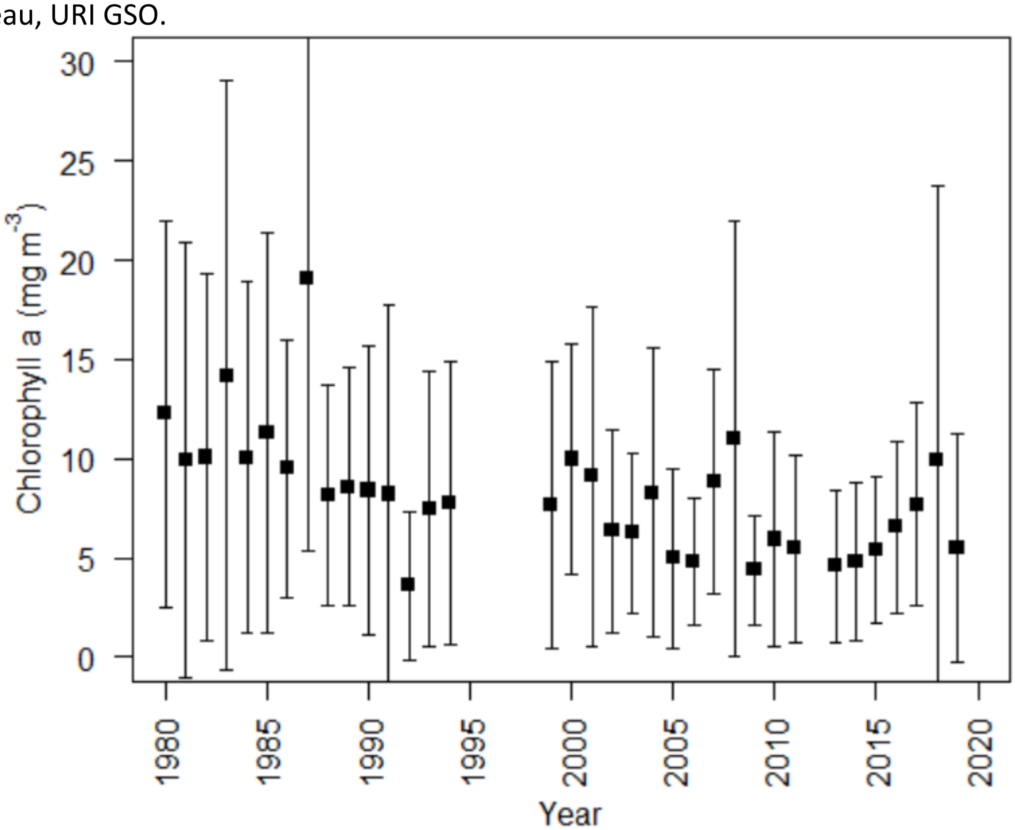


Figure H - 49. Biweekly phytoplankton concentration (cells/mL) at Bullocks Reach (Providence River), 2012-2019. Source: Narragansett Bay Commission Phytoplankton Survey.

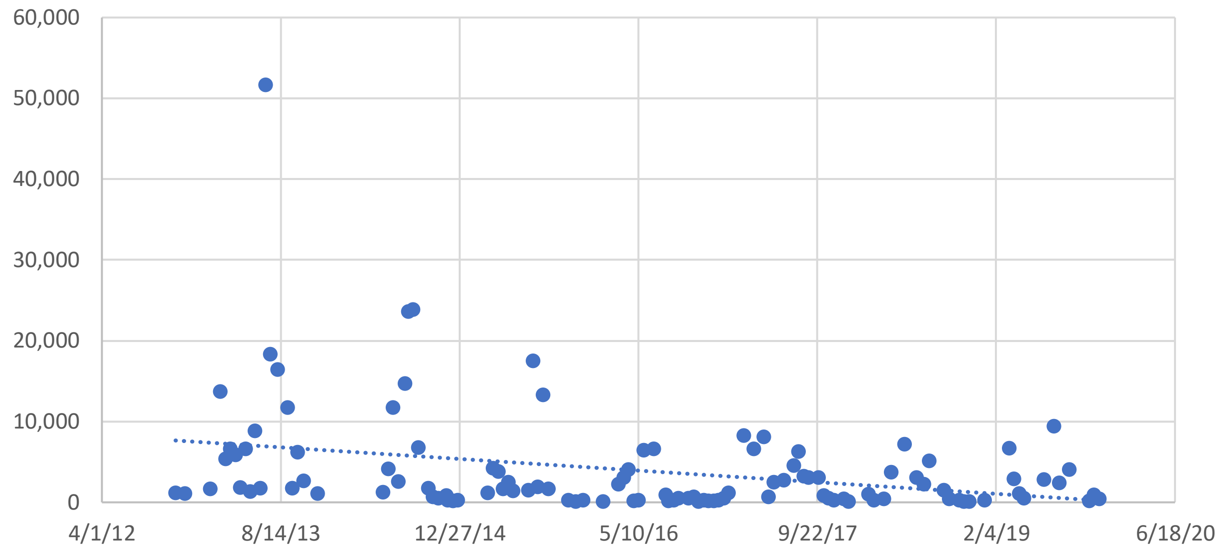


Figure H - 50. Total zooplankton count (individuals/m^3) from the URI GSO plankton survey collection station in the Middle West Passage, 2001-2005 and 2018-2019. Source: URI GSO Narragansett Bay Long-Term Plankton Time Series.

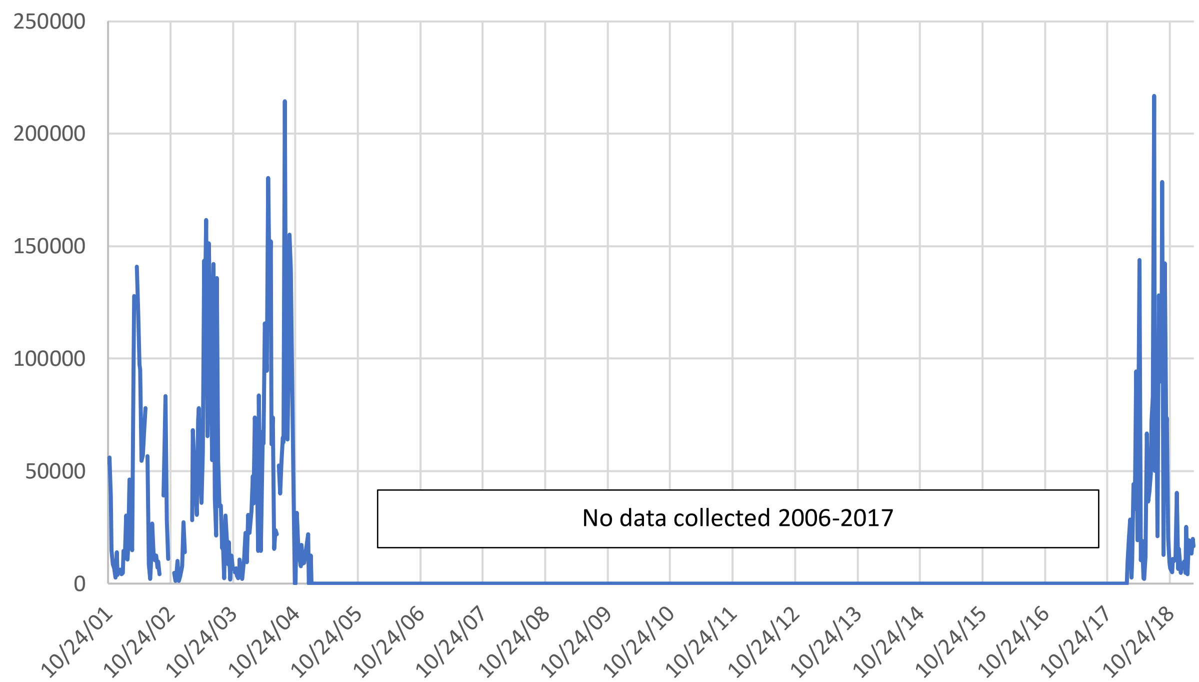
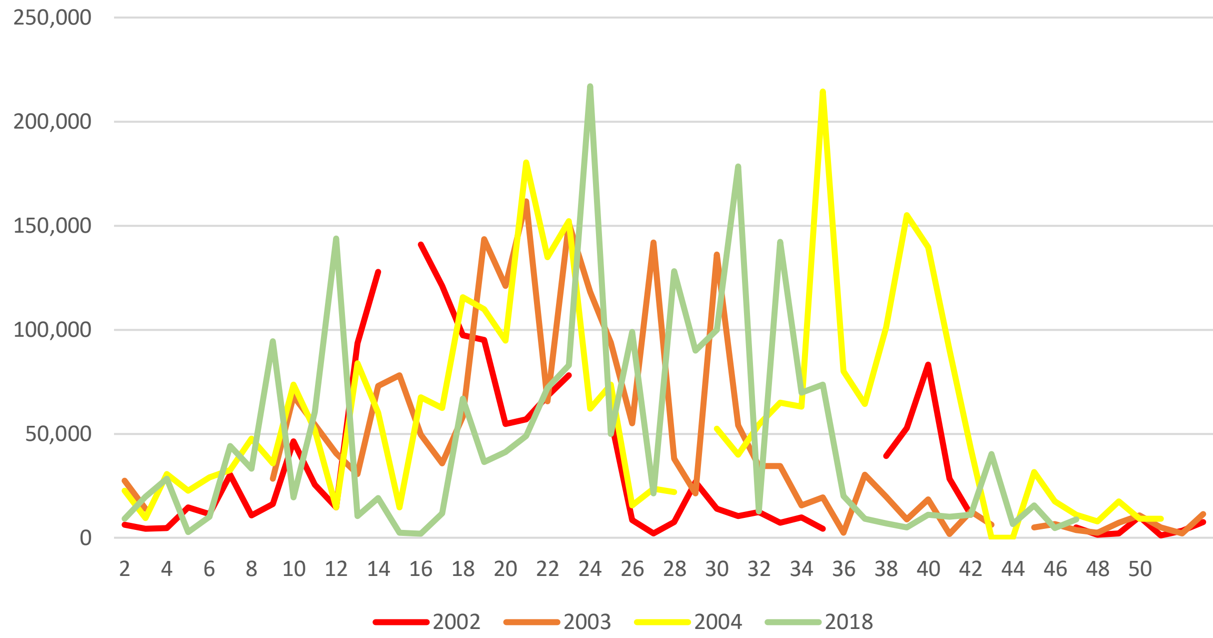


Figure H - 51. Weekly zooplankton (individuals/m^3), from the URI GSO plankton survey collection station in the Middle West Passage, 2002-2004 and 2018. Weeks are numbered 1-52 according to the calendar year. Source: URI GSO Narragansett Long-Term Plankton Time Series.



