Rhode Island Department of Environmental Management

and

Rhode Island Department of Health

Blue mussels (Credit: Meriseal)

Harmful Algal Bloom and Shellfish Biotoxin Monitoring and Contingency Plan

November 2021

Table of Contents

Tables

Figures

Introduction

The RI Harmful Algal Bloom (HAB) and shellfish biotoxin monitoring plan is a cooperative effort between the DEM-OWR, DEM-DMF personnel who collect HAB phytoplankton samples or shellfish samples and the RI Department of Health (RIDOH) Center for Food Protection, Shellfish Inspection Program who collect shellfish samples and the Center for Environmental Sciences Water Microbiology and Organic Chemistry Laboratories personnel who identify and enumerate the HAB taxa and, if required, perform toxin analyses. This arrangement was formalized in a MOU between DEM-OWR and RIDOH dated 2/21/2002. Various changes to the HAB monitoring plan have taken place since that time. These include expansion of HAB species monitored, modification of sampling strategies and contingency plans based on experience gained during the 2016-2017 *Pseudo-nitzschia* bloom and changes in the most recent National Shellfish Sanitation Program (NSSP) guidance on shellfish biotoxin monitoring (NSSP, 2015, 2017, 2019). The RI HAB and Shellfish Biotoxin Monitoring and Contingency Plan had a major revision in 2017 and updates in April 2020 and November 2021 to incorporate these changes.

Goals

The revised HAB and shellfish biotoxin monitoring and contingency plan meets the following goals (based on NSSP, 2017):

- Provides a HAB early warning system to ensure seafood safety and public health.
- Describes administrative procedures, sample collection procedures, laboratory analyses, and patrol procedures, communication procedures in the event of a biotoxin detection or closure.
- Has procedures to define severity of occurrences.
- Includes responses that will minimize risk of illnesses.
- Has procedures to establish re-opening of closed areas.
- Is able to identify blooms of novel and emergent HAB phytoplankton species.
- Provides information on the spatial and temporal extent of HAB events in RI shellfish growing areas (HAB database).
- Assures regulation of RI shellfish harvest and distribution to meet NSSP marine biotoxin control guidelines.

Participating Agencies and Roles:

State agencies are responsible for the majority of RI HAB and biotoxin monitoring activities. These efforts may be augmented with assistance from Federal agencies, academia and independent shellfishing associations and other volunteers as described below.

RI DEM – Office of Water Resources.

Office of Water Resources personnel perform routine HAB sample collection in RI shellfish growing areas; maintain records of environmental conditions (temperature, tide, wind, volume seawater filtered) associated with each sample, maintain the HAB taxa abundance database, communicate biotoxin warning and closure information with agency counterparts in Rhode Island and nearby state regulatory agencies, and, if required, enact biotoxin contingency plans or closures of RI shellfish growing areas.

RIDOH – Center for Environmental Sciences, Water Microbiology Laboratory

Water Microbiology Laboratory are assessed by FDA to perform analyses of shellfish for the Shellfish Inspection Program. Staff conduct light microscopy for identification and quantification of HAB taxa (*Alexandrium* spp., *Dinophysis* spp., *Pseudo-nitzschia* spp.). The staff is trained to be alert for the appearance of novel and emergent HAB phytoplankton species that may appear in the monitoring area. The staff also performs the analytical screening for the presence of biotoxin in plankton and shellfish meat samples.

RIDOH – Center for Environmental Sciences, Organic Chemistry Laboratory

The Organic Chemistry Laboratory performs the quantitative analysis of biotoxin concentration in shellfish meat samples or ships the samples to a FDA approved laboratory for analysis.

RI DEM – Division of Marine Fisheries

DEM Division of Marine Fisheries staff maintain the sentinel mussels at several sites throughout RI shellfish growing waters. DEM DMF staff collect HAB phytoplankton samples as part of the 6X per year synoptic sampling of RI shellfish growing areas. DEM-DMF staff also assist in the collection of plankton samples and shellfish meat samples in the event of a biotoxin warning or closure. In addition, DEM-DMF helps communicate biotoxin closure information to shellfishers and shellfishing associations via listserves that they maintain. DEM-DMF staff will also be prepared to monitor impacts of HAB events on marine organisms (birds, finfish, and marine mammals).

RIDEM – Division of Fish and Wildlife, Wildlife Section

In the event of potential biotoxin related impacts to birds, finfish or marine mammals, the Wildlife Section will make arrangements for tissue toxin analysis.

