2023 RAPID ASSESSMENT SURVEY:

Non-Native, Native, and Cryptogenic Marine Species at Maine and Massachusetts Marinas

September 2025

MASSACHUSETTS OFFICE OF COASTAL ZONE MANAGEMENT

Contributors

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Photos in this report were taken by CZM staff unless otherwise noted.

Cover photos: At the Wells Reserve Laboratory, a scientist observes a sample of algae and mussels colonized by fouling organisms (top); Fouling community at Beverly Public Pier (bottom). (Photo credits: Alex Shure)

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For more information, see Rapid Assessment Surveys of Marine Invasive Species.

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Fouling communities host a wide range of taxa across many phyla, requiring a diverse team of taxonomic experts for the Rapid Assessment Survey. These organisms at Beverly Public Pier in Beverly, Massachusetts, exemplify the colorful and diverse fouling communities that can be found in New England. (*Photo credit: James T. Carlton*)

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Acknowledgments

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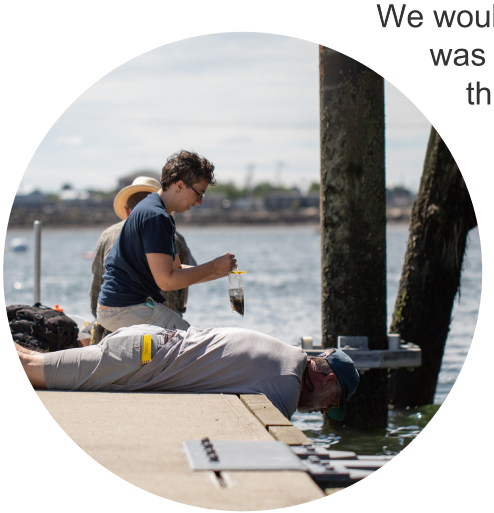


Top and bottom photos by Alex Shure

Introduction

Composed of organisms that attach to hard, submerged substrates and associated motile fauna, marine fouling communities are often found on subtidal structures of the coastal built environment. These communities are extremely dynamic, with population-level factors (such as reproduction rate) and regional and global factors (such as coastal development and climate change) influencing changes in community structure through time (Osman et al., 2010). One of the most significant of these factors is the increasing rate of non-native species introductions to coastal waters (Gebursi & McCarthy, 2017). Since the dawn of early trade, species have made their way across oceans by attaching to surfaces of ships, boring into wooden hulls, and stowing away in solid or water ballast (Carlton, 2010). With technological advancements and demand for transoceanic commerce, the rate of global shipping traffic has substantially increased, and with it, so have species introductions (Hulme, 2009; Williams et al., 2013). In addition to shipping-mediated introductions, aquatic hitchhikers can be introduced to new location through aquaculture (Padilla et al., 2011), marine debris (Kiessling et al., 2015; Carlton et al., 2017), and a suite of other vectors (Williams et al., 2013; Carlton & Ruiz, 2015).

In addition to significant disruptions to coastal ecosystem services and impacts to the marine economy (Anil et al., 2002), bioinvasions associated with marine fouling communities pose a significant threat to native biodiversity. In the summer of 1871, the U.S. Commission of Fish and Fisheries (USCFF), a predecessor to the U.S. Fish and Wildlife Service, published a survey documenting marine invertebrates inhabiting Vineyard Sound, Massachusetts, and its adjacent waters. Among the various habitats surveyed, the report recounts a vivid description of the species that

Glossary

The definitions below have been adapted from Carlton & Schwindt (2024).

Biological invasion (or bioinvasion): The process by which a species arrives in a non-native geographic region and establishes reproducing populations.

Cryptogenic species: Species of a known identity whose evolutionary and biogeographic origins are poorly described or not yet known and thus cannot yet be resolved as either non-native or native.

Cryptovectic species: Species of which no known dispersal mechanism explains its arrival in a new geographic location.

Introduced species: Species that have been transported by human activities into a region where they were previously absent and have become established as evidenced by the presence of self-sustaining reproducing populations.

Native species: Species that have been historically present in a region, as determined by paleontological, archeological, biogeographic, molecular, and other evidence.

Non-native species: Species that have arrived by any vector to a geographic region where they did not exist in historical time.

Range-expanding species: Species whose distributions have expanded into regions where they were previously absent through movement along shore, shelf, or island corridors or poleward movements in the open ocean.

Vector: The physical means or agent by which a species is transported within or between locations.

once made up the fouling communities of wharf and bridge pilings, vessel bottoms, buoys, and other submerged structures. The account describes large *Mytilus edulis* mussel clusters on pilings interspersed with a diversity of abundant macroalgae, on which hydroids grew. The native tunicate *Molgula manhattensis* grew rapidly, and the non-native, solitary *Styela canopus* and colonial, star-patterned *Botryllus schlosseri* tunicates were also described. Over a dozen native gastropods—*Astyris lunata*, *Marshallora nigrocincta*, *Ilyanassa obsoleta*, and more—were commonly observed (Verrill & Smith, 1874; scientific names updated to those currently accepted). The report continues with colorful descriptions of species from invertebrate taxonomic groups associated with the 19th century submerged structures. Contrasting the 1871 USCFF survey observations with modern-day research initiatives exemplifies how non-native species introduced via human activities and warming waters have altered the New England coast. For example, in a 21st century survey that included two Vineyard Sound fouling communities, the increased number and abundance of non-native species is profound. Introduced tunicates and bryozoans—some recently established, others introduced even before the 1871 survey—dominated the two communities. While many of the native species originally described were still present, their abundance was markedly less pronounced than in the 1871 account (Wells et al., 2014).

Comparing comprehensive species records through time is an important method to understand changes in marine biodiversity and non-native species establishment. Recognizing the need for baseline and regularly updated species records, the use of the rapid assessment survey (RAS) as a recurring means to monitor marine species across broad geographic regions has been implemented in the United States and throughout the world (Bishop et al., 2015; Pederson et al., 2005; Cohen, 2005; Wood et al., 2015; Mead et al., 2011; Schwindt et al., 2014). Often, surveys will focus on sampling the marinas of ports and harbors, which serve as hot spots for biological invasions (Carlton, 2010) and allow for ease of access for the survey team (Wells et al., 2014). The surveys function as a means to detect new biological invasions and track species range expansions through time. Additionally, the RAS increases collaboration between researchers and management professionals working to understand the spread of established non-native species and prevent future bioinvasions.

The 2023 New England Rapid Assessment Survey is the seventh of its kind to sample marinas from Maine to Massachusetts since 2000 (Pederson, 2001; Pederson et al., 2005; McIntyre & Pappal, 2013; McIntyre et al., 2013; Wells et al., 2014; Kennedy et al., 2020). These surveys are conducted at

Grateloupia turuturu

regular, three-to-five-year intervals to document the non-native, native, and cryptogenic species at marinas along the New England coast. During each RAS, a team of taxonomic experts samples marinas across the region to comprehensively inventory all encountered invertebrate and algal species within each fouling community. As in previous years, the objectives of the 2023 New England RAS include: (1) identifying native, non-native, and cryptogenic marine species, (2) expanding on data collected in past surveys, (3) assessing introduction status and range expansions of documented non-native species, and (4) detecting new introductions. Results also inform new species additions to CZM's participatory science monitoring program, the Marine Invader Monitoring and Information Collaborative (MIMIC), where volunteers across New England record data on easily identifiable non-native marine species each summer.

This report provides a summary of the taxa collected at nine marina sites in Maine and Massachusetts during the 2023 RAS, describes new non-native species records for the region, and summarizes spatiotemporal and environmental trends for northern New England fouling communities.

A field collection tray with organisms from the fouling community at Beverly Public Pier in Beverly, Massachusetts. (*Photo credit: Alex Shure*)

Methods

This section provides an overview of how the RAS was designed and conducted, including information on: site selection, survey team, field protocols, laboratory identification, and data analysis.

Site Selection

Nine marinas in coastal Maine and Massachusetts were sampled over the course of one week from August 7-11, 2023, corresponding with the time of year of historical surveys (Figure 1). Sites were chosen based on past sampling history, permission for access, travel logistics, distribution across the study region, and sufficient biological community growth on the sampling substrate. When possible, historical sites were selected that had been sampled on at least one previous RAS, allowing for comparative analyses through time. New sites were established to fill in geographic gaps or to replace historical sites that could not be sampled. For example, Hawthorne Cove Marina, a historical RAS site in Salem, Massachusetts, could not be sampled because the floating docks had recently been cleaned, leading to low biological community growth at the time of this survey. Instead, Beverly Public Pier was sampled, a long-term MIMIC sampling site also located in Salem Sound and less than 3 kilometers (km) from Hawthorne Cove Marina.

In total, six historical sites and three new sites were sampled (Table 1). Sites were distributed from north to south, as listed, across five coastal watersheds (as delineated in Maine Rivers Watershed Profiles and the National Estuary Programs in Massachusetts): two sites in the Central Coastal Maine region (Journey's End Marina and Derecktor Robin Hood Marine Center), one site in the Casco Bay Maine region (Brewer South Freeport Marine), one site in the Piscataqua Maine region (Wells Harbor Marina), two sites in the Massachusetts Bay region (Beverly Public Pier and Sandwich Marina), and three sites in the Buzzards Bay Massachusetts region (Massachusetts Maritime Academy, Northeast Maritime Institute, and F.L. Tripp & Sons, Inc.). One site, Port Harbor Marine in South Portland, Maine, was scheduled but was excluded due to extreme inclement weather on the day of sampling. See Appendix 1 for more detailed information on the sampling locations, including sampling date and time, a brief description of the site, and a characterization of the aspect dominant biological community.

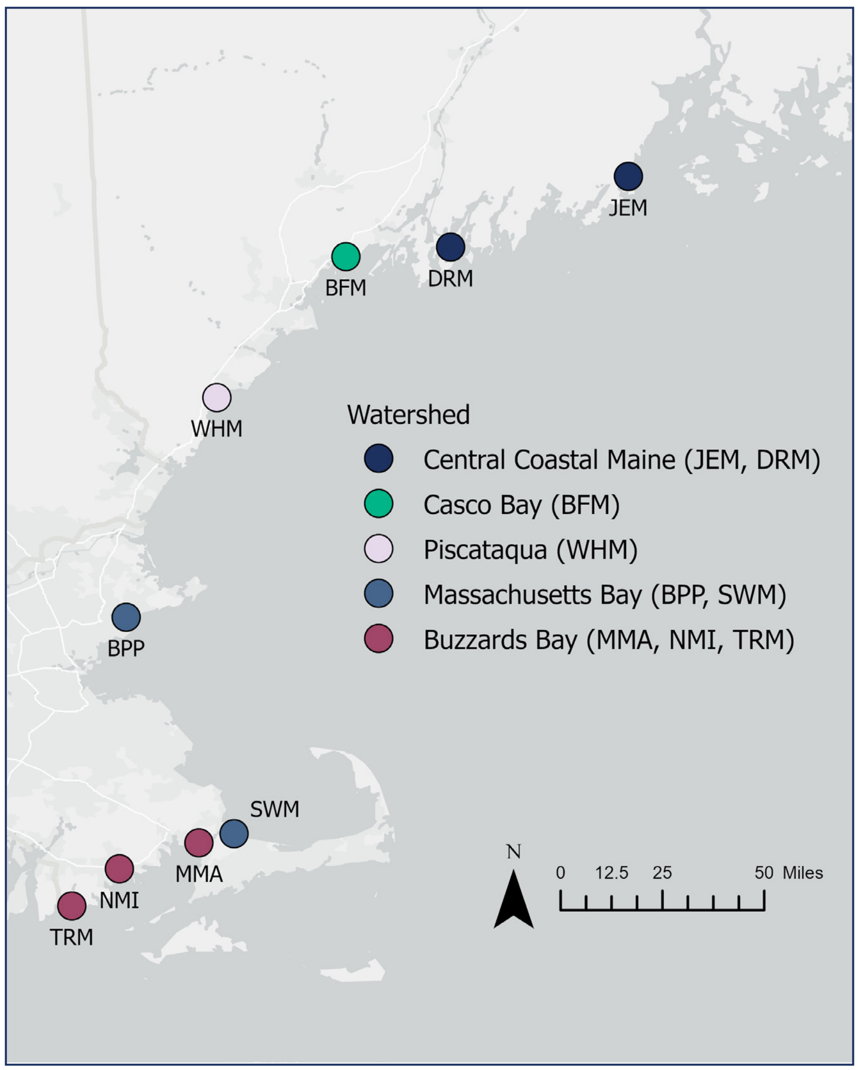


Figure 1: Sites sampled during the 2023 Rapid Assessment Survey. Sites are color-coded by watershed and are labeled with three-letter site codes that correspond with the site information presented in Table 1.

Table 1: Sites sampled during the 2023 Rapid Assessment Survey. Sites are ordered from north to south. Year columns correspond to the years when previous surveys were completed. "Y" in this column indicates that a site was surveyed during the indicated RAS year, and "-" denotes sites that were not sampled. In the 2023 column, "New" indicates that the site was never sampled on a previous RAS and was a new site in 2023.

Code	Site	Location	Watershed	2000	2003	2007	2010	2013	2018	2023
JEM	Journey's End Marina	Rockland, ME	Central Coastal Maine	-	-	Y	-	-	-	Y
DRM	Derecktor Robin Hood Marine Center	Georgetown, ME	Central Coastal Maine	-	-	-	-	-	-	New
BFM	Brewer South Freeport Marine	South Freeport, ME	Casco Bay	-	Y	Y	Y	Y	Y	Y
WHM	Wells Harbor Marina	Wells, ME	Piscataqua	-	-	Y	-	Y	-	Y
BPP	Beverly Public Pier	Beverly, MA	Massachusetts Bay	-	-	-	-	-	-	New
SWM	Sandwich Marina	Sandwich, MA	Massachusetts Bay	Y	-	Y	Y	Y	Y	Y
MMA	Massachusetts Maritime Academy	Buzzards Bay, MA	Buzzards Bay	Y	Y	Y	Y	Y	Y	Y
NMI	Northeast Maritime Institute	Fairhaven, MA	Buzzards Bay	-	-	-	-	-	-	New
TRM	F.L. Tripp and Sons, Inc.	Westport, MA	Buzzards Bay	Y	Y	-	Y	Y	-	Y

Survey Team

The participants on the 2023 RAS included taxonomic experts familiar with native and non-native marine organisms, graduate and undergraduate students, a dive team, a support team to manage logistics, and a photographer. This international, interdisciplinary team included representatives from federal and state government, academic institutions, watershed groups, research reserves and organizations, and museums. See Appendix 2 for details on the RAS survey team, including taxonomic expertise and affiliations of participants.

