# Developing methods for analysis and drawing conclusions from larval settlement monitoring in Narragansett Bay: Is the timing of seasonal recruitment a driver of non-native success in the intertidal fouling community?

By

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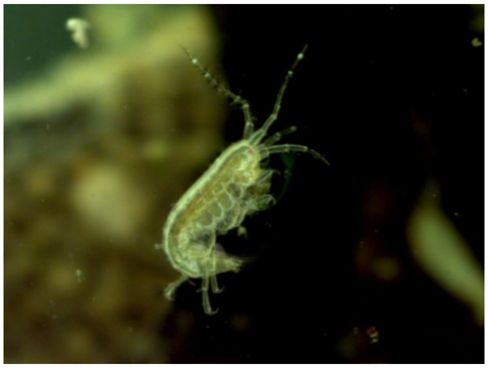

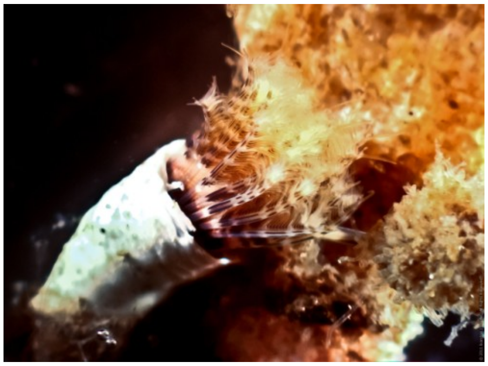

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## Contents

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## Summary

Invasive species are a major threat to marine environments from ecological, economic, and social perspectives. Invasive invertebrates occupy nearly every coastal benthic community in New England, and include ascidians, crustaceans, and bryozoans. The life history of these organisms involves a series of larval, settlement, recruitment, and juvenile phases, and the supply and dispersion of planktonic larvae has long been recognized as a major driver of benthic marine community structure.

While the locations where introduction takes place are fairly obvious, the transition from introduction to establishment is less understood, since these species often arrive as larvae and their small size makes it difficult to track their dispersion. Monitoring is a key component of successfully managing marine invasive species, but efforts have been largely uncoordinated and it is difficult to compare various studies in the absence of a unified tracking method. Settlement plates have begun to standardize this process, and have been used in a variety of different studies to answer questions about larval recruitment, effects of environmental parameters, community structure, and competition.

The Rhode Island Coastal Resources Management Council has been conducting a larval settlement plate study since 2012 in order to track both invasive and native species and understand more about local benthic community ecology. Settlement plates are distributed at 10 sites around Narragansett Bay, and plates are inspected approximately every month between May and December. At each site, some plates are replaced each month, while others are not replaced until the end of the season. The data collected so far has been relatively unorganized and unanalyzed. This project aimed to develop methods for organization and analysis in order to understand the data's potential. In the process, data from 2013 was used to draw conclusions about larval settlement trends, and to determine whether the timing of seasonal recruitment is a driver of non-native success in the intertidal fouling community. The fouling community that develops over the course of the season likely does not reflect the actual planktonic community of

potential settlers, and this difference may be attributed to variation in recruitment timing and duration between species.

Abundance trends on monthly plates indicated that native species begin recruiting slightly earlier than invasive species, but are quickly outcompeted. The negative relationship between native abundances on monthly and seasonal plates early in the year suggests that natives are unable to successfully establish before invasive recruitment rises, despite their temporal advantage. This suggests that the length of recruitment periods combined with competition for space and other resources are likely more important than the timing of recruitment in driving an invasive-dominated community structure.

The data suffers from a few limitations by nature of the monitoring methods. Only three sites were usable for detailed analysis due to inconsistency in sampling months between sites. A more coordinated effort among individual monitors would greatly expand the consistency of the data. Additionally, abundance measurements are highly subjective, and it is suggested that new methods be adopted to standardize this process. Continued monitoring of Narragansett Bay’s intertidal fouling community will provide managers with critical information about invasive ecology, how the local fouling community develops and changes over the course of the year, and how invasive introductions change the community composition. The data amassed so far should be treated as a baseline to which subsequent years can be compared, and against which management efforts can measure success.

## List of Acronyms

| | |
|---|---|
| AHQ | Allen Harbor (Quonset, RI) |
| CRMC | Rhode Island Coastal Resources Management Council |
| FTA | Fort Adams (Newport, RI) |
| GSO | University of Rhode Island Graduate School of Oceanography (Narragansett, RI) |
| LSPS | Larval Settlement Plate Study |
| MIS | Marine Invasive Species |
| MMA | East Passage Marina (Melville, RI) |
| MOB | Matunuck Oyster Bar (South Kingstown, RI) |
| PCP | Prudence Island |
| PJM | Point Judith Marina (South Kingston, RI) |
| RWU | Roger Williams University (Bristol, RI) |
| SERC | Smithsonian Environmental Research Center |
| SPT | Sakonnet Point (Little Compton, RI) |
| STB | Save The Bay (Providence, RI) |

## Overview

### *Marine Invasive Species*

Invasive species are a major threat to marine environments from ecological, economic, and social perspectives (Ricciardi et al. 2000, Bax et al. 2003, Bishop and Hutchings 2011, Switzer et al. 2011, Collin et al. 2013). So damaging is their impact that they are thought to be the most significant cause of decline in native species after habitat loss (Altman and Whitlatch 2007, RIAISWG 2007). Coastal habitats have been identified as one of the most invaded ecosystems in the world (Altman and Whitlatch 2007), with new species arriving daily.

The introduction and establishment of new invasive species can be defined as a four-stage process: 1) transport and introduction, 2) local establishment, 3) regional spread, and 4) population growth (Collin et al. 2013). Unlike terrestrial invaders, marine invasive species (MIS) are introduced through a limited number of vectors, primarily through shipping and boating (e.g. hull-fouling, ballast water), and aquaculture practices (Bax et al. 2003, Occhipinti-Ambrogi and Savini 2003, Collin et al. 2013, Osman and Whitlatch 2007, RIAISWG 2007). Despite this, the potential quantity of transport by each is enormous: at any given moment, upwards of 10,000 different species are being transported in ships' ballast tanks alone (Bax et al. 2003, Delaney et al. 2007). While most of these species cannot tolerate prolonged exposure to the conditions in these tanks and subsequently die en route, some do survive and flourish in the new habitat (Bax et al. 2003), often to the detriment of native species and the local ecology. After the initial introduction, the secondary spread of these species is responsible for determining the scale of the invasion and the ecological and economic impacts associated with it (Johnson et al. 2001).

In 2007, there were over 500 known MIS along the coast of North America (Delaney et al. 2007), and research conducted in United States, Australian, and New Zealand ports suggests that a new estuarine or marine species establishes once every 8 to 21 months (Bax et al. 2003). These numbers are likely conservative at present day.

### *Recruitment and Competition*

The supply and dispersion of planktonic larvae has long been recognized as a major driver of benthic marine community structure (Thorson 1950). Before reaching adulthood, larvae must survive a series of life history stages, including larval, settlement, recruitment, and juvenile phases (Menge 1991). The colonization of suitable substrates is, in turn, a multi-step process, involving the biological development of the larva, testing of various habitats for suitability, and settlement, during which permanent physical attachment to the substrate occurs (Keough and Downes 1982, Rodriguez et al. 1993). Settlement, therefore, can be defined as the abundance of attached larvae $n$ in a given area $a$ (Jenkins et al. 2000, Pineda et al. 2010), and the rate of settlement can be expressed as $n\ a^{-1}\ t^{-1}$ (Pineda et al. 2010).

Because the initial settled larvae are incredibly small, an additional “stage” exists as an artifact of human observational limitations, and is the point where the settled organism is detectable by the observer (Keough and Downes 1982). This is termed “recruitment”, and is generally defined as the number of settled larvae that survive after a given period of time (Pineda et al. 2010), which is dependent on the growth rate and physical size of the larvae.

Because recruitment is much easier to measure than actual settlement, recruitment is generally used to make inferences about settlement, but many studies fail to recognize the difference between these two concepts (Keough and Downes 1982, Jenkins et al. 2000). This can result in exaggerated patterns and misleading conclusions when applied in a strict settlement context, since actual settlement is likely much higher than the observable recruits. The study of recruitment over settlement generally makes more sense, since failed settlers do not contribute to the benthic community beyond the initial larval phase.

Benthic invertebrates rely on early recruitment phases to establish population levels (Duchêne 2012), which can ultimately influence local species assemblages. Research on the relationship between recruitment and community structure often involves conducting surveys on intertidal communities along recruitment gradients (Forde and Raimondi 2004). These studies have shown that variation in recruitment effort can drive differences in community structure on large geographic scales (e.g. Connolly et al. 2001, Menge 1991, Forde and Raimondi 2004), but only temporarily influences community composition on local scales (Forde and Raimondi 2004). In these cases, community composition may be more influenced by competition and predation than recruitment. The recruit-adult hypothesis theorizes that adult densities are inversely proportional to recruitment effort, in part because of increased predation in populations with high recruitment (Gaines and Roughgarden 1985, Menge 2000). Menge (1991) suggested that recruitment explains less than 11% of the variation in sessile invertebrate abundance in New England, compared with 50-78% explained by predation and competition.

### *Nuisance Species of New England*

Invasive invertebrates occupy nearly every coastal benthic community in New England, and include ascidians (e.g. *Botrylloides violaceus*, *Didemnum vexillum*, *Ascidiella aspersa*, *Styela clava*, *Ciona intestinalis*, *Botryllus schlosseri*), crustaceans (e.g. *Hemigrapsus sanguineus*, *Caprella mutica*, *Carcinus maenas*, *Ianiropsis serricaudis*), and bryozoans (e.g. *Bugula neritina*) (Figure 1). Beginning with a series of introductions in the 1980s, invasive ascidians have arguably had one of the largest impacts on benthic community structure of any of these groups (Osman and Whitlatch 2007, Carman et al. 2010), and there are a few species whose invasions have been particularly deleterious. The colonial tunicate *D. vexillum* was first documented on the east coast of the U.S. in 1988, but relatively little is known about its ecology. Recently, *Didemnum* has undergone a rapid worldwide expansion (Bullard et al. 2007), successfully overgrowing extensive areas of subtidal and intertidal habitat in the U.S. and Europe (Bullard et al. 2007, Valentine et al. 2007). Research has shown that 50-90% of available benthic habitat on Georges Bank is overgrown by *Didemnum*, and intertidal coverage is comparable, often overgrowing other fouling organisms. In a Long Island Sound study, Bullard et al. (2007) determined that *Didemnum* recruitment lasts from July through November and peaks in late August, but that asexual fragmentation can further propagate colonies beyond those established by larval settlers.

The solitary tunicate *C. intestinalis* is also highly successful, outcompeting other ascidians (including the invasive *S. clava*) (Ramsay et al. 2009), decreasing species richness, and triggering overall changes in community composition (Blum 2007). *B. violaceus*, a colonial tunicate, is commonly recognized as a nuisance species (Bock 2011), and often overgrows native fouling organisms, dominating subtidal communities (Berman et al. 1992). Like *D. vexillum*, *B. violaceus* can form new colonies through asexual fragmentation, increasing its competitive advantage (Bock 2011).

All tunicates, both invasive and native, are an economic concern for shellfisheries, the gear of which is often overgrown to the detriment of cultured oysters and mussels (Carman et al. 2010). Most mitigation efforts have focused on removing *D. vexillum* using mechanical and chemical methods (McCann et al. 2013). These methods include applying peroxide and anti-fouling paint to shellfishing gear, dousing gear with freshwater for several minutes, or letting gear air-dry for extended periods of time. *D. vexillum* attached directly to shellfish are removed through freshwater rinses, tumbling, and salt brine dips (Carman et al. 2010). Unfortunately, the space made available by removing *D. vexillum* is often colonized by *Botrylloides* shortly after treatment, perpetuating the problem (Switzer et al. 2011).

### *Monitoring as a Management Tool*

Despite our knowledge of the mechanisms that facilitate MIS transport, our understanding of the current status of MIS around the world is quite limited (Campbell et al. 2007). Monitoring is a key component of successfully managing MIS (Delaney et al. 2007, Bishop and Hutchings 2011, Mantelatto et al. 2013), and provides a detection system (Delaney et al. 2007, Bishop and Hutchings 2011, Collin et al. 2013), a baseline for biodiversity, the ability to assess invasion patterns, and information on the impact those invasions have. Unfortunately, intense monitoring is rare due to resource limitations (Delaney et al. 2007). Control and eradication of marine invasions was and is often still viewed as too difficult, impractical, and costly (McCann et al. 2013).

In the last several years, however, a growing body of literature has emerged which has brought new ideas about monitoring and eradication to the table, and the management of MIS has moved up the agenda for a variety of environmental disciplines (McCann et al. 2013). Many countries have adopted MIS management programs to take action against established invaders, as well as proactively combat the threat of so-called “next pests” (Bishop and Hutchings 2011) through the use of new vector management policies and specially designed monitoring programs (Bishop and Hutchings 2011, McCann et al. 2013). Lists of ‘next pests’, or species which have the highest probability of invading in the near future, have become increasingly influential in the development of monitoring frameworks, but have had mixed reception. While a monitoring program optimized for early detection of potential invaders could, in theory, be a valuable tool for proactive MIS management, the ‘next pest’ lists used to design these programs often neglect important biological or ecological factors that determine the potential for an exotic species to become invasive. Consequently, these types of regimes result in actual invaders going undetected, since the monitoring methods are not designed to look specifically for them (Bishop and Hutchings 2011), or because no real method has been established (Collin et al. 2013).

The information that has been assimilated through successful monitoring programs and research is often difficult to compare, precisely because of the lack of a unified method. Identifying the underlying patterns of invasion on local, regional, and global scales presents a challenge to environmental scientists and managers because of the variability in the methods and scale of each program (Campbell et al. 2007, Ojaveer et al. 2014). This is often the weakest link in management plans, since the kinds of conclusions necessary for developing a comprehensive and truly effective framework simply cannot be drawn.

### *Settlement Plate Studies*

The limited number of vectors that transport MIS—namely shipping—means that the locations where introduction takes place are fairly obvious. What remains more mysterious, however, is the transition from introduction to establishment. Since MIS often arrive as larvae, their small size makes it difficult to track their dispersion (Duchêne 2012, Hoffmann et al. 2012, Collin et al. 2013) and uncover patterns that might lead to more successful management frameworks (Collin et al. 2013). The prevailing method for monitoring larval presence of sessile marine organisms is through the use of settlement (fouling) plates, which have been shown to be a good indication of recruitment in the population (Duchêne 2012). These devices generally consist of a thin slab of a given substrate material anchored to a weight or frame and suspended in the water column. The exact design can be modified to suit the needs of the study.

Settlement plates have been widely used in larval recruitment studies (e.g. King et al. 1990, Hurlbut 1991, Broitman et al. 2005), comparative studies between recruitment and environmental parameters (e.g. Smith et al. 2005, Creed and De Paula 2007, Valentine et al. 2009, Dafforn et al. 2012, van der Gaag et al. 2014), and ecological studies dealing with community structure and competition (e.g. Osman and Whitlatch 1995, Stachowicz et al. 1999, Nydam and Stachowicz 2007, Claar et al. 2011, Edwards and Stachowicz 2011). Creed and De Paula (2007) demonstrated the use of wood, cement, steel, ceramic tile, and granite plates to determine coral substratum preference in a study conducted in Brazil. Other studies have generally focused on the use of PVC as a standard settlement surface (Hurlbut 1991, Claar et al. 2001, Nydam and Stachowicz 2007, Edwards and Stachowicz 2011, van der Gaag et al. 2014), but ceramic materials have been used successfully as well (Broitman et al. 2005, Smith et al. 2005).

Settlement plates have helped to begin standardizing the monitoring process, and are increasingly being used in state, national, and international monitoring programs. These ongoing studies are generally carried out at ports and marinas, where settlement plates are suspended in the water column from floating docks. The SETL Project, established by the ANEMOON Foundation in the Netherlands in cooperation with the Smithsonian Environmental Research Center (SERC), is an international invasive species monitoring program that uses a standardized settlement plate protocol to track MIS in every continent (excluding Antarctica) (Salem Sound Coastwatch 2007). Additionally, SERC has established the Alaska Plate Watch program, which uses settlement plates to monitor invasive species in Alaska and along the West Coast of the United States. Settlement plates have also been incorporated into the benthic community and invasive species surveys conducted by the Shallow Marine Surveys Group throughout the Falkland Islands, in collaboration with the Government of South Georgia and South Sandwich Islands and the British Antarctic Survey (Brewin and Brickle 2010).

### *Variation in Settlement Study Methods*

Settlement plate studies fall roughly into two categories: manipulative (e.g. Osman and Whitlatch 1995, Stachowicz et al. 1999, Blum et al. 2007, Osman and Whitlatch 2007, Claar et al. 2011, Edwards and Stachowicz 2011), and non-manipulative (passive monitoring, e.g. Hurlbut 1991, Berman et al. 1992, Broitman et al. 2005, Ramsay et al. 2009). While passive monitoring studies deploy bare plates and let settling occur naturally as it would on any submerged substrate, manipulative experiments often compare settlement on bare plates to that on plates which have been artificially seeded or "planted" with one or more target species (i.e. the "species gardening" method). Stachowicz et al. (1999) used artificially cultured plates of sessile invertebrates to study the effects of biodiversity on invasion resistance in fouling communities. Small settlement plates were used initially to culture native species, simply by regularly removing all other individuals and allowing a target species to monopolize the plate. These monoculture plates were then arranged to form larger plates with varying compositions of one through four native species, and the success of settlement by invasive species was measured and compared to community richness using linear least squares regression.