RIDOH – Center for Food Protection, Shellfish Inspection Program

In the event of a biotoxin closure, Shellfish Inspection Program personnel are responsible for ensuring that shellfish in dealer stock are free of biotoxins. During a biotoxin warning or closure, they will also assist in collection of shellfish samples from RIDOH licensed dealers.

RI DEM – Division of Law Enforcement

DEM Division of Law Enforcement is responsible for patrolling closed areas during a biotoxin closure to ensure no shellfish are taken from closed areas. Enforcement personnel will also assist with sampling vessels and transporting samples during a biotoxin closure event.

RI Universities

DEM-OWR has established a partnership with the University of Rhode Island, Graduate School of Oceanography to incorporate URI-GSO phytoplankton monitoring in the lower West Passage of Narragansett Bay into the RI HAB Monitoring Plan. URI-GSO will alert DEM-OWR of any unusual HAB phytoplankton observations made during their weekly phytoplankton monitoring program. DEM Shellfish staff also monitor HAB species presence at local *in situ* imaging flow cytobots (IFCB) sites at the URI-GSO dock and south of Martha's Vineyard. Other RI universities may also assist with sample collection and sample analyses during HAB events.

Narragansett Bay Commission

DEM-OWR has established a partnership with the Narragansett Bay Commission (NBC) to incorporate NBC's Upper Narragansett Bay phytoplankton monitoring data into the RI HAB Monitoring Plan. DEM OWR staff are regular communication with NBC staff about observation of HAB phytoplankton species in Upper Narragansett Bay.

Federal Agencies

Federal agencies may assist with HAB monitoring and bloom responses including access to the best technology and expertise available, providing supplemental financial support for investigating a unique event, and ensuring proper scientific documentation of the event. During the 2016 and 2017 *Pseudo-nitzschia* bloom, the NOAA - NCCOS Harmful Algal Bloom (HAB) Event Response Program through the ECOHAB Program (Quay Dortch, Coordinator) and the MERHAB Program (Marc Suddleson, Manager) coordinated communications and data sharing between scientists and environmental managers in the region (Maine to RI) impacted

by the bloom. In addition, the US FDA Regional Shellfish Specialist will coordinate with RI DEM on HAB monitoring to ensure shellfish seafood safety and with the RIDOH Division of Laboratories to assess its shellfish testing capability for the state.

Other Institutions: Academia, Shellfishing Associations, Aquaculturists, Volunteers

In the event of a biotoxin closure, a network of allied academic and shellfish organizations is available to assist in sample collection, sample analysis, and collection of oceanographic data related to a HAB bloom. DEM – Office of Water Resources staff will coordinate sample collection and other monitoring efforts made by volunteers and allied organizations during a HAB event.

CONTACT INFORMATION FOR KEY PERSONNEL IN EACH ORGANIZATION ARE IN ATTACHED APPENDIX A.

General Structure of HAB and Biotoxin Monitoring and Contingency Plan

The RI HAB monitoring and biotoxin plan uses routine HAB phytoplankton abundance estimates as an early warning, followed by contingency plans for biotoxin analyses in plankton and shellfish samples if HAB taxa abundance contingency thresholds are reached (Figure 2, Table 4). Closure of shellfish growing areas will be primarily based upon toxin concentration in shellfish meats (Table 6). This is consistent with US, European Union (EU) and NSSP biotoxin monitoring guidance for monitoring of shellfish growing areas to provide an early warning of potential biotoxin presence and to protect public health in the event of a HAB outbreak.

HAB Phytoplankton Monitoring Sample Collection and Abundance Estimates

Estimates of HAB phytoplankton abundance in shellfish growing areas provides an early warning for the potential of biotoxin accumulation in shellfish. Routine HAB phytoplankton monitoring sample collection will be conducted by DEM-OWR staff with assistance from DEM-DMF following this standard operating procedure:

1. ***Equipment:***
    a. Plankton net: HAB phytoplankton monitoring samples will be collected using a 20 μm mesh plankton net of at least 0.25m diameter mouth, equipped with a flowmeter. 20 μm mesh nets are widely used for HAB monitoring (Anderson et al., 2001) and this mesh was selected based on the ability to sample relatively large volumes of water to maximize power to detect relatively low abundance HAB taxa.
    b. Calibrated flowmeter. Each plankton net will be fitted with a calibrated flowmeter to allow determination of the volume of seawater passed through the plankton net. In situations where a flow meter is not available, a bucket calibrated in 5L increments may be used to measure a volume of ~20 L to be passed through the plankton net.
    c. Tow line and bridle. Plankton nets will be equipped with a 3-point bridle and a tow line of sufficient length to allow sampling the upper 20 feet of the water column.
    d. Sample jars. HAB phytoplankton samples will be concentrated by the net to a volume of approximately 150 ml and placed in plastic sample jars supplied by RI Department of Health.
    e. Sample forms. A sample data sheet will accompany each HAB phytoplankton sample collected. The data sheet will be used to record the date, location, water

temperature, wind, tide, personnel collecting the sample, volume seawater filtered through net and final volume of sample.