On Monday, August 7, Rapid Assessment Survey scientists, divers, students, and organizers took a group photo on the grounds of the host laboratory, the Wells Reserve at Laudholm in Wells, Maine. (*Photo credit: Alex Shure*)

At Beverly Public Pier in Beverly, Massachusetts, RAS scientists remove a rope from the water to observe the fouling species attached. (*Photo cedit: Alex Shure*)

Field Protocols

The RAS team, consisting of approximately 30-40 individuals per site, visited one to two sites per day, recording species presence and collecting samples for exactly one hour at each site. The sampling objective was to record a representative characterization of taxa within the fouling community during the allotted sampling period. Marine invertebrates and algae within and associated with the fouling community were sampled from permanently installed floating docks and associated subtidal structures, such as ropes, wires, buoys, and the submerged pilings supporting the docks. Organisms attached to submerged substrate were collected by hand or with scraping tools, while motile animals, such as shrimp, were collected with dip nets. The undersides of the floats, pilings, and associated structures were sampled by the dive team at Journey's End Marina, Derecktor Robin Hood Marine Center, Brewer South Freeport Marine, and F.L. Tripp & Sons, Inc. Due to logistical constraints or water quality concerns, the remaining sites were unable to be sampled by the dive team.

Preliminary identifications were made on site for easily identifiable and common taxa, many of which were photographed in situ using an Olympus TG-6. The remaining taxa were collected in bags, jars, or vials with seawater and stored in coolers with ice for further identification in the laboratory. Fish, larger pelagic organisms (such as jellyfish), unattached marine algae, and organisms that floated into the marina with the tide were not the target of the survey and therefore were not included in this report, but observations of these taxa were recorded anecdotally in notes for each site location and, often, photographed in situ. Many images of organisms observed at each site were uploaded to the 2023 New England Rapid Assessment Survey page on iNaturalist, a community science-based, biodiversity web platform.

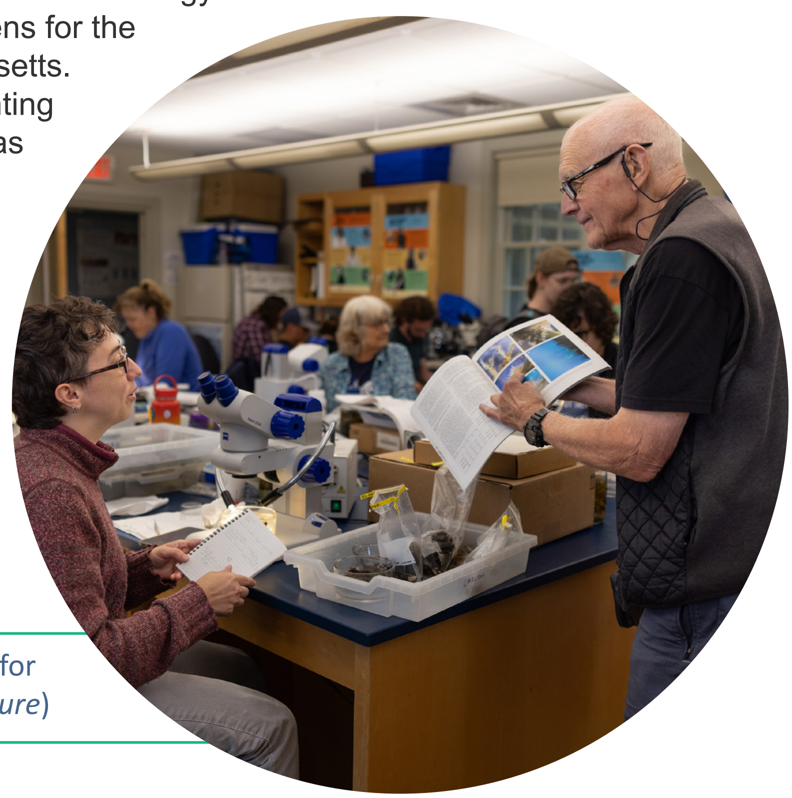
A diver enters the water at Brewer South Freeport Marine in Freeport, Maine. Where logistically possible, divers took video and recorded data on the fouling community on the submerged pilings of the marinas. (*Photo credit: Alex Shure*)

Scientists surround a collection tray of fouling community samples at Beverly Public Pier in Beverly, Massachusetts. (*Photo credit: Alex Shure*)

Water temperature, salinity, and dissolved oxygen were measured at each site using a handheld YSI PRO 2030 multiparameter sonde. Measurements were taken every meter starting at the surface with a final reading at either the maximum water depth or the maximum depth allowable by the 4-meter (m) length sonde cord. Water transparency and bottom depth were measured with a Secchi disk.

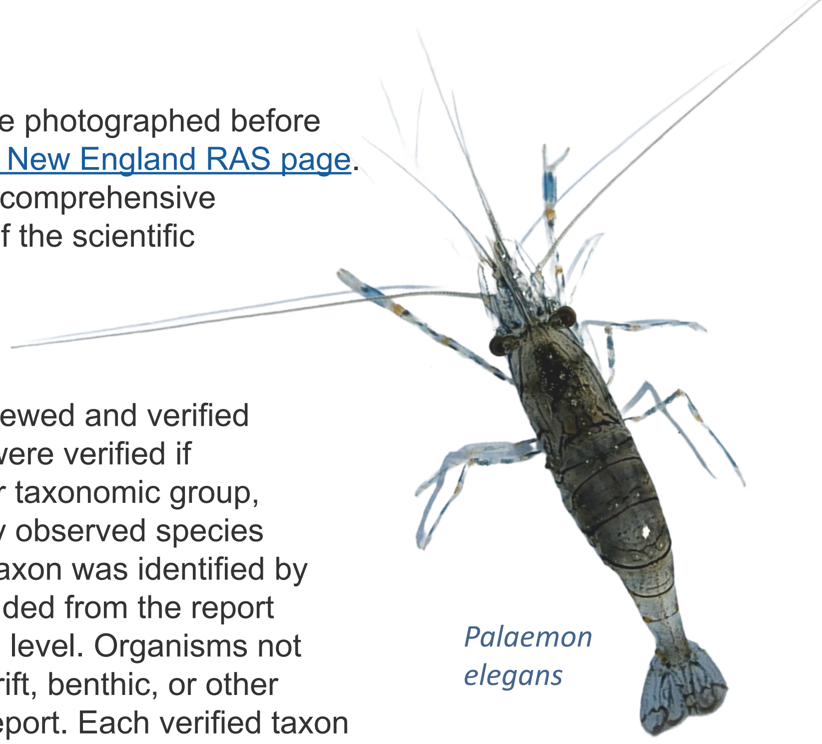
Laboratory Identification

Collected specimens were brought back to the Wells National Estuarine Research Reserve in Wells, Maine, on August 7-8 and Massachusetts Maritime Academy in Buzzards Bay, Massachusetts, on August 9-11 for taxonomic identification and verification. Survey participants from the Harvard University Museum of Comparative Zoology also collected and preserved voucher specimens for the museum's collection in Cambridge, Massachusetts. In addition, a collection of specimens representing the fouling community sampled at each site was preserved and archived at the North Carolina Museum of Natural Sciences in Raleigh. Morphological hydroid specimen vouchers (Cnidaria: Hydrozoa) were catalogued and deposited in the Invertebrate Zoology collection at the Royal BC Museum in Victoria, British Columbia, Canada. Specimens requiring further analysis before confirming identification were preserved and transported by taxonomic specialists to their respective academic institutions.



Two scientists discuss species identification for a particular organism. (*Photo credit: Alex Shure*)

Some live specimens from collected samples were photographed before preservation and uploaded to the iNaturalist [2023 New England RAS page](). Once all specimen identifications were complete, comprehensive taxa presence lists were submitted by members of the scientific team to the CZM survey organizers.



Palaemon elegans

Data Analysis

All data submitted by the scientific team were reviewed and verified through a quality control protocol. Identifications were verified if confirmed by an expert for a specimen's particular taxonomic group, if the identification corresponded with a commonly observed species that a general taxonomist could identify, or if the taxon was identified by at least two general taxonomists. Taxa were excluded from the report if they could not be identified at least to the genus level. Organisms not associated with the fouling community (pelagic, drift, benthic, or other organisms) were additionally excluded from the report. Each verified taxon was assigned an invasion status of native, non-native, or cryptogenic as determined by taxonomic experts on the scientific team, review of relevant literature, and best professional judgment from multiple lines of evidence.

Several individuals of the Sargassum nudibranch, *Scyllaea pelagica*, were found drifting among eelgrass and algae at F.L. Tripp & Sons, Inc., in Westport, Massachusetts. Organisms associated with drift are not included in the fouling community species list, but they are interesting finds nonetheless! (*Photo credit: Aria Lupo*)

Taxonomists on the Rapid Assessment Survey utilize the equipment at host laboratories to identify organisms to the species level. To make these identifications, microscopy is used to identify small anatomical features on collected organisms, such as for the two polychaete worms (top, bottom left) and corophiid amphipod (bottom right) in this photo.

Results and Discussion

This section covers taxonomic findings, new non-native species and population records, and environmental and spatiotemporal trends from the 2023 RAS.

Taxonomic Findings

During the 2023 RAS, 222 taxa were identified, including 131 native (59.0%), 32 non-native (14.4%), and 50 cryptogenic species (22.5%) across the nine sites sampled (Figure 2). Nine taxa (4.1%) were left uncategorized, either because the organism was not identified to the species level or the native designation of the species was unresolved at the time of publication (*Dipolydora socialis* and *Echinogammarus finmarchicus incertae sedis*). Additionally, two amphipods (Appendix 3d, Unknown Amphipod 1 and 2) required further taxonomic investigation that was not resolved at the time of publishing. Genus-level identifications that may be redundant of already reported species-level records were not included in reporting, analysis, or visualization in this report (see Appendix 3b and 3d for details). Of the 32 non-native taxa identified, 31 were classified as introduced, meaning they were determined to have arrived and established in New England via anthropogenic vectors. The remaining non-native species, *Chthamalus fragilis*, found at Massachusetts Maritime Academy in Buzzards Bay, is a historical (1890s) species range expansion to Cape Cod from its prior northern range limit of the Chesapeake Bay. Since it is unclear if the range of this species has expanded due to natural or human-mediated vectors, it is an example of a cryptovectic species and is not considered an introduced species in this report. Excluding the species not found within the fouling communities, images of 72 of the collected taxa (32%) can be found on the iNaturalist 2023 New England Rapid Assessment Survey page.

Sandwich Marina in Sandwich, Massachusetts, had the greatest number (23) of non-native species across all sites, and Beverly Public Pier in Beverly, Massachusetts, had the greatest percentage (32.4%) of non-native taxa relative to native, cryptogenic, and uncategorized taxa. Derecktor Robinhood Marine Center in Georgetown, Maine, was the least invaded site, with the lowest number (9) and the lowest percentage (12.5%) of non-native taxa (Figure 3, Table 2). At the remaining seven sites, the number of non-natives identified ranged between 14 and 22 taxa and between 22.2% and 30.7% of taxa collected (Figure 3, Table 2). The colonial tunicates *Botrylloides violaceus* and *Didemnum vexillum* were the most ubiquitous non-native species, with each found at all nine sites. The green crab *Carcinus maenas*, the tunicates *Ciona intestinalis* and *Diplosoma listerianum*, and the bryozoans *Membranipora membranacea* and *Tricellaria inopinata* were also common non-native species with each found at eight of nine sites. The most common non-native algal species was *Grateloupia turuturu*, which was found at all five of the Massachusetts sites, and *Codium fragile* subsp. *fragile*, which was found at five sites throughout the survey's geographic range.

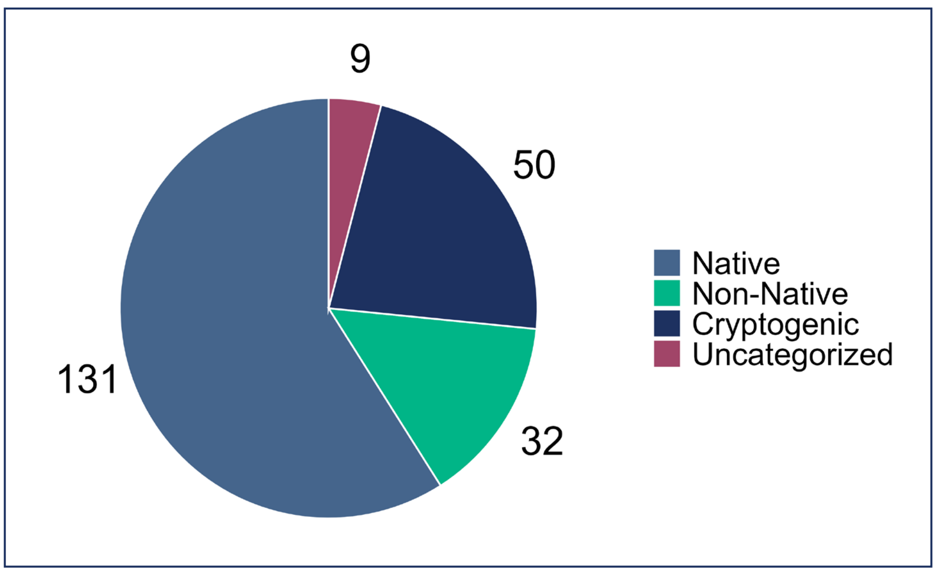


Figure 2: Total number of native, non-native, cryptogenic, and uncategorized taxa across all nine sites sampled during the 2023 RAS.

Massachusetts Maritime Academy in Buzzards Bay, Massachusetts, had the greatest number of native taxa (56), percentage of native taxa relative to non-native, cryptogenic, and uncategorized taxa (62.2%), and number of overall taxa (taxa richness; 90). Northeast Maritime Institute in Fairhaven, Massachusetts, had the lowest number of native taxa (28), as well as the lowest taxa richness (58). Beverly Public Pier had the lowest percentage (42.6%) of native taxa. For a complete list of all identified native, non-native, cryptogenic, and uncategorized taxa by site, see Appendix 3.