This method for cultivating monocultures was used by Osman and Whitlatch (1995) to study the effects of individual resident species on the pattern of larval settlement. Plates were gardened for one of four ascidians to produce plates with 30-50% (low) and 70-90% (high) cover of the target species. Bare plates were used as a control. All plates were then suspended for 24 hours and newly settled individuals were counted and identified. A distinction was made between settlement on the target species and on the plate itself. The authors evaluated and compared the density of settlement by each taxa on the target species and the plate surface, and grouped the data by treatment and surface type. A two-way mixed-model analysis of variance (ANOVA) was used to analyze total settlement between treatments (high/low coverage, and control) and between settlement densities (control, plate and species surfaces on low cover treatments, plate and species surfaces on high cover treatments) with 2-4 replicates per each target species. This allowed for significant interactions between settlement density and the effect of the target species to be tested.

Similarly, Claar et al. (2011) used settlement plates to test the effects of the solitary tunicate *Ascidia ceratodes* on the settlement rates of competitive species. The authors deployed treatment plates, on which *Ascidia* were attached, and control plates, which were bare. Upon retrieval, the number of inferior competitors which had settled on *Ascidia* and on bare PVC plates was counted, on a per-species basis. The amount of *Ascidia* surface area was also measured to correct for the variation in settling surface area provided by each individual. The experiment was conducted twice during two separate weeks in July, to capture temporal variation in recruitment. Analysis of covariance (ANCOVA) was performed for each inferior species and included three main effects (temporal set, treatment, and available *Ascidia* surface area), as well as one interaction effect (temporal set by treatment). This type of experimental design and analysis is typical of a multi-factor settlement plate study.

In addition to manipulative experiments, settlement plates have also been used for passive data collection, where only bare plates are deployed and remain unaltered until they are collected. These types of studies use selective data analysis to answer research questions instead of a manipulative component, and sometimes use the data in association with physical or chemical oceanography to understand spatial and temporal correlations between settlement, recruitment, and environmental parameters. For example, Broitman et al. (2005) used settlement plates to monitor barnacle recruitment in a study designed to investigate associations between barnacle and mussel recruitment patterns and oceanographic variability (using sea surface temperature as a metric). Raw recruitment counts were interpolated using ordinary kriging, a Gaussian method, to visualize the data on temporal and spatial scales.

More simply, Hurlbut (1991) explored settlement rates and juvenile mortality in the fouling community in Hawaii. Settlement plates were deployed for a period of two weeks and monitored daily for new settlement and mortality. A portion of the plates were replaced daily, while another portion remained deployed for the study duration but were removed temporarily each day for inspection. A control group of plates were left undisturbed for the two-week period. Settlement and mortality rates were compared between species and days (mortality rates were additionally compared between age and density) using multivariate analysis of variance (MANOVA), and one-way ANOVA was used to identify significant differences between treatments for individual species in the case of significant main effects, as determined by Wilks criterion. Comparisons of means for all species were performed using Tukey's HSD tests.

### *Study Goals*

The Rhode Island Coastal Resources Management Council (CRMC) has been conducting a larval settlement plate study (LSPS) since 2012. The CRMC aims to track recruitment and settlement of larval and juvenile marine invasive species, and compare these rates to those of native species. LSPS data is collected by observing settlement on PVC plates suspended from floating docks, and notating the abundance of 20 established invasive species on a 0-4 scale. At each site, two collectors are left suspended for the duration of the study (termed “seasonal” plates), and three collectors are replaced on a monthly basis (termed “monthly” plates) during the study season (May – December). Currently, there are approximately 12-16 months of LSPS data from 10-13 sites around Narragansett Bay and Block Island Sound (Figure 2).

Although the study is relatively new, an enormous amount of data has already been collected: two seasons of data on 20 established invasive species at 10 sites, with 5 replications per site. This amounts to a total of 50 settlement plates and 1000 data points per species, with approximately 20,000 data points in all. The challenge remains how to convert the largely qualitative data into a form from which statistically meaningful information can be drawn, and then later communicated to scientific, public, and legislative audiences to support new and continued management efforts.

While LSPS data can be used in a variety of ways, it is important to consider the value of having both seasonal and monthly settlement collectors when developing research questions, and acknowledge these as the main ecological objectives of the study (most studies only deploy plates on timescales of days to months). Because the design of the study affords views of per-species recruitment during 6-8 distinct periods of the season, as well as a comprehensive look at how the actual fouling community develops over the long term, we can begin to understand the relationship between temporal patterns of settlement and recruitment and the seasonal community assemblages that ultimately result. More specifically, and more importantly for management concerns, we can compare these patterns between native and non-native species to gain a new perspective on invasion mechanisms and success.

Here, I explored this vein of analysis and focused on investigating a fundamental question: Is the timing of seasonal recruitment a driver of non-native success in the fouling community? The fouling community that develops over the course of the season likely does not reflect the actual planktonic community of potential settlers, and this difference may be attributed to variation in recruitment timing and duration between species (Hurlbut 1991). Species which recruit for most of the season may appear to have a competitive advantage over species with shorter recruitment periods, but the timing of recruitment may in fact play a more important role in determining which species will ultimately establish. Invasive species that vigorously recruit for short periods early in the season may come to dominate the fouling community and render the recruitment periods of native species obsolete, thus driving non-native success.

In addition to investigating ecological questions, this project aimed to demonstrate how LSPS data may be organized, visualized, and analyzed. Results of this project will provide environmental managers (e.g. the CRMC) with the information needed to support continued and improved monitoring efforts, as well as the development of management frameworks which target individual pest species efficiently and with scientific support.

## Methods

### *Study Scope and Sites*

This study focused on identifying trends and patterns using data collected in 2013 from 10 sites around Narragansett Bay: Allen Harbor, Quonset (AHQ); Fort Adams, Newport (FTA); University of Rhode Island Graduate School of Oceanography, Narragansett (GSO); East Passage Marina, Melville (MMA); Matunuck Oyster Bar, South Kingstown (MOB); Prudence Island (PCP); Point Judith Marina, South Kingstown (PJM); Roger Williams University, Bristol (RWU); Sakonnet Point, Little Compton (SPT); and Save The Bay, Providence (STB). These sites represent a spatially diverse sample of Narragansett

Bay, extending from Block Island Sound to Providence Harbor, south of the Blackstone River mouth (Figure 2).

While the study encompassed data from May through December, not all sites were sampled each month during this period (Table 1). For this reason, analysis could not include data from all sites. Instead, detailed analysis was drawn from AHQ, FTA, and STB, which met the following criteria: 1) May data, which is crucial for identifying early recruitment trends, was available; 2) data extended until at least November; and 3) data was available for at least 5 of the same months, with no more than a 1-month gap between sampling months. The use of these sites maximized both the number of sampling sites and the number of sampling months available for analysis. From this point, increasing the number of sampling sites would decrease the number of sampling months, and increasing the number of sampling months would decrease the number of sampling sites.

### *Plate Construction and Placement*

Settlement collectors were constructed using PVC plates measuring approximately 12.5 x 22.5cm. Each plate was attached to a clay brick using plastic zip ties and suspended in the water column from a nylon rope attached to the top of the brick, such that the exposed surface of the PVC plate faced downward. Collectors were suspended from docks such that, in the case of floating docks, the plate was not in contact with the benthos during low tide, and in the case of stationary docks, the plate was not exposed during low tide. Collectors were placed at varying distances apart based on site conditions, but were no closer than 0.5 m in all cases, and were placed clear of all submerged dock surfaces and pilings. A total of five collectors were placed at each site. Collectors were arranged along the dock such that, from left to right, collectors 1 and 5 were designated as “seasonal” (n=2), and collectors 2-4 were designated as “monthly” (n=3).

### *Data Collection*

After the initial collector deployment (which ranged from May to August depending on site), sites were visited approximately every 4-6 weeks for plate inspection. A pre-determined "watch list" of 20 established invasive species (Table 2) was used to facilitate a more rapid inspection and was amended on a per-site/per-month basis if other invasive species and native species were found. Organisms not on the list were identified to the most specific taxa possible. At each site, all plates were inspected one at a time.

Each monthly collector was pulled and placed in a shallow basin of seawater for photography and inspection. Photographs of the bottom and top of the collector (including the brick) were taken, as well as detail photographs of any unusual or interesting aspects of plate growth. A five-finger system was used in photographs to identify the collector number and to provide scale for later reference. All fouling organisms present on each plate were identified on-site and ranked abundance was recorded using the following notation: "R" indicated the species was rare, with only one or two individuals present; "F" indicated a few individuals were present (approximately <1/3 plate coverage); "C" indicated the species was common (approximately 1/3-2/3 plate coverage); and "A" indicated the species was abundant, or dominant (approximately >2/3 plate coverage). After inspection, each monthly plate was removed from its brick and placed in a heavy-duty ziplock bag labeled with site ID, date, and plate number. Bags were placed in an iced cooler for transportation to a lab facility for further identification, preservation, and long-term storage. Each monthly collector was replaced with a new brick-and-plate assembly.

Seasonal collectors were processed in a similar manor to monthly collectors. Each collector was pulled and placed in a shallow basin of seawater for photography and inspection. Seasonal plates were marked with a small notch along one edge, and all monthly photographs were taken with the same plate orientation, using the notch as a reference point. All fouling organisms were identified and abundances were recorded similarly to monthly collectors. Additional notation was made for each species if fouling appeared newly settled since last inspection. After processing, seasonal collectors were lowered back into the water column.

Weather and water conditions (including temperature and salinity) were recorded at each site visit for later reference (not included in this project). At the end of the study season (generally November – December), seasonal collectors were removed along with the monthly collectors and preserved in the manor previously described. Organisms which could not be identified in the field were later identified in a laboratory setting by microscopy. Unusual specimens (i.e. those indicative of a new introduction) were individually preserved in ethanol for further analysis and storage. After final inspection, all fouling material was removed intact from each plate and preserved in ethanol for long-term storage. Monthly plates collected from a single site during the same month were treated as one collection and stored together, as were seasonal plates from a single site.

### *Digitization and Visual Analysis*

For initial digitization, field data was entered into a series of Excel (Microsoft, Inc) spreadsheets. Each spreadsheet was dedicated to a single site and data was grouped by month. For each taxon, a monthly and a seasonal abundance were entered for each month, consisting of the average abundance on the three monthly collectors and the average abundance on the two permanent collectors, respectively. In order to facilitate this, the alpha abundance scale ("R-F-C-A") was converted to a numeric scale ("1-2-3-4"). Some taxa were combined based on the ecological significance of tracking individual species verses the broader taxonomic group (Table 3). Ambiguous field data was cross-referenced with plate photographs and revised or rebuilt before digital entry.

Data from AHQ, FTA, and STB were compiled from their respective spreadsheets and two separate datasets were created. For the dataset "PRES", all species or taxa which were not present at any time at

AHQ, FTA, or STB were eliminated; this dataset represents the abundances of all present organisms at these sites and consists of 15 invasive and 18 native taxa. For the dataset “FOUL”, 10 invasive and 10 native sessile taxa were chosen which best represent the fouling community, and all other species were eliminated; this dataset represents the abundances of the sessile fouling community (i.e. excludes all gastropods, crustaceans, echinoderms, and polychaetes). Both datasets were organized hierarchically by treatment (monthly/seasonal), site, and month. Conditional formatting was used to colorize cells according to their relative abundance value in order to visualize large trends on per-taxa and per-site levels (see Appendix B).

### *Statistical Analysis*

The design of this study lends itself to a number of different statistical approaches. FOUL and PRES contain two settlement durations, or treatments (monthly and seasonal), plus indigeneity (invasive or native), temporal (5 different months) and spatial (3 different sites) factors, with one dependent variable (abundance). Additionally, FOUL contains 10 native and 10 invasive species, while PRES contains 18 native and 15 invasive species. Mixed-model repeated measures ANOVA could treat species as subjects, or treat sites as subjects with native and invasive species averaged for each treatment. For a more complex analysis, repeated measures MANOVA could be used to compare treatments, indigeneity, and months across a matrix of species abundances, treating all species as dependent variables, although this method is likely to suffer from rank deficiency.

To reduce the amount of analysis, and to reflect the statistical robustness of the data, mixed-model repeated measures ANOVA was used to determine the effects of treatment, indigeneity, and temporal factors on abundance using the FOUL and PRES data sets. Species were treated as subjects, with months treated as repeated measures within-species, and treatment and indigeneity as between-species effects. Two-sample two-tail t-tests assuming unequal variances were used to determine differences between invasive and native pooled abundances for each month at each site, and for each month using abundance data averaged across sites. Similar t-tests were used to determine differences in abundance between monthly and seasonal plates of the same month, testing pooled invasive and pooled native abundances separately. Tukey HSD tests were used to determine differences in abundance between pairs of species on monthly and seasonal plates using data averaged between sites. Linear regression analysis was used to identify trends in pooled invasive and pooled native abundances on monthly and seasonal plates across months for each site, and for abundance data averaged across sites. Linear regression analysis and t-tests were conducted on both FOUL and PRES data sets. All analysis was conducted at the $\alpha=0.05$ level; t-tests were conducted in Microsoft Excel (Microsoft Corporation 2007), all other analysis was conducted in R (R Core Team 2004).

## Results

### *PRES: Abundances*

There were significant differences between monthly plate abundances of pooled invasive (n=15) and native (n=18) species at FTA during August ($t_{21}=3.40$, p=0.003), September ($t_{25}=2.26$, p=0.033), and November ($t_{19}=2.91$, p=0.009), as well as between the overall monthly averages for that site ($t_{19}=2.66$, p=0.016). There were significant differences between seasonal plate abundances during June ($t_{15}=2.26$, p=0.039), August ($t_{20}=3.66$, p=0.002), September ($t_{21}=3.50$, p=0.002), and November ($t_{23}=2.96$, p=0.007), as well as between the overall monthly averages for that site ($t_{19}=3.31$, p=0.004). There were significant differences between monthly plate abundances of pooled invasive (n=15) and native (n=18) species at STB during June ($t_{27}=-2.45$, p=0.021) and August ($t_{21}=-2.37$, p=0.027), as well as between the overall monthly averages for that site ($t_{23}=-2.44$, p=0.023).

There was a highly significant main effect of treatment (monthly vs. seasonal) on abundance ($F_{1,165}=8.46$, p=0.004), and a significant interaction between treatment and sampling month ($F_{4,165}=2.76$, p=0.030).

There was a highly significant main effect of sampling month on abundance ($F_{4,132}$=5.04, p>0.001), and a significant interaction between indigeneity (invasive vs. native) and sampling month ($F_{4,132}$=2.67, p=0.036). There was no main effect of indigeneity on abundance ($F_{1,32}$=0.87, p=0.358), nor was there an interaction between indigeneity and treatment ($F_{4,165}$=1.61, p=0.207). The three-way interaction between indigeneity, treatment, and sampling month was not significant ($F_{4,165}$=0.239, p=0.916).

### *PRES: Settlement and Recruitment Trends*

Using data averaged across sites, there was a significant positive trend in pooled invasive abundances on seasonal plates across sampling months ($R^2$=0.845, p=0.027). There were no significant trends in pooled invasive abundances on monthly plates ($R^2$=0.579, p=0.135), pooled native abundances on monthly plates ($R^2$=0.011, p=0.866), or pooled native abundances on seasonal plates ($R^2$=0.661, p=0.094) across sampling months (Figure 3, Figure 4). At AHQ, there were significant positive trends in pooled invasive abundances on seasonal plates ($R^2$=0.845, p=0.027) and pooled native abundances on seasonal plates ($R^2$=0.945, p=0.006) across sampling months. There were no significant trends in pooled invasive abundances on monthly plates ($R^2$=0.521, p=0.168) or pooled native abundances on monthly plates ($R^2$=0.423, p=0.235) across sites for AHQ. At FTA, there was a significant positive trend in pooled invasive abundances on seasonal plates across sampling months ($R^2$=0.845, p=0.027). There were no significant trends in pooled invasive abundances on monthly plates ($R^2$=0.327, p=0.314), pooled native abundances on monthly plates ($R^2$=0.046, p=0.730), or pooled native abundances on seasonal plates ($R^2$=0.004, p=0.922) across sampling months for FTA. There were no significant trends at STB ($0.005< R^2<0.271$, $0.369<p<0.909$).

### *FOUL: Abundances*

There were significant differences between monthly plate abundances of pooled invasive (n=10) and native (n=10) species at FTA during August ($t_{14}$=2.52, p=0.025), September ($t_{14}$=2.51, p=0.025), and

November ($t_9$=3.28, p=0.010), as well as between the overall monthly averages for that site ($t_{13}$=2.33, p=0.037). There were significant differences between seasonal plate abundances during August ($t_{15}$=2.66, p=0.018), September ($t_9$=3.81, p=0.004), and November ($t_{18}$=2.72, p=0.014), as well as between the overall monthly averages for that site ($t_{14}$=2.84, p=0.013). There were significant differences between monthly and seasonal plate abundances of pooled invasive species at FTA in November ($t_{16}$=-2.25, p=0.039). There were significant differences between monthly plate abundances of pooled invasive (n=10) and native (n=10) species at STB during June ($t_{10}$=-3.09, p=0.011) and August ($t_9$=-2.56, p=0.030), as well as between the overall monthly averages for that site ($t_9$=-2.51, p=0.032). There was a significant difference between the seasonal plate abundance during June ($t_{14}$=-2.32, p=0.036).