Finfish

Long-term monitoring data on finfish abundance in Narragansett Bay derives chiefly from two sources: the URI GSO Fish Trawl Survey and the DEM Coastal Trawl Survey. Landings data are also available, but since finfish are widely caught throughout Rhode Island state waters, landings data are not very useful for understanding dynamics within Narragansett Bay alone.

Black Sea Bass (*Centropristis striata*)

Figure H - 52. Mean annual number of black sea bass (*Centropristis striata*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

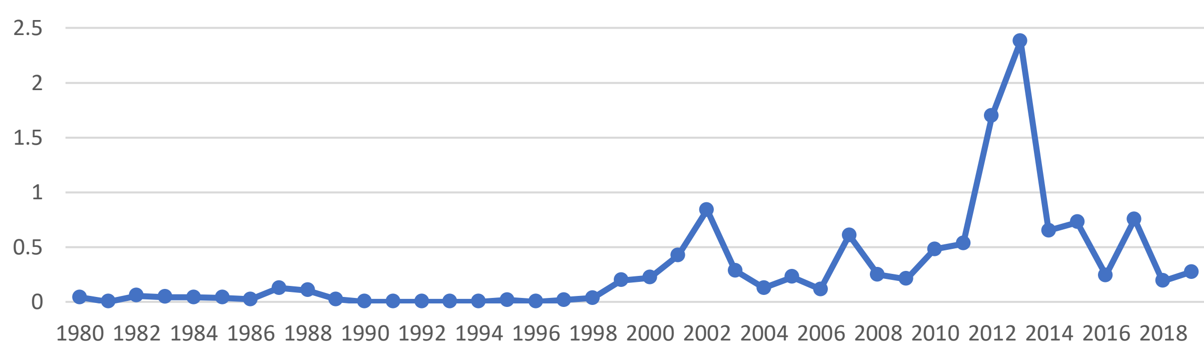
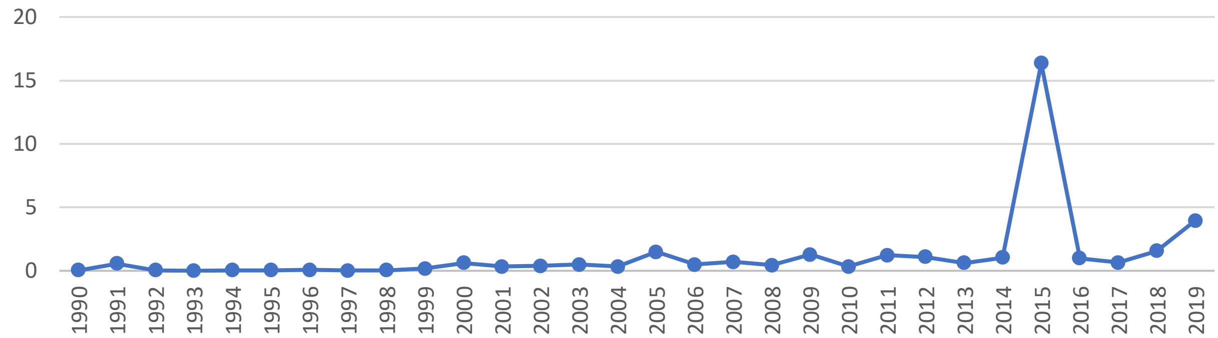
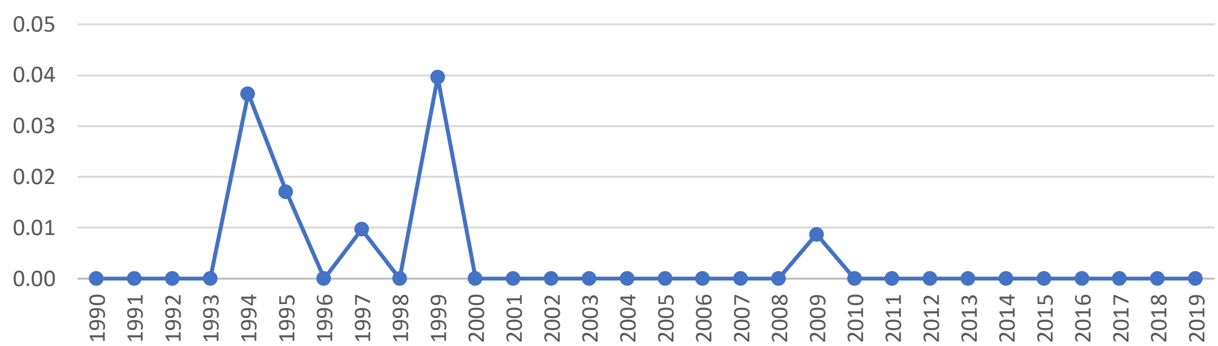


Figure H - 53. Mean annual number of black sea bass (*Centropristis striata*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



Eels (*Anguilla rostrata*)

Figure H - 54. Mean annual number of eels (*Anguilla rostrata*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



Scup (*Stenotomus chrysops*)

Figure H - 55. Mean annual number of scup (*Stenotomus chrysops*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

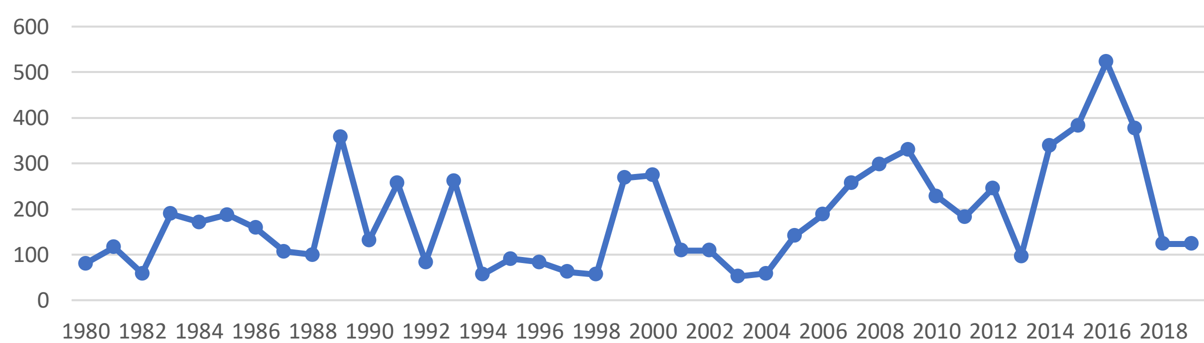
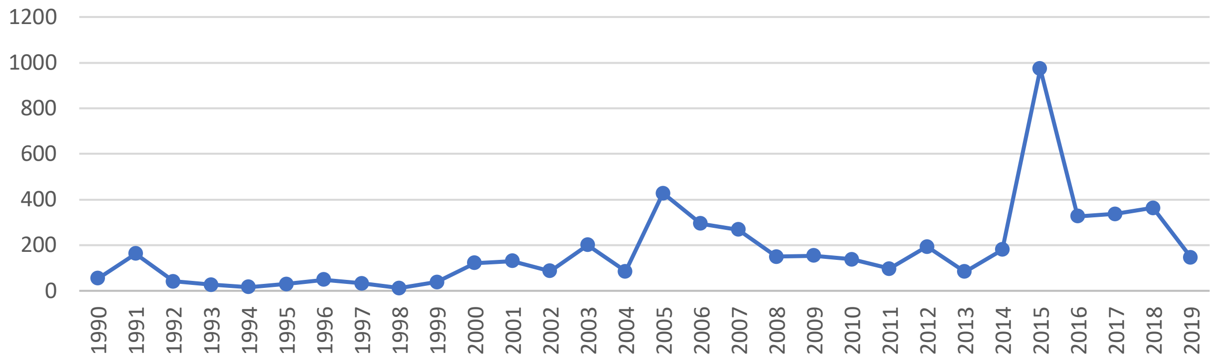


Figure H - 56. Mean annual number of scup (*Stenotomus chrysops*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



<u>Winter flounder (*Pseudopleuronectes americanus*)</u>

Figure H - 57. Mean annual number of winter flounder (*Pseudopleuronectes americanus*) per tow, 1980-2019, at the Fox Island Station in the <u>Middle West Passage</u>. Source: URI GSO Fish Trawl Survey.