During the RAS, qualitative accounts of the fouling organisms most visually apparent at a site were used to determine the aspect dominant taxa. While data on taxa counts and relative percentages provide useful information on non-native diversity, the aspect dominant taxa are an important complement to understand where and which non-native species are abundant within the fouling community. Non-native species were among the aspect dominant taxa at eight of the nine sites sampled during the RAS. Taxa that made up the aspect dominant group varied between each site, but native mussels were commonly interspersed with non-native species, such as the bryozoan *Tricellaria inopinata*, colonial and solitary tunicates, and the anemone *Diadumene lineata*. Derecktor Robinhood Marine Center supported only native species as aspect dominant taxa. The base of the fouling community was made up of adult *Mytilus edulis* mussels, the hydroid *Ectopleura crocea*, *Metridium senile* anemones, and large blades of the kelp *Saccharina latissima*, largely interspersed with molluscs, polychaetes, and other native taxa. For complete details of aspect dominant taxa by site, see Appendix 1.

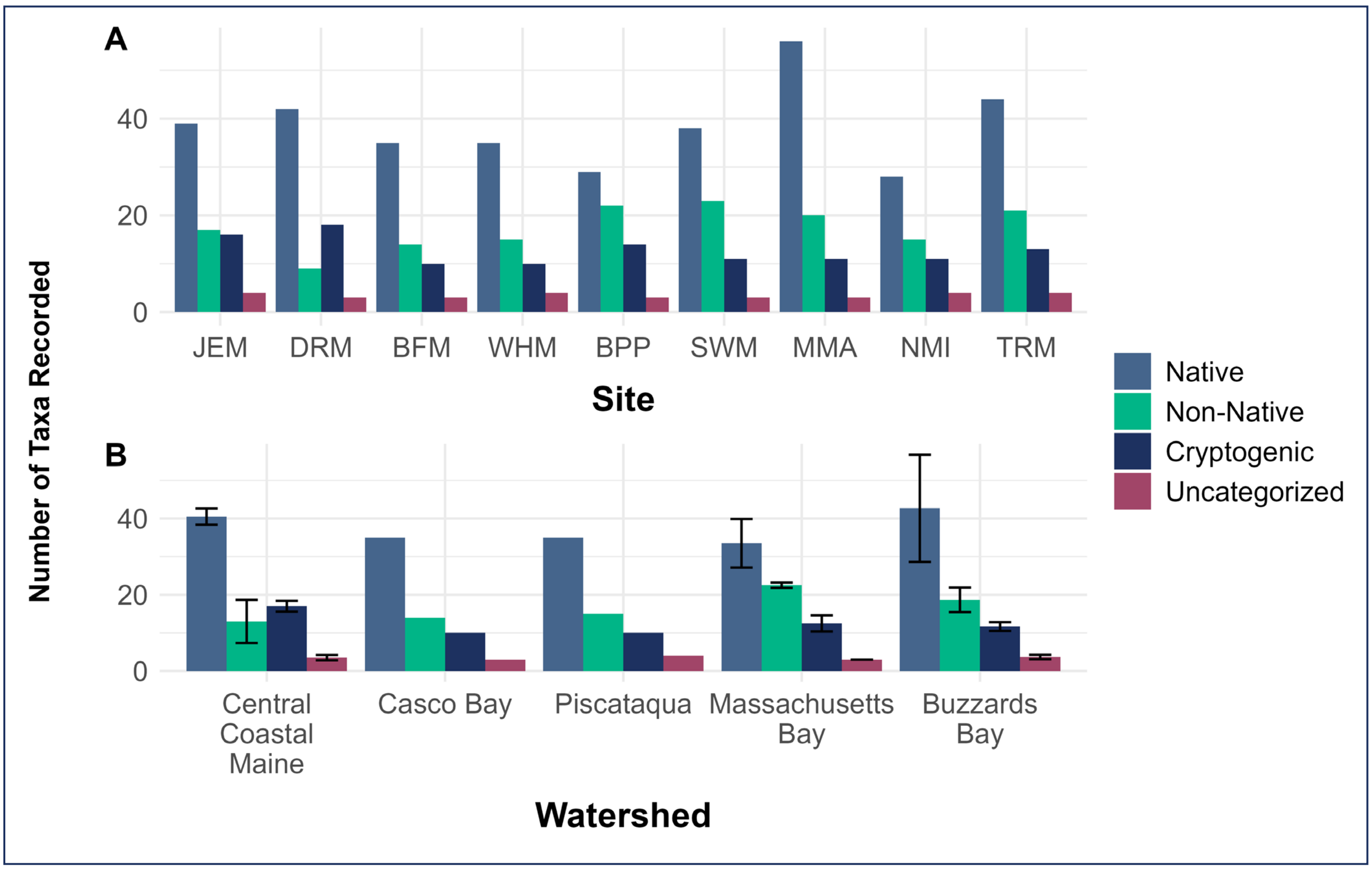


Figure 3: The total number of native, non-native, cryptogenic, and uncategorized taxa collected across 2023 sites (A), and the average number of native, non-native, cryptogenic, and uncategorized taxa when 2023 sites are grouped by watershed (B). Error bars represent one standard deviation from the mean (Central Coastal Maine, n = 2; Casco Bay, n = 1; Piscataqua, n = 1; Massachusetts Bay, n = 2; Buzzards Bay, n = 3). Sites and watersheds are ordered from north to south.

Table 2: Taxa richness and the number and percentage of native, non-native, cryptogenic, and uncategorized taxa found at each site. Sites are ordered from north to south.

Site (Code)	Taxa Richness	Native Count	Native Percent	Non-Native Count	Non-Native Percent	Cryptogenic Count	Cryptogenic Percent	Uncategorized Count	Uncategorized Percent
Journey's End Marina (JEM)	76	39	51.3	17	22.4	16	21.1	4	5.3
Derecktor Robin Hood Marine Center (DRM)	72	42	58.3	9	12.5	18	25.0	3	4.2
Brewer South Freeport Marine (BFM)	62	35	56.5	14	22.6	10	16.1	3	4.8
Wells Harbor Marina (WHM)	64	35	54.7	15	23.4	10	15.6	4	6.3
Beverly Public Pier (BPP)	68	29	42.6	22	32.4	14	20.6	3	4.4
Sandwich Marina (SWM)	75	38	50.7	23	30.7	11	14.7	3	4.0
Massachusetts Maritime Academy (MMA)	90	56	62.2	20	22.2	11	12.2	3	3.3
Northeast Maritime Institute (NMI)	58	28	48.3	15	25.9	11	19.0	4	6.9
F.L. Tripp and Sons, Inc. (TRM)	82	44	53.7	21	25.6	13	15.9	4	4.9

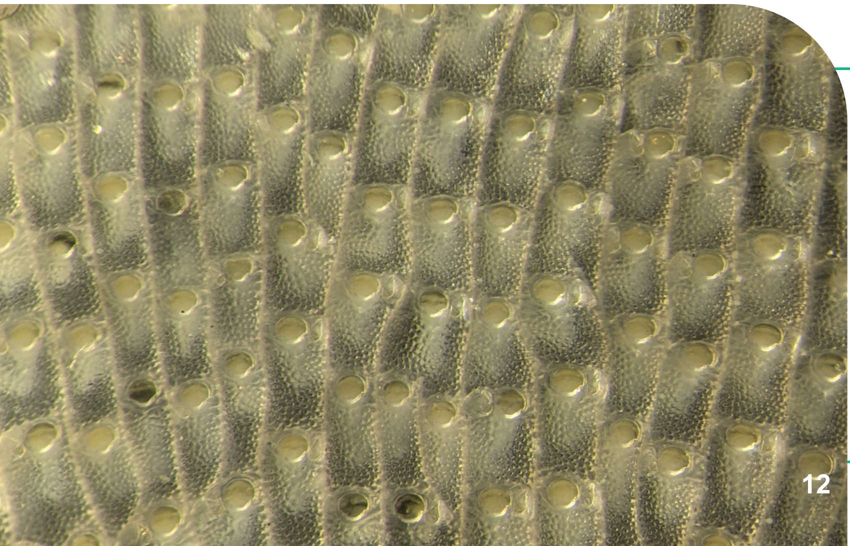
Caprella mutica

This bright orange *Schizoporella japonica* colony caught the eye of scientists on a buoy at Sandwich Marina in Sandwich, Massachusetts. During the 2023 survey, this non-native encrusting bryozoan was found at both Sandwich Marina and Journey's End Marina in Rockland, Maine—representing the first record of the introduced species on the U.S. Atlantic coast. (*Photo credit: James T. Carlton*)

New Non-Native Species Record

The encrusting bryozoan *Schizoporella japonica* was identified at Sandwich Marina in Sandwich, Massachusetts, and at Journey's End Marina in Rockland, Maine, representing the first detection of the species on the U.S. Atlantic coast. Native to the northwest Pacific, *S. japonica* has known introduced populations along the North American Pacific coast from Alaska to southern California and in Europe, Malaysia, and Australia (Loxton et al., 2017). On the east coast of North America, the species was detected in 2021 in the Magdalen Islands in the Gulf of St. Lawrence, Canada (McKenzie et al., 2022). Within its introduced range, the species has been observed fouling floating docks, aquaculture equipment, vessels, and other submerged artificial structures, as well as on natural substrates in the intertidal (Collin et al., 2015; Porter et al., 2015; Ashton et al., 2014).

During the 2023 RAS, *S. japonica* was identified at the survey's northernmost (Journey's End Marina, Rockland, Maine) and southernmost (Sandwich Marina, Sandwich, Massachusetts) Gulf of Maine sites. The distance between these observations suggests that the species is likely already established throughout the Gulf of Maine. Bioinvasions of encrusting bryozoans in New England and across the globe have impacted native species (O'Brien et al., 2013; Berman et al., 1992), facilitated colonization of other invaders (Zabin et al., 2010), and caused economic impacts in coastal communities (Miranda et al., 2018). For example, in the Gulf of Maine, the introduced bryozoan *Membranipora membranacea* has been documented to heavily encrust native kelp, making blades more susceptible to fracturing and leading to kelp bed habitat loss (Lambert et al., 1992; O'Brien et al., 2013; Berman et al., 1992). Further monitoring will be needed to determine the full distribution, spread, and impacts of *S. japonica* in New England.



Along with taxonomic expertise, accurate identification of organisms to the species level can require laboratory investigation under a microscope or even genetic analysis. By observing morphometric features of the bryozoan colony sample, the identification of the introduced bryozoan *Schizoporella japonica* was confirmed by RAS scientists. (*Photo credit: Megan McCuller*)

New Population Records

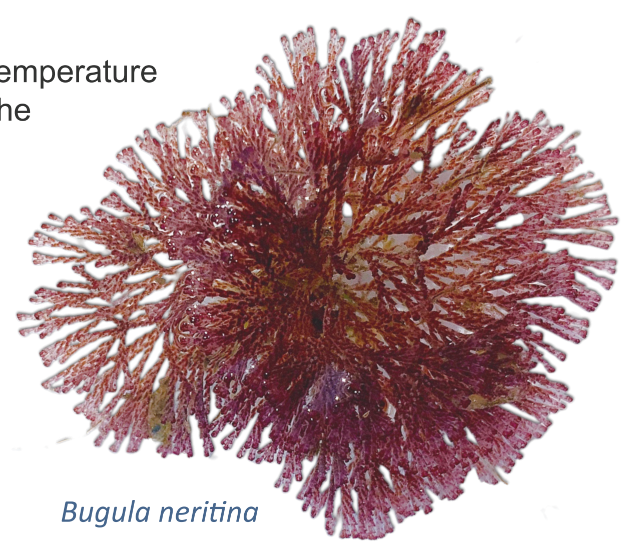
The European flat oyster, *Ostrea edulis*, was purposefully introduced to Maine in the 1950s in an attempt to establish a new shellfish fishery (Loosanoff, 1955). The species is now commonly found throughout Massachusetts Bay (Pederson et al., 2005; Kennedy et al., 2020) and north to Canada (Burke et al., 2008). However, south and west of Cape Cod, *O. edulis* has been reported largely through personal observation, with a few published records from unspecific locations in Rhode Island from 1991-1992 (Carlton, 1992; Karlsson and Ganz, 1993). During the 2013 RAS, *O. edulis* was reported at Popes Island Marina in New Bedford, Massachusetts, and Fort Adams State Park in Newport, Rhode Island (Wells et al., 2014). Between 2013 and 2024, monitors from CZM's MIMIC program also recorded *O. edulis* at multiple locations within Buzzards Bay (Dartmouth, Bourne, and Wareham), on Nantucket, and in Barnstable. Since morphology can be variable in both *O. edulis* and the native *Crassostrea virginica*, verification of earlier records of the non-native species is challenging, and no specimens are readily available to verify the 2013 RAS or MIMIC observations (J. T. Carlton, pers. comm., 2025).

During the 2023 RAS, a robust population of large (10-15 centimeter [cm]) *O. edulis* was found in the fouling community on the floating docks at Massachusetts Maritime Academy. Specimens were collected, photographed, measured, genetically analyzed (see GenBank record for the *Ostrea edulis* specimen nucleotide sequence, OR797004, Davinack & Sheedy), and archived at the Yale University Peabody Museum of Natural History and Harvard University Museum of Comparative Zoology. Both morphological and genetic analyses confirmed the identification as *O. edulis*. If the *O. edulis* population at Massachusetts Maritime Academy in Bourne is not self-reproducing, the source of larvae that resulted in one or more recruitment events here is not yet known.

Environmental Trends

Dissolved oxygen and temperature measurements generally followed spatial trends across the survey region, in which dissolved oxygen was greater and temperatures were cooler at northern sites. Derecktor Robinhood Marine Center in Georgetown, Maine, had the coolest surface water temperature (15.3 °Celsius [C]), and Northeast Maritime Institute in Fairhaven, Massachusetts, was the warmest (24.3 °C). Dissolved oxygen concentration in surface waters was greatest at Journey's End Marina in Rockland, Maine (7.89 milligrams per liter [mg/L]), and lowest at F.L. Tripp & Sons, Inc., in Westport, Massachusetts (4.75 mg/L). Derecktor Robinhood Marine Center in Georgetown, Maine, had the lowest salinity (26.2 parts per thousand [ppt]), and Sandwich Marina in Sandwich, Massachusetts, had the greatest salinity (31.6 ppt). The remaining sites had salinity measurements between 29.2 and 30.7 ppt (Table 3).