There was a highly significant main effect of treatment (monthly vs. seasonal) on abundance ($F_{1,100}$=14.35, $p<0.001$), and a highly significant interaction between treatment and sampling month ($F_{4,100}$=4.53, p=0.002). There was a significant main effect of sampling month on abundance ($F_{4,80}$=2.91, p=0.027), and a significant interaction between indigeneity (invasive vs. native) and sampling month ($F_{4,80}$=3.17, p=0.019). There was no main effect of indigeneity on abundance ($F_{1,19}$=0.147, p=0.706), nor was there an interaction between indigeneity and treatment ($F_{1,100}$=0.158, p=0.692). The three-way interaction between indigeneity, treatment, and sampling month was not significant ($F_{4,100}$=0.128, p=0.972).

### *FOUL: Settlement and Recruitment Trends*

Using data averaged across sites, there was a significant positive trend in pooled invasive abundances on seasonal plates across sampling months ($R^2$=0.964, p=0.003). There were no significant trends in pooled invasive abundances on monthly plates ($R^2$=0.627, p=0.110), pooled native abundances on monthly plates ($R^2$=0.348, p=0.295), or pooled native abundances on seasonal plates ($R^2$=0.102, p=0.600) across sampling months (Figure 3, Figure 4). At FTA, there was a significant positive trend in pooled invasive abundance on seasonal plates across sampling months ($R^2$=0.830, p=0.031). There were no significant trends in pooled invasive abundances on monthly plates ($R^2$=0.267, p=0.373), pooled native abundances on monthly plates ($R^2$=0.701, p=0.077), or pooled native abundances on seasonal plates ($R^2$=0.009, p=0.877) across sampling months at FTA. There were no significant trends at AHQ and STB ($0.001<R^2<0.761$, $0.540<p<0.951$).

### *Fouling Community Composition*

*B. violaceus* was the most abundant species overall on both monthly and seasonal plates. Within the fouling community (FOUL species, plus *Tricellaria inopinata*), the abundance of *B. violaceus* on monthly plates was significantly greater than that of *A. aspersa* (p=0.034), *B. neretina* (p=0.001), *Diadumene lineata* (p<0.001), *D. vexillum* (p<0.001), *Membranipora membranacea* (p=0.026), *S. clava* (p<0.001), *Anomia* (p<0.001), native *Bugula* spp. (p=0.001), *Mytilus edulis* (p=0.011), Porifera (p<0.001), and *Spirorbis* (p=0.045). Differences between all other pairs of species were not significant. Within the fouling community (FOUL species, plus *Tricellaria inopinata*), the abundance of *B. violaceus* on seasonal plates was significantly greater than that of *B. neretina* (p=0.018), *Tricellaria inopinata* (p=0.006), *Anomia* (p=0.009), and Porifera (p=0.009). The abundance of *Molgula manhatensis* on seasonal plates was significantly greater than that of *B. neretina* (p=0.025), *T. inopinata* (p=0.009), *Anomia* (p=0.012), and Porifera (p=0.012). Differences between all other pairs of species were not significant.

## **Discussion**

### *Abundance Trends*

In general, native species begin recruiting earlier in the season than invasive species, as exemplified by abundance trends on monthly fouling plates (Figure 3). This advantage lasts until the end of June, after which invasive recruitment rates surpass those of natives. Between June and August, native recruitment rates are fairly constant, falling off to a slightly lower plateau from September to November. Despite the early timing and vigor of native recruitment, abundance trends on seasonal plates suggest that early recruits are unable to successfully establish in the face of rising invasive recruitment rates. Additionally, the negative relationship between seasonal and monthly plate abundances between May and mid-July suggests that these recruits are outcompeted until late in the season. Because of this, the timing of recruitment is likely less influential in non-native success than the length of their recruitment periods, and their ability to outcompete natives for space resources.

The growth of the invasive community on seasonal plates is fairly linear, and is in fact the only significant trend apparent. The positive relationship between seasonal and monthly plate abundances generally increases throughout the season, suggesting that invasive species are very successful at establishing and accumulating. Late in the season, both native and invasive abundances on seasonal plates increase despite declining recruitment, likely due to the lateral growth of colonial tunicates.

In the fouling community, many of these trends are temporally shifted or magnified, making this perhaps a more interesting dataset to study. The early recruitment advantage lasts approximately one month longer than the overall native community, extending through July, after which recruitment plateaus and eventually falls off during late summer. Recruitment rates of invasive species do not surpass those of native species until the beginning of August. A positive relationship between seasonal and monthly plate abundances begins around mid June, suggesting that some recruitment is successful and species have begun establishing and accumulating by this time. As with native species, invasive fouling trends are magnified when compared to the entire community.

These general trends are rather poor predictors of recruitment activity at each individual site, and with the current data it is difficult to determine the reasons behind site variation. At Fort Adams (FTA), a lower-bay site, invasive species are much more prevalent than natives, and the recruitment and community development patterns are similar to the general trends. Here, native recruitment and abundance remain very low throughout the entire season, while invasive abundances increase rapidly from May through August, and plateau from September through November. Both native and invasive recruitment declines from September through November, as exemplified by abundance trends on monthly plates (Figure 5).

At Allen Harbor (AHQ), a mid-bay site, native and invasive abundances are relatively low throughout the entire season, and the recruitment and accumulation of each are generally parallel. Unlike recruitment rates at Fort Adams, native and invasive recruitment increases from September through November (Figure 5). At Save The Bay (STB), an upper-bay site, native species are much more prevalent than invasive species. Native recruitment peaks around the beginning of June and declines throughout the rest of the season, while invasive recruitment and overall community development remain very low. Similar to Fort Adams, native and invasive recruitment at Save The Bay is in decline from September through November (Figure 5).

The reasons for this variation are unclear given the current data. Because these three sites represent a broad spatial sampling of the bay, environmental parameters likely play a key role, but have yet to be correlated with invasive or native abundances. Even so, a general pattern does emerge, in which native abundance generally increases with latitude, while invasive abundance generally decreases. This may be a function of the natural salinity gradient present in the bay, which ranges from full-strength sea water at the mouth to nearly fresh water at the apex where the Blackstone River drains. However, it is difficult to make this assumption using only three sites and with the data available. In the future, consistency between sampling months at all 10 sites would help illuminate these types of trends if present, but could not determine whether any relationship between salinity and indigeneity was causal. Studies subjecting individual species to varying levels of salinity and noting their tolerance might be able to support this spatial distribution.

*Community Assemblages*

If the three sites are to be viewed as a comprehensive sampling of Narragansett Bay's benthic ecology, there appear to be few differences between invasive and native prevalence. As a whole, the bay fouling community is rather diverse. The invasive community is dominated by the orange sheath tunicate *B. violaceus* and the native community by the sea grape tunicate *M. manhattensis*, but by narrow margins (Figure 6-Study Means). This may indicate that the bay is in a transitional period between dominance by native and dominance by invasive species; continuing the settlement study for several years might help answer this question.

The diversity at independent sites, however, varies widely. At the northern end of the bay, the fouling community is dominated by native species, most prevalently by *M. manhattensis*, the acorn barnacles *Balanus* and *Semibalanus*, and native bryozoans. Only two invasive foulers are present: the striped anemone *Diadumene lineata* and the lacy crust bryozoan *M. membranacea* (Figure 6-STB). The mid-bay contains a more uniform mixture of invasive and native species; *B. violaceus* and the golden star tunicate *B. schlosseri* dominate the invasive fouling community, while the native fouling community is dominated by native bryozoans and *M. manhattensis*, but there is no significant difference between overall invasive and native abundances. Non-fouling organisms, such as the amphipod *C. mutica*, the green crab *C. maenas*, and the Asian shore crab *H. sanguineus* begin to appear in the mid-bay as well (Figure 6-AHQ).

At the southern end of the bay, the community has shifted to overwhelming dominance by invasive species. Here, the fouling community is composed primarily of invasive tunicates (*B. violaceus*, *C. intestinalis*, *B. schlosseri*, *A. aspera*, *Diplosoma listerianum*, *D. vexillum*) of comparable abundance, and *C. mutica* is by far the most dominant predator (Figure 6-FTA). This latitudinal shift from native dominance to invasive dominance may be related to environmental gradients in the bay, such as salinity, but it is difficult to correlate this with the present data. Additionally, it is possible that the shift reflects increased propagule pressure in the southern bay. This pressure is unlikely related to ballast water discharge, since port operations are mostly located in the north, but it may indicate that introductions into the bay occur via range expansion from the south, and spread throughout the bay from south to north. This makes sense geographically, and is supported by the principles of invasion biology, but cannot be verified by this study alone.

It is important to note that the accumulation of invasive species throughout the season is generally supported by a few tunicates with recruitment periods spanning several months. Conversely, the relatively stable abundance of native species throughout the season is maintained by different species each month. As the recruitment period of some species ends, other species begin recruiting, supporting a constant overall native community abundance. This can be visualized through the conditional colorization of PRES and FOUL datasets (see Appendix B).

### *Improving Monitoring Efforts*

A fully comprehensive analysis was impossible due to inconsistency in the months sampled between all 10 sites. This was likely due to the fact that monitoring was conducted by various individuals whose efforts, despite a monitoring protocol, were largely uncoordinated. Additionally, even when sites were monitored during the same month, monitoring often occurred several days or weeks apart, making it rather inaccurate to classify data collected near the beginning and end of the same month as categorically equivalent. Because of this, much of the data, while still valuable for individual analysis (see Appendix C), is unsuitable for side-by-side comparisons using common statistical approaches.

As such, the results presented here are certainly interesting and informative from a general perspective, but fall short of what a study of this nature might afford. I suggest that monitoring efforts can be much more statistically appreciable by making a few changes to the monitoring protocol. The first major limitation for analysis, as previously mentioned, was the inconsistency of sampling months between sites. The coordination of individual monitoring efforts to cover all sites during all months of the season would greatly increase the amount of usable data in future analysis. Sites should be checked every 4 weeks, and a specific monitoring date or date range (2-4 days maximum) within each month should be determined in advance to facilitate this. The schedules of individual monitors can then be coordinated to meet these targets. Furthermore, it is important that all sites be checked on the same date or during the same date range so that they can be classified as replicates later on. This will allow resulting data to be analyzed using a higher resolution time scale (days instead of months), and visualization of abundance fluctuations will be more accurate and precise.

The second major limitation is the method by which abundance is measured. The current method relies on the individual monitor to estimate the percent cover of each organism using very broad intervals (essentially 33% increments). This leads to inaccurate conclusions for two reasons: 1) individual monitoring efforts are highly subjective, since no real metric is used to standardize the percent cover measurement; and 2) the abundance categories are too few and too broad, causing the results to suffer from low sensitivity, and increasing the risk of type II errors in analysis (i.e. erroneously failing to reject the null hypothesis).

Vegetation studies, such as those used to assess salt marsh flora communities, often use point analysis to determine abundance of each species present in a particular study plot. A grid is overlaid on the plot, and the presence or absence of each species at each grid point is recorded. The total abundance for each species, therefore, is expressed as a fraction out of the total possible grid points. For example, a 1 $m^2$ plot might use a 20x20 cm grid, for 36 total possible points, and the abundance of a particular species present at *n* points would be expressed as *n*/36. This method standardizes the abundance measurements of each species, normalizes spatial distribution, and has sensitivity proportional to the resolution of the grid.

I suggest that this method be adapted for settlement plate monitoring as a means of standardizing abundance measurements of sessile species (e.g. Berman et al. 1992). While this is a more time-consuming method, results will benefit greatly from the higher resolution scale and be more statistically comparable. Motile species (i.e. gastropods, crustaceans, echinoderms, and polychaetes) should be individually counted whenever possible, and recorded as such. Very small, highly abundant motile species (e.g. amphipods) might be individually counted in two or three smaller “plots” on the plate, and an overall abundance could be estimated from those samples.

Additionally, there were inconsistencies with the data which suggest a varying knowledge and/or precision of effort between monitors, adding to the subjectivity of the study. It is incredibly important that all monitors conduct each survey with the same precision and scrutiny. While the settlement plate method has begun to standardize the overall monitoring process both locally and globally, such monitoring is only as good as its weakest link. Adopting a standardized approach to the actual *measuring* of abundance might help to homogenize precision across monitoring individuals.

### *Implications for Management*

Managing MIS is costly and labor-intensive, and funding is generally insufficient to support a comprehensive program (Larson et al. 2011). Additionally, from the standpoint of natural resource economics, mitigation is not always the most cost-effective approach to dealing with invasive species. Depending on the situation, it may benefit society to adapt to the consequences of invasion rather than fight it (Hyytiäinen et al. 2013). However, this purely economic view fails to appreciate the costs of not managing, primarily from an environmental perspective. The consequences of potential ecosystem damage, loss of ecosystem services and native species must all be considered in a balanced, sustainable approach to management, and in the cost-benefit analyses used to determine optimal management strategies (Larson et al. 2013).

Understanding the composition and life histories of MIS on local scales is incredibly important for informing management practices. The lack of local data is the leading cause for difficulty in modeling population dynamics used in management decisions (Hyytiäinen et al. 2013). The CRMC LSPS has begun to provide us with clues about Narragansett Bay's invasive and native fouling community and ecology, and the trends reveal interesting recruitment patterns which can be used to predict when certain species will appear on a seasonal basis. This is important for understanding how the local fouling community develops and changes over the course of the year, and, when combined with future years of data, how invasive introductions change the community composition. Therefore, the data amassed so far should be treated as a baseline to which subsequent years can be compared, and against which management efforts can measure success.

### *Conclusions and Future Study*

The future of marine invasive species management is dependent on our growing understanding of invasion biology, pathways, and the ecology of establishment and spread. Continued monitoring of Narragansett Bay's intertidal fouling community will provide managers with critical information about invasive ecology, but only if such monitoring is carried out in an accurate, standardized manner. The data analyzed here illustrates the potential of this program to explore invasive and native ecological interactions, and the current monitoring methods should be revised with those kinds of questions in mind.

Exploring the temporal and durational variation in recruitment between native and non-native species will allow us to better understand the mechanisms that govern fouling community assemblages, and isolate which invasive species are most influential in those communities' development. Additionally, the dataset and methods may be expanded to encompass a spatial component, which will be necessary for understanding native and non-native recruitment patterns around Narragansett Bay, and inform the development of GIS applications. Environmental properties measured during plate inspection may also be factored into later analysis to answer additional questions about the correlation between temperature, salinity, and invasion success. Continued monitoring over the next several years will provide a comprehensive picture of how invasions spread throughout the bay and allow new introductions to be detected.

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## Appendix A: Figures

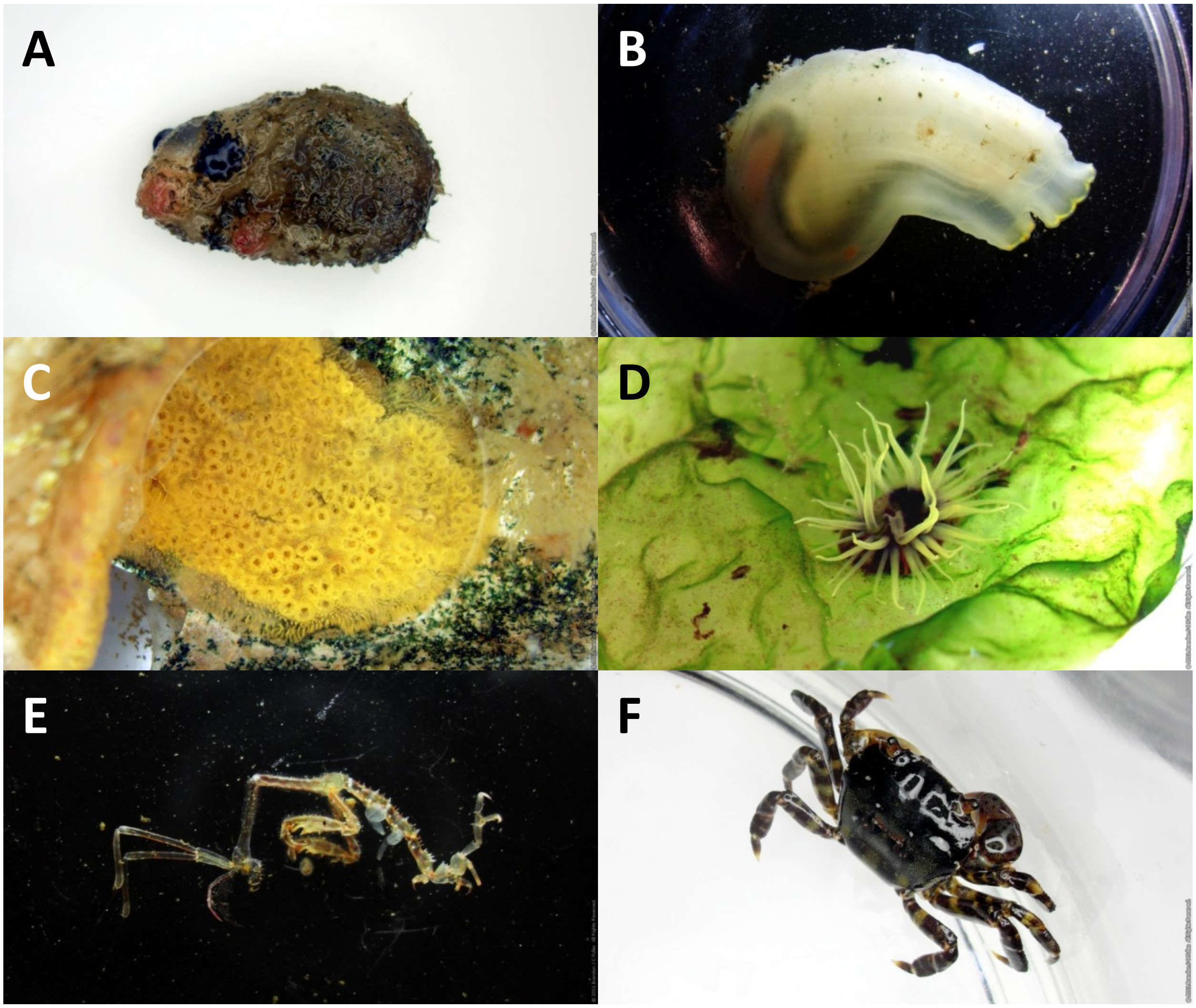


**FIGURE 1** Examples of marine invasive species of New England. **A)** *Ascidiella aspersa*; **B)** *Ciona intestinalis*; **C)** *Botrylloides violaceus*; **D)** *Diadumene lineate*; **E)** *Caprella mutica*; **F)** *Hemigrapsus sanguineus*. Photographs by the author.