2. Sample collection procedure:

When possible, HAB phytoplankton samples will be collected by vertical oblique tows of a 20 μm mesh plankton net made from the surface to a depth of approximately 5-6 m (15-20 feet), as outlined below. If weather or other conditions prevent a vertical tow then a 20 liter surface water sample will be collected and passed through the plankton net.

a. Rinse net and cod-end then attach cod-end to net and zero flow meter.
b. Place net in water cod-end first on up-wind side of boat. Be sure no air is trapped in net.
c. Feed out line to allow net to sink to depth, retrieve net to surface.
d. Check flow meter. If < ~20 revolutions (equivalent to ~20 liters seawater passing through net), empty and rinse the net and then repeat another vertical oblique tow.
e. Allow plankton sample to drain through mesh in cod-end until concentrated sample volume is < ~150 mL.
f. Place concentrated sample in plastic sample jar, record flowmeter value, concentrated sample volume, sample date, time, location using established station IDs where relevant, and field data on sample form.
g. Place sample on ice in cooler, transport to RIDOH for analysis.
h. RIDOH will identify HAB phytoplankton by scanning all cells in a 0.1 ml Palmer-Maloney counting chamber. Default plankton tow volume (20 L) and concentrated sample volume (150 mL) will yield a HAB species detection level of approximately 75 cells per liter.
i. In the event of *Pseudo-nitzschia* spp. abundance exceeding the action threshold (Table 4), paired 10 μm and 20 μm mesh net plankton tows may be conducted to assess the presence of smaller *Pseudo-nitzschia* species (members of the *Pseudo-nitzschia delicatissima* group).
j. Monitoring of Block Island waters will be done through a cooperative effort between the Block Island Harbormaster and DEM-OWR staff. The Block Island Harbormaster will collect 8-12 liters of seawater during monthly bacteriological monitoring. This seawater will be shipped to DEM-OWR via airplane or ferry on the same day as it is collected. DEM-OWR staff will concentrate the phytoplankton sample (20 μm mesh net) to ~150 ml volume and deliver the concentrated sample and related paperwork to RIDOH for HAB species analysis.

3. Sample collection and analysis frequency:

HAB phytoplankton samples will be collected during routine shellfish growing area fecal coliform monitoring surveys made by DEM-OWR staff year round (January to December). DEM-OWR staff will collect phytoplankton samples at fixed HAB phytoplankton monitoring stations within each growing area and submit them to the RIDOH Water Microbiology Laboratory for plankton identification and abundance counting. Two (2) HAB phytoplankton samples will be collected from most growing areas on each day that the growing area is visited. Thirty-eight (38) routine HAB phytoplankton monitoring stations were selected to maximize the geographic range of sample coverage in RI's shellfish growing waters (Figs 4 – 7, at end of document). This sampling scheme will result in collection of 224 samples/yr and is presented in Table 1 below.

Table 1 Schedule of Routine HAB monitoring of RI shellfish growing areas.

This routine monitoring will be augmented by synoptic HAB phytoplankton sampling and abundance counting to be conducted six times per year (Table 2).

Grow Area	Name	# Phyto stations	# Times sampled per year (routine)	# Routine Phyto samples /year
1	Upper Narragansett Bay	3	12	36
3	East Middle Bay	2	6	12
4	Sakonnet River	2	6	12
5	Kickemuit River	1	12	12
6	East Passage	2	6	12
7	West Passage	2	6	12
8	Greenwich Bay	2	12	24
9	West Middle Bay	2	6	12
10	Pt. Judith & Potter Ponds	2	6	12
11NG	Ninigret & Green Hill Ponds	2	6	12
11QW	Quonochontaug & Winnapaug Ponds	2	6	12
12	Little Narragansett Bay	1	6	6
13	Block Island	1	12	12
14BI	Offshore - Block Island	2	2	4
14E	Offshore - East	3	2	6
14W	Offshore - West	2	2	4
17	Mt Hope Bay	2	12	24
			TOTAL	224

In addition to the routine HAB monitoring, DEM-OWR and DEM-DMF personnel will collect and RIDOH Water Microbiology Laboratory scientists will identify and count HAB phytoplankton samples from areas having visibly discolored water and in areas in which unusual animal behaviors (lethargic animals, fish kills) are reported or noted. This includes responding to the presence of water-discoloring marine cyanobacteria blooms (Preece et al., 2016) that may have potential to impact RI shellfish growing waters. DEM-OWR will also maintain communication with and request routine reporting from the University of Rhode Island's Graduate School of Oceanography and Narragansett Bay Commission scientists collecting routine phytoplankton samples respectively from lower West Passage (Fox Island site) and Providence River.