Derecktor Robinhood Marine Center, which had the coolest temperature and the lowest salinity among sites, is also the site that had the lowest number and percentage of non-native species (Table 2). Located in a relatively protected cove, this site was the only location where native species appeared to be the aspect dominant taxa, including native kelp, hydroids, sea anemones, and mussel clusters (Appendix 1). The relatively cold, fresh nature of this least-invaded site corresponds with studies that suggest low seawater temperature (Lord et al., 2015) and very low salinity (Ruiz et al., 2000) may be less suitable environmental conditions for non-native species establishment in marine fouling communities.



Bugula neritina

Table 3: Water quality parameters recorded during the 2023 RAS. Sites are ordered from north to south. Secchi and bottom depth were recorded with a Secchi disk. Surface and bottom temperature, salinity, and dissolved oxygen were recorded using a YSI Pro 2030 sonde.

Site (Code)	Secchi Depth (m)	Bottom Depth (m)	Surface Temperature (°C)	Bottom Temperature (°C)	Surface Salinity (ppt)	Bottom Salinity (ppt)	Surface Dissolved Oxygen (mg/L)	Bottom Dissolved Oxygen (mg/L)
Journey's End Marina (JEM)	3.1	3.1	17.3	16.7	29.4	29.5	7.9	6.2
Derecktor Robin Hood Marine Center (DRM)	2.5	4.7	15.3	13.2	26.2	29.2	6.4	6.9
Brewer South Freeport Marine (BFM)	1.3	3.6	18.2	18.1	29.8	30.0	7.0	6.2
Wells Harbor Marina (WHM)	2.6	4.8	16.3	16.1	30.0	30.1	7.6	7.6
Beverly Public Pier (BPP)	1.9	1.9	18.3	17.7	30.7	30.3	5.5	4.9
Sandwich Marina (SWM)	1.9	5.5	20.0	17.5	31.6	31.6	5.3	5.3
Massachusetts Maritime Academy (MMA)	1.3	4.2	21.9	21.4	30.5	31.4	7.6	5.7
Northeast Maritime Institute (NMI)	1.4	2.4	24.3	24.4	29.2	30.7	4.8	1.3
F.L. Tripp & Sons, Inc. (TRM)	1.2	1.5	22.8	22.7	29.7	29.8	4.8	3.3

Spatiotemporal Trends

Six of the nine 2023 RAS sites were sampled during at least one previous New England RAS (Table 1). Each repeatedly sampled site had a generally increasing trend for the number and percentage of non-native taxa when compared to all previous years' sampling events (Figure 4). In the 2023 RAS, four of the resampled sites (Journey's End Marina, Wells Harbor Marina, Sandwich Marina, and F.L. Tripp & Sons, Inc.) had the greatest number and percentage of non-native species through time. Brewer South Freeport Marine found a greater number of non-native species in 2013 (15) than in 2023 (14), but the percentage of non-native species was greater in 2023. In 2023, the number of non-native species at Massachusetts Maritime Academy was tied with the maximum number found in 2013 (20). For this site, the greatest percentage of non-native species was recorded in 2018 (24.7%), but this is due to less overall taxa being recorded that year (73 total taxa in 2018 versus 90 in 2023). Generally, the number and percentage of non-natives were greater for recurring Massachusetts sites than Maine sites across all RAS sampling years between 2000 and 2023 (Figure 4).

Since the inception of the New England RAS, 41 unique sites have been sampled in Massachusetts, New Hampshire, and Maine. When all historically sampled sites are grouped by the five major coastal watersheds, the mean number and percentage of non-native species generally increases for each watershed through time (Figure 5). Sites within the southernmost watersheds (Massachusetts Bay and Buzzards Bay) have been the most invaded through time, and which of these two watersheds has higher levels of invasion fluctuates based on sampling year. In the 2023 survey, Massachusetts Bay (2 sites) had the greatest mean number (22.5) and percentage (31.5%) of non-native taxa. The northernmost watersheds (Central Coastal Maine, Casco Bay, and Piscataqua)

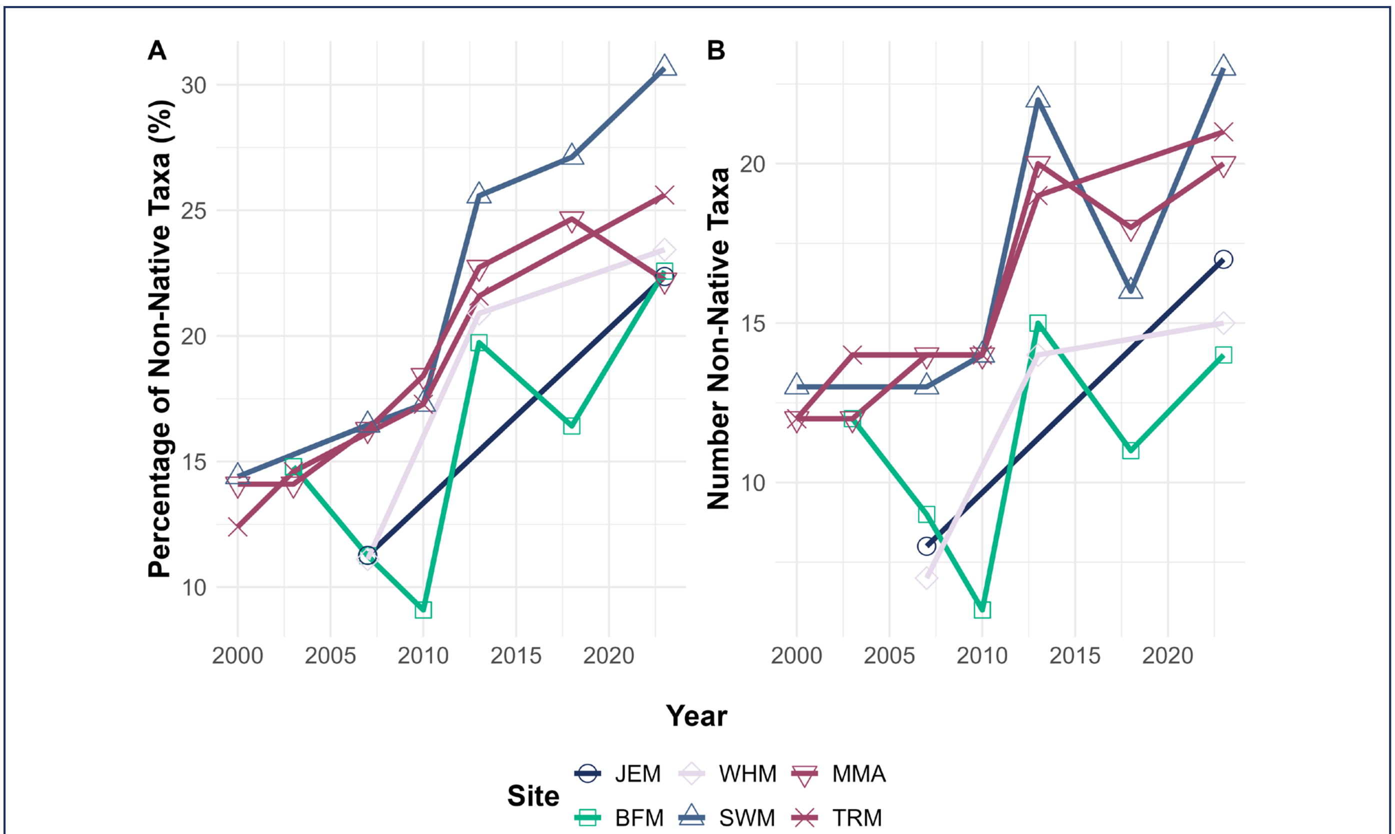


Figure 4: Temporal trends for the percentage (A) and number (B) of non-native taxa collected at 2023 RAS sites that have been sampled during at least one other historical RAS (2000, 2003, 2007, 2010, 2013, or 2018). Sites are colored in accordance with the watershed color key in Figure 1. For details on the historical sampling years for the six sites presented, see Table 1. Native, non-native, and cryptogenic classifications represent those assigned at the time of survey.

have been less invaded across previous surveys, generally remaining below 20% non-native taxa. However, in 2023, the percentage of non-native taxa in the Casco Bay and Piscataqua watersheds (22.6% and 23.4%, respectively) nearly approached the mean non-native percentage in Buzzards Bay (24.6%; 3 sites). Whereas the most northern watershed sampled (Central Coastal Maine) continues to have the least number of non-native species through time.

The increase in the number and percentage of non-native species across individual sites and watersheds mirrors the global trend of increasing bioinvasions through time (IPBES, 2023). The increasing rate of species introductions has been attributed mainly to the acceleration of maritime commerce with technological advancements and globalization of the world economy (Carlton & Geller, 1993; Hulme, 2009). Along the east coast of North America, species introduction via ship fouling and ballast discharge is the dominant vector explaining the increase in non-native species richness through time (Ruiz et al., 2015). Increasing seawater temperatures with global climate change additionally allow for introduced species to survive in locations previously not within their thermal tolerance range and can facilitate species range expansions toward the poles (Canning-Clode & Carlton, 2017; Occhipinti-Ambrogi, 2007). After establishment, species introduced to marine environments are nearly impossible to eradicate (IPBES, 2023). Therefore, increased introductions due to global shipping, climate change, and a suite of other vectors are only expected to grow without preventative management tactics implemented on a global scale (Hewitt & Campbell, 2007) and enforced on a regional scale.

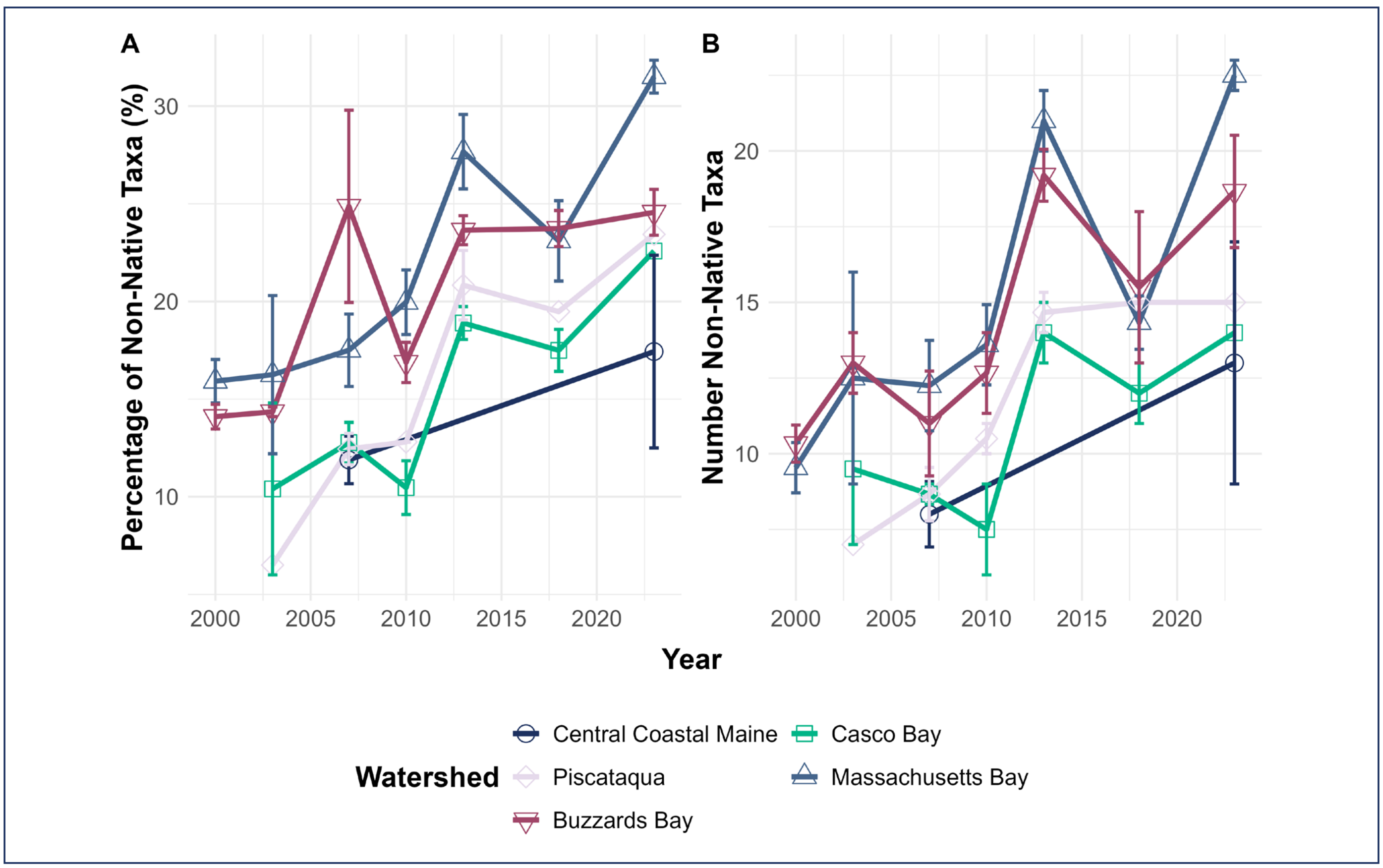


Figure 5: Temporal trends for the percentage (A) and number (B) of non-native taxa collected for all historic RAS sites grouped by watershed. Watersheds are colored in accordance with the watershed color key in Figure 1. Error bars represent one standard deviation from the mean. For the number of sites sampled by watershed during each RAS year, see Appendix 4. Native, non-native, and cryptogenic classifications represent those assigned at the time of survey.

Conclusion

As in previous New England surveys, the 2023 RAS comprehensively documented the marine invertebrate and algal taxa comprising fouling communities at marinas from Maine to Massachusetts, sampling each site for a one-hour period.