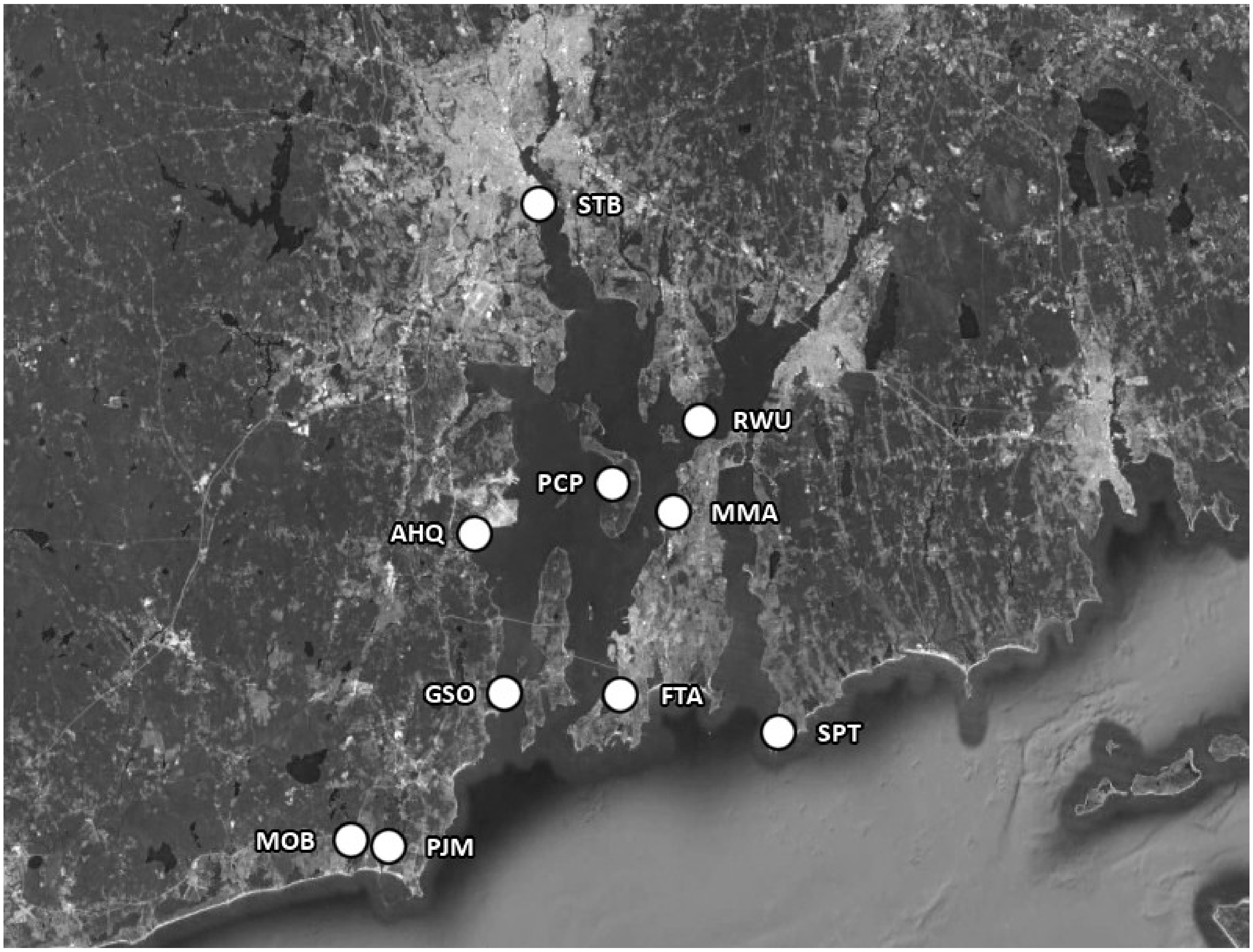


**FIGURE 2** Geographic distribution of sites around Narragansett Bay. Imagery from Google Earth.

**TABLE 1** Available months of data for each site in 2013

| | Month | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Site** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| AHQ | X | X | | X | X | | X | X |
| FTA | X | X | | X | X | X | X | X |
| GSO | | X | | X | X | | X | X |
| MMA | X | X | | | X | X | X | X |
| MOB | | | | | X | | X | X |
| PCP | | X | X | X | X | | | |
| PJM | | | | X | X | | X | X |
| RWU | X | X | | | X | X | X | X |
| SPT | | X | | X | X | | X | |
| STB | X | X | | X | X | X | X | |

**TABLE 2** Invasive species watch list

| **Species** | **Common Name** |
|---|---|
| *Ascidiella aspersa* | Rough Clear Sea Squirt |
| *Botrylloides violaceus* | Orange Sheath Tunicate |
| *Botryllus schlosseri* | Golden Star Tunicate |
| *Bugula neritina* | Purple Bush Bryozoan |
| *Caprella mutica* | Asian Skeleton Shrimp |
| *Carcinus maenas* | Green Crab |
| *Ciona intestinalis* | Sea Vase Tunicate |
| *Codium fragile* | Green Fleece |
| *Diadumene lineata* | Striped Anemone |
| *Didemnum vexillum* | Colonial Tunicate |
| *Diplosoma listerianum* | Diplosoma Tunicate |
| *Grateloupia turuturu* | Red Alga |
| *Hemigrapsus sanguineus* | Asian Shore Crab |
| *Ianiropsis serricaudis* | Asian Isopod |
| *Littorina littorea* | Common Periwinkle |
| *Membranipora membranacea* | Lacy Crust Bryozoan |
| *Ostrea edulis* | European Oyster |
| *Palaemon elegans* | European shrimp |
| *Palaemon macrodactylus* | Asian shrimp |
| *Styela clava* | Club Tunicate |

**TABLE 3** Native taxonomic groupings

| **Taxon** | **Grouping** |
|---|---|
| **Amphipoda** | |
| *Corophium spp.* | |
| *Jassa marmorata* | |
| All others | Gammeridae |
| **Balanomorpha** | |
| *Semibalanus spp.* | Balanomorpha |
| *Balanus spp.* | |
| **Bryozoa** | |
| *Bugula simplex* | *Bugula* (native) |
| *Bugula turturra* | |
| *Bugula stolonifera* | |
| All others | Bryozoa |
| **Crepidula** | |
| *C. fornicata* | *Crepidula* |
| *C. plana* | |
| **Panopeidae** | |
| *Dyspanopeus sayi* | Panopeidae |
| *Panopeus spp.* | |
| *Eurypanopeus spp.* | |
| **Porifera** | |
| *Halichondria spp.* | Porifera |
| All others | |

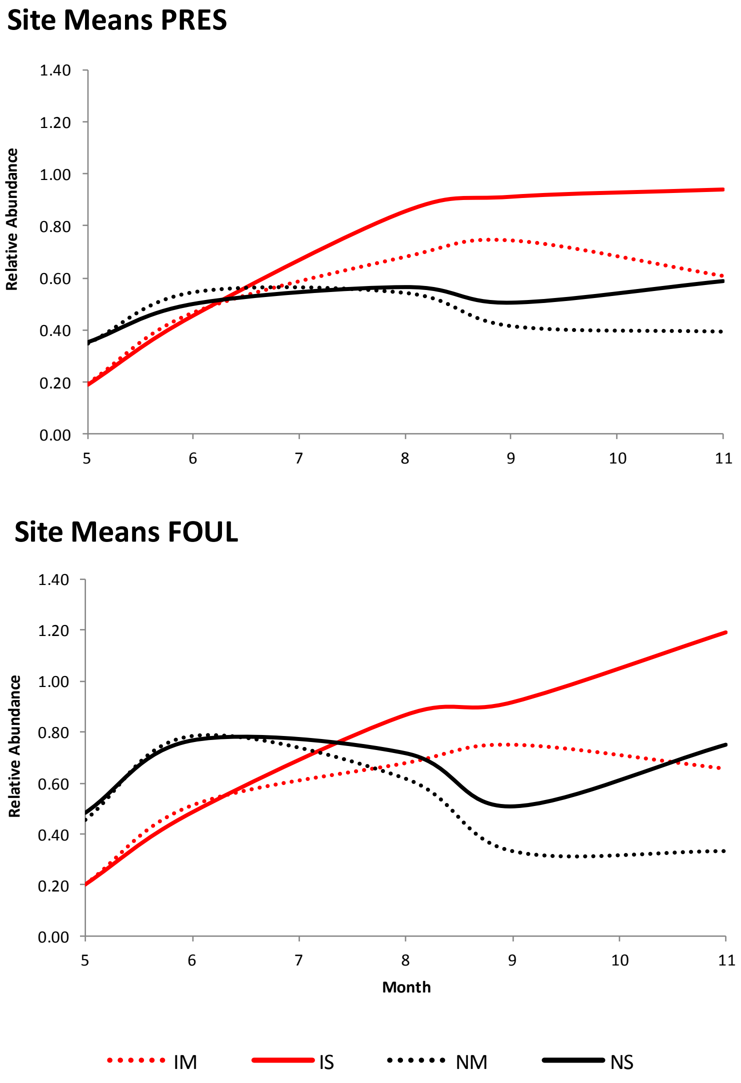


**FIGURE 3** Overall abundance trends from data averaged between sites, using PRES and FOUL datasets. Legend abbreviations: IM, invasive abundance on monthly plates; IS, invasive abundance on seasonal plates; NM, native abundance on monthly plates; NS, native abundance on seasonal plates.

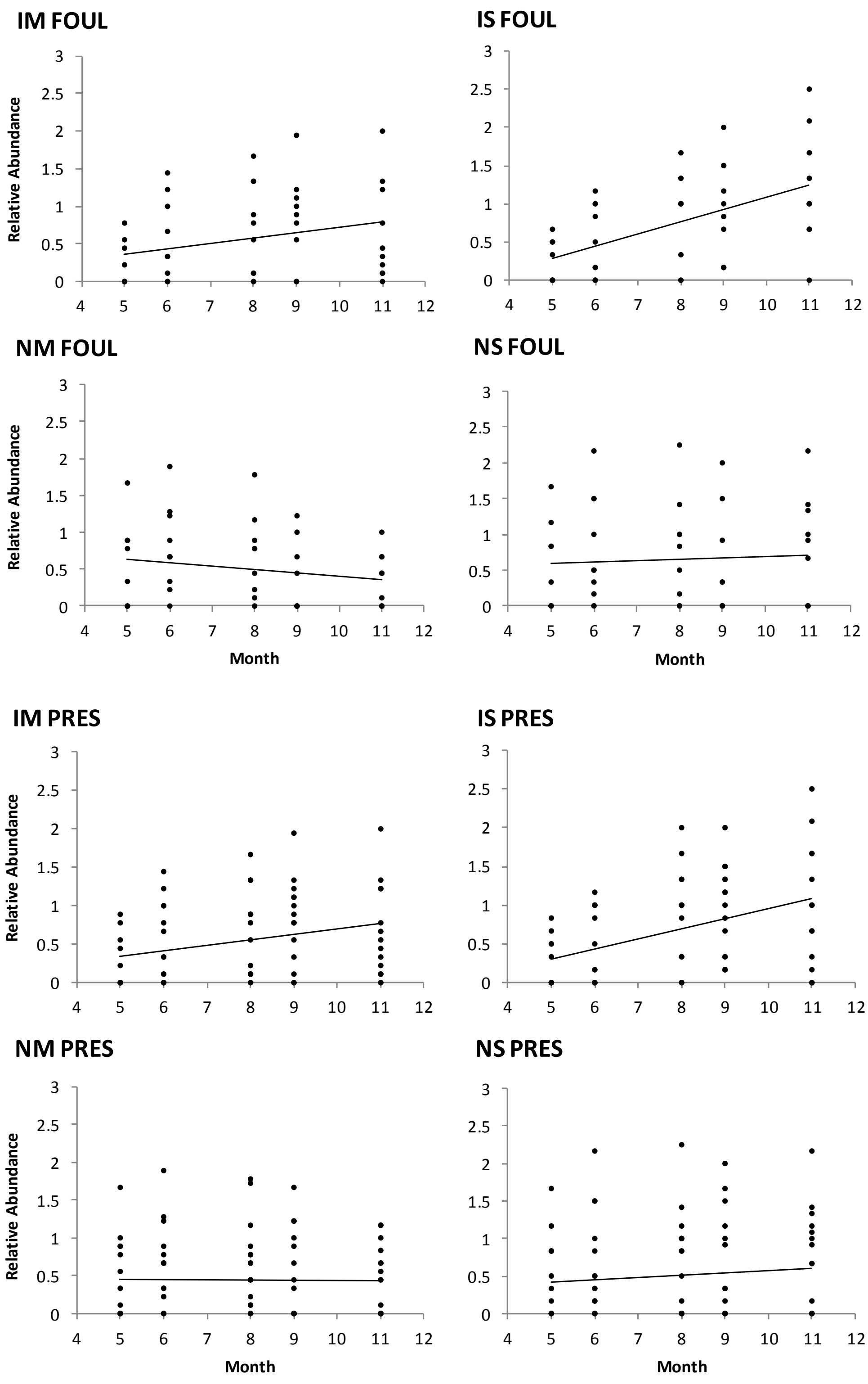


**FIGURE 4** Distribution of species abundances from data averaged between sites, using PRES and FOUL datasets. Abbreviations: IM, invasive abundance on monthly plates; IS, invasive abundance on seasonal plates; NM, native abundance on monthly plates; NS, native abundance on seasonal plates. Lines are linear regressions; IS FOUL and IS PRES are significant for monthly means (R2=0.845, p=0.027 and R2=0.964, p=0.003, respectively).

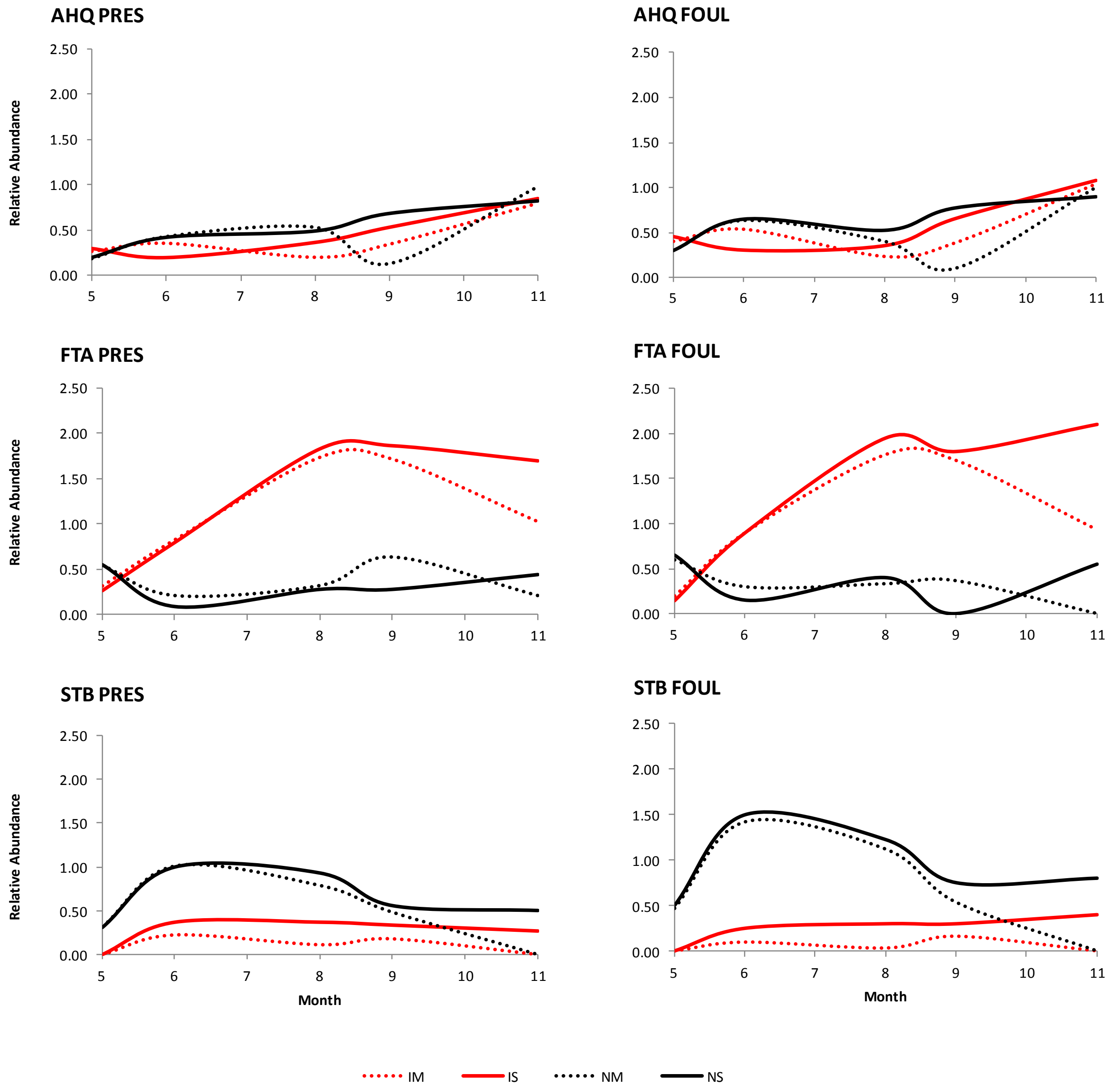


**FIGURE 5** Abundance trends at AHQ, FTA, and STB using PRES and FOUL datasets. Legend abbreviations: IM, invasive abundance on monthly plates; IS, invasive abundance on seasonal plates; NM, native abundance on monthly plates; NS, native abundance on seasonal plates.