The routine HAB phytoplankton monitoring completed by DEM-OWR and RIDOH Water Microbiology Laboratory (sample schedule in Table 1 above) may result in a low sampling frequency of some shellfish growing areas. This is of particular concern during the May – October period when there is potential for increased HAB phytoplankton abundance. To increase sampling frequency, an additional six (6) synoptic HAB phytoplankton monitoring cruises will be conducted each year at a frequency of approximately one (1) sampling cruise per month during the May to October period. These synoptic cruises will sample multiple shellfish growing areas in a single day. The additional HAB phytoplankton monitoring cruises will be completed by DEM-OWR and DEM-DMF staff, and will be scheduled to minimize the time interval between routine HAB sampling and abundance counting in shellfish growing areas. Sampling stations are selected to provide coverage of Upper Narragansett Bay, Lower Narragansett Bay (East and West Passages), Sakonnet Passage, coastal salt ponds and Block Island (Figures 3 – 6). This added monitoring effort will result in collecting approximately 138 HAB phytoplankton samples per year for abundance counting in addition to the routine HAB monitoring, as shown in Table 2 below.

Table 2 Schedule of Synoptic HAB monitoring of RI Shellfish Growing Areas

Collection conducted by DEM-OWR and DEM-DMF and analysis by RIDOH Water Microbiology Laboratory 6-times per year during synoptic HAB monitoring of RI Shellfish growing areas. This HAB monitoring augments routine monitoring summarized in Table 1.

Grow Area	Name	# Stations	# TIMES sampled /year	TOTAL # Phyto Samples /year
1	Upper Narragansett Bay	3	6	18
3	East Middle Bay	2	6	12
4	Sakonnet River	2	6	12
6	East Passage	2	6	12
7	West Passage	2	6	12
8	Greenwich Bay	1	6	6
9	West Middle Bay	2	6	12
10	Pt. Judith & Potter Ponds	2	6	12
11NG	Ninigret and Green Hill Ponds	1	6	6
11QW	Quonochontaug and Winnapaug Ponds	2	6	12
14E	Offshore - East	3	6	18
17	Mt Hope Bay	1	6	6
		23		138

The two complementary HAB phytoplankton monitoring efforts outlined in Table 1 (routine sampling and analysis) and Table 2 (synoptic sampling and analysis) will result in HAB phytoplankton monitoring in each of RI's main shellfish growing areas at a frequency of at least

twice per month during the seasonal period (May to October) of maximum potential of HAB occurrence.

Table 3 Combined Schedule of Routine and Synoptic HAB Monitoring of RI Shellfish Growing Areas

The combined schedule of routine and synoptic HAB phytoplankton sample collection, identification and abundance counting conducted by DEM-OWR, DEM-DMF and RIDOH Water Microbiology Laboratory for HAB monitoring of RI shellfish growing areas.

Grow Area	Name	# TIMES sampled /year	TOTAL # Phyto Samples /year
1	Upper Narragansett Bay	18	54
3	East Middle Bay	12	24
4	Sakonnet River	12	24
5	Kickemuit River	12	12
6	East Passage	12	24
7	West Passage	12	24
8	Greenwich Bay	18	30
9	West Middle Bay	12	24
10	Pt. Judith & Potter Ponds	12	24
11NG	Ninigret and Green Hill Ponds	12	12
11QW	Quonochontaug and Winnapaug Ponds	12	24
12	Little Narragansett Bay	6	6
13	Block Island	12	12
14BI	Offshore - Block Island	2	4
14E	Offshore - East	8	24
14W	Offshore - West	2	4
17	Mt Hope Bay	18	30
		TOTAL	362

4. Collaboration with other monitoring programs

DEM OWR staff will routinely be in communication with and receive HAB phytoplankton information from other monitoring programs in RI and regionally. The University of Rhode Island, Graduate School of Oceanography performs weekly, year round phytoplankton sampling and analysis (including HAB species identification) at a station in the lower west passage of Narragansett Bay (Grow Area 7). This information is shared with DEM and supplements the data collection summarized above. The Narragansett Bay Commission routinely analyzes phytoplankton samples collected in the Providence River and upper Narragansett Bay and shares that information with DEM-OWR. Finally, DEM-OWR staff routinely monitor regional (URI-GSO dock, MVCO south of Martha's Vineyard, Buzzards Bay IFCB) imaging flow cytobot (IFCB) data streams for the presence of HAB species.