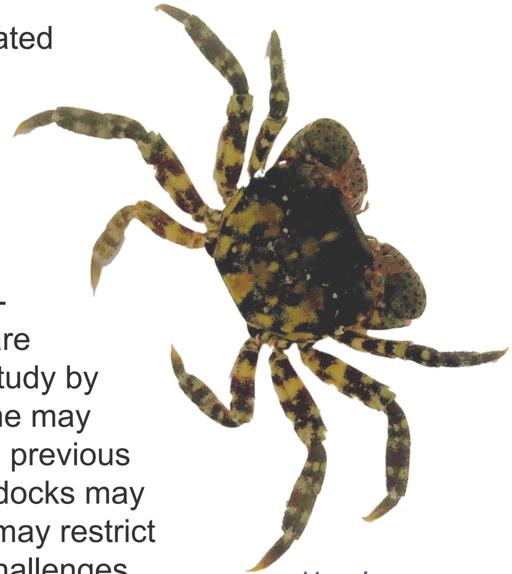
Summary

The survey documented the continued establishment of 31 non-native species and identified one new species introduction for the region: the encrusting bryozoan *Schizoporella japonica* from the Northwest Pacific. The survey also revealed a large, previously unknown population of the European flat oyster, *Ostrea edulis*, south of Cape Cod at the head of Buzzards Bay. Non-native species were the aspect dominant taxa at eight of nine sites—all but Derecktor Robinhood Marine Center in Georgetown, Maine, which had the lowest salinity and was the coldest site. Massachusetts sites had greater counts and percentages of non-native species than sites in Maine. Mirroring global trends for marine bioinvasions, the presence of non-native taxa has increased across watersheds and at resampled sites through time. The findings of the 2023 RAS, the seventh survey of its kind for the region, contribute to the long-term dataset detailing taxa within New England marine fouling communities.

Strengths and Limitations of Rapid Assessment Surveys

Rapid Assessment Surveys are an efficient, cost-effective method for both detecting new species introductions and tracking the spread of prior bioinvasions in targeted habitats (Carlton & Schwindt, 2023). The fouling communities at marinas can be sampled regardless of tides, making these sites more accessible than other habitat types. The surveys also typically involve a broad range of participants, including taxonomic experts, undergraduate students, graduate students, and volunteers. Bringing together a diverse range of taxonomic experts allows for the comprehensive inventorying of native, non-native, and cryptogenic species across a broad region within a short period of time, which allows for updates to records of marine biofouling

Divers can supplement dock-based sampling by observing otherwise unreachable underwater locations. Introduced tunicates and other species were observed by the dive team on the pilings of Journey's End Marina in Rockland, Maine. (*Photo credit: U.S. EPA Region 1*) diversity on a recurring basis. Additionally, RAS results have stimulated local and regional actions to attempt to track the pace of marine bioinvasions, including supporting preventative management approaches, developing new collaboratives, and informing participatory science programs (Pederson et al., 2005).



Hemigrapsus sanguineus

By design, a RAS is restricted in time, space, and habitat studied. These surveys are not designed to assess the total diversity of non-native species across habitat types. Therefore, other habitats that are known to be invaded, such as mudflats and salt marshes, require study by other surveys. The ability to resample the same study sites over time may also be limited. In sampling the built environment of active marinas, previous sites may become inaccessible or infeasible to resample—floating docks may have had the biological communities scraped, ownership changes may restrict access, or other barriers to resampling may be presented. These challenges have led to inconsistencies in site selection through the years, which can make site-based temporal trends difficult to discern, though broader regional trends may be inferred. Other factors that influence site selection, such as funding level, weather, or other logistics, may influence which sites can be resampled during a given year.

Management and Future Research

Prevention is key to reducing the rate of new bioinvasions, since control of marine introduced species has been accomplished only in rare, contained situations (IPBES, 2023; Roy et al., 2024). Recent initiatives at various geographic scales have worked to develop more robust regulatory frameworks, build collaboratives, and raise public awareness to prevent aquatic bioinvasions. For example, the GloBallast Partnerships Project is an international, public-private cooperative working to develop and pilot an international framework for ballast water management (GloBallast Partnerships Programme, 2017). In the United States, the U.S. Environmental Protection Agency (EPA) recently developed national standards for vessel discharges, and the Coast Guard is in the process of developing implementation, compliance, and enforcement regulations for the new EPA

A large survey team of scientists, students, organizers, funders, and other partners are needed to make each Rapid Assessment Survey possible, encouraging cross-sectoral collaboration.

standards. At the local and regional level, public awareness campaigns on aquatic introduced species focus on communicating best practices to reduce introductions for recreational boaters. As ongoing initiatives to prevent marine biological invasions advance, efforts like the RAS will help regulators and managers understand whether the implemented actions have been effective.

Until collective efforts at the global, federal, and regional scale are successful in reducing marine species introductions, research on the establishment, spread, and impact of introduced and range-expanding species is vital. The study of marine bioinvasions is still in its infancy, relative to other scientific fields researching the marine environment (Carlton & Schwindt, 2023). Therefore, many gaps still exist in our understanding of species historical origins and range, non-native species distributions, the impact scale of bioinvasions, and vector dynamics. For robust management frameworks to be developed, high-quality, current, and comprehensive data are needed. Recurring rapid assessment surveys allow for a continuously updated register of marine communities, early detection of new introductions, and long-term understanding of non-native species distribution and spread. New England RAS partners are dedicated to completing surveys every three to five years to continue regular updates of this long-term dataset. Another survey, which sampled 10 sites from southern New England (Rhode Island and Connecticut) to New York, was completed in August of 2024. Since 2000, the results of the Northeast U.S. surveys have fueled enhanced, cross-sectoral planning and collaboration efforts to track and address non-native marine species along our shared coast. With New England's sustained effort as a model, surveys like the RAS can help scientists communicate the breadth of species introductions and their ecological and economic impacts to inform a sense of urgency to action on this global issue.

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Colpomenia peregrina

Appendix 1: Site Descriptions

Descriptions of the nine sites sampled during the 2023 Rapid Assessment Survey are listed from north to south. Descriptions include sampling date and time, characterization of marina conditions, an overview of the biological communities and aspect dominant taxa, and other site-specific observations of note.

Journey's End Marina (JEM) - Rockland, Maine

Central Coastal Maine Watershed

August 7, 2023, 10:00 AM

Located on Penobscot Bay in the mid-coast Maine town of Rockland, Journey's End Marina is the largest marina in Rockland Harbor with over 85 deep water slips. The harbor houses a U.S. Coast Guard Station and the Rockland Ferry Terminal, which provides ferries to and from island communities in Penobscot Bay. Common introduced species fouling the marina's floating docks included the branching bryozoan *Tricellaria inopinata*, the amphipod *Caprella mutica*, and several non-native ascidians. Other common organisms included *Mytilus edulis* mussel clusters; the anemone *Metridium senile*; fucoid and *Ulva* spp. algae; and *Ectopleura crocea* and *Obelia dichotoma* hydroids. The kelp *Saccharina latissima* was often covered with encrusting bryozoan colonies. The barnacle *Semibalanus balanoides* densely covered the intertidal portion of the pilings. Divers recorded tunicates, branching bryozoans, and the sea star *Asterias* spp. on the subtidal pilings. The non-native, encrusting bryozoan *Schizoporella japonica* was observed here—the first of two observations during the 2023 RAS, which represent the first published records of the species in the Gulf of Maine. This site was sampled on one previous RAS (2007) and is a newly established Marine Invader Monitoring and Information Collaborative (MIMIC) monitoring site for the Wells National Estuarine Research Reserve starting in 2024.

The Rapid Assessment Survey team walks down to the floating docks at Journey's End Marina in Rockland, Maine.

Scientists observe species fouling the underside of a bumper buoy.

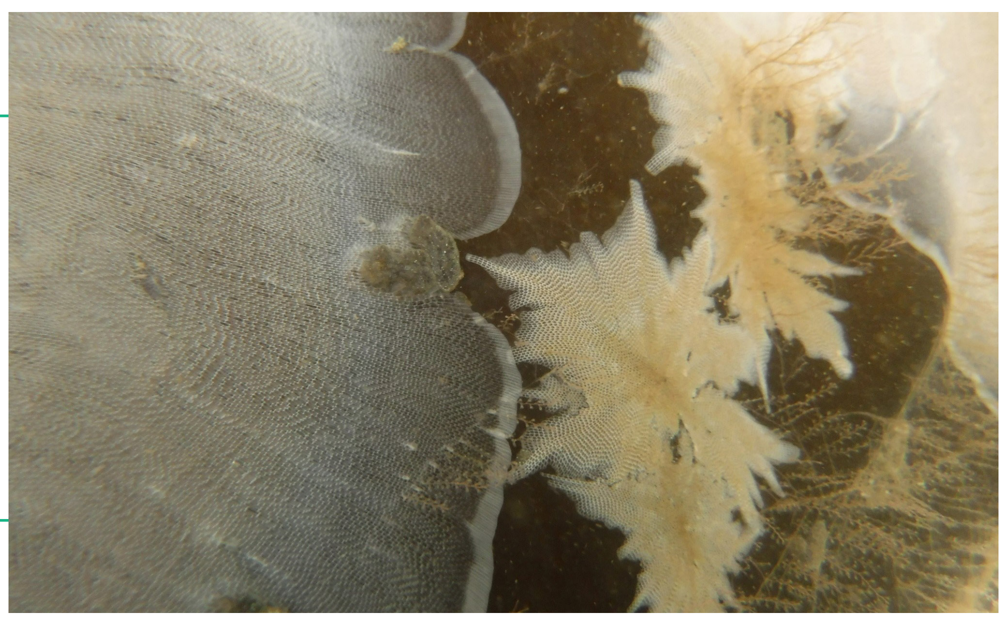
Derecktor Robinhood Marine Center (DRM) - Georgetown, Maine

Central Coastal Maine Watershed

August 7, 2023, 1:45 PM

Derecktor Robinhood Marine Center is located on Rigg's Cove, an inlet on the Sasanoa River, which connects the Kennebec with the Sheepscot River. This marina, which offers 115 slips for vessels up to 55 feet, was the most rural, sheltered site and had the lowest water temperature and salinity. Derecktor was the only marina that hosted largely native aspect dominant taxa within the fouling community. Adult *Mytilus edulis* mussels, which hosted *Hiatella arctica* clams and terebellid polychaetes, were found interspersed with the hydroid *Ectopleura crocea* and *Metridium senile* anemones. Large blades of *Saccharina latissima* hosted *Lacuna vincta* snails and their eggs, along with hydroids and young anemones. Divers recorded that pilings were far less densely colonized than other sites, sporting barnacles, algae, and large crabs. This site was the least invaded by number and percentage of non-native species. This site was not previously sampled across the historical New England RAS, and it is not currently a MIMIC monitoring site.

At Derecktor Robinhood Marine Center in Georgetown, Maine, the team searches for organisms along the floating docks.



These docks are characterized by large blades of kelp, sometimes found encrusted with bryozoans, such as *Membranipora membranacea* (left side of photo) and *Electra pilosa* (right side of photo).

Brewer South Freeport Marine (BFM) - South Freeport, Maine

Casco Bay Watershed

August 8, 2023, 8:40 AM

Along the Harraseeket River on the edge of Casco Bay, Brewer South Freeport Marine offers 100 slips and 15 moorings servicing recreational and commercial lobstering vessels. Downstream of Freeport, Maine, and seaward of I-295, the marina is surrounded by small residential communities and conservation land and is adjacent to the Town Pier, which receives the ferryboat for Bustins Island, an island community in Casco Bay. The base of the fouling community was dominated by adult *Mytilus edulis* mussels with native *Metridium senile* sea anemones and *Ulva* spp. green algae. The community was interspersed with *Crepidula fornicata* slipper snails and *Ectopleura crocea* hydroids. Introduced tunicates were common in the fouling community, along with other common non-native organisms including bryozoans, the anemone *Diadumene lineata*, and the amphipod *Caprella mutica*. Divers recorded large colonies of introduced *Didemnum vexillum*, other introduced tunicates, algae, barnacles, and crabs on the pilings. This site has been sampled on the New England RAS since 2003 (including 2003, 2007, 2010, 2013, and 2018). It is not currently a MIMIC monitoring site.

On a rainy day at Brewer South Freeport Marine in South Freeport, Maine, a student carefully carries a collected specimen. (*Photo credit: Alex Shure*)

An algae specialist sorts through specimens and observes a horseshoe crab molt. (*Photo credit: Alex Shure*)

Wells Harbor Marina (WHM) - Wells, Maine

Piscataqua Watershed

August 9, 2023, 8:20 AM

Bordered by salt marsh and located at the mouth of the Webhannet River, Wells Harbor Marina is within the town-operated harbor area and hosts limited boat slips and moorings for up to 150 vessels. The marina is north of the Wells National Estuarine Research Reserve, surrounded by salt marsh, and landward of the Wells barrier beach and dune system. The fouling base was dominated by *Mytilus edulis* mussels and masses of *Ectopleura crocea* hydroids, with associated anemones, corophiid amphipods, and bryozoans. Barnacles with *Ulva* spp. algae and *Obelia dichotoma* hydroids were common along the waterline. Common introduced species included the tunicates *Botrylloides violaceus* and *Botryllus schlosseri*. While sampling, families were utilizing the docks to trap abundant non-native *Carcinus maenas* crabs. Divers did not sample this site. Wells Harbor Marina was also sampled during the 2007 and 2013 RAS and has been a long-term MIMIC monitoring site for the Wells National Estuarine Research Reserve since 2008.

The team looks for specimens along the floating docks at Wells Harbor Marina in Wells, Maine.

Abundant *Ectopleura crocea* hydroids are observed at Wells Harbor Marina in Wells, Maine.