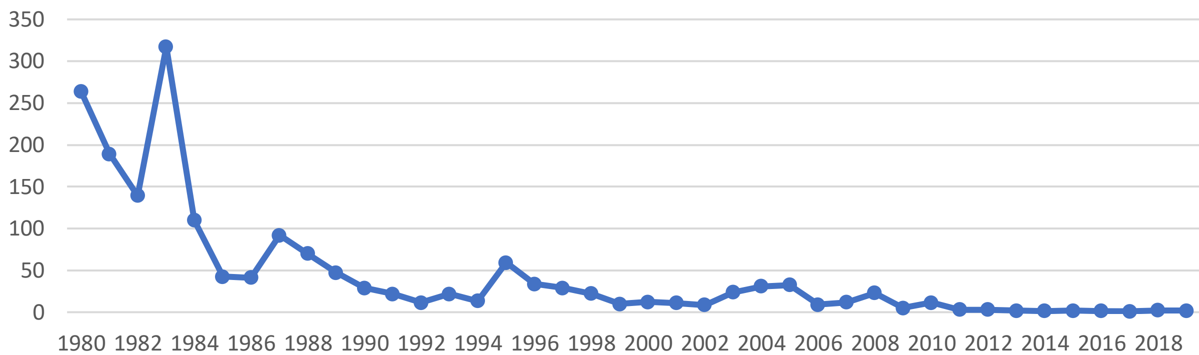
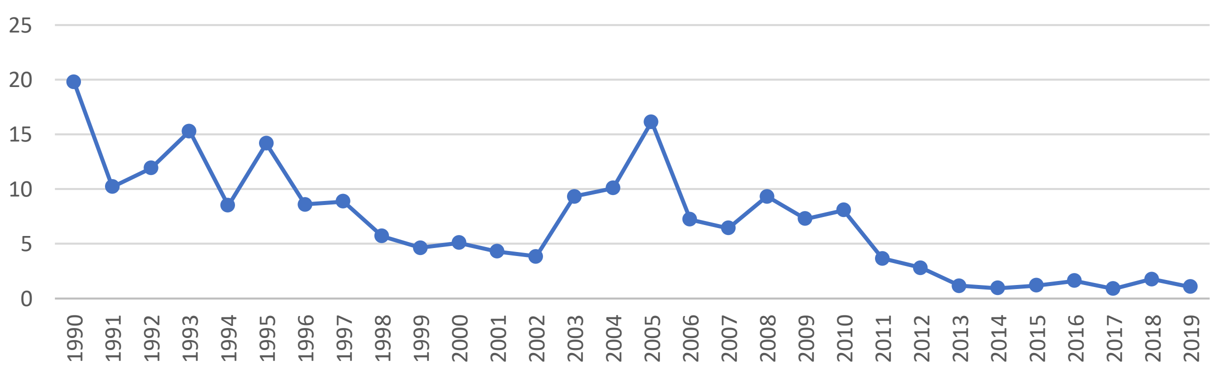


Figure H - 58. Mean annual number of winter flounder (*Pseudopleuronectes americanus*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



Menhaden (*Brevoortia tyrannus*)

Figure H - 59. Mean annual number of menhaden (*Brevoortia tyrannus*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

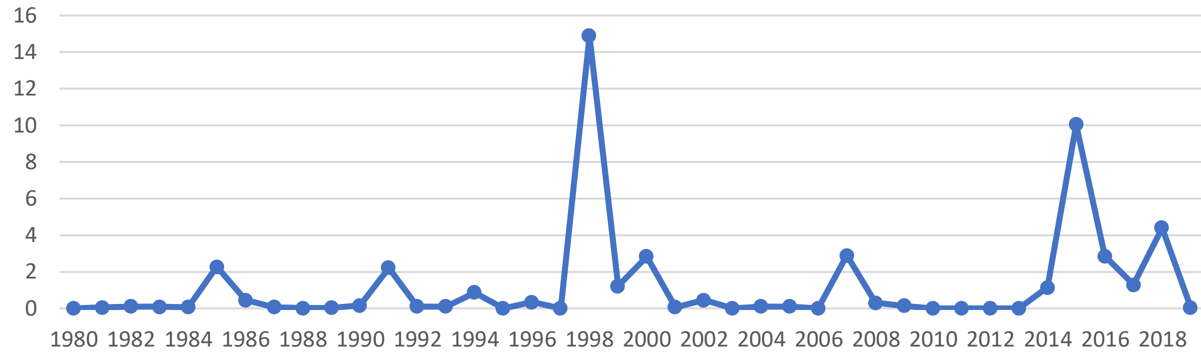
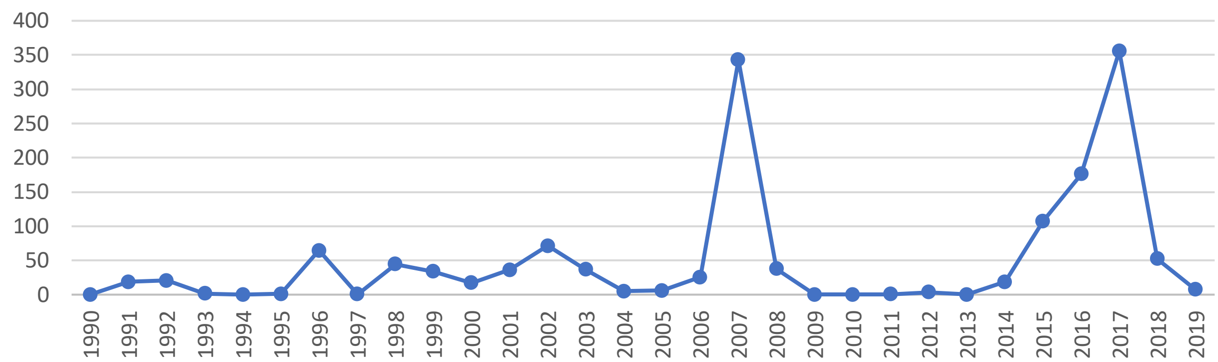


Figure H - 60. Mean annual number of menhaden (*Brevoortia tyrannus*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



Tautog (*Tautoga onitis*)

Figure H - 61. Mean annual number of tautog (*Tautoga onitis*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

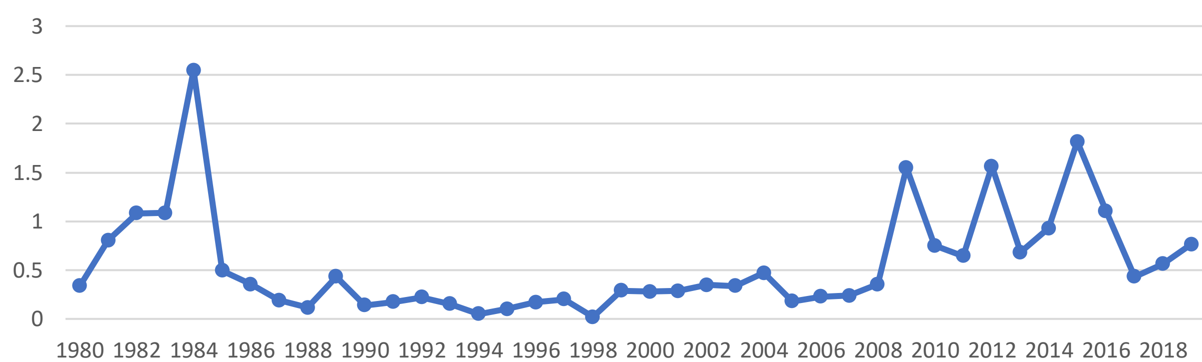
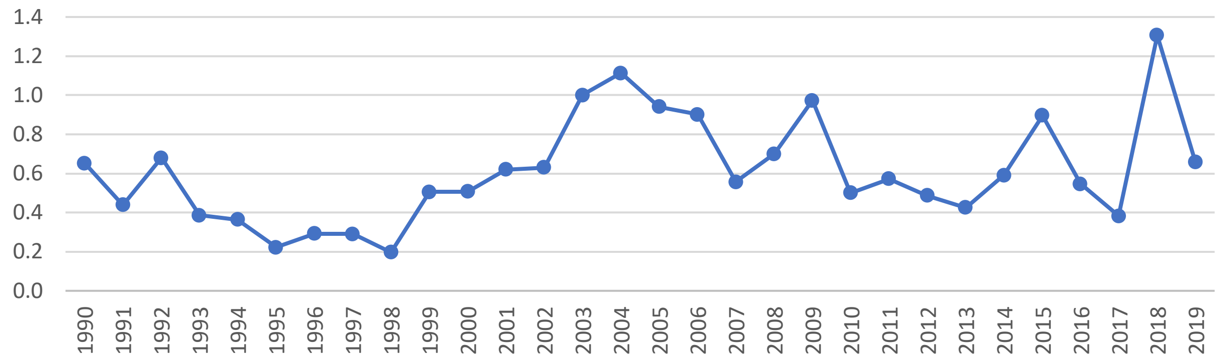


Figure H - 62. Mean annual number of tautog (*Tautoga onitis*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



Sea robins (*Prionotus evolans*)

Figure H - 63. Mean annual number of striped sea robins (*Prionotus evolans*) per tow, 1980-2019, at the Fox Island Station in the Middle West Passage. Source: URI GSO Fish Trawl Survey.

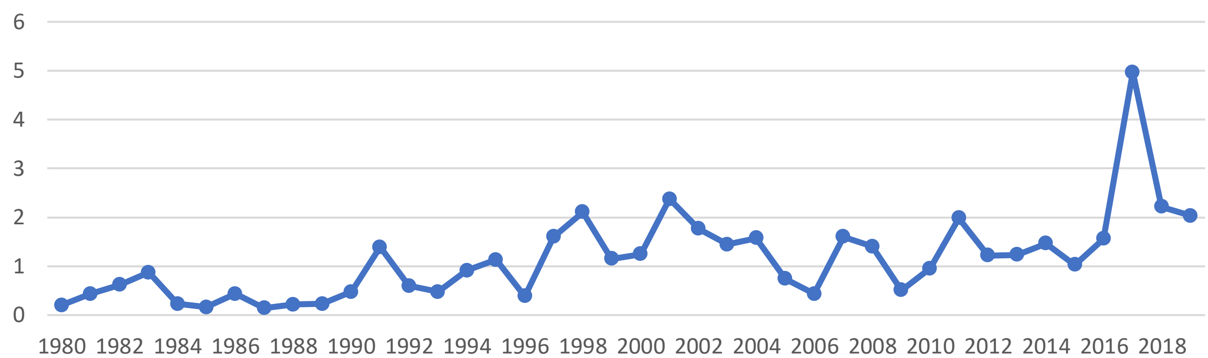
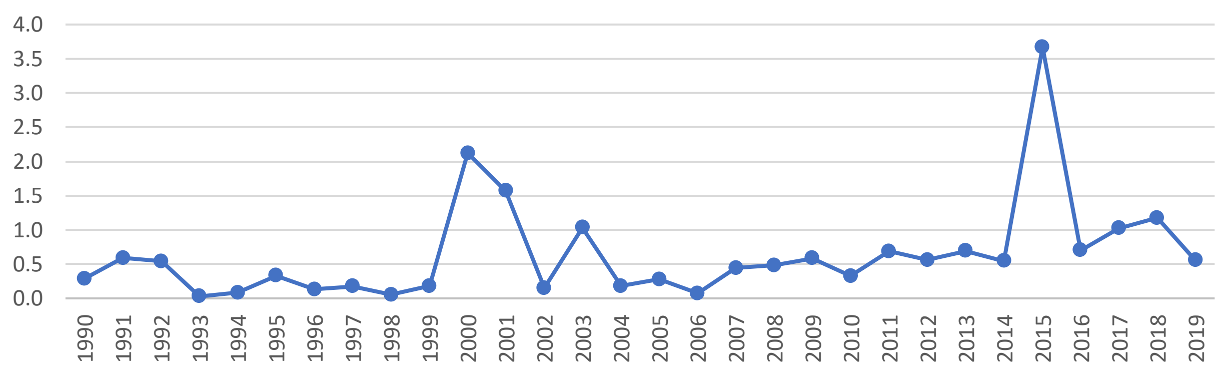