5. Reporting Results

Responding to a harmful algae bloom requires timely and accurate analysis of plankton and subsequent shellfish tissue screening and toxicity analyses. Ensuring that accurate information is exchanged between the responsible decision-making parties is paramount to making timely decisions on closures and/or stock holdings or recalls. RIDOH Laboratories will develop a protocol for transmitting documentation of sample collection and chain of custody and subsequent analytical results to all necessary parties in a timely, accurate and efficient manner. As per the existing laboratory agreement between RIDEM and RIDOH all documents relative to sample submittal and analysis shall be provided. In addition to pdf or paper copies, protocols shall be developed for the method and form for transmitting results electronically to all parties.

HAB taxa abundance threshold levels

A literature survey and analysis of RI phytoplankton data indicate that there are three HAB phytoplankton taxa that are most likely to affect shellfish seafood safety in RI shellfish growing waters and therefore require routine monitoring: *Alexandrium* spp. (PSP), *Pseudo-nitzschia* spp. (ASP) and *Dinophysis* spp. (DSP). Abundance thresholds of these HAB phytoplankton taxa at which increased monitoring and toxin analysis actions are required were based on a literature survey (Anderson et al, 2001; Bates et al., 1989; Borkman et al., 2012, 2014; Deshpande, 2002; Hargraves and Maranda, 2002; Hattenrath et al., 2013; Maranda and Shimizu, 1987; UK Food Standards, 2014), FDA and NSSP (2017) guidance, national HAB monitoring plans (Jewett et al., 2008) and experience in RI and nearby shellfish harvesting areas (Table 4).

The *Alexandrium* threshold of 1,000 cells L^{-1} is consistent with that used as a warning for accumulation of saxitoxin in shellfish in nearby states (Crespo et al., 2011) and is protective of public health given the relatively low toxin per cell levels generally present in *Alexandrium* spp. analyzed from southern New England waters (Maranda et al., 1987; Anderson, 1997; Borkman et al., 2012; 2014).

Similarly, southern New England isolates of *Dinophysis acuminata* also produce relatively low levels of Okadaic Acid (OA), with prolonged bloom levels in excess of 100,000 cells L^{-1} associated with accumulation of OA toxin in shellfish in New York waters (Hattenrath et al., 2013).

The threshold for *Pseudo-nitzschia* spp. is based on comparative analyses of thresholds in other temperate shellfish harvesting waters and a review of RI *Pseudo-nitzschia* levels. Thresholds of 15,000 *Pseudo-nitzschia* spp. cells per liter (Maine; Biotoxin Contingency Plan) to 50,000 cells per liter (WA state; Trainer et al., 2015; Scotland, UK; UK Food Standards Agency, 2014) are in use. Selection of a *Pseudo-nitzschia* alert threshold is complicated by interspecific and physiological variability in domoic acid production; with the 20,000 cells per liter threshold selected as a level to be protective of public health in RI shellfish harvesting waters. The 20,000 *Pseudo-nitzschia* cell per liter action level proved effective in identifying areas having potentially harmful biotoxin levels during the 2016-2017 RI *Pseudo-nitzschia* bloom (Borkman et al., 2017).

In addition to the routinely monitored HAB species (*Alexandrium, Dinophysis, Pseudo-nitzschia* spp.), the HAB monitoring program is alert to the potential of emergent HAB specie as described in the next section.

Table 4 HAB phytoplankton contingency threshold abundances.

HAB Taxa	Biotoxin	Shellfish Syndrome	Abundance threshold
Alexandrium spp.	Saxitoxins	Paralytic Shellfish Poisoning (PSP)	1,000 cells L^{-1}
Dinophysis spp.	Okadaic Acid	Diarrhetic Shellfish Poisoning (DSP)	30,000 cells L^{-1}
Pseudo-nitzschia spp.	Domoic Acid	Amnesic Shellfish Poisoning (ASP)	20,000 cells L^{-1}
Karenia brevis	Brevetoxins	Neurotoxic Shellfish Poisoning (NSP)	5,000 cells L^{-1}
Azadinium spp.	Azaspiracids	Azaspiracid Shellfish Poisoning (AZP)	5,000,000 cells L^{-1}