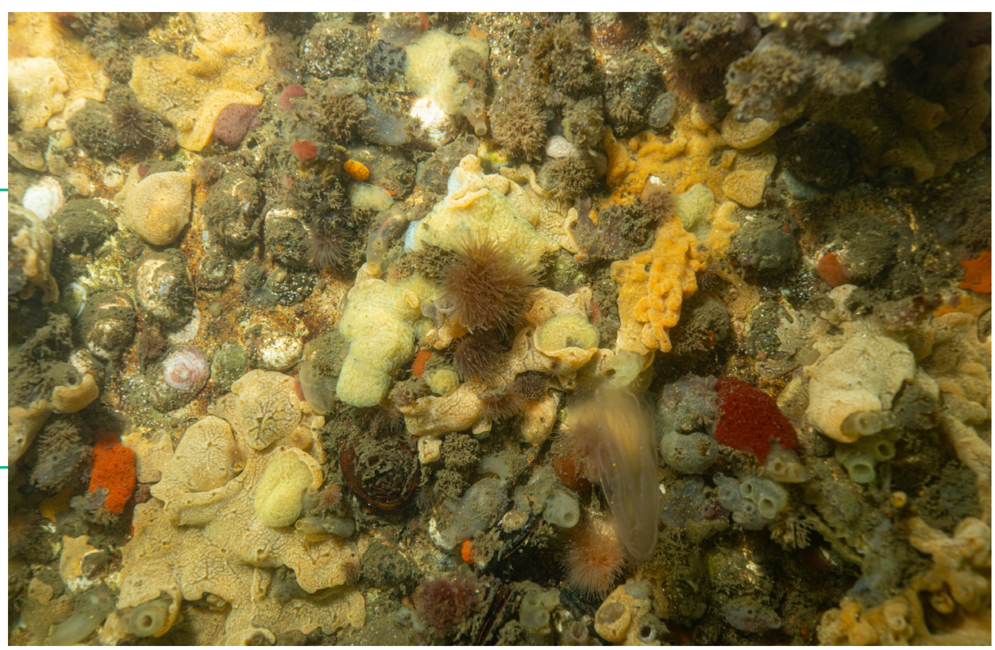
Beverly Public Pier (BPP) - Beverly, Massachusetts

Massachusetts Bay Watershed

August 9, 2023, 11:15 AM

Emptying into Salem Sound, Beverly Harbor is located at the mouth of the Danvers River, which drains highly urbanized sections of Salem, Peabody, Danvers, and Beverly. Within the harbor, Beverly Public Pier and Glover Wharf Municipal Marina offer 24 recreational and 23 commercial slips. The site had the greatest percentage of non-native species relative to native species of the sites sampled in 2023. The *Mytilus edulis* mussels and large *Metridium senile* anemones were invaded by a dense coverage of introduced colonial and solitary tunicates and the introduced bryozoan *Tricellaria inopinata*, which dominated in the fouling community. Divers did not sample this site. This site was sampled for the first time for a New England RAS, but Beverly Pier has been a long-term MIMIC monitoring site for Salem Sound Coastwatch from 2008-present.

At Beverly Pier in Beverly, Massachusetts, the team retrieves a settling plate. (*Photo credit: Alex Shure*)



Abundant introduced ascidians contribute to the community fouling the sides of the floating docks, among other species. (*Photo credit: Alex Shure*)

Sandwich Marina (SWM) - Sandwich, Massachusetts

Massachusetts Bay Watershed

August 11, 2023, 8:10 AM

The municipally run [Sandwich Marina] is located at the northeast end of the Cape Cod Canal, which empties into Cape Cod Bay. The Canal provides a transit pathway for about 15,000 vessels each year, according to the U.S. Army Corps of Engineers. The relatively large marina hosts 164 recreational and 42 commercial slips. This site had the greatest number of non-native taxa at 23 species. The fouling community was dominated by *Mytilus edulis* mussels, along with introduced solitary and colonial tunicates and the non-native bryozoan *Tricellaria inopinata*. This site was the location of the second detection of the new non-native encrusting bryozoan *Schizoporella japonica*. Divers did not sample this site. The marina was sampled on five previous surveys (2000, 2007, 2010, 2013, and 2018) and has been a long-term MIMIC monitoring site—for CZM from 2008-2019 and for Massachusetts Maritime Academy since 2020.

At Sandwich Marina in Sandwich, Massachusetts, the team samples the fouling community on the marina's submerged structures.

Many introduced solitary and colonial tunicates are found at Sandwich Marina, like these two *Ciona intestinalis* individuals with colonies of *Diplosoma listerianum* growing over them.

Massachusetts Maritime Academy (MMA) - Buzzards Bay, Massachusetts

Buzzards Bay Watershed

August 11, 2023, 10:05 AM

Massachusetts Maritime Academy is located at the southwest end of the Cape Cod Canal, which empties into Buzzards Bay at the opposite end of the canal from the Sandwich Marina. The site features one permanent floating dock of approximately 70 meters, which is used by a fleet of training vessels for Academy students. Scientists sampled the sides of floating docks, traps on longlines, and upwelling baskets. Large, non-native *Styela clava* solitary tunicates formed the fouling base, with other abundant introduced species, such as tunicates, bryozoans, and the algae *Grateloupia turuturu*. A large population of European flat oysters, *Ostrea edulis*, was discovered here. The site also featured a relatively high barnacle density and hydroid diversity, as well as the native slipper limpet, *Crepidula fornicata*, and *Ulva* spp. green algae. Divers did not sample this site. Massachusetts Maritime Academy is the most frequently resampled site on the RAS, having been sampled on every previous survey (2000, 2003, 2007, 2010, 2013, and 2018). It has been sampled by Massachusetts Maritime Academy for MIMIC since 2020.

Team members reach for samples at the docks of Massachusetts Maritime Academy in Buzzards Bay, Massachusetts.

Scientists investigate submerged structures, such as this trap covered with tunicates.

Northeast Maritime Institute (NMI) - Fairhaven, Massachusetts

Buzzards Bay Watershed

August 10, 2023, 10:30 AM

Located on the Acushnet River leading to Buzzards Bay, Northeast Maritime Institute's Marina at Slocum Cove hosts 72 slips used by the public and for the school's training vessels, sailing team, and boat building lab. The site's location within New Bedford Habor is upstream of the New Bedford Hurricane Barrier, sits within the New Bedford Harbor Superfund site, and is adjacent to the port of New Bedford—the largest commercial fishing port by value in the United States. This site had the lowest recorded number of native taxa and the lowest taxa richness (total species). The fouling community featured a base of introduced branching bryozoans, non-native tunicates, and a crust of the non-native bryozoan *Conopeum seurati*. Other common organisms included red filamentous and *Ulva* spp. algae and *Obelia bidentata* and *Obelia hyalina* hydroids. Divers did not sample this site. The site was sampled for the first time for a New England RAS and was first sampled for a MIMIC training in 2023.

Scientists cover the docks of Northeast Maritime Institute's Marina at Slocum Cove in Fairhaven, Massachusetts. (*Photo credit: John Robson*)

Scientists observe the association between the encrusting bryozoan *Schizoporella variabilis* and the polychaete worm *Hydroides dianthus*. (*Photo credit: John Robson*)

F. L. Tripp & Sons, Inc. (TRM) - Westport, Massachusetts

Buzzards Bay Watershed

August 10, 2023, 8:30 AM

F.L. Tripp & Sons, Inc. is the southernmost site sampled during the 2023 RAS. It is located along the landward side of Westport's Horseneck Beach barrier system on the Westport River, which empties into Buzzards Bay. The marina is one of the largest sampled on this survey, hosting 175 slips. The introduced bryozoans *Tricellaria inopinata* and *Bugula neritina*, colonial tunicates, and the introduced rockpool shrimp *Palaemon elegans* were common in the fouling community. While mussels were few on the floating docks, divers reported larger *Mytilus edulis* on the pilings. Drifting eelgrass and the holopelagic offshore seaweed *Sargassum* sp. brought in a number of interesting associated pelagic species, such as two species of polychaete worms, the native nudibranch *Scyllaea pelagica*, the native swimming crab *Portunus gibbesii*, and *Aglaophenia latecarinata* hydroids. The marina was sampled on four previous surveys (2000, 2003, 2010, and 2013) and is not currently a MIMIC monitoring site.

The team searches the docks at F.L. Tripp & Sons, Inc., in Westport, Massachusetts.

Several pelagic species, including this swimming crab *Achelous gibbesii,* drifted into the marina on eelgrass and algae.

Appendix 2: Participants

This table lists the scientists, students, and organizers that supported the 2023 RAS.

Name	Role	Affiliation
Adrienne Pappal	Co-organizer and logistics, general taxonomy	Massachusetts Office of Coastal Zone Management
Aidan Webb	Ascidian taxonomy	Massachusetts Maritime Academy
Alana Rivera	Voucher collection	Harvard Museum of Comparative Zoology
Alex Shure	Photographer	Independent Photographer
Alexis Neffinger	Co-organizer and logistics, dock master	Massachusetts Office of Coastal Zone Management
Andrew Davinack	Polychaete taxonomy	Wheaton College
Angela Brewer	Diver	Maine Department of Marine Resources
Aria Lupo	Barnacle taxonomy	Princeton University
Avril Lynch	Water quality, lab and field assistance	Massachusetts Office of Coastal Zone Management
Brandon O'Brien	Algal taxonomy	University of New Hampshire
Brian Drake	Diver	U.S. Environmental Protection Agency
Carol Thornber	Algal taxonomy	University of Massachusetts Boston
Carolina Bastidas	General taxonomy	Massachusetts Institute of Technology Sea Grant
Danielle Gaito	Diver	U.S. Environmental Protection Agency
El Fernekees Hartshorn	Crustacean taxonomy	University of Rhode Island
Emily Savage	General taxonomy	Southern Maine Community College
Emily Zimmerman	Diver	Maine Department of Marine Resources
Eric Nelson	Diver	U.S. Environmental Protection Agency
Evelyn Spencer	Diver	U.S. Environmental Protection Agency
Gabrielle Kuba	Algal taxonomy	University of Rhode Island
Heather Glon	Anemone taxonomy	Maine Department of Marine Resources
Henry Choong	Hydroid taxonomy	Royal British Columbia Museum
James Carlton	General taxonomy, barnacle taxonomy	Williams College
Jean Brochi	Diver	U.S. Environmental Protection Agency
Jeff Goddard	Heterobranch taxonomy	University of California Santa Barbara
Jenn Dijkstra	Ascidian taxonomy	University of New Hampshire
Jeremy Miller	Laboratory host, lab and field assistance	Wells National Estuarine Research Reserve
Jessica Rotondo	Ascidian taxonomy	Massachusetts Maritime Academy
Josh Noll	Diver	Maine Department of Marine Resources
Judith Pederson	General taxonomy	Massachusetts Institute of Technology Sea Grant
Katie Brandler	Barnacle taxonomy	Duke University
Kristin Osborne	Laboratory host, ascidian taxonomy	Massachusetts Maritime Academy
Larry G. Harris	General taxonomy	University of New Hampshire
Megan McCuller	Bryozoan taxonomy	North Carolina Museum of Natural History
Melissa Merkel	Voucher collection	Harvard Museum of Comparative Zoology
Michele Tremblay	Logistics	Naturesource Communications
Michelle Tang	Voucher collection	Harvard Museum of Comparative Zoology
Nancy Prentiss	Polychaete taxonomy	University of Maine at Farmington
Niels Hobbs	Crustacean taxonomy	University of Rhode Island
Phil Colarusso	Diver	U.S. Environmental Protection Agency
Robert Russell	General taxonomy	Maine Department of Marine Resources
Sara Grady	General taxonomy, dock master	Mass Audubon (Formerly North and South Rivers Watershed Association/Massachusetts Bay National Estuary Partnership)
Sean Duffey	Co-organizer and logistics, water quality	Massachusetts Office of Coastal Zone Management
Tom Trott	General taxonomy	Suffolk University
Walt Lambert	General taxonomy	Framingham State University

Appendix 3: Taxa Recorded on the 2023 RAS

The following tables list all taxa identified to the species or genus level during the 2023 Rapid Assessment Survey. Sites are listed from north to south and are labeled by the site code: Journey's End Marina (JEM), Derecktor Robinhood Marine Center (DRM), Brewer South Freeport Marine (BFM), Wells Harbor Marina (WHM), Beverly Public Pier (BPP), Sandwich Marina (SWM), Massachusetts Maritime Academy (MMA), Northeast Maritime Institute (NMI), and F.L. Tripp & Sons, Inc. (TRM). Scientific names were approved by the RAS taxonomist team and taxonomic authorities (including formatting) were derived from the World Register of Marine Species Database. "X" indicates that the taxon was found at a site, and "-" indicates it was not found. The iNaturalist 2023 New England Rapid Assessment Survey page contains images of living specimens observed during the survey, including 72 total taxa from the fouling community and a few non-target drift and pelagic species encountered.

Appendix 3a: Non-Native Taxa

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	WHM	BFM	BPP	SWM	MMA	NMI	TRM
Neodexiospira brasiliensis	Annelida	(Grube, 1872)	-	-	-	-	-	-	X	-	-
Caprella mutica	Arthropoda	Schurin, 1935	X	X	X	X	X	X	X	-	-
Carcinus maenas	Arthropoda	(Linnaeus, 1758)	X	X	X	X	X	X	X	-	X
Chthamalus fragilis[1]	Arthropoda	Darwin, 1854	-	-	-	-	-	-	X	-	-
Hemigrapsus sanguineus	Arthropoda	(De Haan, 1835)	-	-	X	X	X	X	X	X	X
Ianiropsis serricaudis	Arthropoda	Gurjanova, 1936	-	-	-	-	X	X	-	X	X
Palaemon elegans	Arthropoda	Rathke, 1836	X	-	X	-	X	X	X	-	X
Palaemon macrodactylus	Arthropoda	Rathbun, 1902	-	-	-	-	-	-	-	X	X
Praunus flexuosus	Arthropoda	(Müller, 1776)	X	X	-	X	-	-	-	-	-
Bugula neritina	Bryozoa	(Linnaeus, 1758)	-	-	-	-	X	X	X	X	X
Bugulina simplex	Bryozoa	(Hincks, 1886)	-	-	-	-	-	-	-	-	X
Conopeum sp. cf. *seurati*	Bryozoa	Gray, 1848	-	-	-	-	X	-	-	X	-
Membranipora membranacea	Bryozoa	(Linnaeus, 1767)	X	X	X	-	X	X	X	X	X
Schizoporella japonica	Bryozoa	Ortmann, 1890	X	-	-	-	-	X	-	-	-

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	WHM	BFM	BPP	SWM	MMA	NMI	TRM
Tricellaria inopinata	Bryozoa	d'Hondt & Occhipinti Ambrogi, 1985	X	-	X	X	X	X	X	X	X
Ascidiella aspersa	Chordata	(Müller, 1776)	X	-	-	X	X	X	X	-	X
Botrylloides violaceus	Chordata	Oka, 1927	X	X	X	X	X	X	X	X	X
Botryllus schlosseri[2]	Chordata	(Pallas, 1766)	X	X	X	X	X	X	X	X	X
Ciona intestinalis	Chordata	(Linnaeus, 1767)	X	X	X	X	X	X	X	-	X
Didemnum vexillum	Chordata	Kott, 2002	X	X	X	X	X	X	X	X	X
Diplosoma listerianum	Chordata	(Milne Edwards, 1841)	X	-	X	X	X	X	X	X	X
Styela canopus	Chordata	(Savigny, 1816)	-	-	-	-	-	X	-	-	X
Styela clava	Chordata	Herdman, 1881	X			X	X	X	X	X	X
Diadumene lineata	Cnidaria	(Verrill, 1869)	-	X	X	X	X	X	-	X	X
Littorina littorea	Mollusca	(Linnaeus, 1758)	X	-	-	X	-	-	-	-	-
Ostrea edulis	Mollusca	Linnaeus, 1758	-	-	X	-	X	X	X	-	-
Colpomenia peregrina	Ochrophyta	Sauvageau, 1927	X	-	-	-	-	X	-	-	-
Codium fragile subsp. *fragile*	Chlorophyta	(Suringar) Hariot, 1889	X	-	-	-	X	-	X	X	X
Bonnemaisonia hamifera	Rhodophyta	Hariot, 1891	-	-	X	-	-	X	-	-	-
Dasysiphonia japonica	Rhodophyta	(Yendo) H.-S. Kim, 2012	-	-	X	-	X	X	X	-	-
Grateloupia turuturu	Rhodophyta	Yamada, 1941	-	-	-	-	X	X	X	X	X
Lomentaria clavellosa	Rhodophyta	(Lightfoot ex Turner) Gaillon, 1828	-	-	-	-	X	-	-	-	X

[1] All species listed in this table are considered introduced species to the region, since their presence in the region is due to human-mediated vectors. However, *Chthamalus fragilis*, while still considered a non-native species, is not considered an introduced species given that it is unclear if range expansion is due to natural or human-mediated vectors. Consequently, *C. fragilis* is defined as a non-native, cryptovectic species.