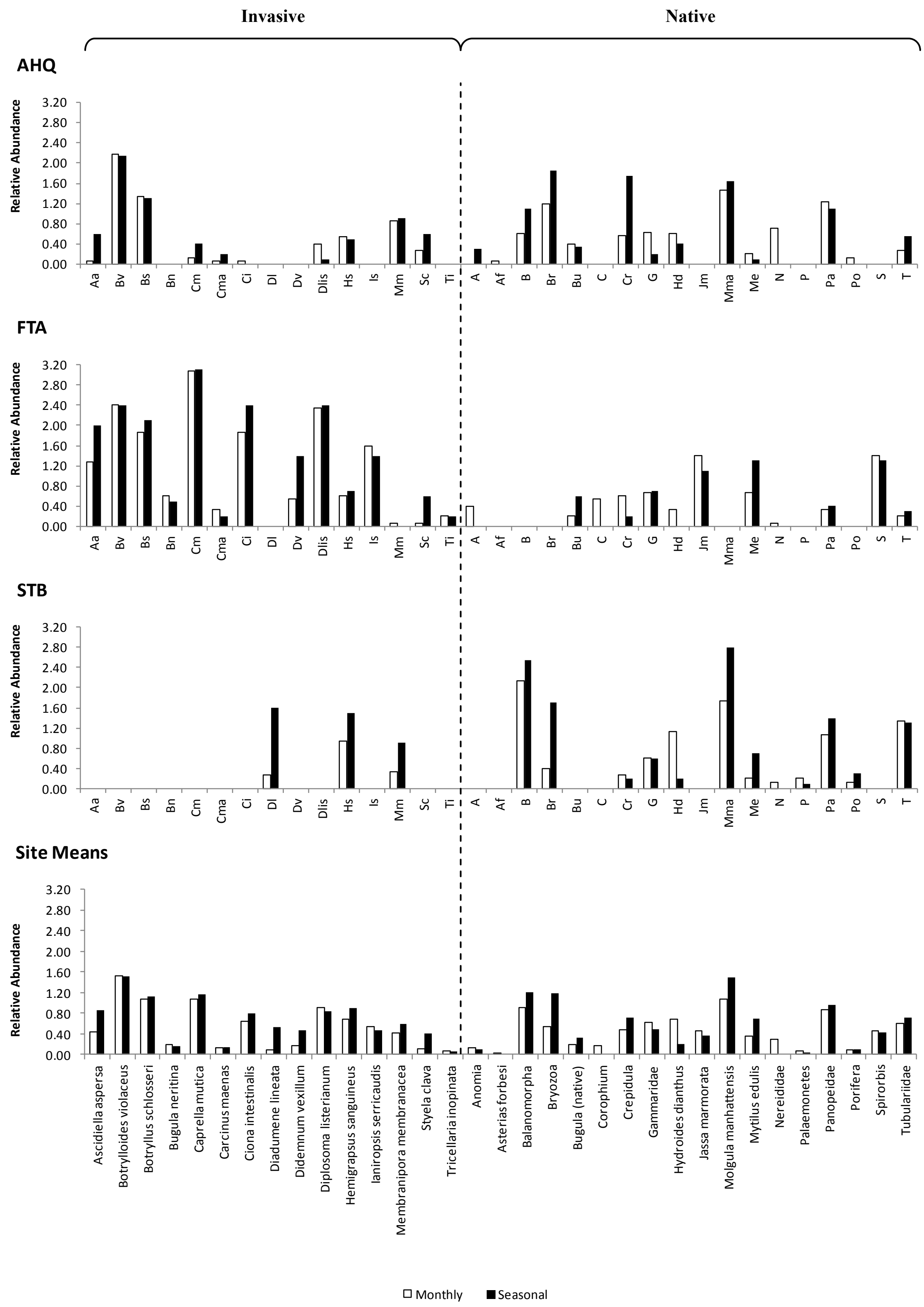


**FIGURE 6** Average species abundances on monthly and seasonal plates at each site, and using data averaged between sites.

# Appendix B: Datasets

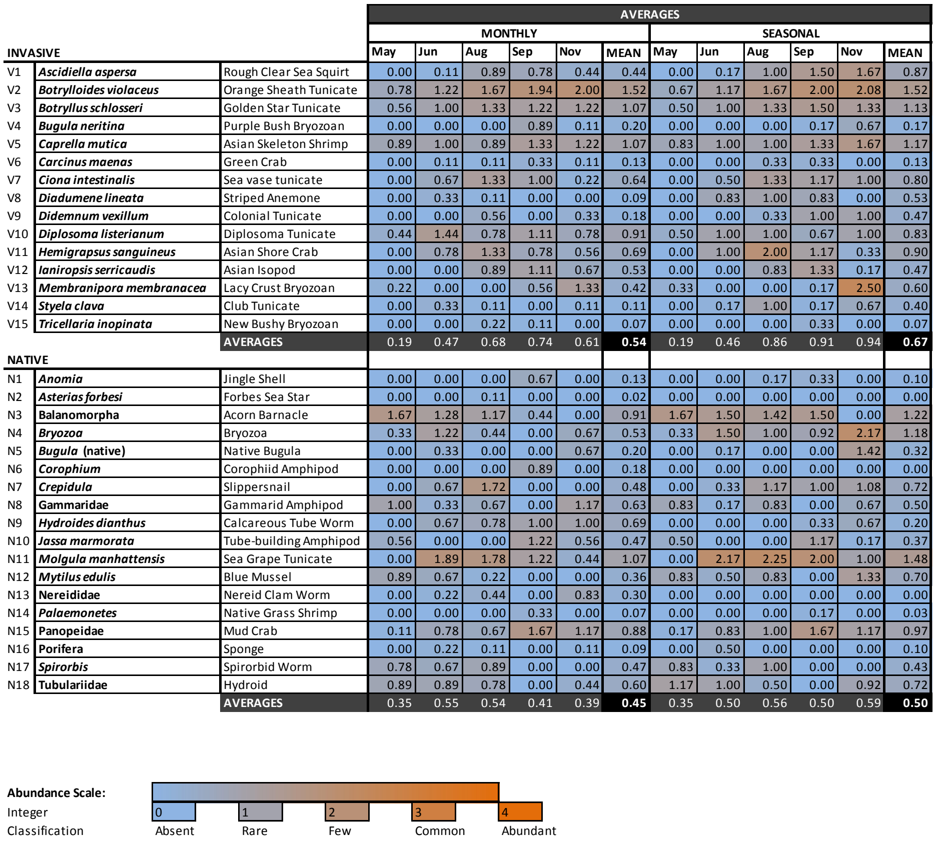
## *PRES Dataset: Per-Site Abundances*

| | | | MONTHLY | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AHQ | | | | | | FTA | | | | | | STB | | | | | |
| **INVASIVE** | | | **May** | **Jun** | **Aug** | **Sep** | **Nov** | **MEAN** | **May** | **Jun** | **Aug** | **Sep** | **Nov** | **MEAN** | **May** | **Jun** | **Aug** | **Sep** | **Nov** | **MEAN** |
| V1 | ***Ascidiella aspersa*** | Rough Clear Sea Squirt | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 2.67 | 2.33 | 1.33 | 1.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V2 | ***Botrylloides violaceus*** | Orange Sheath Tunicate | 2.00 | 1.00 | 1.33 | 2.83 | 3.67 | 2.17 | 0.33 | 2.67 | 3.67 | 3.00 | 2.33 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V3 | ***Botryllus schlosseri*** | Golden Star Tunicate | 1.67 | 0.67 | 1.00 | 1.00 | 2.33 | 1.33 | 0.00 | 2.33 | 3.00 | 2.67 | 1.33 | 1.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V4 | ***Bugula neritina*** | Purple Bush Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67 | 0.33 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V5 | ***Caprella mutica*** | Asian Skeleton Shrimp | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.13 | 2.67 | 3.00 | 2.67 | 4.00 | 3.00 | 3.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V6 | ***Carcinus maenas*** | Green Crab | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.07 | 0.00 | 0.33 | 0.00 | 1.00 | 0.33 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V7 | ***Ciona intestinalis*** | Sea vase tunicate | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 1.67 | 4.00 | 3.00 | 0.67 | 1.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V8 | ***Diadumene lineata*** | Striped Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.33 | 0.00 | 0.00 | 0.27 |
| V9 | ***Didemnum vexillum*** | Colonial Tunicate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 1.00 | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V10 | ***Diplosoma listerianum*** | Diplosoma Tunicate | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.40 | 1.33 | 2.33 | 2.33 | 3.33 | 2.33 | 2.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V11 | ***Hemigrapsus sanguineus*** | Asian Shore Crab | 0.00 | 0.00 | 0.33 | 1.33 | 1.00 | 0.53 | 0.00 | 0.00 | 2.33 | 0.00 | 0.67 | 0.60 | 0.00 | 2.33 | 1.33 | 1.00 | 0.00 | 0.93 |
| V12 | ***Ianiropsis serricaudis*** | Asian Isopod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67 | 3.33 | 2.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V13 | ***Membranipora membranacea*** | Lacy Crust Bryozoan | 0.33 | 0.00 | 0.00 | 0.00 | 4.00 | 0.87 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 0.33 |
| V14 | ***Styela clava*** | Club Tunicate | 0.00 | 1.00 | 0.00 | 0.00 | 0.33 | 0.27 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V15 | ***Tricellaria inopinata*** | New Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.33 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **AVERAGES** | 0.27 | 0.36 | 0.20 | 0.34 | 0.80 | 0.39 | 0.31 | 0.82 | 1.73 | 1.71 | 1.02 | 1.12 | 0.00 | 0.22 | 0.11 | 0.18 | 0.00 | 0.10 |
| **NATIVE** | | | | | | | | | | | | | | | | | | | | |
| N1 | ***Anomia*** | Jingle Shell | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N2 | ***Asterias forbesi*** | Forbes Sea Star | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N3 | **Balanomorpha** | Acorn Barnacle | 2.00 | 0.67 | 0.33 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 3.17 | 3.17 | 1.33 | 0.00 | 2.13 |
| N4 | ***Bryozoa*** | Bryozoa | 1.00 | 2.33 | 0.67 | 0.00 | 2.00 | 1.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 0.67 | 0.00 | 0.00 | 0.40 |
| N5 | ***Bugula*** **(native)** | Native Bugula | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.40 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N6 | ***Corophium*** | Corophiid Amphipod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67 | 0.00 | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N7 | ***Crepidula*** | Slippersnail | 0.00 | 0.00 | 2.83 | 0.00 | 0.00 | 0.57 | 0.00 | 0.67 | 2.33 | 0.00 | 0.00 | 0.60 | 0.00 | 1.33 | 0.00 | 0.00 | 0.00 | 0.27 |
| N8 | **Gammaridae** | Gammarid Amphipod | 0.00 | 1.00 | 0.00 | 0.00 | 2.17 | 0.63 | 2.00 | 0.00 | 0.00 | 0.00 | 1.33 | 0.67 | 1.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.60 |
| N9 | ***Hydroides dianthus*** | Calcareous Tube Worm | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.60 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 0.33 | 0.00 | 2.00 | 2.33 | 1.33 | 0.00 | 1.13 |
| N10 | ***Jassa marmorata*** | Tube-building Amphipod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 0.00 | 3.67 | 1.67 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N11 | ***Molgula manhattensis*** | Sea Grape Tunicate | 0.00 | 2.33 | 2.67 | 1.00 | 1.33 | 1.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.33 | 2.67 | 2.67 | 0.00 | 1.73 |
| N12 | ***Mytilus edulis*** | Blue Mussel | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 | 2.67 | 0.00 | 0.67 | 0.00 | 0.00 | 0.67 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 |
| N13 | **Nereididae** | Nereid Clam Worm | 0.00 | 0.00 | 1.33 | 0.00 | 2.17 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 0.07 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.13 |
| N14 | ***Palaemonetes*** | Native Grass Shrimp | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.20 |
| N15 | **Panopeidae** | Mud Crab | 0.33 | 0.33 | 1.00 | 1.33 | 3.17 | 1.23 | 0.00 | 0.00 | 0.00 | 1.33 | 0.33 | 0.33 | 0.00 | 2.00 | 1.00 | 2.33 | 0.00 | 1.07 |
| N16 | **Porifera** | Sponge | 0.00 | 0.00 | 0.33 | 0.00 | 0.33 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.13 |
| N17 | ***Spirorbis*** | Spirorbid Worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.33 | 2.00 | 2.67 | 0.00 | 0.00 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N18 | **Tubulariidae** | Hydroid | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 0.27 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 1.67 | 2.67 | 2.33 | 0.00 | 0.00 | 1.33 |
| | | **AVERAGES** | 0.19 | 0.43 | 0.53 | 0.13 | 0.97 | 0.45 | 0.54 | 0.20 | 0.31 | 0.63 | 0.20 | 0.38 | 0.31 | 1.01 | 0.79 | 0.48 | 0.00 | 0.52 |

| **Abundance Scale:** | | | | | |
|---|---|---|---|---|---|
| Integer | 0 | 1 | 2 | 3 | 4 |
| Classification | Absent | Rare | Few | Common | Abundant |

| | | | SEASONAL | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AHQ | | | | | | FTA | | | | | | STB | | | | | |
| **INVASIVE** | | | **May** | **Jun** | **Aug** | **Sep** | **Nov** | **MEAN** | **May** | **Jun** | **Aug** | **Sep** | **Nov** | **MEAN** | **May** | **Jun** | **Aug** | **Sep** | **Nov** | **MEAN** |
| V1 | ***Ascidiella aspersa*** | Rough Clear Sea Squirt | 0.00 | 0.50 | 0.00 | 1.50 | 1.00 | 0.60 | 0.00 | 0.00 | 3.00 | 3.00 | 4.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V2 | ***Botrylloides violaceus*** | Orange Sheath Tunicate | 2.00 | 1.00 | 1.50 | 3.00 | 3.25 | 2.15 | 0.00 | 2.50 | 3.50 | 3.00 | 3.00 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V3 | ***Botryllus schlosseri*** | Golden Star Tunicate | 1.50 | 0.50 | 1.00 | 1.50 | 2.00 | 1.30 | 0.00 | 2.50 | 3.00 | 3.00 | 2.00 | 2.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V4 | ***Bugula neritina*** | Purple Bush Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 2.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V5 | ***Caprella mutica*** | Asian Skeleton Shrimp | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.40 | 2.50 | 3.00 | 3.00 | 4.00 | 3.00 | 3.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V6 | ***Carcinus maenas*** | Green Crab | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V7 | ***Ciona intestinalis*** | Sea vase tunicate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 4.00 | 3.50 | 3.00 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V8 | ***Diadumene lineata*** | Striped Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 3.00 | 2.50 | 0.00 | 1.60 |
| V9 | ***Didemnum vexillum*** | Colonial Tunicate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 3.00 | 3.00 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V10 | ***Diplosoma listerianum*** | Diplosoma Tunicate | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.10 | 1.50 | 2.50 | 3.00 | 2.00 | 3.00 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V11 | ***Hemigrapsus sanguineus*** | Asian Shore Crab | 0.00 | 0.00 | 1.00 | 1.50 | 0.00 | 0.50 | 0.00 | 0.00 | 2.50 | 0.00 | 1.00 | 0.70 | 0.00 | 3.00 | 2.50 | 2.00 | 0.00 | 1.50 |
| V12 | ***Ianiropsis serricaudis*** | Asian Isopod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 4.00 | 0.50 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V13 | ***Membranipora membranacea*** | Lacy Crust Bryozoan | 1.00 | 0.00 | 0.00 | 0.00 | 3.50 | 0.90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 4.00 | 0.90 |
| V14 | ***Styela clava*** | Club Tunicate | 0.00 | 0.50 | 1.00 | 0.50 | 1.00 | 0.60 | 0.00 | 0.00 | 2.00 | 0.00 | 1.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V15 | ***Tricellaria inopinata*** | New Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **AVERAGES** | 0.30 | 0.20 | 0.37 | 0.53 | 0.85 | 0.45 | 0.27 | 0.80 | 1.83 | 1.87 | 1.70 | 1.29 | 0.00 | 0.37 | 0.37 | 0.33 | 0.27 | 0.27 |
| **NATIVE** | | | | | | | | | | | | | | | | | | | | |
| N1 | ***Anomia*** | Jingle Shell | 0.00 | 0.00 | 0.50 | 1.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N2 | ***Asterias forbesi*** | Forbes Sea Star | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N3 | **Balanomorpha** | Acorn Barnacle | 2.00 | 1.00 | 1.00 | 1.50 | 0.00 | 1.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 3.50 | 3.25 | 3.00 | 0.00 | 2.55 |
| N4 | ***Bryozoa*** | Bryozoa | 1.00 | 2.00 | 1.00 | 2.75 | 2.50 | 1.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 2.00 | 0.00 | 4.00 | 1.70 |
| N5 | ***Bugula*** **(native)** | Native Bugula | 0.00 | 0.00 | 0.00 | 0.00 | 1.75 | 0.35 | 0.00 | 0.50 | 0.00 | 0.00 | 2.50 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N6 | ***Corophium*** | Corophiid Amphipod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N7 | ***Crepidula*** | Slippersnail | 0.00 | 0.00 | 2.50 | 3.00 | 3.25 | 1.75 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.20 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 |
| N8 | **Gammaridae** | Gammarid Amphipod | 0.00 | 0.50 | 0.00 | 0.00 | 0.50 | 0.20 | 2.00 | 0.00 | 0.00 | 0.00 | 1.50 | 0.70 | 0.50 | 0.00 | 2.50 | 0.00 | 0.00 | 0.60 |
| N9 | ***Hydroides dianthus*** | Calcareous Tube Worm | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.20 |
| N10 | ***Jassa marmorata*** | Tube-building Amphipod | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 0.00 | 0.00 | 3.50 | 0.50 | 1.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N11 | ***Molgula manhattensis*** | Sea Grape Tunicate | 0.00 | 3.00 | 2.75 | 2.50 | 0.00 | 1.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.50 | 4.00 | 3.50 | 3.00 | 2.80 |
| N12 | ***Mytilus edulis*** | Blue Mussel | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.10 | 2.50 | 0.00 | 1.00 | 0.00 | 3.00 | 1.30 | 0.00 | 1.00 | 1.50 | 0.00 | 1.00 | 0.70 |
| N13 | **Nereididae** | Nereid Clam Worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N14 | ***Palaemonetes*** | Native Grass Shrimp | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.10 |
| N15 | **Panopeidae** | Mud Crab | 0.50 | 0.50 | 1.00 | 1.50 | 2.00 | 1.10 | 0.00 | 0.00 | 0.00 | 1.50 | 0.50 | 0.40 | 0.00 | 2.00 | 2.00 | 2.00 | 1.00 | 1.40 |
| N16 | **Porifera** | Sponge | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 0.00 | 0.00 | 0.00 | 0.30 |
| N17 | ***Spirorbis*** | Spirorbid Worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 1.00 | 3.00 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N18 | **Tubulariidae** | Hydroid | 0.00 | 0.00 | 0.00 | 0.00 | 2.75 | 0.55 | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 2.00 | 3.00 | 1.50 | 0.00 | 0.00 | 1.30 |
| | | **AVERAGES** | 0.19 | 0.42 | 0.49 | 0.68 | 0.82 | 0.52 | 0.56 | 0.08 | 0.28 | 0.28 | 0.44 | 0.33 | 0.31 | 1.00 | 0.93 | 0.56 | 0.50 | 0.66 |