Figure H - 64. Mean annual number of striped sea robins (*Prionotus evolans*) per tow in Narragansett Bay, 1990-2019. Source: DEM Coastal Trawl Survey.



Birds

Cormorants (*Phalacrocorax auritus*)

An index of cormorant abundance can be found in the Environmental Protection Agency (EPA) Winter Waterfowl Survey, which has taken place on a single day each January since 2005 at 67 sites around Narragansett Bay. In addition, Raposa (2009) published a count of cormorant nests in Rhode Island as a whole from 1963-2009.

Figure H - 65. Total annual winter cormorant (*Phalacrocorax auritus*) count, from 67 sites around Narragansett Bay. Source: EPA Winter Waterfowl Survey.

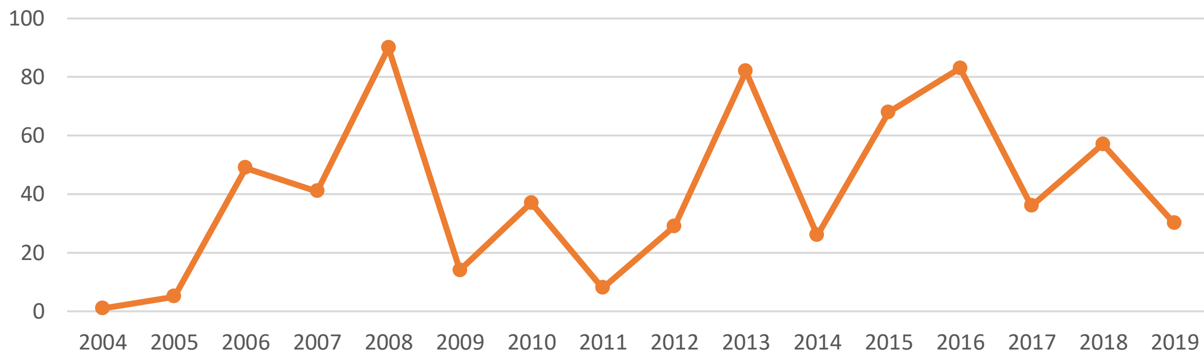
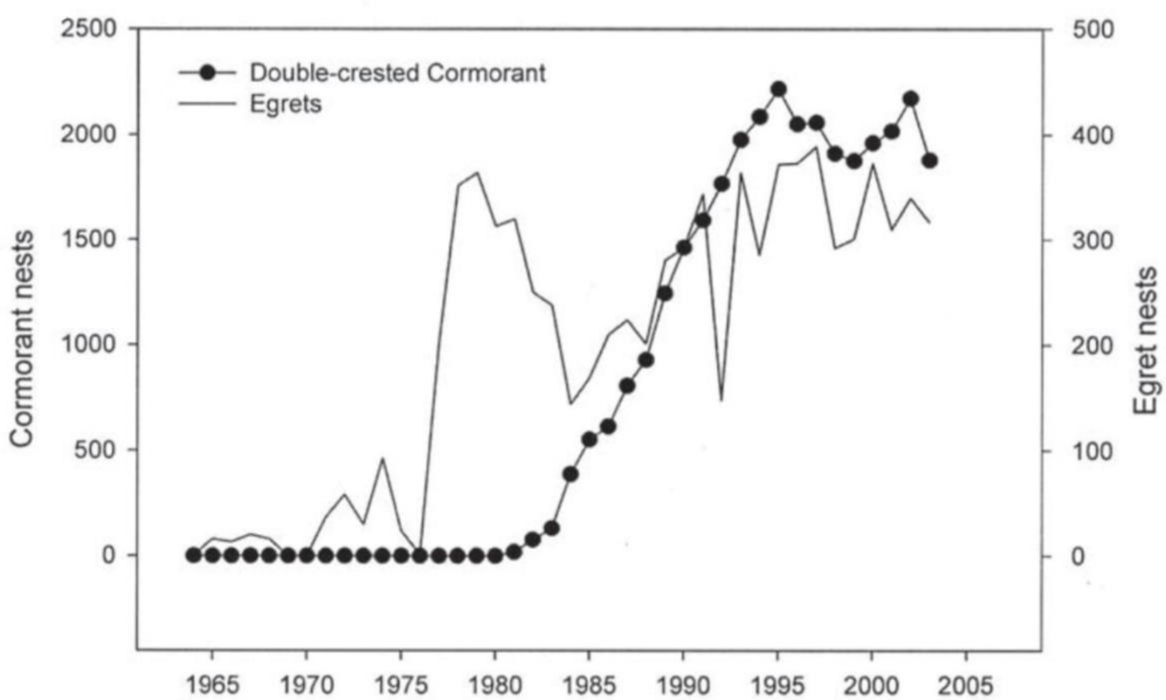


Figure H - 66. Number of double crested cormorants (dotted line) nests in Narragansett Bay and Rhode Island. Source: Raposa (2009).



Mammals

<u>Seals (e.g., *Phoca vitulina*)</u>

Long-term data on seal abundance have been available through Save the Bay's volunteer seal count since 1994. Save the Bay conducts two types of survey: an annual bay-wide seal count (since 2009), which takes place on one day per winter, and a seasonal monitoring survey (since 1994) that surveys certain sites regularly over the course of the winter seal season. Data from the Save the Bay annual bay-wide count is presented in Figure H - 68 through Figure H - 71. Data from prior to the start of Save the Bay's count in 1994 was extracted from Schroeder (2000) and presented in Figure H - 67.

Figure H - 67. Schroeder (2000) plotted the number of concurrently surveyed seals ("Concurrent No.," i.e., total number of seals surveyed simultaneously at multiple haul-out sites) and the maximum number of seals observed at a single haul-out ("Max no.") for the months September to May, in Rhode Island waters between 1973 and 1998. These data show a significant increase over time in the maximum number of seals observed in Rhode Island waters (slope=5.694, standard error=1.090, P<0.001). The plot below is reproduced from Shroeder (2000).

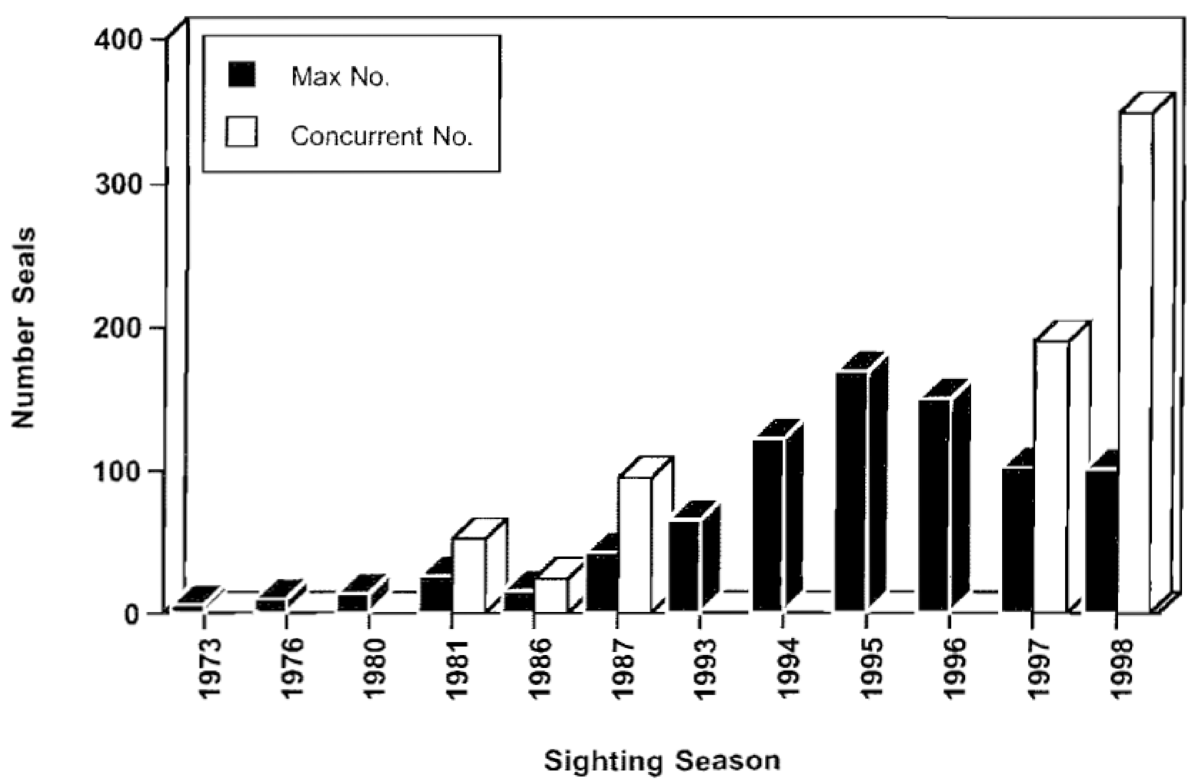


Figure H - 68. Annual concurrent bay-wide seal counts in Narragansett Bay, 2009-2019. Source: Save the Bay Seal Count. Reproduced from Save the Bay 2019.