[2] Populations of *Botryllus schlosseri* in New England consist of both non-native and native clades (Yund et al., 2015). Identification can only be determined via genetic analysis.

Appendix 3b: Native Taxa

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Alitta succinea	Annelida	(Leuckart, 1847)	-	X	-	-	-	-	-	-	X
Hydroides dianthus	Annelida	(Verrill, 1873)	-	-	-	-	-	X	X	X	X
Pista palmata	Annelida	(Verrill, 1873)	-	-	-	-	-	-	-	-	X
Polydora aggregata[1]	Annelida	Blake, 1969	-	-	-	-	-	-	X	-	X
Sabella sp.	Annelida	Linnaeus, 1767	-	-	-	-	X	-	X	-	-
Amphibalanus eburneus	Arthropoda	(Gould, 1841)	-	-	-	-	X	-	X	X	-
Amphibalanus improvisus	Arthropoda	(Darwin, 1854)	-	-	-	-	-	-	X	-	-
Amphibalanus venustus	Arthropoda	(Darwin, 1854)	-	-	-	-	-	-	X	-	-
Ampithoe longimana	Arthropoda	Smith, 1873	-	-	-	-	-	X	-	-	-
Ampithoe valida	Arthropoda	S.I. Smith, 1873	-	-	-	-	-	X	X	X	-
Apocorophium acutum	Arthropoda	(Chevreux, 1908)	-	-	-	-	-	-	X	-	-
Balanus crenatus	Arthropoda	Bruguière, 1789	X	X	X	X	X	X	X	X	X
Calliopius laeviusculus	Arthropoda	(Krøyer, 1838)	X	X	X	X	-	-	-	-	-
Dyspanopeus sayi	Arthropoda	(Smith, 1869)	-	-	-	-	-	X	X	X	X
Elasmopus levis	Arthropoda	(S.I. Smith in Verrill & Smith, 1874)	-	-	-	-	-	-	-	X	X
Gammarellus angulosus	Arthropoda	(Rathke, 1843)	X	-	-	X	-	-	-	-	-
Gammarus mucronatus	Arthropoda	Say, 1818	-	-	X	-	-	X	-	-	-
Gammarus oceanicus	Arthropoda	Segerstråle, 1947	X	X	-	X	-	-	-	-	-
Idotea balthica	Arthropoda	(Pallas, 1772)	-	-	X	X	X	-	X	-	X
Idotea metallica	Arthropoda	Bosc, 1801	-	-	X	X	-	-	-	-	-
Idotea sp.[2]	Arthropoda	Fabricius, 1798	-	X	-	-	-	-	-	-	-
Jaera albifrons subsp. albifrons	Arthropoda	Leach, 1814	-	-	X	-	-	-	-	-	-
Jassa marmorata	Arthropoda	Holmes, 1905	X	X	X	X	X	X	X	-	-

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Libinia dubia	Arthropoda	H. Milne Edwards, 1834	-	-	-	-	-	-	-	-	X
Libinia emarginata	Arthropoda	Leach, 1815	-	-	-	-	-	-	X	-	X
Monocorophium tuberculatum	Arthropoda	(Shoemaker, 1934)	-	-	X	-	-	X	-	X	-
Palaemon pugio	Arthropoda	(Holthuis, 1949)	-	-	X	-	-	-	-	X	-
Palaemon vulgaris	Arthropoda	Say, 1818	-	-	-	-	-	X	-	X	X
Panopeus herbstii	Arthropoda	H. Milne Edwards, 1834	-	-	X	X	-	X	-	-	X
Phoxichilidium femoratum	Arthropoda	(Rathke, 1799)	-	-	-	-	-	-	X	-	-
Ptilohyale plumulosus	Arthropoda	(Stimpson, 1857)	-	-	-	-	-	-	X	-	-
Semibalanus balanoides	Arthropoda	(Linnaeus, 1767)	X	-	X	X	X	X	X	X	X
Neomysis americana	Arthropoda	(S.I. Smith, 1873)	-	-	X	-	-	-	-	-	-
Aetea arcuata	Bryozoa	Winston & Hayward, 2012	-	-	-	-	-	-	X	-	-
Alcyonidium maculosum	Bryozoa	Winston & Hayward, 2012	-	X	-	-	-	-	-	-	-
Amathia dichotoma	Bryozoa	(Verrill, 1873)	-	-	-	-	-	-	X	-	X
Amathia gracilis	Bryozoa	(Leidy, 1855)	X	-	X	X	X	X	X	-	X
Amathia tertia	Bryozoa	(Winston & Hayward, 2012)	-	X	-	-	-	-	X	X	-
Biflustra tenuis	Bryozoa	(Desor, 1848)	-	-	-	-	-	-	X	-	-
Bugulina fulva	Bryozoa	(Ryland, 1960)	X	-	-	-	-	-	-	X	-
Bugulina stolonifera	Bryozoa	(Ryland, 1960)	X	X	X	-	X	X	X	X	X
Celleporella hyalina	Bryozoa	(Linnaeus, 1767)	-	X	-	-	X	-	X	-	-
Conopeum tenuissimum	Bryozoa	(Canu, 1908)	-	X	-	X	-	-	-	-	-
Crisia sp.	Bryozoa	Lamouroux, 1812	-	-	-	-	-	-	X	-	-
Crisularia turrita	Bryozoa	(Desor, 1848)	-	-	-	-	-	X	X	-	-
Electra monostachys[3]	Bryozoa	(Busk, 1854)	-	X	-	-	-	-	-	-	-
Electra pilosa[3]	Bryozoa	(Linnaeus, 1761)	X	X	-	X	X	-	X	X	-
Nolella blakei	Bryozoa	Rogick, 1949	-	-	-	X	-	-	-	-	-
Schizoporella variabilis	Bryozoa	(Leidy, 1855)	-	-	-	-	-	-	X	X	X

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Aplidium constellatum	Chordata	(Verrill, 1871)	-	-	-	-	-	X	X	-	-
Aplidium glabrum	Chordata	(Verrill, 1871)	-	-	-	-	X	X	X	-	-
Aplidium pallidum	Chordata	(Verrill, 1871)	-	-	X	-	-	-	-	-	-
Aplidium pellucidum	Chordata	(Leidy, 1855)	-	-	-	-	X	-	X	-	X
Molgula manhattensis	Chordata	(De Kay, 1843)	X	X	X	-	-	X	X	X	-
Molgula provisionalis[3]	Chordata	Van Name, 1945	-	-	X	-	-	-	-	-	-
Molgula sp.[2]	Chordata	Forbes, 1848	-	-	-	X	-	-	-	-	X
Perophora viridis	Chordata	Verrill, 1871	-	-	-	-	-	-	X	-	X
Bougainvillia sp. cf. *carolinensis*	Cnidaria	(McCrady, 1859)	-	-	-	-	-	-	X	-	-
Diadumene leucolena	Cnidaria	(Verrill, 1866)	-	-	-	-	-	-	X	-	-
Ectopleura crocea	Cnidaria	(Agassiz, 1862)	X	X	X	X	-	-	X	-	-
Edwardsiella lineata	Cnidaria	(Verrill in Baird, 1873)	-	-	-	-	X	X	-	-	-
Halopteris tenella	Cnidaria	(Verrill, 1874)	-	-	-	-	-	-	X	-	-
Metridium senile	Cnidaria	(Linnaeus, 1761)	X	X	X	X	X	X	X	-	X
Asterias forbesi	Echinodermata	(Desor, 1848)	X	-	-	-	-	-	-	-	-
Asterias rubens	Echinodermata	Linnaeus, 1758	X	-	-	-	-	-	-	-	-
Strongylocentrotus droebachiensis	Echinodermata	(O.F. Müller, 1776)	X	-	-	-	-	-	-	-	-
Notoplana sp.	Platyhelminthes	Laidlaw, 1903	X	-	-	-	-	-	-	-	-
Aeolidia papillosa	Mollusca	(Linnaeus, 1761)	-	-	-	X	-	-	X	-	-
Anadara transversa	Mollusca	(Say, 1822)	-	-	-	-	-	-	-	-	X
Anomia simplex	Mollusca	A. d'Orbigny, 1853	X	X	X	X	X	X	-	-	X
Astyris lunata	Mollusca	(Say, 1826)	-	-	-	X	X	X	X	-	X
Bittiolum alternatum	Mollusca	(Say, 1822)	-	-	-	-	-	-	-	-	X
Corambe obscura	Mollusca	(A.E. Verrill, 1870)	-	-	-	-	X	X	-	-	X
Crepidula fornicata	Mollusca	(Linnaeus, 1758)	X	X	X	X	X	X	X	X	X

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Crepidula plana	Mollusca	Say, 1822	X	X	X	X	X	X	X	-	X
Dendronotus frondosus	Mollusca	(Ascanius, 1774)	-	X	-	-	-	-	-	-	-
Doto coronata	Mollusca	(Gmelin, 1791)	-	X	-	-	-	-	-	-	-
Eubranchus exiguus	Mollusca	(Alder & Hancock, 1848)	X	X	-	-	-	-	-	-	-
Eubranchus rupium	Mollusca	(Møller, 1842)	-	X	-	-	-	-	-	-	-
Heteranomia squamula	Mollusca	(Linnaeus, 1758)	-	X	-	X	-	-	-	-	-
Hiatella arctica	Mollusca	(Linnaeus, 1767)	X	X	X	X	X	X	-	-	-
Lacuna vincta	Mollusca	(Montagu, 1803)	X	X	-	-	-	-	-	-	-
Lunarca ovalis	Mollusca	(Bruguière, 1789)	-	-	-	-	-	-	-	-	X
Modiolus modiolus	Mollusca	(Linnaeus, 1758)	X	X	-	-	-	X	-	-	-
Mya arenaria	Mollusca	Linnaeus, 1758	-	-	-	X	-	-	-	-	-
Mytilus edulis	Mollusca	Linnaeus, 1758	X	X	X	X	X	X	X	X	X
Onchidoris bilamellata	Mollusca	(Linnaeus, 1767)	X	X	-	-	-	-	-	-	-
Onchidoris muricata	Mollusca	(O.F. Müller, 1776)	-	X	-	-	-	-	-	-	-
Periploma sp.	Mollusca	Schumacher, 1817	-	-	X	-	-	-	-	-	-
Placida dendritica	Mollusca	(Alder & Hancock, 1843)	-	-	-	-	-	-	X	-	-
Polycerella emertoni	Mollusca	A.E. Verrill, 1880	-	-	-	-	-	-	-	-	X
Seila adamsii	Mollusca	(H.C. Lea, 1845)	-	-	-	-	-	-	-	-	X
Tergipes tergipes	Mollusca	(Forsskål, 1775)	-	X	-	X	-	X	X	-	-
Testudinalia testudinalis	Mollusca	(O.F. Müller, 1776)	-	X	-	-	-	-	-	-	-
Lineus ruber	Nemertea	(Müller, 1774)	-	-	-	X	-	-	-	-	-
Lineus sanguineus	Nemertea	(Rathke, 1799)	-	-	X	-	-	-	-	X	-
Chalinula loosanoffi	Porifera	(Hartman, 1958)	-	X	-	-	-	-	-	-	-
Clathria prolifera	Porifera	(Ellis & Solander, 1786)	-	-	-	-	-	-	-	X	-
Cliona celata	Porifera	Grant, 1826	-	-	-	-	X	-	X	X	-
Halichondria panicea	Porifera	(Pallas, 1766)	X	X	X	X	-	-	X	X	-