Novel and emerging HAB species

RI waters have had relatively few HAB shellfish closures, with only three biotoxin closures during 1979 to the present (2020). Despite having well-characterized phytoplankton community patterns (Smayda, 1957; Karentz and Smayda, 1985, 1998), Narragansett Bay, and coastal waters generally, can experience blooms of novel phytoplankton species, including HAB

species. For example, in 1985 a novel bloom of the HAB 'brown tide' Pelagophyte *Aureococcus anophagefferns*; was first described in Narragansett Bay, RI; this species and class of phytoplankton had not been previously described (Sieburth et al., 1988). Similarly, HAB species can have extensive range extensions during specific oceanographic and climate conditions. Such was the case during 1987 when the neurotoxin (NSP) producing dinoflagellate *Karenia brevis* was transported from Florida 800 km northward to North Carolina where it closed shellfish harvest for five months (Tester et al., 1991). Because of the unpredictable and irruptive nature of HAB blooms (Smayda, 1997), HAB monitoring programs must be alert for the appearance of novel species.

The RI HAB monitoring program prepares for detection of novel HAB species through regular training, review of HAB phytoplankton literature and communication with regional HAB monitoring and shellfish monitoring programs. In addition to the routine monitoring for ASP, PSP and DSP causing HAB species known to be present in the area, the RI HAB monitoring program is also alert for the presence of novel HAB phytoplankton taxa that can cause other shellfish poisoning syndromes.

Phytoplankton that produce Neurotoxic Shellfish Poisoning (NSP) are not common in RI waters (Hargraves and Maranda, 2002). A *Karenia brevis* cell count trigger of 5,000 cells per liter was previously used as guidance (NSSP, 2017) and RI will use a *Karenia brevis* abundance threshold of 5,000 cells per liter to initiate the RI HAB contingency plan to ensure seafood safety (Table 4).

Dinoflagellates in the genus *Azadinium* can produce azaspiracids which may cause Azaspiracid Shellfish Poisoning (AZP). *Azadinium* spp., including *Azadinium spinosum*, blooms have been related to AZP and shellfish closures in the Western European countries adjacent to the North Sea (Tillmann et al., 2009). Azaspiracids associated with *Azadinium* spp. have also been reported in eastern Canada (Twiner et al., 2008). In culture studies, mussels exposed to an *Azadinium spinosum* concentration of 5 X 10^6 cells per liter were demonstrated to accumulate azaspiracids in a 24-hour period (Salas et al., 2011, Jauffrais et al., 2012). Accordingly, an *Azadinium* spp. abundance threshold of 5 X 10^6 cells per liter will be used to trigger RI HAB contingency plan actions (Table 4). An azaspiracid (AZP) biotoxin guidance level of 0.16 ppm wet weight in shellfish meats has been established (NSSP, 2017). If a bloom of greater than 5 X 10^6 *Azadinium* spp. cells per liter is detected in RI shellfish growing waters, shellfish meat testing for azaspiracids will be initiated and the RI HAB contingency plan will be enacted to protect seafood safety. Precautionary shellfish closures may be enacted if shellfish meat azasppiracid levels are 0.08 to 0.15 ppm and a mandatory shellfish closure will be enacted if azaspiracid levels in shellfish are 0.16 ppm or greater (Table 6).

HAB and Biotoxin Contingency Plan

If abundance of HAB taxa exceed the abundance action thresholds (Table 4) during routine HAB monitoring, a series of intensified phytoplankton sampling and biotoxin determinations will begin.

1. Intensified Phytoplankton and Shellfish Sampling and Biotoxin Determination

1. If HAB abundance is determined by RIDOH Water Microbiology to be in excess of the threshold levels (Table 4) the following actions will occur:
    a. RIDOH Water Microbiology will communicate these results to DEM-OWR and RIDOH Center for Food Protection.
    b. RIDOH Water Microbiology Laboratory will screen the phytoplankton sample for presence of PSP-saxitoxin and the ASP-domoic acid biotoxins using immunoassay kits specific to the toxin produced by HAB plankton identified. There are no screening kits available to test for DSP-Okadaic acid. In lieu, a second confirmatory phytoplankton sample will be collected; if *Dinophysis* abundance exceeds threshold level, proceed to shellfish collection part 3. (Below). Similarly, If *Azadinium spinosum* abundance exceeds the threshold level, proceed to shellfish collection part 3. (Below).
    c. DEM OWR and RIDOH Water Microbiology will conduct intensified follow-up phytoplankton monitoring in the affected shellfish growing areas and adjacent areas.
    d. DEM-OWR will contact Shellfish Programs in nearby states to inform them of RI's HAB monitoring results and to investigate regional extent of the HAB event.