# *PRES Dataset: Mean (Pooled Site) Abundances*



| | | | AVERAGES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MONTHLY | | | | | | SEASONAL | | | | | |
| **INVASIVE** | | | May | Jun | Aug | Sep | Nov | MEAN | May | Jun | Aug | Sep | Nov | MEAN |
| V1 | ***Ascidiella aspersa*** | Rough Clear Sea Squirt | 0.00 | 0.11 | 0.89 | 0.78 | 0.44 | 0.44 | 0.00 | 0.17 | 1.00 | 1.50 | 1.67 | 0.87 |
| V2 | ***Botrylloides violaceus*** | Orange Sheath Tunicate | 0.78 | 1.22 | 1.67 | 1.94 | 2.00 | 1.52 | 0.67 | 1.17 | 1.67 | 2.00 | 2.08 | 1.52 |
| V3 | ***Botryllus schlosseri*** | Golden Star Tunicate | 0.56 | 1.00 | 1.33 | 1.22 | 1.22 | 1.07 | 0.50 | 1.00 | 1.33 | 1.50 | 1.33 | 1.13 |
| V4 | ***Bugula neritina*** | Purple Bush Bryozoan | 0.00 | 0.00 | 0.00 | 0.89 | 0.11 | 0.20 | 0.00 | 0.00 | 0.00 | 0.17 | 0.67 | 0.17 |
| V5 | ***Caprella mutica*** | Asian Skeleton Shrimp | 0.89 | 1.00 | 0.89 | 1.33 | 1.22 | 1.07 | 0.83 | 1.00 | 1.00 | 1.33 | 1.67 | 1.17 |
| V6 | ***Carcinus maenas*** | Green Crab | 0.00 | 0.11 | 0.11 | 0.33 | 0.11 | 0.13 | 0.00 | 0.00 | 0.33 | 0.33 | 0.00 | 0.13 |
| V7 | ***Ciona intestinalis*** | Sea vase tunicate | 0.00 | 0.67 | 1.33 | 1.00 | 0.22 | 0.64 | 0.00 | 0.50 | 1.33 | 1.17 | 1.00 | 0.80 |
| V8 | ***Diadumene lineata*** | Striped Anemone | 0.00 | 0.33 | 0.11 | 0.00 | 0.00 | 0.09 | 0.00 | 0.83 | 1.00 | 0.83 | 0.00 | 0.53 |
| V9 | ***Didemnum vexillum*** | Colonial Tunicate | 0.00 | 0.00 | 0.56 | 0.00 | 0.33 | 0.18 | 0.00 | 0.00 | 0.33 | 1.00 | 1.00 | 0.47 |
| V10 | ***Diplosoma listerianum*** | Diplosoma Tunicate | 0.44 | 1.44 | 0.78 | 1.11 | 0.78 | 0.91 | 0.50 | 1.00 | 1.00 | 0.67 | 1.00 | 0.83 |
| V11 | ***Hemigrapsus sanguineus*** | Asian Shore Crab | 0.00 | 0.78 | 1.33 | 0.78 | 0.56 | 0.69 | 0.00 | 1.00 | 2.00 | 1.17 | 0.33 | 0.90 |
| V12 | ***Ianiropsis serricaudis*** | Asian Isopod | 0.00 | 0.00 | 0.89 | 1.11 | 0.67 | 0.53 | 0.00 | 0.00 | 0.83 | 1.33 | 0.17 | 0.47 |
| V13 | ***Membranipora membranacea*** | Lacy Crust Bryozoan | 0.22 | 0.00 | 0.00 | 0.56 | 1.33 | 0.42 | 0.33 | 0.00 | 0.00 | 0.17 | 2.50 | 0.60 |
| V14 | ***Styela clava*** | Club Tunicate | 0.00 | 0.33 | 0.11 | 0.00 | 0.11 | 0.11 | 0.00 | 0.17 | 1.00 | 0.17 | 0.67 | 0.40 |
| V15 | ***Tricellaria inopinata*** | New Bushy Bryozoan | 0.00 | 0.00 | 0.22 | 0.11 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.07 |
| | | **AVERAGES** | 0.19 | 0.47 | 0.68 | 0.74 | 0.61 | **0.54** | 0.19 | 0.46 | 0.86 | 0.91 | 0.94 | **0.67** |
| **NATIVE** | | | | | | | | | | | | | | |
| N1 | ***Anomia*** | Jingle Shell | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.13 | 0.00 | 0.00 | 0.17 | 0.33 | 0.00 | 0.10 |
| N2 | ***Asterias forbesi*** | Forbes Sea Star | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N3 | **Balanomorpha** | Acorn Barnacle | 1.67 | 1.28 | 1.17 | 0.44 | 0.00 | 0.91 | 1.67 | 1.50 | 1.42 | 1.50 | 0.00 | 1.22 |
| N4 | ***Bryozoa*** | Bryozoa | 0.33 | 1.22 | 0.44 | 0.00 | 0.67 | 0.53 | 0.33 | 1.50 | 1.00 | 0.92 | 2.17 | 1.18 |
| N5 | ***Bugula*** **(native)** | Native Bugula | 0.00 | 0.33 | 0.00 | 0.00 | 0.67 | 0.20 | 0.00 | 0.17 | 0.00 | 0.00 | 1.42 | 0.32 |
| N6 | ***Corophium*** | Corophiid Amphipod | 0.00 | 0.00 | 0.00 | 0.89 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N7 | ***Crepidula*** | Slippersnail | 0.00 | 0.67 | 1.72 | 0.00 | 0.00 | 0.48 | 0.00 | 0.33 | 1.17 | 1.00 | 1.08 | 0.72 |
| N8 | **Gammaridae** | Gammarid Amphipod | 1.00 | 0.33 | 0.67 | 0.00 | 1.17 | 0.63 | 0.83 | 0.17 | 0.83 | 0.00 | 0.67 | 0.50 |
| N9 | ***Hydroides dianthus*** | Calcareous Tube Worm | 0.00 | 0.67 | 0.78 | 1.00 | 1.00 | 0.69 | 0.00 | 0.00 | 0.00 | 0.33 | 0.67 | 0.20 |
| N10 | ***Jassa marmorata*** | Tube-building Amphipod | 0.56 | 0.00 | 0.00 | 1.22 | 0.56 | 0.47 | 0.50 | 0.00 | 0.00 | 1.17 | 0.17 | 0.37 |
| N11 | ***Molgula manhattensis*** | Sea Grape Tunicate | 0.00 | 1.89 | 1.78 | 1.22 | 0.44 | 1.07 | 0.00 | 2.17 | 2.25 | 2.00 | 1.00 | 1.48 |
| N12 | ***Mytilus edulis*** | Blue Mussel | 0.89 | 0.67 | 0.22 | 0.00 | 0.00 | 0.36 | 0.83 | 0.50 | 0.83 | 0.00 | 1.33 | 0.70 |
| N13 | **Nereididae** | Nereid Clam Worm | 0.00 | 0.22 | 0.44 | 0.00 | 0.83 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N14 | ***Palaemonetes*** | Native Grass Shrimp | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.03 |
| N15 | **Panopeidae** | Mud Crab | 0.11 | 0.78 | 0.67 | 1.67 | 1.17 | 0.88 | 0.17 | 0.83 | 1.00 | 1.67 | 1.17 | 0.97 |
| N16 | **Porifera** | Sponge | 0.00 | 0.22 | 0.11 | 0.00 | 0.11 | 0.09 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.10 |
| N17 | ***Spirorbis*** | Spirorbid Worm | 0.78 | 0.67 | 0.89 | 0.00 | 0.00 | 0.47 | 0.83 | 0.33 | 1.00 | 0.00 | 0.00 | 0.43 |
| N18 | **Tubulariidae** | Hydroid | 0.89 | 0.89 | 0.78 | 0.00 | 0.44 | 0.60 | 1.17 | 1.00 | 0.50 | 0.00 | 0.92 | 0.72 |
| | | **AVERAGES** | 0.35 | 0.55 | 0.54 | 0.41 | 0.39 | **0.45** | 0.35 | 0.50 | 0.56 | 0.50 | 0.59 | **0.50** |

| **Abundance Scale:** | | | | | |
|---|---|---|---|---|---|
| Integer | 0 | 1 | 2 | 3 | 4 |
| Classification | Absent | Rare | Few | Common | Abundant |

# *FOUL Dataset: Per-Site Abundances*

| | | | MONTHLY | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AHQ | | | | | | FTA | | | | | | STB | | | | | |
| **INVASIVE** | | | MAY | JUN | AUG | SEP | NOV | MEAN | MAY | JUN | AUG | SEP | NOV | MEAN | MAY | JUN | AUG | SEP | NOV | MEAN |
| V1 | ***Ascidiella aspersa*** | Rough Clear Sea Squirt | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 2.67 | 2.33 | 1.33 | 1.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V2 | ***Botrylloides violaceus*** | Orange Sheath Tunicate | 2.00 | 1.00 | 1.33 | 2.83 | 3.67 | 2.17 | 0.33 | 2.67 | 3.67 | 3.00 | 2.33 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V3 | ***Botryllus schlosseri*** | Golden Star Tunicate | 1.67 | 0.67 | 1.00 | 1.00 | 2.33 | 1.33 | 0.00 | 2.33 | 3.00 | 2.67 | 1.33 | 1.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V4 | ***Bugula neritina*** | Purple Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67 | 0.33 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V5 | ***Ciona intestinalis*** | Sea Vase Tunicate | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 1.67 | 4.00 | 3.00 | 0.67 | 1.87 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V6 | ***Diadumene lineata*** | Striped Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.33 | 0.00 | 0.00 | 0.27 |
| V7 | ***Didemnum vexillum*** | Colonial Tunicate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 1.00 | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V8 | ***Diplosoma listerianum*** | Diplosoma Tunicate | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.40 | 1.33 | 2.33 | 2.33 | 3.33 | 2.33 | 2.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V9 | ***Membranipora membranacea*** | Lacy Crust Bryozoan | 0.33 | 0.00 | 0.00 | 0.00 | 4.00 | 0.87 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 0.33 |
| V10 | ***Styela clava*** | Club Tunicate | 0.00 | 1.00 | 0.00 | 0.00 | 0.33 | 0.27 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **AVERAGES** | 0.40 | 0.53 | 0.23 | 0.38 | 1.03 | 0.52 | 0.20 | 0.90 | 1.77 | 1.70 | 0.93 | 1.10 | 0.00 | 0.10 | 0.03 | 0.17 | 0.00 | 0.06 |
| **NATIVE** | | | | | | | | | | | | | | | | | | | | |
| N1 | ***Anomia*** | Jingle Shell | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N2 | ***Balanus*** | Barnacle | 2.00 | 0.67 | 0.33 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 3.17 | 3.17 | 1.33 | 0.00 | 2.13 |
| N3 | **Bryozoa (encrusting)** | Encrusting Bryozoan | 1.00 | 2.33 | 0.67 | 0.00 | 2.00 | 1.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 0.67 | 0.00 | 0.00 | 0.40 |
| N4 | ***Bugula* (native)** | Native Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.40 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N5 | ***Hydroides dianthus*** | Calcareous Tube Worm | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.60 | 0.00 | 0.00 | 0.00 | 1.67 | 0.00 | 0.33 | 0.00 | 2.00 | 2.33 | 1.33 | 0.00 | 1.13 |
| N6 | ***Molgula manhattensis*** | Sea Grape Tunicate | 0.00 | 2.33 | 2.67 | 1.00 | 1.33 | 1.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.33 | 2.67 | 2.67 | 0.00 | 1.73 |
| N7 | ***Mytilus edulis*** | Blue Mussel | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 | 2.67 | 0.00 | 0.67 | 0.00 | 0.00 | 0.67 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.20 |
| N8 | **Porifera** | Sponge | 0.00 | 0.00 | 0.33 | 0.00 | 0.33 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.13 |
| N9 | ***Spirorbis*** | Tube Worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.33 | 2.00 | 2.67 | 0.00 | 0.00 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N10 | **Tubulariidae** | Hydroid | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 0.27 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 1.67 | 2.67 | 2.33 | 0.00 | 0.00 | 1.33 |
| | | **AVERAGES** | 0.30 | 0.63 | 0.40 | 0.10 | 1.00 | 0.49 | 0.60 | 0.30 | 0.33 | 0.37 | 0.00 | 0.32 | 0.47 | 1.42 | 1.12 | 0.53 | 0.00 | 0.71 |

**Abundance Scale:**

| | | | | | |
|---|---|---|---|---|---|
| Integer | 0 | 1 | 2 | 3 | 4 |
| Classification | Absent | Rare | Few | Common | Abundant |

| | | | SEASONAL | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AHQ | | | | | | FTA | | | | | | STB | | | | | |
| **INVASIVE** | | | MAY | JUN | AUG | SEP | NOV | MEAN | MAY | JUN | AUG | SEP | NOV | MEAN | MAY | JUN | AUG | SEP | NOV | MEAN |
| V1 | ***Ascidiella aspersa*** | Rough Clear Sea Squirt | 0.00 | 0.50 | 0.00 | 1.50 | 1.00 | 0.60 | 0.00 | 0.00 | 3.00 | 3.00 | 4.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V2 | ***Botrylloides violaceus*** | Orange Sheath Tunicate | 2.00 | 1.00 | 1.50 | 3.00 | 3.25 | 2.15 | 0.00 | 2.50 | 3.50 | 3.00 | 3.00 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V3 | ***Botryllus schlosseri*** | Golden Star Tunicate | 1.50 | 0.50 | 1.00 | 1.50 | 2.00 | 1.30 | 0.00 | 2.50 | 3.00 | 3.00 | 2.00 | 2.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V4 | ***Bugula neritina*** | Purple Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 2.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V5 | ***Ciona intestinalis*** | Sea Vase Tunicate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 4.00 | 3.50 | 3.00 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V6 | ***Diadumene lineata*** | Striped Anemone | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 3.00 | 2.50 | 0.00 | 1.60 |
| V7 | ***Didemnum vexillum*** | Colonial Tunicate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 3.00 | 3.00 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V8 | ***Diplosoma listerianum*** | Diplosoma Tunicate | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.10 | 1.50 | 2.50 | 3.00 | 2.00 | 3.00 | 2.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| V9 | ***Membranipora membranacea*** | Lacy Crust Bryozoan | 1.00 | 0.00 | 0.00 | 0.00 | 3.50 | 0.90 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 4.00 | 0.90 |
| V10 | ***Styela clava*** | Club Tunicate | 0.00 | 0.50 | 1.00 | 0.50 | 1.00 | 0.60 | 0.00 | 0.00 | 2.00 | 0.00 | 1.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | **AVERAGES** | 0.45 | 0.30 | 0.35 | 0.65 | 1.08 | 0.57 | 0.15 | 0.90 | 1.95 | 1.80 | 2.10 | 1.38 | 0.00 | 0.25 | 0.30 | 0.30 | 0.40 | 0.25 |
| **NATIVE** | | | | | | | | | | | | | | | | | | | | |
| N1 | ***Anomia*** | Jingle Shell | 0.00 | 0.00 | 0.50 | 1.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N2 | ***Balanus*** | Barnacle | 2.00 | 1.00 | 1.00 | 1.50 | 0.00 | 1.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 3.50 | 3.25 | 3.00 | 0.00 | 2.55 |
| N3 | **Bryozoa (encrusting)** | Encrusting Bryozoan | 1.00 | 2.00 | 1.00 | 2.75 | 2.50 | 1.85 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 2.00 | 0.00 | 4.00 | 1.70 |
| N4 | ***Bugula* (native)** | Native Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.00 | 1.75 | 0.35 | 0.00 | 0.50 | 0.00 | 0.00 | 2.50 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N5 | ***Hydroides dianthus*** | Calcareous Tube Worm | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.20 |
| N6 | ***Molgula manhattensis*** | Sea Grape Tunicate | 0.00 | 3.00 | 2.75 | 2.50 | 0.00 | 1.65 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.50 | 4.00 | 3.50 | 3.00 | 2.80 |
| N7 | ***Mytilus edulis*** | Blue Mussel | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.10 | 2.50 | 0.00 | 1.00 | 0.00 | 3.00 | 1.30 | 0.00 | 1.00 | 1.50 | 0.00 | 1.00 | 0.70 |
| N8 | **Porifera** | Sponge | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 | 0.00 | 0.00 | 0.00 | 0.30 |
| N9 | ***Spirorbis*** | Tube Worm | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 1.00 | 3.00 | 0.00 | 0.00 | 1.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| N10 | **Tubulariidae** | Hydroid | 0.00 | 0.00 | 0.00 | 0.00 | 2.75 | 0.55 | 1.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 2.00 | 3.00 | 1.50 | 0.00 | 0.00 | 1.30 |
| | | **AVERAGES** | 0.30 | 0.65 | 0.53 | 0.78 | 0.90 | 0.63 | 0.65 | 0.15 | 0.40 | 0.00 | 0.55 | 0.35 | 0.50 | 1.50 | 1.23 | 0.75 | 0.80 | 0.96 |