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Haliclona oculata	Porifera	(Linnaeus, 1759)	-	X	-	-	-	-	-	-	-
Ascophyllum nodosum	Ochrophyta	(Linnaeus) Le Jolis, 1863	X	X	X	X	-	-	X	-	X
Fucus sp.[2]	Ochrophyta	Linnaeus, 1753	X	-	-	-	-	-	X	-	-
Fucus spiralis	Ochrophyta	Linnaeus, 1753	-	X	-	-	-	-	-	-	-
Fucus vesiculosus	Ochrophyta	Linnaeus, 1753	-	-	X	-	X	-	-	-	X
Laminaria digitata	Ochrophyta	(Hudson) J.V. Lamouroux, 1813	-	X	-	-	-	-	-	-	-
Punctaria sp.	Ochrophyta	Greville, 1830	X	-	-	-	-	-	-	-	-
Saccharina latissima	Ochrophyta	(Linnaeus) C.E. Lane, C. Mayes, Druehl & G.W. Saunders, 2006	X	X	-	X	X	X	-	-	-
Sargassum filipendula	Ochrophyta	C. Agardh, 1824	-	-	-	-	-	-	X	X	X
Bryopsis plumosa	Chlorophyta	(Hudson) C. Agardh, 1823	-	-	-	-	-	X	X	X	X
Chaetomorpha ligustica	Chlorophyta	(Kützing) Kützing, 1849	X	-		X	-	-	-	-	-
Chaetomorpha linum	Chlorophyta	(O.F. Müller) Kützing, 1845	-	-	X	-	-	X	-	-	-
Agardhiella subulata	Rhodophyta	(C. Agardh) Kraft & M.J. Wynne, 1979	-	-	-	-	-	X	X	X	X
Antithamnion cruciatum	Rhodophyta	(C. Agardh) Nägeli, 1847	X	X	-	-	X	-	-	-	-
Antithamnionella floccosa	Rhodophyta	(O.F. Müller) Whittick, 1980	-	-	-	-	-	X	-	-	-
Callithamnion corymbosum	Rhodophyta	(Smith) Lyngbye, 1819	X	-	-	-	-	X	-	-	-
Ceramium virgatum	Rhodophyta	Roth, 1797	X	-	X	X	X	X	X	-	-
Champia parvula	Rhodophyta	(C. Agardh) Harvey, 1853	-	-	-	-	-	-	-	-	X
Chondrus crispus	Rhodophyta	Stackhouse, 1797	X	-	-	X	X	X	X	-	-
Dasya baillouviana	Rhodophyta	(S.G. Gmelin) Montagne, 1841	-	-	-	-	-	-	-	-	X
Erythrotrichia carnea	Rhodophyta	(Dillwyn) J. Agardh, 1883	-	X	-	-	-	-	-	-	-
Grinnellia americana	Rhodophyta	(C. Agardh) Harvey, 1853	-	-	-	-	-	X	X	-	X

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Gymnogongrus griffithsiae	Rhodophyta	(Turner) C. Martius, 1833	-	-	-	-	-	-	X	-	-
Kapraunia schneideri	Rhodophyta	(Stuercke & Freshwater) Savoie & G.W. Saunders, 2019	-	-	-	-	-	-	-	X	X
Melanothamnus harveyi	Rhodophyta	(Bailey) Díaz-Tapia & Maggs, 2017	X	X	X	X	-	X	X	X	X
Palmaria palmata	Rhodophyta	(Linnaeus) F. Weber & D. Mohr, 1805	-	X	-	-	-	-	-	-	-
Polysiphonia flexicaulis	Rhodophyta	(Harvey) F.S. Collins, 1911	X	-	-	-	-	-	-	-	-
Polysiphonia stricta	Rhodophyta	(Mertens ex Dillwyn) Greville, 1824	X	-	X	-	X	-	-	-	X
Porphyra purpurea	Rhodophyta	(Roth) C. Agardh, 1824	-	-	X	-	X	-	-	-	-
Porphyra umbilicalis	Rhodophyta	Kützing, 1843	-	-	-	X	-	-	-	-	-
Spermothamnion repens	Rhodophyta	(Dillwyn) Magnus, 1873	-	-	-	X	-	-	X	X	X
Spyridia filamentosa	Rhodophyta	(Wulfen) Harvey, 1833	-	-	-	-	-	-	-	-	X
Vertebrata fucoides	Rhodophyta	(Hudson) Kuntze, 1891	X	-	-	-	-	-	-	-	-
Vertebrata nigra	Rhodophyta	(Hudson) Díaz-Tapia & Maggs, 2017	-	-	X	-	-	-	-	-	-

[1] *Polydora aggregata* was listed as a cryptogenic species in previous RAS reports. However, a recent paper (Davinack et al., 2024) has revised the status of polychaete species in New England fouling communities. This species has been updated to native per this paper.
[2] The indicated taxa left at the genus level are likely one of the native species already represented in this table. These taxa were not included in the overall native species count, as it would likely be redundant of already represented native species.
[3] *Electra monostachys*, *Electra pilosa*, and *Molgula provisionalis* were listed as a cryptogenic species in previous RAS reports, but the species' statuses have since been updated to native (J. T. Carlton, pers. comm.).

Appendix 3c: Cryptogenic Taxa

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Alitta virens[1]	Annelida	(M. Sars, 1835)	X	X	-	X	X	-	-	-	-
Amphitrite cirrata	Annelida	Müller, 1776	-	-	-	-	X	-	-	-	-
Circeis spirillum[1]	Annelida	(Linnaeus, 1758)	-	-	-	-	-	-	-	-	X
Dodecaceria concharum[1]	Annelida	Örsted, 1843	-	-	-	-	X	-	-	-	-
Eulalia viridis[1]	Annelida	(Linnaeus, 1767)	X	-	-	-	X	-	-	-	-
Harmothoe imbricata	Annelida	(Linnaeus, 1767)	X	-	-	-	X	-	-	-	X
Hediste diversicolor	Annelida	(O.F. Müller, 1776)	-	X	X	-	-	-	-	-	-
Janua heterostropha[2]	Annelida	(Montagu, 1803)	-	-	-	-	-	X	-	X	-
Lepidonotus squamatus	Annelida	(Linnaeus, 1758)	X	X	X	-	X	X	X	X	X
Neoamphitrite figulus	Annelida	(Dalyell, 1853)	-	X	X	-	X	-	-	-	-
Nereis pelagica[1]	Annelida	Linnaeus, 1758	-	X	-	-	-	-	-	-	-
Phyllodoce maculata	Annelida	(Linnaeus, 1767)	X	-	-	-	X	-	-	-	X
Phyllodoce mucosa	Annelida	Örsted, 1843	X	-	-	-	-	-	-	-	-
Platynereis sp.[1]	Annelida	Kinberg, 1865	X	-	-	-	-	-	-	-	X
Polydora cornuta[1]	Annelida	Bosc, 1802	X	-	-	-	-	-	-	-	-
Polydora neocaeca	Annelida	Williams & Radashevsky, 1999	-	-	-	-	-	X	-	-	-
Polydora websteri[1]	Annelida	Hartman in Loosanoff & Engle, 1943	-	-	-	-	X	X	X	-	X
Potamilla neglecta	Annelida	(Sars, 1851)	-	-	-	-	X	-	X	X	-
Syllis gracilis[1]	Annelida	Grube, 1840	-	X	X	-	-	-	-	-	-
Caprella penantis	Arthropoda	Leach, 1814	-	-	-	-	-	-	X	-	-
Monocorophium acherusicum	Arthropoda	(A. Costa, 1853)	X	-	X	X	-	X	-	-	-
Monocorophium insidiosum[3]	Arthropoda	(Crawford, 1937)	-	X	-	-	-	X	-	-	X

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Tanais dulongii	Arthropoda	(Audouin, 1826)	-	-	-	-	-	X	X	-	-
Alcyonidium sp.	Bryozoa	Lamouroux, 1813	X	X	X	-	-	-	-	-	-
Amathia imbricata	Bryozoa	(Adams, 1800)	X	X	-	-	-	-	-	-	-
Cryptosula pallasiana	Bryozoa	(Moll, 1803)	X	-	-	-	X	X	X	X	X
Clava multicornis	Chordata	(Forsskål, 1775)	-	X	-	X	-	-	-	-	-
Clytia sp. cf. *gracilis*	Chordata	(M. Sars, 1851)	-	-	-	-	-	-	-	-	X
Clytia hemisphaerica	Chordata	(Linnaeus, 1767)	-	-	-	-	-	-	-	-	X
Dynamena pumila	Chordata	(Linnaeus, 1758)	-	X	-	-	-	-	-	-	-
Eudendrium capillare	Chordata	Alder, 1856	-	-	-	-	-	-	X	-	-
Gonothyraea loveni	Chordata	(Allman, 1859)	-	X	-	-	X	-	-	-	-
Laomedea calceolifera	Chordata	(Hincks, 1871)	-	-	-	-	-	-	X	-	-
Obelia bidentata	Chordata	Clark, 1875	-	-	-	-	-	-	-	X	-
Obelia dichotoma	Chordata	(Linnaeus, 1758)	X	X	-	X	X	-	-	-	-
Obelia geniculata[4]	Chordata	(Linnaeus, 1758)	-	X	-	-	X	-	-	-	-
Obelia hyalina	Chordata	Clarke, 1879	-	-	-	-	-	-	-	X	-
Pachycordyle michaeli	Chordata	(Berrill, 1948)	-	-	-	X	-	-	-	-	-
Pennaria disticha	Chordata	Goldfuss, 1820	-	-	-	-	-	-	X	-	-
Podocorynoides minima	Chordata	(Trinci, 1903)	X	-	-	-	-	-	-	-	-
Facelina bostoniensis	Mollusca	(Couthouy, 1838)	-	-	-	X	-	-	-	-	-
Tenellia adspersa	Mollusca	(von Nordmann, 1845)	-	X	-	X	-	-	-	-	-
Tenellia gymnota	Mollusca	(Couthouy, 1838)	-	-	-	X	-	-	-	-	-
Halichondria bowerbanki	Porifera	Burton, 1930	X	X	X	X	-	X	-	X	X
Haliclona cinerea	Porifera	(Grant, 1826)	-	-	X	X	-	-	-	X	X
Leucosolenia botryoides	Porifera	(Ellis & Solander, 1786)	X	X	X	-	-	X	-	-	-
Sycon ciliatum	Porifera	(Fabricius, 1780)	-	-	-	-	-	X	X	X	-

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Cladophora ruchingeri	Chlorophyta	(C. Agardh) Kützing, 1845	-	-	-	-	-	-	X	-	-
Cladophora sericea	Chlorophyta	(Hudson) Kützing, 1843	-	X	X	-	-	-	-	X	-
Ceramium cimbricum	Rhodophyta	H.E. Petersen, 1924	-	-	-	-	-	-	-	X	X

[1] The indicated polychaete species were listed as native in previous RAS reports. However, a recent paper (Davinack et al., 2024) has revised the status of polychaete species in New England fouling communities. These species have been updated to cryptogenic per this paper.

[2] *Juana heterostropha* was listed as a non-native species in previous RAS reports; however, a recent paper (Davinack et al., 2024) revised the status of polychaete species in New England fouling communities. This species has been updated to cryptogenic per this paper.

[3] *Monocorophium insidiosum* was listed as a native species in previous RAS reports, but the status has been updated to cryptogenic in this report. The species is thought to be native to the North Atlantic, but it is unclear if it originated in the Eastern or Western Atlantic (Carlton, 1979; Bousfield & Hoover, 1997).

[4] *Obelia geniculata* was listed as a native species in previous RAS reports. The status has been updated to cryptogenic in this report based on a genetic study on the species, which found a Massachusetts population of the species may represent a more recent colonization event (Govindarajan et al., 2005).

Appendix 3d: Uncategorized Taxa

Scientific Name	Phylum	Taxonomic Authority	JEM	DRM	BFM	WHM	BPP	SWM	MMA	NMI	TRM
Alitta sp.[1]	Annelida	Kinberg, 1865	-	-	X	-	-	-	-	-	-
Dipolydora socialis[2]	Annelida	(Schmarda, 1861)	-	-	X	-	-	X	X	-	-
Harmothoe sp.[1]	Annelida	Kinberg, 1856	-	X	-	-	-	X	-	-	-
Nereimyra sp.	Annelida	Blainville, 1828	-	-	-	-	X	-	-	-	-
Phyllodoce sp.[1]	Annelida	Lamarck, 1818	-	-	-	-	-	X	-	-	-
Polydora sp.[1]	Annelida	Bosc, 1802	X	-	-	-	-	-	-	-	-
Echinogammarus incertae sedis finmarchicus	Arthropoda	(Dahl, 1938)	X	-	-	-	-	-	-	-	-
Stenothoe sp.	Arthropoda	Dana, 1852	-	-	-	X	-	-	-	-	-
Unknown Amphipod 1[1]	Arthropoda	N/A	-	-	-	-	-	X	-	-	-
Unknown Amphipod 2[1]	Arthropoda	N/A	-	-	-	-	-	-	X	-	-
Clytia sp.[1]	Cnidaria	Lamouroux, 1812	-	-	-	-	-	-	-	-	X
Laomedea sp.[1]	Cnidaria	Lamouroux, 1812	-	-	-	-	-	-	-	X	-
Obelia sp.[1]	Cnidaria	Péron & Lesueur, 1810	X	-	-	-	-	-	-	-	-
Barentsia sp.	Entoprocta	Hincks, 1880	X	X	-	X	X	X	-	X	X
Eubranchus sp.[1]	Mollusca	Forbes, 1838	-	-	-	X	-	-	-	-	-
Flabellina sp.	Mollusca	McMurtrie, 1831	-	-	-	-	-	-	X	-	-
Halichondria sp.[1]	Porifera	Fleming, 1828	-	-	-	-	X	-	-	-	-
Haliclona sp.[1]	Porifera	Grant, 1841	-	-	-	-	-	-	X	-	-
Ulva spp. (blade)	Chlorophyta	Linnaeus, 1753	X	X	X	X	X	X		X	X
Ulva spp. (tube)	Chlorophyta	Linnaeus, 1753	X	X	X	X	-	-	X	X	X
Gracilaria sp.	Rhodophyta	Greville, 1830	-	-	-	-	-	-	-	X	X
Porphyra sp.[1]	Rhodophyta	C. Agardh, 1824	-	X	-	-	-	-	-	-	-

[1] Indicated taxa could not be identified to the species level but may represent taxa identified to species level already represented in Appendix 3. Thus, these taxa were left out of overall taxa counts and analyses to avoid potential redundancies.
[2] Per Davinack et al. (2024), this species is described as an “unresolved cosmopolitan species.” Therefore, it was not categorized into the non-native, native, or cryptogenic groups.

Appendix 4: Number of Sites Sampled by Watershed through Time

This table details the number of sites sampled by watershed during each RAS year, informing the error bars on the plots in Figure 5, which represent one standard deviation from the mean. Figure 5 visualizes the number and percentage of non-native species for sites across watersheds (Central Coastal Maine, Casco Bay, Piscataqua, Massachusetts Bay, Buzzards Bay) for each RAS year since 2000.

Watershed	2000	2003	2007	2010	2013	2018	2023
Central Coastal Maine	0	0	4	0	0	0	2
Casco Bay	0	3	3	3	2	2	1
Piscataqua	0	2	3	3	3	1	1
Massachusetts Bay	13	2	4	6	4	3	2
Buzzards Bay	6	3	3	3	5	2	3