2. If no Biotoxin is detected
    a. For PSP and ASP only, if no biotoxin is detected in plankton screening tests, HAB phytoplankton monitoring will continue within the affected water until bloom abundance declines below the established warning thresholds.
    b. For DSP, NSP and AZP, if cell abundance exceedance, follow-up monitoring of HAB phytoplankton abundance in the plankton will be carried out by DEM-OWR.

3. If PSP, ASP biotoxin is detected in the plankton, or if widespread elevated abundance of *Dinophysis, Karenia or Azadinium* is confirmed, collection of shellfish will begin as follows :
    a. RIDOH Water Microbiology will communicate positive plankton screening results to DEM-OWR.
    b. OWR will communicate these results to RIDOH Center for Food Protection and DEM-DMF and request that representative shellfish be collected from affected shellfish tagging areas.

c. DEM DMF will collect shellfish in accordance with the HAB Contingency Shellfish Monitoring Plan developed by DEM DMF and RIDOH Center for Environmental Sciences (described below). Unless shellfish are needed from other shellfish tagging areas, DEM DMF will acquire a sample (min 1 lb. shell on mussels/site) at established sentinel sites (Figure 1). Sentinel shellfish will be restocked with new dated bags of mussels.
d. DEM DMF will provide RIDOH Center for Environmental Sciences with labeled mussel samples collected from docks using field/lab submission forms (see Appendix B) and a labelled subset of the restocking mussel source for baseline testing of the newly deployed bag.
e. A baseline record of HAB toxins in stock mussels associated with deployed numbered, labelled bags will be maintained by RIDOH Center for Environmental Sciences so they can be compared in the future with that group when taken off the dock in the future sampling.
f. RIDOH Center for Food Protection Shellfish Inspection Program will assist in the collection of samples by obtaining shellfish from RIDOH dealer(s) having shellfish stock from affected shellfish tagging areas, utilizing established shellfish harvest IDs when possible, maintaining chain of custody and completing required field/lab submission forms (Appendix B). A list of dealers is provided in the key contacts section in Appendix A.
g. The order of preference for shellfish collected for purposes of biotoxin screening is mussels, quahog, and oyster, in accordance with their biotoxin uptake rate.
    i. Mussels: A minimum of 1lb of whole market size animals with shell on will yield approximately 1 cup (150 grams) of meats are needed for analysis.
    ii. Quahogs: A minimum of twelve market size with shell on will yield approximately 1 cup of meats (150 grams) for analysis.
    iii. Oysters: A minimum of 6-10 medium market sized animals are needed for analysis which yields approximately 1 cup (150 grams) of oyster meats.
    iv. At the time of shellfish collection, all personnel will complete field/lab submission forms identifying shellfish type, date harvested from the Bay, harvest location using established sample station IDs when possible and other details utilizing field/lab submission form (Appendix B). All samples will be delivered to the RIDOH Water Microbiology Laboratory for analyses.

RIDOH Water Microbiology Laboratory will screen these shellfish for toxin presence (PSP, ASP, DSP) utilizing rapid test kits. States are permitted to use methods of their choice for biotoxin screening; an NSSP Approved Method is only required to reopen after a closure. Rapid test kits such as: Eurofins Abraxis (https://abraxis.eurofins-technologies.com/home/products/rapid-

test-kits/algal-toxins/ [abraxis.eurofins-technologies.com]), Neogen (https://www.neogen.com/en-gb/categories/seafood/reveal-2-psp/ [neogen.com]), or Biosense (https://www.biosense.com/algal.html) [biosense.com] will be used for biotoxin screening. AZP analysis will be by methods described in NSSP (2017). RIDOH Water Microbiology Laboratory will communicate shellfish meat biotoxin screening results to DEM-OWR.

4. If shellfish meat biotoxin screening results are negative DEM-OWR and RIDOH Water Microbiology Laboratory will continue HAB phytoplankton monitoring within the affected water until bloom abundance declines below the established warning thresholds.
5. If ASP-domoic acid biotoxin is detected in shellfish meats, the RIDOH Organic Chemistry Laboratory will perform quantitative analysis by liquid chromatography combined with tandem mass spectrometry or UV analysis for closure decisions. For all other quantitative analysis including ASP-domoic acid for decisions to open previously closed harvesting areas and analysis of PSP-saxitoxin or DSP-okadaic acid, the RIDOH Center for Environmental Sciences will arrange to have quantitative analysis conducted at the FDA approved laboratory, . Bigelow Analytical Services, 60 Bigelow Drive, P.O. Box 380, East Boothbay, ME 05444, Office: (207) 315-2567 ext. 512, Lab: (207) 315-2567 ext. 706. Contact: Carlton Rauschenberg, M.S. Bigelow Analytical Services Manager carlton@bigelow.org or info@bigelow.org.