# *FOUL Dataset: Mean (Pooled Site) Abundances*

| | | | **AVERAGES** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MONTHLY | | | | | | SEASONAL | | | | | |
| **INVASIVE** | | | **MAY** | **JUN** | **AUG** | **SEP** | **NOV** | **MEAN** | **MAY** | **JUN** | **AUG** | **SEP** | **NOV** | **MEAN** |
| V1 | ***Ascidiella aspersa*** | Rough Clear Sea Squirt | 0.00 | 0.11 | 0.89 | 0.78 | 0.44 | 0.44 | 0.00 | 0.17 | 1.00 | 1.50 | 1.67 | 0.87 |
| V2 | ***Botrylloides violaceus*** | Orange Sheath Tunicate | 0.78 | 1.22 | 1.67 | 1.94 | 2.00 | 1.52 | 0.67 | 1.17 | 1.67 | 2.00 | 2.08 | 1.52 |
| V3 | ***Botryllus schlosseri*** | Golden Star Tunicate | 0.56 | 1.00 | 1.33 | 1.22 | 1.22 | 1.07 | 0.50 | 1.00 | 1.33 | 1.50 | 1.33 | 1.13 |
| V4 | ***Bugula neritina*** | Purple Bushy Bryozoan | 0.00 | 0.00 | 0.00 | 0.89 | 0.11 | 0.20 | 0.00 | 0.00 | 0.00 | 0.17 | 0.67 | 0.17 |
| V5 | ***Ciona intestinalis*** | Sea Vase Tunicate | 0.00 | 0.67 | 1.33 | 1.00 | 0.22 | 0.64 | 0.00 | 0.50 | 1.33 | 1.17 | 1.00 | 0.80 |
| V6 | ***Diadumene lineata*** | Striped Anemone | 0.00 | 0.33 | 0.11 | 0.00 | 0.00 | 0.09 | 0.00 | 0.83 | 1.00 | 0.83 | 0.00 | 0.53 |
| V7 | ***Didemnum vexillum*** | Colonial Tunicate | 0.00 | 0.00 | 0.56 | 0.00 | 0.33 | 0.18 | 0.00 | 0.00 | 0.33 | 1.00 | 1.00 | 0.47 |
| V8 | ***Diplosoma listerianum*** | Diplosoma Tunicate | 0.44 | 1.44 | 0.78 | 1.11 | 0.78 | 0.91 | 0.50 | 1.00 | 1.00 | 0.67 | 1.00 | 0.83 |
| V9 | ***Membranipora membranacea*** | Lacy Crust Bryozoan | 0.22 | 0.00 | 0.00 | 0.56 | 1.33 | 0.42 | 0.33 | 0.00 | 0.00 | 0.17 | 2.50 | 0.60 |
| V10 | ***Styela clava*** | Club Tunicate | 0.00 | 0.33 | 0.11 | 0.00 | 0.11 | 0.11 | 0.00 | 0.17 | 1.00 | 0.17 | 0.67 | 0.40 |
| | | **AVERAGES** | 0.20 | 0.51 | 0.68 | 0.75 | 0.66 | **0.56** | 0.20 | 0.48 | 0.87 | 0.92 | 1.19 | **0.73** |
| **NATIVE** | | | | | | | | | | | | | | |
| N1 | ***Anomia*** | Jingle Shell | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.13 | 0.00 | 0.00 | 0.17 | 0.33 | 0.00 | 0.10 |
| N2 | ***Balanus*** | Barnacle | 1.67 | 1.28 | 1.17 | 0.44 | 0.00 | 0.91 | 1.67 | 1.50 | 1.42 | 1.50 | 0.00 | 1.22 |
| N3 | **Bryozoa (encrusting)** | Encrusting Bryozoan | 0.33 | 1.22 | 0.44 | 0.00 | 0.67 | 0.53 | 0.33 | 1.50 | 1.00 | 0.92 | 2.17 | 1.18 |
| N4 | ***Bugula* (native)** | Native Bushy Bryozoan | 0.00 | 0.33 | 0.00 | 0.00 | 0.67 | 0.20 | 0.00 | 0.17 | 0.00 | 0.00 | 1.42 | 0.32 |
| N5 | ***Hydroides dianthus*** | Calcareous Tube Worm | 0.00 | 0.67 | 0.78 | 1.00 | 1.00 | 0.69 | 0.00 | 0.00 | 0.00 | 0.33 | 0.67 | 0.20 |
| N6 | ***Molgula manhattensis*** | Sea Grape Tunicate | 0.00 | 1.89 | 1.78 | 1.22 | 0.44 | 1.07 | 0.00 | 2.17 | 2.25 | 2.00 | 1.00 | 1.48 |
| N7 | ***Mytilus edulis*** | Blue Mussel | 0.89 | 0.67 | 0.22 | 0.00 | 0.00 | 0.36 | 0.83 | 0.50 | 0.83 | 0.00 | 1.33 | 0.70 |
| N8 | **Porifera** | Sponge | 0.00 | 0.22 | 0.11 | 0.00 | 0.11 | 0.09 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.10 |
| N9 | ***Spirorbis*** | Tube Worm | 0.78 | 0.67 | 0.89 | 0.00 | 0.00 | 0.47 | 0.83 | 0.33 | 1.00 | 0.00 | 0.00 | 0.43 |
| N10 | **Tubulariidae** | Hydroid | 0.89 | 0.89 | 0.78 | 0.00 | 0.44 | 0.60 | 1.17 | 1.00 | 0.50 | 0.00 | 0.92 | 0.72 |
| | | **AVERAGES** | 0.46 | 0.78 | 0.62 | 0.33 | 0.33 | **0.50** | 0.48 | 0.77 | 0.72 | 0.51 | 0.75 | **0.65** |

| **Abundance Scale:** | | | | | |
|---|---|---|---|---|---|
| Integer | 0 | 1 | 2 | 3 | 4 |
| Classification | Absent | Rare | Few | Common | Abundant |

# Appendix C: Individual Site Data

## AHQ

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | | 0.33 | • | | | • | | | | 0.50 | • | | 1.50 | • | 1.00 | 0.50 |
| *Botrylloides violaceus* | 2.00 | 1.00 | • | 1.33 | 2.83 | • | 3.67 | 1.00 | 2.00 | 1.00 | • | 1.50 | 3.00 | • | 3.25 | 3.00 |
| *Botryllus schlosseri* | 1.67 | 0.67 | • | 1.00 | 1.00 | • | 2.33 | | 1.50 | 0.50 | • | 1.00 | 1.50 | • | 2.00 | 2.00 |
| *Caprella mutica* | | | • | | | • | 0.67 | | | | • | | | • | 2.00 | 2.00 |
| *Carcinus maenas* | | | • | 0.33 | | • | | | | | • | 1.00 | | • | | |
| *Ciona intestinalis* | | 0.33 | • | | | • | | | | | • | | | • | | |
| *Diplosoma listerianum* | | 2.00 | • | | | • | | | | 0.50 | • | | | • | | |
| *Hemigrapsus sanguineus* | | | • | 0.33 | 1.33 | • | 1.00 | | | | • | 1.00 | 1.50 | • | | |
| *Membranipora membranacea* | 0.33 | | • | | | • | 4.00 | | 1.00 | | • | | | • | 3.50 | |
| *Styela clava* | | 1.00 | • | | | • | 0.33 | | | 0.50 | • | 1.00 | 0.50 | • | 1.00 | |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | | | • | | | • | | | | | • | 0.50 | 1.00 | • | | |
| *Asterias forbesi* | | | • | 0.33 | | • | | | | | • | | | • | | |
| Balanomorpha | 2.00 | 0.67 | • | 0.33 | | • | | | 2.00 | 1.00 | • | 1.00 | 1.50 | • | | |
| *Bryozoa* | 1.00 | 2.33 | • | 0.67 | | • | 2.00 | | 1.00 | 2.00 | • | 1.00 | 2.75 | • | 2.50 | 2.50 |
| *Bugula* (native) | | | • | | | • | 2.00 | | | | • | | | • | 1.75 | 1.50 |
| *Crepidula* | | | • | 2.83 | | • | | | | | • | 2.50 | 3.00 | • | 3.25 | 3.00 |
| Gammaridae | | 1.00 | • | | | • | 2.17 | | | 0.50 | • | | | • | 0.50 | |
| *Hydroides dianthus* | | | • | | | • | 3.00 | | | | • | | | • | 2.00 | 2.00 |
| *Molgula manhattensis* | | 2.33 | • | 2.67 | 1.00 | • | 1.33 | | | 3.00 | • | 2.75 | 2.50 | • | | |
| *Mytilus edulis* | | 1.00 | • | | | • | | | | 0.50 | • | | | • | | |
| Nereididae | | | • | 1.33 | | • | 2.17 | | | | • | | | • | | 0.50 |
| Panopeidae | 0.33 | 0.33 | • | 1.00 | 1.33 | • | 3.17 | | 0.50 | 0.50 | • | 1.00 | 1.50 | • | 2.00 | 2.00 |
| Porifera | | | • | 0.33 | | • | 0.33 | | | | • | | | • | | |
| Tubulariidae | | | • | | | • | 1.33 | | | | • | | | • | 2.75 | |

## FTA

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | | | • | 2.67 | 2.33 | 1.00 | 1.33 | 2.00 | | | • | 3.00 | 3.00 | 3.50 | 4.00 | 4.00 |
| *Botrylloides violaceus* | 0.33 | 2.67 | • | 3.67 | 3.00 | 2.33 | 2.33 | 2.17 | | 2.50 | • | 3.50 | 3.00 | 3.00 | 3.00 | 2.50 |
| *Botryllus schlosseri* | | 2.33 | • | 3.00 | 2.67 | 3.00 | 1.33 | 2.00 | | 2.50 | • | 3.00 | 3.00 | 2.00 | 2.00 | 2.25 |
| *Bugula neritina* | | | • | | 2.67 | 3.00 | 0.33 | | | | • | | 0.50 | 1.50 | 2.00 | 2.00 |
| *Caprella mutica* | 2.67 | 3.00 | • | 2.67 | 4.00 | 3.00 | 3.00 | 3.00 | 2.50 | 3.00 | • | 3.00 | 4.00 | 3.00 | 3.00 | 3.75 |
| *Carcinus maenas* | | 0.33 | • | | 1.00 | | 0.33 | | | | • | | 1.00 | | | |
| *Ciona intestinalis* | | 1.67 | • | 4.00 | 3.00 | 2.00 | 0.67 | | | 1.50 | • | 4.00 | 3.50 | 3.50 | 3.00 | 2.75 |
| *Didemnum vexillum* | | | • | 1.67 | | 3.00 | 1.00 | | | | • | 1.00 | 3.00 | 3.50 | 3.00 | 3.25 |
| *Diplosoma listerianum* | 1.33 | 2.33 | • | 2.33 | 3.33 | 1.67 | 2.33 | 3.00 | 1.50 | 2.50 | • | 3.00 | 2.00 | | 3.00 | 3.00 |
| *Grateloupia turuturu* | | | • | | | 0.67 | | | | | • | | | | | 0.50 |
| *Hemigrapsus sanguineus* | | | • | 2.33 | | 3.00 | 0.67 | | | | • | 2.50 | | 3.00 | 1.00 | |
| *Ianiropsis serricaudis* | | | • | 2.67 | 3.33 | | 2.00 | 3.00 | | | • | 2.50 | 4.00 | | 0.50 | 2.00 |
| *Littorina littorea* | | | • | | | 2.33 | | | | | • | | | 2.00 | | |
| *Membranipora membranacea* | 0.33 | | • | | | | | 1.83 | | | • | | | | | 1.00 |
| *Styela clava* | | | • | 0.33 | | | | | | | • | 2.00 | | 1.50 | 1.00 | 1.50 |
| *Tricellaria inopinata* | | | • | 0.67 | 0.33 | | | | | | • | | 1.00 | | | |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | | | • | | 2.00 | 2.67 | | | | | • | | | | | |
| Balanomorpha | | | • | | | 0.33 | | | | | • | | | | | |
| *Bugula* | | 1.00 | • | | | 3.00 | | | | 0.50 | • | | | 1.50 | 2.50 | |
| *Corophium* | | | • | | 2.67 | 3.00 | | | | | • | | | 2.00 | | |
| *Crepidula* | | 0.67 | • | 2.33 | | 1.33 | | | | | • | 1.00 | | | | |
| Gammaridae | 2.00 | | • | | | 2.67 | 1.33 | 3.00 | 2.00 | | • | | | 2.50 | 1.50 | 2.50 |
| *Hydroides dianthus* | | | • | | 1.67 | 1.00 | | 3.00 | | | • | | | | | 2.00 |
| *Jassa marmorata* | 1.67 | | • | | 3.67 | | 1.67 | | 1.50 | | • | | 3.50 | | 0.50 | |
| *Mytilus edulis* | 2.67 | | • | 0.67 | | 2.33 | | | 2.50 | | • | 1.00 | | 3.00 | 3.00 | 3.00 |
| Nereididae | | | • | | | | 0.33 | | | | • | | | | | |
| Panopeidae | | | • | | 1.33 | 2.00 | 0.33 | | | | • | | 1.50 | 1.00 | 0.50 | |
| Porifera | | | • | | | 1.00 | | | | | • | | | | | |
| *Spirorbis* | 2.33 | 2.00 | • | 2.67 | | | | | 2.50 | 1.00 | • | 3.00 | | | | |
| Tubulariidae | 1.00 | | • | | | 2.00 | | | 1.50 | | • | | | 2.50 | | |

## GSO

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | • | | • | | | • | | | • | | • | 3.00 | 2.50 | • | | |
| *Botrylloides violaceus* | • | 2.00 | • | 3.33 | 2.00 | • | 1.00 | 1.00 | • | 1.00 | • | 3.00 | 3.00 | • | 3.00 | 3.00 |
| *Botryllus schlosseri* | • | 3.00 | • | 0.67 | 1.00 | • | 0.33 | | • | 3.00 | • | 2.50 | 3.50 | • | 3.50 | 4.00 |
| *Bugula neritina* | • | | • | 2.67 | 1.00 | • | | | • | | • | 1.00 | 2.00 | • | | 0.50 |
| *Caprella mutica* | • | 3.00 | • | 3.00 | 2.67 | • | | | • | 3.00 | • | 2.00 | 3.00 | • | | |
| *Carcinus maenas* | • | | • | 3.33 | 2.00 | • | | 0.33 | • | | • | 3.00 | 1.50 | • | | 0.50 |
| *Ciona intestinalis* | • | | • | | | • | | | • | | • | 1.00 | | • | | |
| *Didemnum vexillum* | • | | • | 4.00 | | • | | | • | | • | 1.50 | 2.50 | • | 3.00 | 3.00 |
| *Diplosoma listerianum* | • | | • | | 1.67 | • | | | • | | • | | 1.00 | • | 1.00 | |
| *Styela clava* | • | | • | | | • | | | • | | • | | 0.50 | • | | |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Balanomorpha | • | | • | | | • | | | • | | • | | | • | | 2.00 |
| *Bugula* (native) | • | | • | | | • | | | • | | • | | | • | | 0.50 |
| *Mytilus edulis* | • | | • | | | • | | | • | | • | | | • | | 1.00 |
| Nereididae | • | | • | | | • | | | • | | • | | | • | | 1.50 |
| Panopeidae | • | | • | | | • | | 0.67 | • | | • | | | • | | 2.00 |
| Tubulariidae | • | | • | 0.67 | | • | | 1.00 | • | | • | | | • | | |