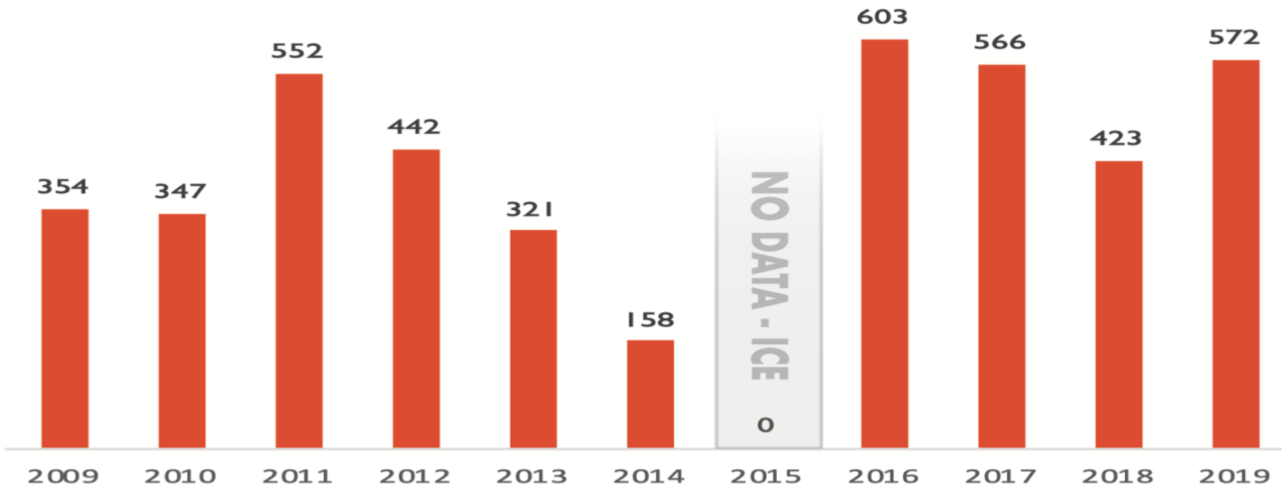


Figure H - 69. Maximum number of seals seen per visit, Church Cove (Mount Hope Bay), 1995-2018. Source: Save the Bay Seal Count. Reproduced from Save the Bay 2019.

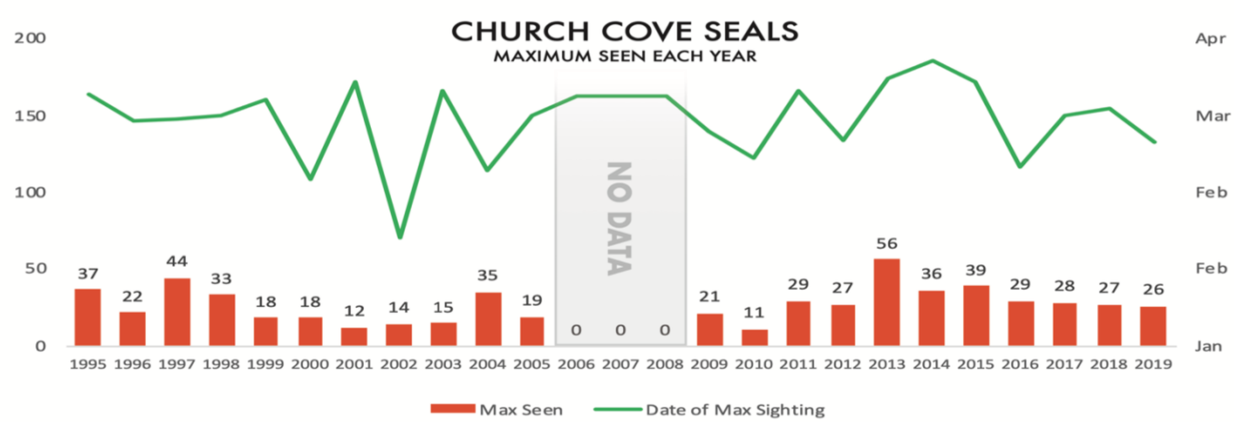


Figure H - 70. Maximum number of seals seen per visit, Rome Point (Middle West Passage), 1995-2018. Source: Save the Bay Seal Count. Reproduced from Save the Bay 2019.

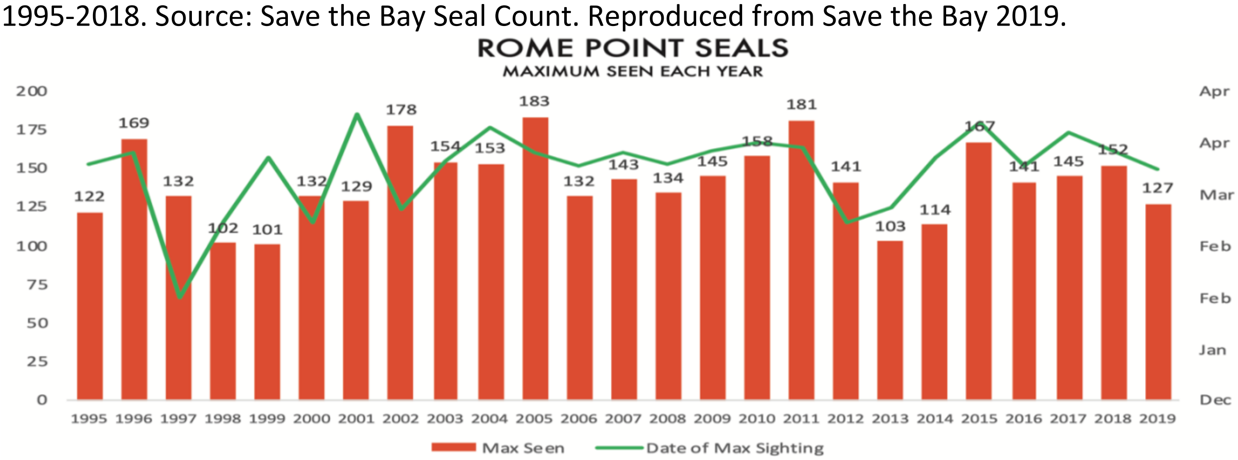
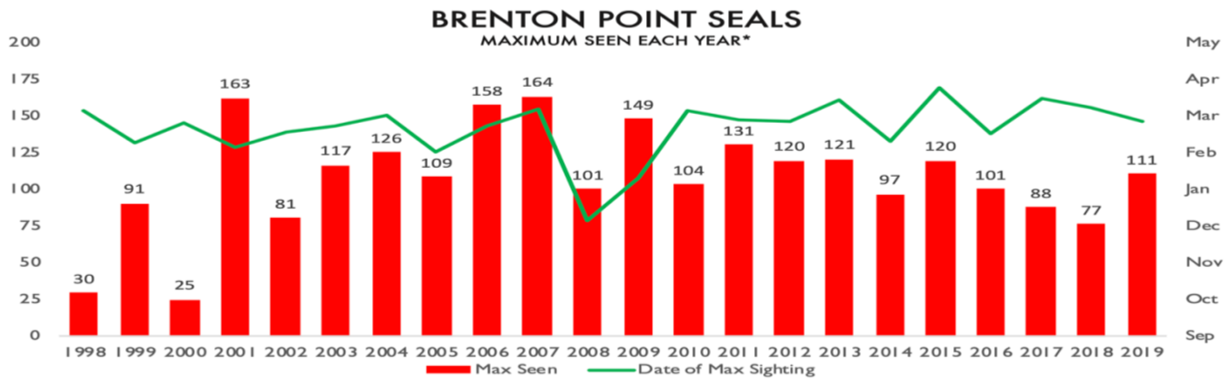


Figure H - 71. Maximum number of seals seen per visit, Brenton Point (<u>Mouth of Narragansett Bay</u>), 1998-2018. Source: Save the Bay Seal Count. Reproduced from Save the Bay 2019.

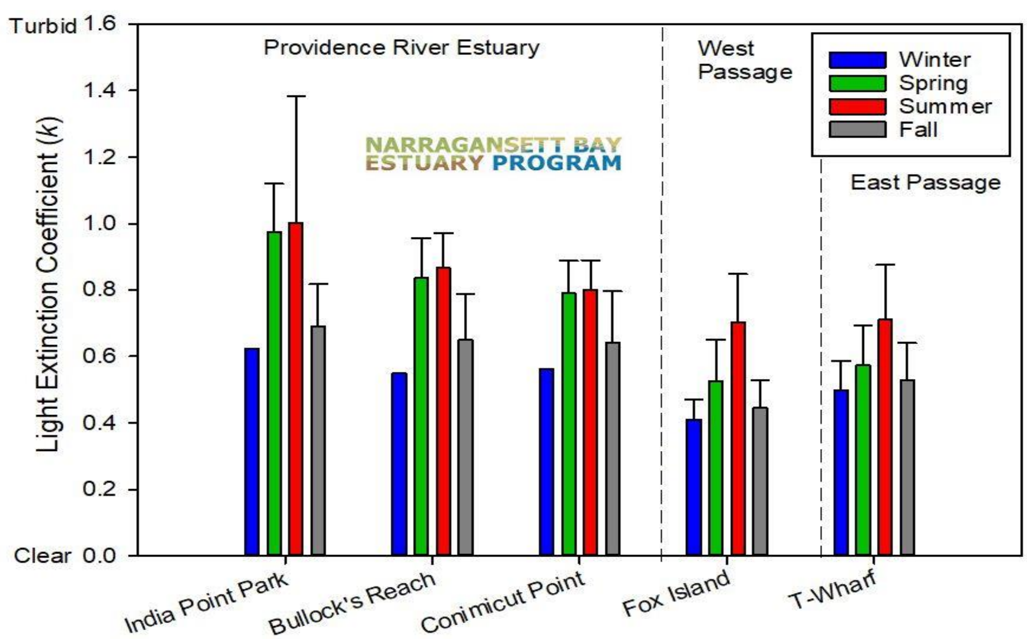


Abiotic Factors

<u>Water Clarity</u>

The images in this subsection are taken from the *State of Narragansett Bay and Its Watershed* (NBEP 2017b). Data are presented as light extinction coefficients (*k*). Clear water has a low *k*, and turbid water has a high *k*. For all figures, Secchi depth data were converted to *k*, introducing an error of approximately 20 percent. Very rainy years could have poorer water clarity than dry years.

Figure H - 72. Light extinction coefficients (k), derived from Secchi depth, by season in 2014. Stations are listed north to south. Seasons: winter (January-March), spring (April-June), summer (July-September), fall (October-December). Sample sizes: winter, n > 8 (except Providence



River estuary, n = 1); spring, n > 7; summer, n > 10; fall, n > 8. Error bars are standard deviations.

Figure H - 73. Summer averaged light extinction coefficients (k), calculated from Secchi depth, at Fox Island (Middle West Passage). The solid line represents a linear regression for 1972 to 1997 data. Data were collected weekly. Error bars are standard deviations. Sample size (n) is greater than ten for all years.

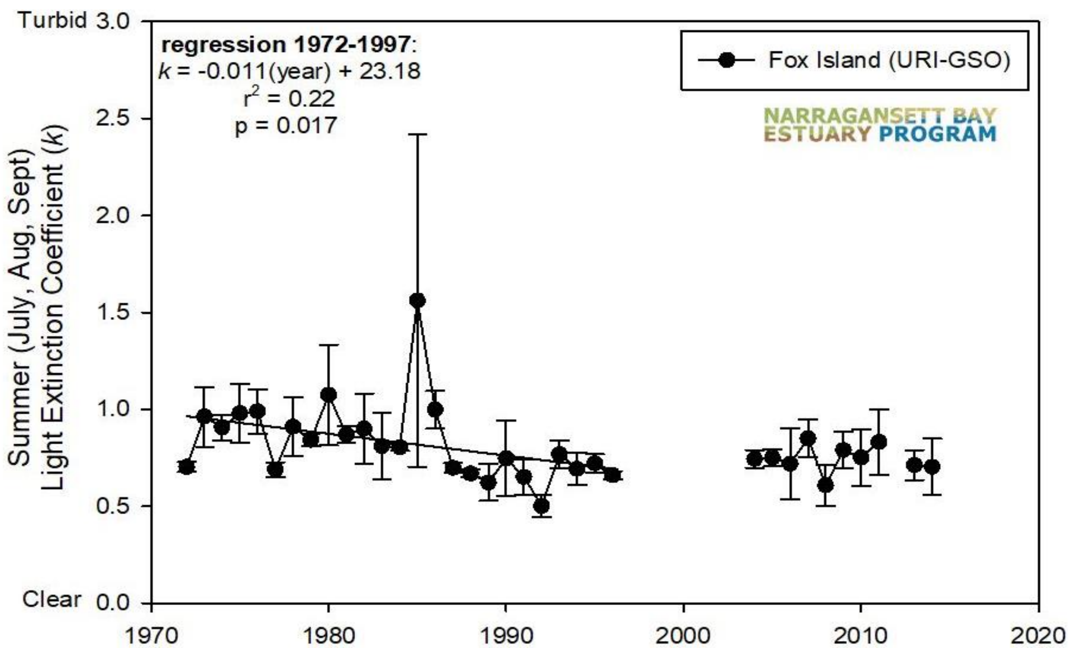


Figure H - 74 (next page). Summer (July-September) light extinction coefficients (k) for 2007 to 2014 based on PAR data for the Providence River estuary and Secchi depth data for the West and East Passages. Stations are listed from north to south. Gray bars (2007 to 2012) indicate the time period before the wastewater treatment facility 50 percent nitrogen-reduction goal was met. Colored bars (2013 and 2014) indicate the time period after the nitrogen reduction goal was met. Error bars are standard deviations. Sample sizes: For the Providence River estuary stations (India Point Park, Bullock's Reach, Conimicut Point), n > 2 for 2007 to 2011, except 2008 at India Point Park and Conimicut Point where n = 1, and n > 10 for 2012 to 2014. For Fox Island (Middle West Passage) and T-Wharf (Middle East Passage), n > 8 for all years.

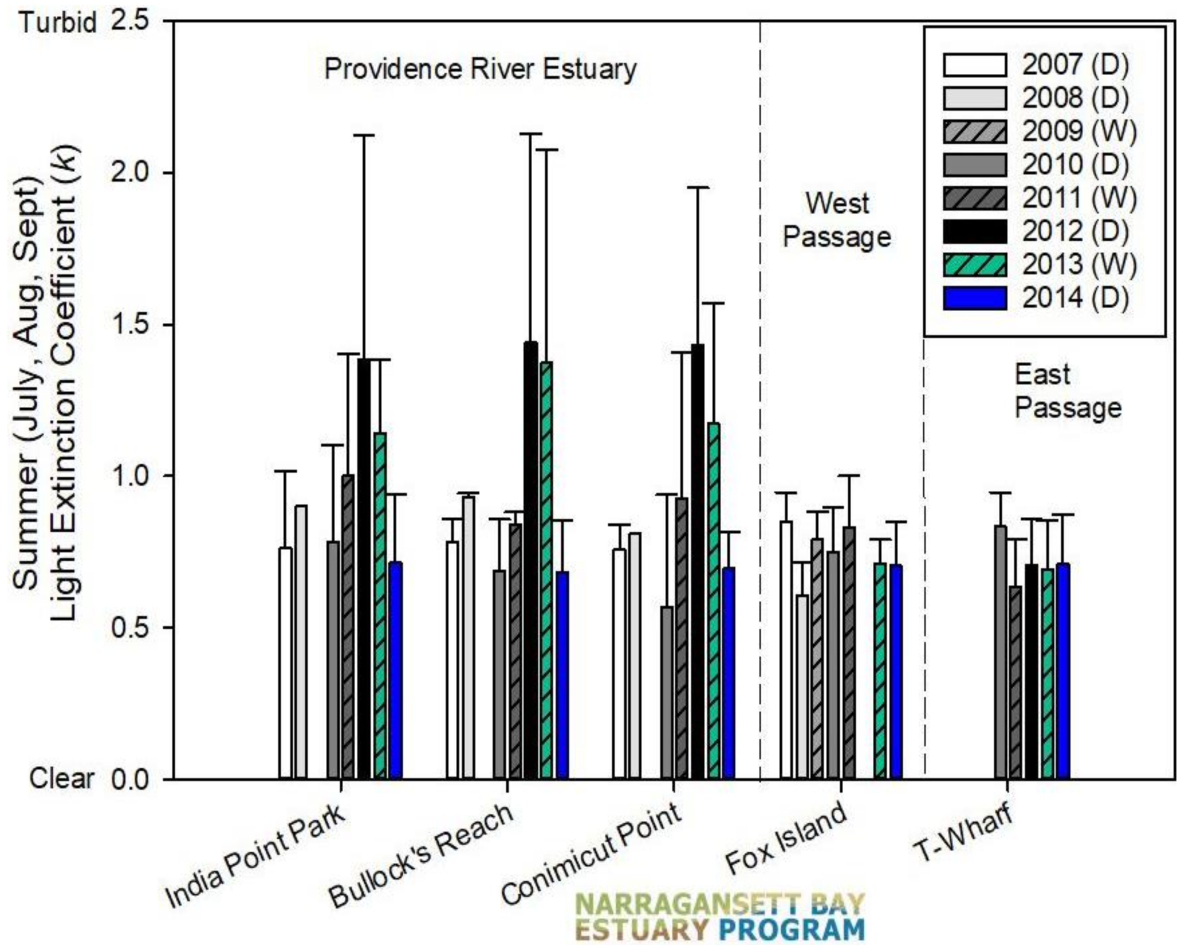
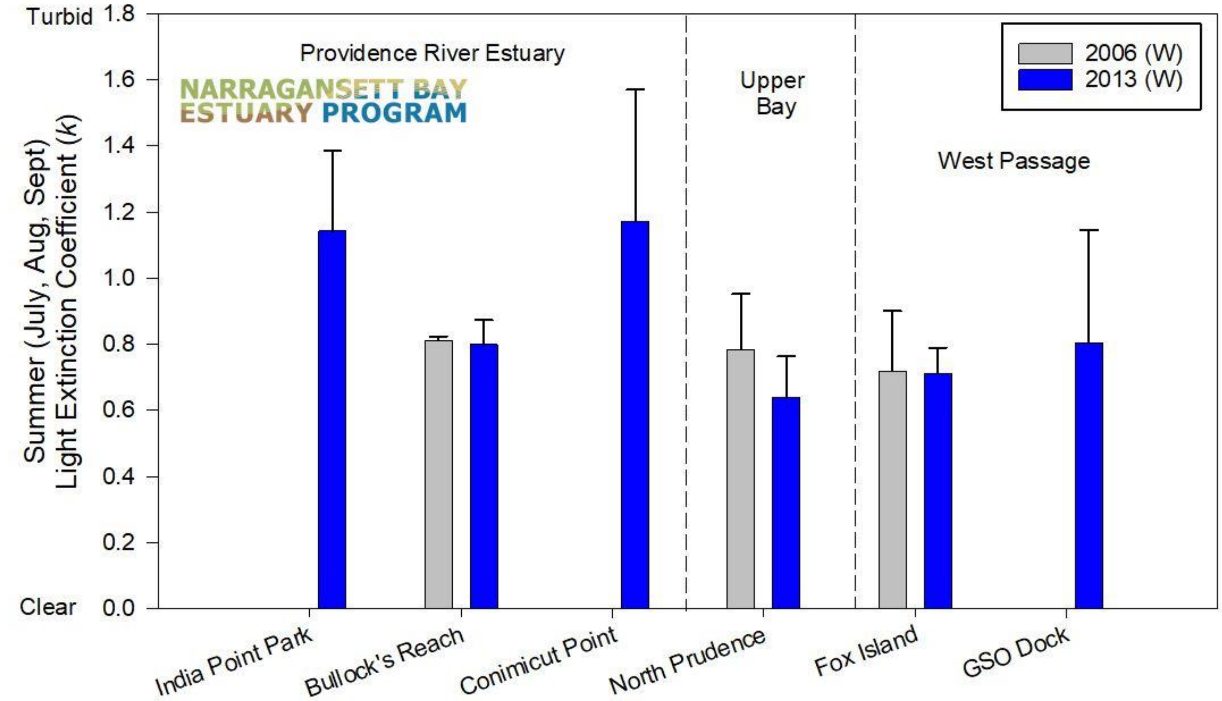
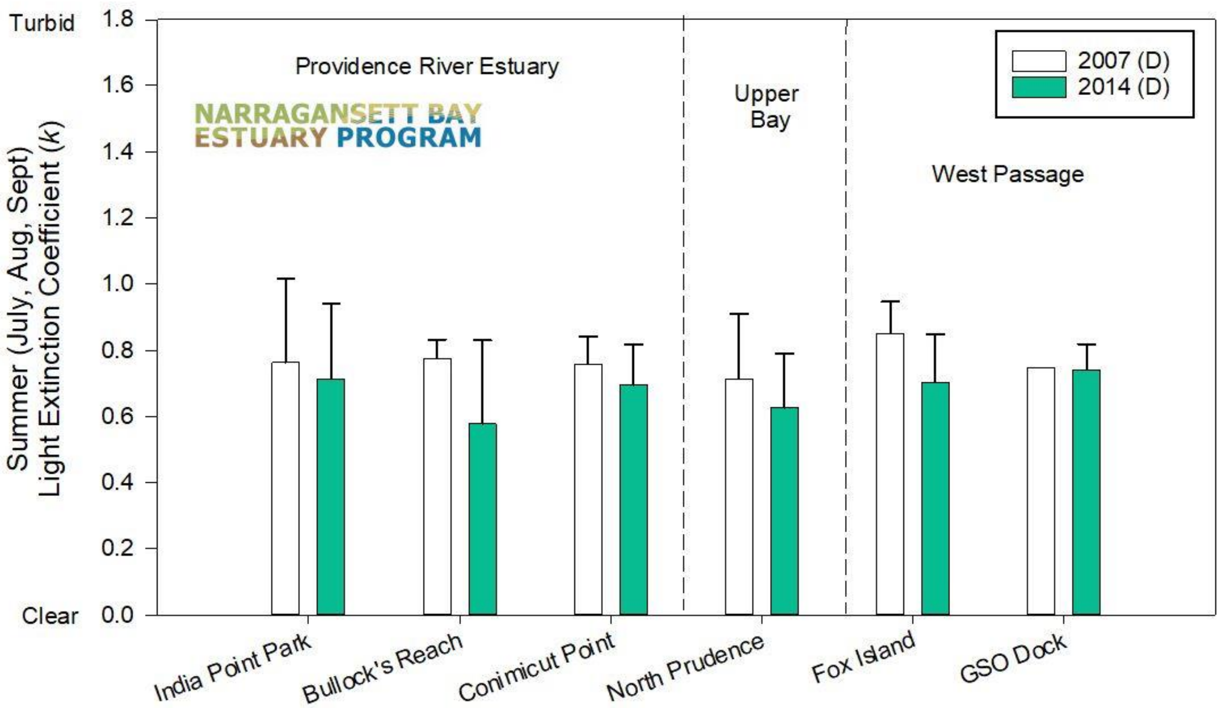