## MMA

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | 0.67 | | • | • | | | | | | | • | • | | | | |
| *Botrylloides violaceus* | 1.33 | 3.83 | • | • | 3.33 | 3.33 | 1.50 | | | 3.00 | • | • | 3.00 | 0.50 | 3.00 | 2.75 |
| *Botryllus schlosseri* | 3.67 | 4.00 | • | • | 3.00 | 3.17 | 1.33 | | 3.75 | 4.00 | • | • | | | | |
| *Bugula neritina* | | | • | • | | | | | | | • | • | | | | |
| *Caprella mutica* | | | • | • | 3.00 | 3.40 | | | | 1.25 | • | • | | 4.00 | | |
| *Carcinus maenas* | | | • | • | | | | | | | • | • | 1.00 | | | |
| *Ciona intestinalis* | 2.67 | | • | • | | | | | 1.75 | 1.00 | • | • | | | | |
| *Didemnum vexillum* | | | • | • | | | | | | | • | • | | | 0.50 | |
| *Membranipora membranacea* | 3.67 | | • | • | | 1.17 | | | 3.75 | 1.00 | • | • | 4.00 | 0.50 | 4.00 | |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | | | • | • | | | | | | | • | • | | | | 0.50 |
| Balanomorpha | | | • | • | | | | | | | • | • | | 4.00 | 1.25 | 1.25 |
| *Bryozoa* | | | • | • | | | | | | | • | • | | | | 4.00 |
| *Corophium* | 3.00 | 1.00 | • | • | | | | | | | • | • | | | | |
| *Crepidula* | | | • | • | | | | | | | • | • | 1.00 | 3.50 | 1.75 | 1.50 |
| Gammaridae | 4.00 | 4.00 | • | • | 3.50 | 2.00 | | | 4.00 | 4.00 | • | • | 3.50 | 2.50 | | |
| *Idotea* | | 0.33 | • | • | 0.67 | | | | | 0.50 | • | • | | | | |
| *Jassa marmorata* | | 2.00 | • | • | | 1.33 | | | | | • | • | | 3.00 | | |
| *Molgula manhattensis* | | 2.33 | • | • | 4.00 | | | | | 1.50 | • | • | 1.25 | | | |
| *Mytilus edulis* | | | • | • | | | | | 0.50 | | • | • | 0.50 | 1.00 | 0.50 | 1.00 |
| Nereididae | | 0.33 | • | • | | 2.00 | | | | | • | • | 0.50 | 0.50 | 0.50 | 0.50 |
| *Palaemonetes* | | 0.33 | • | • | | | 1.00 | | | | • | • | | | 1.50 | |
| Panopeidae | | 2.33 | • | • | 3.17 | | | | | 3.00 | • | • | 2.50 | 1.00 | 0.50 | |
| Porifera | | | • | • | | | | | | | • | • | | 1.50 | | 0.50 |
| Tubulariidae | | | • | • | | 0.33 | 1.00 | | | | • | • | | | 1.00 | |

## MOB

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | • | • | • | • | | • | 0.33 | | • | • | • | • | | • | | |
| *Botrylloides violaceus* | • | • | • | • | 3.33 | • | 2.67 | | • | • | • | • | 2.50 | • | | 2.00 |
| *Botryllus schlosseri* | • | • | • | • | 2.00 | • | 1.67 | | • | • | • | • | | • | 0.50 | |
| *Bugula neritina* | • | • | • | • | 1.67 | • | 4.00 | | • | • | • | • | | • | | 2.50 |
| *Caprella mutica* | • | • | • | • | 3.00 | • | 3.33 | | • | • | • | • | 3.00 | • | 2.50 | 3.00 |
| *Carcinus maenas* | • | • | • | • | 2.00 | • | | | • | • | • | • | 2.00 | • | | |
| *Didemnum vexillum* | • | • | • | • | | • | | | • | • | • | • | 4.00 | • | 4.00 | 4.00 |
| *Diplosoma listerianum* | • | • | • | • | | • | 3.83 | | • | • | • | • | | • | | |
| *Hemigrapsus sanguineus* | • | • | • | • | | • | | | • | • | • | • | | • | | 1.50 |
| *Membranipora membranacea* | • | • | • | • | | • | 1.33 | | • | • | • | • | | • | | |
| *Styela clava* | • | • | • | • | | • | | | • | • | • | • | 1.00 | • | | |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | • | • | • | • | | • | | | • | • | • | • | | • | | 0.50 |
| *Bugula* (native) | • | • | • | • | | • | 2.00 | | • | • | • | • | | • | | |
| Gammaridae | • | • | • | • | | • | 3.00 | | • | • | • | • | | • | 3.00 | |
| *Jassa marmorata* | • | • | • | • | | • | 3.00 | | • | • | • | • | | • | 3.00 | |
| *Mytilus edulis* | • | • | • | • | | • | | | • | • | • | • | | • | | 3.00 |
| Panopeidae | • | • | • | • | | • | 2.33 | | • | • | • | • | | • | 2.00 | |

## PCP

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Botrylloides violaceus* | • | 0.67 | 0.33 | 3.00 | 3.00 | • | • | • | • | | 3.50 | 4.00 | 2.00 | • | • | • |
| *Botryllus schlosseri* | • | 3.33 | | 4.00 | 3.83 | • | • | • | • | 2.50 | 4.00 | 4.00 | 3.00 | • | • | • |
| *Caprella mutica* | • | 4.00 | 3.67 | 3.50 | 2.67 | • | • | • | • | 2.00 | 4.00 | 3.75 | 3.00 | • | • | • |
| *Hemigrapsus sanguineus* | • | | | | 0.33 | • | • | • | • | | | 1.25 | 0.75 | • | • | • |
| *Membranipora membranacea* | • | | 0.67 | | 0.83 | • | • | • | • | | | | | • | • | • |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | • | | | 2.00 | | • | • | • | • | | | 0.50 | | • | • | • |
| Balanomorpha | • | 2.00 | 4.00 | 1.00 | | • | • | • | • | | 1.25 | 2.75 | 3.00 | • | • | • |
| *Crepidula* | • | | 0.67 | 1.67 | 0.33 | • | • | • | • | | | 2.00 | 2.00 | • | • | • |
| Gammaridae | • | 4.00 | 3.50 | 2.67 | 1.00 | • | • | • | • | 4.00 | 3.00 | 3.00 | 1.50 | • | • | • |
| *Libinia* | • | | | 0.33 | | • | • | • | • | | | | | • | • | • |
| *Molgula manhattensis* | • | | | 0.67 | 2.33 | • | • | • | • | | | | | • | • | • |
| *Mytilus edulis* | • | 4.00 | 3.33 | 2.17 | | • | • | • | • | 4.00 | 0.50 | | 0.75 | • | • | • |
| Nereididae | • | | 3.00 | 2.17 | | • | • | • | • | | | | | • | • | • |
| Nudibranchia | • | | 0.67 | | | • | • | • | • | | 0.50 | | | • | • | • |
| *Palaemonetes* | • | | | | 0.67 | • | • | • | • | | | | | • | • | • |
| Panopeidae | • | | 0.67 | 1.00 | 1.33 | • | • | • | • | | 3.00 | 2.50 | 2.25 | • | • | • |
| Tubulariidae | • | | 0.67 | 1.00 | 1.00 | • | • | • | • | | 4.00 | | 2.00 | • | • | • |

## PJM

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | • | • | • | 2.67 | 3.33 | • | | | • | • | • | 4.00 | 2.50 | • | 3.50 | 3.25 |
| *Botrylloides violaceus* | • | • | • | 3.33 | 2.33 | • | 3.67 | 2.00 | • | • | • | 3.00 | 3.00 | | 3.00 | 3.25 |
| *Botryllus schlosseri* | • | • | • | 2.00 | | • | 2.67 | | • | • | • | 2.00 | | | 1.00 | |
| *Bugula neritina* | • | • | • | 2.00 | 4.00 | • | 3.67 | | • | • | • | 2.50 | 3.00 | | | 2.00 |
| *Caprella mutica* | • | • | • | 2.00 | | • | 2.00 | | • | • | • | 2.00 | 1.00 | | 2.00 | 2.00 |
| *Carcinus maenas* | • | • | • | 3.00 | 3.00 | • | | | • | • | • | 3.00 | 3.00 | | | |
| *Ciona intestinalis* | • | • | • | | | • | 2.00 | | • | • | • | | | | 3.25 | 3.50 |
| *Didemnum vexillum* | • | • | • | | | • | | | • | • | • | 1.00 | 2.50 | | 3.50 | 3.00 |
| *Diplosoma listerianum* | • | • | • | 1.00 | | • | 2.33 | | • | • | • | | | | | |
| *Hemigrapsus sanguineus* | • | • | • | | | • | | | • | • | • | | | | 0.50 | 1.00 |
| *Membranipora membranacea* | • | • | • | | | • | 1.67 | | • | • | • | | | | | |
| *Styela clava* | • | • | • | | | • | | | • | • | • | | | | | 0.50 |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Bugula* (native) | • | • | • | | | • | 4.00 | | • | • | • | | | | | |
| *Crepidula* | • | • | • | | | • | | | • | • | • | | | | 1.00 | 3.00 |
| *Idotea balthica* | • | • | • | | | • | | | • | • | • | | | | 1.00 | |
| *Molgula manhattensis* | • | • | • | | | • | 1.33 | | • | • | • | | | | | |
| *Mytilus edulis* | • | • | • | | | • | | | • | • | • | | | | | 2.00 |
| Nereididae | • | • | • | | | • | | | • | • | • | | | | | 1.50 |
| Panopeidae | • | • | • | | | • | | | • | • | • | | | | 1.00 | |
| *Spirorbis* | • | • | • | | | • | 3.00 | | • | • | • | | | | | |
| Tubulariidae | • | • | • | | | • | 4.00 | 3.00 | • | • | • | | | | | |

## RWU

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Botrylloides violaceus* | 0.67 | 4.00 | • | • | • | 3.67 | 3.67 | • | 1.25 | 3.25 | • | • | 3.25 | 3.00 | • | • |
| *Botryllus schlosseri* | 0.33 | 4.00 | • | • | • | 3.00 | | • | | 4.00 | • | • | 3.75 | | • | • |
| *Bugula neritina* | | | • | • | • | | | • | | | • | • | | | • | • |
| *Caprella mutica* | 3.17 | 3.33 | • | • | • | 0.33 | 3.67 | • | 3.00 | 4.00 | • | • | 3.50 | 1.25 | • | • |
| *Didemnum vexillum* | | | • | • | • | | | • | | 1.00 | • | • | | 3.75 | • | • |
| *Hemigrapsus sanguineus* | | | • | • | • | 0.33 | | • | 0.50 | | • | • | | 1.00 | • | • |
| *Littorina littorea* | 0.33 | | • | • | • | | | • | | | • | • | | | • | • |
| *Membranipora membranacea* | | 2.67 | • | • | • | 3.33 | | • | | 0.50 | • | • | 0.50 | 2.00 | • | • |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native Species** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Balanus* | 0.67 | 4.00 | • | • | • | | | • | 1.00 | 1.25 | • | • | 1.75 | 3.00 | • | • |
| *Crepidula* | | | • | • | • | | 0.33 | • | | | • | • | 3.00 | 4.00 | • | • |
| Gammaridae | 0.67 | 3.17 | • | • | • | 1.00 | | • | | | • | • | 3.75 | 1.00 | • | • |
| *Jassa marmorata* | 2.00 | 2.67 | • | • | • | | 0.33 | • | 3.00 | 3.75 | • | • | | | • | • |
| *Libinia* | | | • | • | • | 0.33 | | • | | | • | • | | | • | • |
| *Mya arenaria* | | | • | • | • | | | • | | 0.50 | • | • | | | • | • |
| *Mytilus edulis* | 0.33 | | • | • | • | | | • | 1.00 | | • | • | | 1.00 | • | • |
| Nereididae | | | • | • | • | 0.33 | | • | | | • | • | | | • | • |
| Nudibranchia | 2.33 | | • | • | • | | | • | 1.50 | | • | • | | | • | • |
| *Palaemonetes* | | | • | • | • | | | • | | 0.50 | • | • | | | • | • |
| Panopeidae | 0.33 | 0.67 | • | • | • | 1.33 | | • | | 2.25 | • | • | 3.00 | 2.00 | • | • |
| Porifera | 0.67 | | • | • | • | | | • | | | • | • | | | • | • |
| Tubulariidae | | 3.50 | • | • | • | 1.33 | | • | | 4.00 | • | • | 3.25 | | • | • |

## SPT

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Ascidiella aspersa* | • | | • | | | • | 1.67 | • | • | | • | 0.50 | | • | 2.00 | • |
| *Botrylloides violaceus* | • | 3.00 | • | 3.67 | 3.00 | • | 3.00 | • | • | 3.00 | • | 3.50 | 3.00 | • | 3.00 | • |
| *Botryllus schlosseri* | • | 2.67 | • | 3.00 | 3.17 | • | 3.33 | • | • | 2.50 | • | 3.50 | 2.00 | • | 2.75 | • |
| *Bugula neritina* | • | 3.67 | • | 2.67 | 4.00 | • | 0.33 | • | • | 4.00 | • | 2.50 | 3.00 | • | 4.00 | • |
| *Caprella mutica* | • | 2.67 | • | 2.67 | 3.33 | • | 2.00 | • | • | 3.00 | • | 3.00 | 3.00 | • | 2.75 | • |
| *Carcinus maenas* | • | 2.67 | • | 0.67 | 2.67 | • | | • | • | 2.00 | • | 1.00 | 2.00 | • | | • |
| *Ciona intestinalis* | • | 0.33 | • | | | • | | • | • | 1.00 | • | | | • | 0.50 | • |
| *Didemnum vexillum* | • | 0.67 | • | 0.33 | 1.00 | • | | • | • | 0.50 | • | | 1.50 | • | 1.00 | • |
| *Diplosoma listerianum* | • | 3.67 | • | 3.67 | 2.67 | • | 4.00 | • | • | 3.50 | • | 4.00 | 2.50 | • | 3.00 | • |
| *Hemigrapsus sanguineus* | • | 1.33 | • | 1.33 | 2.33 | • | 0.67 | • | • | 1.00 | • | 0.50 | 2.50 | • | 0.50 | • |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | • | | • | 2.67 | 1.67 | • | | • | •<br>• | | • | | | • | 3.00 | • |
| Balanomorpha | • | | • | | | • | | • | • | | • | 0.50 | | • | 2.50 | • |
| *Corophium* | • | 2.00 | • | | | • | | • | • | | • | | | • | | • |
| *Crepidula* | • | 2.00 | • | | | • | | • | • | | • | | | • | 0.50 | • |
| Gammaridae | • | 3.00 | • | | 2.00 | • | 4.00 | • | • | 3.00 | • | | 2.50 | • | 4.00 | • |
| *Hydroides dianthus* | • | 0.67 | • | | 2.33 | • | | • | • | | • | | | • | | • |
| *Palaemonetes* | • | | • | 1.67 | 0.67 | • | 2.00 | • | • | | • | 1.00 | | • | 2.00 | • |
| Panopeidae | • | 1.00 | • | | | • | 1.00 | • | • | 1.00 | • | | | • | 2.25 | • |

## STB

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Invasive** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Diadumene lineata* | | 1.00 | • | 0.33 | | | | • | | 2.50 | • | 3.00 | 2.50 | 1.00 | | • |
| *Hemigrapsus sanguineus* | | 2.33 | • | 1.33 | 1.00 | 1.00 | | • | | 3.00 | • | 2.50 | 2.00 | 2.25 | | • |
| *Membranipora membranacea* | | | • | | 1.67 | 4.00 | | • | | | • | | 0.50 | 4.00 | 4.00 | • |

| | Monthly | | | | | | | | Seasonal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native** | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| *Anomia* | | | • | | | | | • | | | • | | | 0.50 | | • |
| Balanomorpha | 3.00 | 3.17 | • | 3.17 | 1.33 | 4.00 | | • | 3.00 | 3.50 | • | 3.25 | 3.00 | 4.00 | | • |
| *Bryozoa* | | 1.33 | • | 0.67 | | | | • | | 2.50 | • | 2.00 | | | 4.00 | • |
| *Crepidula* | | 1.33 | • | | | 1.83 | | • | | 1.00 | • | | | 1.50 | | • |
| Gammaridae | 1.00 | | • | 2.00 | | 2.00 | | • | 0.50 | | • | 2.50 | | 2.50 | | • |
| *Hydroides dianthus* | | 2.00 | • | 2.33 | 1.33 | 2.50 | | • | | | • | | 1.00 | 2.00 | | • |
| *Molgula manhattensis* | | 3.33 | • | 2.67 | 2.67 | 3.50 | | • | | 3.50 | • | 4.00 | 3.50 | 3.00 | 3.00 | • |
| *Mytilus edulis* | | 1.00 | • | | | 0.67 | | • | | 1.00 | • | 1.50 | | | 1.00 | • |
| Nereididae | | 0.67 | • | | | 1.00 | | • | | | • | | | 0.50 | | • |
| *Palaemonetes* | | | • | | 1.00 | 2.00 | | • | | | • | | 0.50 | 0.50 | | • |
| Panopeidae | | 2.00 | • | 1.00 | 2.33 | 2.67 | | • | | 2.00 | • | 2.00 | 2.00 | 1.50 | 1.00 | • |
| Polychaetae | | | • | | | 2.17 | | • | | | • | | | | | • |
| Porifera | | 0.67 | • | | | 1.33 | | • | | 1.50 | • | | | 1.00 | | • |
| Tubulariidae | 1.67 | 2.67 | • | 2.33 | | 2.33 | | • | 2.00 | 3.00 | • | 1.50 | | 2.50 | | • |