Figure H - 75 (next page). Summer light extinction coefficients (k) in wet years (top: 2006 and 2013) and dry years (bottom: 2007 and 2014) based on PAR data and Secchi depth data (Fox Island only). Stations are listed according to geographic position from Providence (left) to the lower bay (right). Error bars are standard deviations. Sample sizes: For 2006, n > 2 for Bullock's Reach and North Prudence; Fox Island n = 14. For 2013, n > 5 for Bullock's Reach, North Prudence, and GSO Dock; n = 11 for India Point Park and Conimicut Point; n = 14 for Fox Island. For 2007, n > 4 for all stations but Fox Island (n = 10) and GSO Dock (n = 1). For 2014, n > 3 for Bullock's Reach, North Prudence, and GSO Dock; n > 11 for India Point Park, Conimicut Point, and Fox Island.



Turbid
Clear
Summer (July, Aug, Sept)
Light Extinction Coefficient (k)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Providence River Estuary
NARRAGANSETT BAY
ESTUARY PROGRAM
Upper Bay
West Passage
2006 (W)
2013 (W)
India Point Park
Bullock's Reach
Conimicut Point
North Prudence
Fox Island
GSO Dock



Turbid
Clear
Summer (July, Aug, Sept)
Light Extinction Coefficient (k)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Providence River Estuary
NARRAGANSETT BAY
ESTUARY PROGRAM
Upper Bay
West Passage
2007 (D)
2014 (D)
India Point Park
Bullock's Reach
Conimicut Point
North Prudence
Fox Island
GSO Dock

APPENDIX I. COMPARISON OF SCIENTIFIC MONITORING AND FISHERMEN'S OBSERVATIONS IN TERMS OF SPECIES, SPATIAL, AND TEMPORAL COVERAGE

The tables in this appendix compare established scientific monitoring programs of Narragansett Bay with fishermen's observations in terms of species sampled, segments of the bay sampled (according to the NBEP 2017b geographic segmentation of the bay), duration and frequency of sampling, and seasonal coverage of sampling. The purpose of this exercise is to illuminate species, spatial areas, and times or seasons that are observed by fishermen but under-sampled by scientific monitoring programs. We proposed that such species, areas, and times should be prioritized when considering a long-term platform to collect fishermen's knowledge and observations of ecosystem change in Narragansett Bay.

Table I - 1. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for sessile benthic invertebrates in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.				**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	DEM Shellfish Dredge Survey	DEM Landings Statistics	NOAA Landings Statistics	URI GSO Long-Term Plankton Time Series	Aquaculture	Lobstermen	Quahoggers	Trawl fishermen
Species Coverage								
Quahogs	X	X*	X*		7		88	
Oysters		X*	X*				19	1
Soft shell clams		X*	X*				11	
Bay scallops		X*	X*		4		17	
Mussels		X*	X*		1	9	11	
Deckers (larvae)				X			11	
Spatial Coverage								
Apponaug Cove		X*			1		1	
Barrington River		X*					1	

Bristol Harbor	X	X*					1	
Buttonwoods Cove		X*						
Dutch Harbor	X	X*					3	
Eastern Greenwich Bay	X	X*					7	
Greenwich Cove		X*			1		2	
Kickemuit River		X*					1	
Lower East Passage		X*				5		
Lower West Passage	X	X*					3	
Middle East Passage		X*			3		1	
Middle West Passage	X	X*					19	
Mill Gut		X*					2	
Mount Hope Bay	X	X*					1	
Mouth of Narragansett Bay		X*						
Nannakuaket Pond		X*					2	
Newport Harbor		X*				1		
Potowomut River		X*						
Providence River	X	X*					3	
Potter's Cove	X	X*					1	
Quonset Harbor		X*					1	
The Cove		X*			2		33	
Upper Bay	X	X*					7	
Upper East Passage	X	X*			1		16	
Upper West Passage	X	X*					3	
Warren River		X*			1			
Warwick Cove		X*			1		8	
Western Greenwich Bay	X	X*					2	
Wickford Harbor		X*						
Longitudinal Coverage								
Years sampled	1993-present	2006-present	2004-present	2001-2005, 2018-present	1977-present	1946-present	1959-present	1970-present
Seasonal Coverage								
Winter		X*			NA			
Spring		X*						
Summer	X	X*						
Fall	X	X*						

Table I - 2. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for mobile benthic invertebrates in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.								**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	DEM Trawl Survey	URI GSO Trawl Survey	DEM Ventless Trap Survey	DEM Juvenile Finfish Survey	DEM Horseshoe Crab Survey	DEM Blue Crab Dredge Survey	DEM Shellfish Dredge Survey	DEM Shellfish Landings Data	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage												
Starfish			X						2	9	7	1
Lobsters	X	X	X							24		
Blue crabs	X	X	X			X				3	3	3
Horseshoe crabs	X	X			X						5	1
Spider crabs		X	X	X					1		4	1
Green Crabs			X							2	1	
Whelks	X		X				X	X			3	
Urchins										4		
Spatial Coverage												
Apponaug Cove						X		X*				
Barrington River								X*				
Bristol Harbor						X	X	X*				
Buttonwoods Cove						X		X*				
Dutch Harbor						X	X	X*				
Eastern Greenwich Bay			X			X	X	X*			1	
Greenwich Cove						X		X*				
Kickemuit River				X				X*				
Lower East Passage	X		X	X		X		X*		8		

Lower West Passage	X		X	X		X	X	X*		2		
Middle East Passage	X		X	X		X		X*		3		
Middle West Passage	X	X	X	X		x	X	X*		1		
Mill Gut						X		X*				
Mount Hope Bay	X		X	X		X	X	X*				2
Mouth of Narragansett Bay	X		X			X		X*				
Nannakuaket Pond						X		X*				
Newport Harbor						X		X*		4		
Potowomut River								X*				
Providence River				X	X		X	X*				
Potter's Cove				X		X	X	X*				
Quonset Harbor						X		X*				
The Cove				X				X*		3	3	
Upper Bay	X		X	X	X	X	X	X*		1		
Upper East Passage			X	X		X	X	X*			1	
Upper West Passage			X	X		X	X	X*				
Warren River				X				X*				
Warwick Cove						X		X*			3	
Western Greenwich Bay			X	X		X	X	X*			1	
Wickford Harbor						X		X*				
Longitudinal Coverage												
Years sampled	1993-present	1959-present	2006-present	1998-present	2000-present	2021-present	1993-present	2006-present	1977-present	1946-present	1959-present	1970-present
Seasonal Coverage												
Winter	X	X				X		X*	NA			
Spring	X	X			X			X*				
Summer	X	X	X	X			X	X*				
Fall	X	X		X			X	X*				

Table I - 3. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for fouling invertebrates in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.	**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	CRMC Floating Docks and Settlement Plate Surveys	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage					
Barnacles		2	8		
Sea Grapes			6		
Sea Squirts	X		3		
Hydroids	X		5		
Spatial Coverage					
Apponaug Cove					
Barrington River					
Bristol Harbor					
Buttonwoods Cove					
Dutch Harbor					
Eastern Greenwich Bay					
Greenwich Cove					
Kickemuit River					
Lower East Passage			8		
Lower West Passage					
Middle East Passage	X		3		
Middle West Passage					
Mill Gut					
Mount Hope Bay					
Mouth of Narragansett Bay			4		
Nannakuaket Pond					

Newport Harbor	X		6		
Potowomut River					
Providence River	X				
Potter's Cove					
Quonset Harbor	X				
The Cove					
Upper Bay					
Upper East Passage					
Upper West Passage					
Warren River					
Warwick Cove					
Western Greenwich Bay					
Wickford Harbor					
Longitudinal Coverage					
Years surveyed	2009 – present (floating docks) 2012-present (settlement plates)	1977-present	1946-present	1959-present	1970-present
Seasonal Coverage					
Winter				NA	
Spring	X				
Summer	X	X			
Fall	X				

Table I - 4. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for macroalgae/seaweeds and submerged aquatic vegetation (SAV) in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.			**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	Intermittent macroalgae surveys	Bioinvasive Species Rapid Assessment Surveys	Aerial SAV surveys	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage							
Kelp	X				6		1
Rockweeds	X				15		2
Sea lettuce	X				3	5	
Other seaweed	X	X			9	11	9
Eelgrass			X	1	2	2	
Spatial Coverage							
Apponaug Cove							
Barrington River			X				
Bristol Harbor			X		3	1	2
Buttonwoods Cove	X		X				
Dutch Harbor			X				1
Eastern Greenwich Bay	X		X				
Greenwich Cove			X			1	
Kickemuit River			X		1		
Lower East Passage	X	X	X		18		1
Lower West Passage	X	X	X				1
Middle East Passage		X	X	1	3	1	
Middle West Passage	X		X			1	1
Mill Gut			X				
Mount Hope Bay		X	X				2
Mouth of Narragansett Bay	X	X	X		3		

Nannakuaket Pond			X				
Newport Harbor		X	X				
Potowomut River			X				
Providence River		X	X				
Potter's Cove		X	X			1	
Quonset Harbor		X	X				
The Cove			X		1	7	
Upper Bay	X	X	X			1	
Upper East Passage			X			1	
Upper West Passage			X		1	1	
Warren River			X				
Warwick Cove		X	X			2	
Western Greenwich Bay	X		X				
Wickford Harbor		X	X				
Longitudinal Coverage							
Years surveyed	1963-1965 (Wood and Hargraves 1969), 1980 (Brady-Campell *et al*. 1984), 1983-1984 (Peckol *et al.* 1988), early 1990s (Harlin and Rines 1993; Harlin et al. 1996; Villalard-Bohnsack and Harlin 1992), 2007-2012 (DEM), 2009-2010 (Raposa *et al.* 2011), 2009-2010 (Guidone and Thornber 2013), 2018 (Feehan *et al*. 2019), 2005 - present (Thornber *et al.* 2017), 2019 (Green-Gavrielidis *et al.* 2019)	2000, 2003, 2005, 2007, 2010, 2013, 2019	2006, 2012, 2016	1977-present	1946-present	1959-present	1970-present
Seasonal Coverage							
Winter	variable	X		NA			
Spring	variable		X				
Summer	variable		X				
Fall	variable						

Table I - 5. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for plankton in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.			**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	URI GSO Long-Term Plankton Time Series	Narragansett Bay Fixed Site Monitoring Program	Narragansett Bay Commission Phytoplankton Monitoring	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage							
Phytoplankton	X		X		6 (unspecified or grouped together)		
Chlorophylll	X	X					
Zooplankton	X						
Ctenophores	X						
Spatial Coverage							
Apponaug Cove			X				
Barrington River							
Bristol Harbor							
Buttonwoods Cove							
Dutch Harbor							
Eastern Greenwich Bay			X				
Greenwich Cove							
Kickemuit River							
Lower East Passage			X		2		
Lower West Passage							
Middle East Passage			X		1		
Middle West Passage	X		X				

Mill Gut							
Mount Hope Bay			X				
Mouth of Narragansett Bay					1		
Nannakuaket Pond							
Newport Harbor							
Potowomut River							
Providence River			X				
Potter's Cove			X				
Quonset Harbor							
The Cove							
Upper Bay			X				
Upper East Passage			X				
Upper West Passage			X				
Warren River							
Warwick Cove							
Western Greenwich Bay							
Wickford Harbor							
Longitudinal Coverage							
Years surveyed	1959-present	2004-present	2012-present	1977-present	1946-present	1959-present	1970-present
Seasonal Coverage							
Winter	X	X	X	NA			
Spring	X	X	X				
Summer	X	X	X				
Fall	X	X	x				

Table I - 6. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for finfish in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.			**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	URI GSO Trawl Survey	DEM Coastal Trawl Survey	DEM Juvenile Finfish Survey	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage							
Black sea bass	X	X		1	5	3	3
Eels	X	X				10	
Scup	X	X		1	4	2	2
Winter flounder	X	X			2	2	3
Menhaden	X	X		1	2	2	1
Tautog	X	X			1	1	1
Sea robins	X	X		1		1	
Sea horses					3		
Other	X	X		2	1		1
Spatial Coverage							
Apponaug Cove						2	
Barrington River							
Bristol Harbor							
Buttonwoods Cove						2	
Dutch Harbor							
Eastern Greenwich Bay							
Greenwich Cove						2	
Kickemuit River			X				
Lower East Passage		X	X		4		1

Lower West Passage		X	X			2	
Middle East Passage		X	X				1
Middle West Passage	X	X	X			2	
Mill Gut							
Mount Hope Bay		X	X				3
Mouth of Narragansett Bay		X					
Nannakuaket Pond							
Newport Harbor					2		
Potowomut River						2	
Providence River			X				
Potter's Cove			X				
Quonset Harbor							
The Cove			X	1		1	
Upper Bay		X	X			1	
Upper East Passage			X			1	
Upper West Passage			X		1		
Warren River			X			2	
Warwick Cove							
Western Greenwich Bay			X			1	
Wickford Harbor							
Longitudinal Coverage							
Years surveyed	1959-present	1993-present		1977-present	1946-present	1959-present	1970-present
Seasonal Coverage							
Winter	X	X		NA			
Spring	X	X					
Summer	X	X					
Fall	X	X					

Table I - 7. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for birds in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.	**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	EPA Winter Waterfowl Survey	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage					
Cormorants	X		1	1	
Spatial Coverage					
Apponaug Cove	X				
Barrington River					
Bristol Harbor	X				
Buttonwoods Cove	X				
Dutch Harbor					
Eastern Greenwich Bay	X				
Greenwich Cove	X				
Kickemuit River	X				
Lower East Passage	X		1		
Lower West Passage	X				
Middle East Passage	X				
Middle West Passage	X				
Mill Gut					
Mount Hope Bay					
Mouth of Narragansett Bay	X				
Nannakuaket Pond	X				
Newport Harbor	X				
Potowomut River	X				
Providence River	X				

Potter's Cove	X				
Quonset Harbor	X				
The Cove	X				
Upper Bay	X				
Upper East Passage	X				
Upper West Passage	X				
Warren River	X				
Warwick Cove	X				
Western Greenwich Bay	X				
Wickford Harbor	X				
Longitudinal Coverage					
Years surveyed	2005-present	2001-2005, 2018-present	1977-present	1946-present	1959-present
Seasonal Coverage					
Winter	X	NA			
Spring					
Summer					
Fall					

Table I - 8. Comparison of scientific monitoring programs (left-hand columns) and fishermen's observations (right hand columns, by primary gear type) for mammals in Narragansett Bay.

	Scientific Monitoring Programs An X represents that coverage occurs for a given species, segment, or season. An asterisk (*) indicates that data are only available for areas that are open to harvest and that these data are subject to the "rule of three" to protect harvester confidentiality.	**Fishermen's Observations** Numbers represent the number of observational statements gathered collectively in the NB 2019, SH 2014, and RF 2017 interviews			
	Save the Bay Seal Count	Aquaculture	Lobstermen	Quahogger	Trawl fishermen
Species Coverage					
Seals	X		2		
Spatial Coverage					
Apponaug Cove					
Barrington River					
Bristol Harbor	X				
Buttonwoods Cove					
Dutch Harbor					
Eastern Greenwich Bay					
Greenwich Cove					
Kickemuit River					
Lower East Passage	X				
Lower West Passage	X				
Middle East Passage	X				
Middle West Passage	X				
Mill Gut					
Mount Hope Bay	X				

Mouth of Narragansett Bay	X				
Nannakuaket Pond					
Newport Harbor					
Potowomut River					
Providence River	X				
Potter's Cove					
Quonset Harbor					
The Cove					
Upper Bay	X				
Upper East Passage	X				
Upper West Passage					
Warren River					
Warwick Cove					
Western Greenwich Bay					
Wickford Harbor					
Longitudinal Coverage					
Years surveyed	1994-present	2001-2005, 2018-present	1977-present	1946-present	1959-present
Seasonal Coverage					
Winter	X	NA			
Spring	X				
Summer					
Fall	X				