2. Biotoxin sentinel shellfish

The RI DEM Division of Marine fisheries (DMF) has established a stock of blue mussels, *Mytilus edulis*, at seven sentinel dock sites (+ one backup if needed) in RI state waters for testing of biotoxin levels in shellfish meats during Harmful Algae Blooms (HABs). Blue mussels (*Mytilus edulis*) were selected because both the literature and Rhode Island HAB monitoring experience has shown this species to concentrate HAB toxins more rapidly than other shellfish species. This is likely due to near year-round high filter-pumping rates (see below), thus mussels serve as an ideal "canary" sentinel warning species. As resources allow, stocks of quahogs (*Mercenaria mercenaria*) will be added at some sentinel sites to allow for shellfish species comparisons under the same exposure environment.

RIDEM DMF has established a system of sentinel shellfish in cages at key sites in the Bay (Figure 1). These sites will be maintained throughout the year and sampled when requested by RIDEM OWR. All dock sites will be accessible from land so weather limitation will not preclude sampling. The prepositioned sentinel mussel bags or cages will allow for sampling live shellfish at key sites to characterize HAB biotoxin concentrations in shellfish in the lower and mid Bay shellfish harvest areas (Table 1).

Table 5 Locations of HAB monitoring sentinel mussel sites.

Site #	Sentinel mussel location	Station ID
01	URI GSO Docks	7B-S01
02	Fort Wetherill Docks	6B-S02
03	Sakonnet Point Marina Docks	4D-S03
04	Conanicut Point (Residential Dock)	9A-S04
05	Prudence Island T-Wharf (back up site)	3A-S05
06	Warwick Neck (private residential)	9A-S06
07	Roger Williams University	17-S07
08	Coastal Fish Lab dock Pt Judith Pond Jerusalem (possible south coast salt pond site)	10PJ-S08

Blue mussels are stocked in bags suspended from dock locations (Tabe 1) at adequate densities (min of 25 mussels /sample/site x4 = min 100 mussels / site). RIDEM OWR and DMF have collaborated on these sites to provide optimal spatial distribution to cover critical Bay areas. We have located a source of mussels (American Mussel Harvesters -local aquaculture operation that farms mussels) and routinely receive mussel stock to replenish mussels as needed. Mussels of adequate size (1 ½ - 2" length) are available year-round from this source. As needed, quahog stock will be gathered from the ongoing DMF shellfish dredge survey and added to sentinel sites.

Prior to deployment at sentinel sites, shellfish stock will be kept in the flow-through wet lab at DEM Marine Lab at Fort Wetherill. This shellstock will be used to restock bags as needed. Stored shellstock will not be used if HAB toxins are detected in the source waters supplying seawater to the DEM Marine Lab. Sentinel sites have limited public access (to minimize pilfering, etc.). Sentinel mussels will be deployed and maintained year-round and will be available when DEM OWR and RIDOH Center for Food Protection request samples. Prior to each new deployment of shellfish, we will send a subset of these shellfish to RIDOH Center for Environmental Sciences for testing to ensure the source shellfish are free from pre-existing contaminates. If the Fort Wetherill source water is found to carry HABS, we will search for alternative flow-through sites not affected by toxins (e.g., GSO wet lab or MERL).

DMF staff will check on the sentinel mussel bags occasionally to ensure the mussels are still alive (the frequency of this checking will evolve based on experiences as we proceed with this approach), but we will sample them only when RIDEM OWR request samples. This is expected to occur when phytoplankton monitoring indicates HAB cell count thresholds have been exceeded. After harvest or sampling, sentinel shellfish will be replenished in a new labelled bag (date and source will be on the label) to ensure we can track how long mussels have been exposed at each site. When new shellfish are re-stocked, a subset will be tested by RIDOH prior

to deployment to verify the absence of biotoxin. A schedule will be developed between DMF, OWR, and RIDOH Center for Environmental Sciences for the transfer of shellfish samples and chain of custody needs. RIDOH Center for Environmental Sciences will provide DMF with the needed lead time necessary to prepare the lab for the samples. Each bag will have enough shellfish for up to 5-6 samples (125-150 mussels split up into several bags to ensure food source etc. is adequate per bag). The bags will be restocked as needed. The dock locations allow for a better regional characterization of an event in the Bay as well as its progression through the Bay. The sentinel mussel part of the HAB contingency plan will provide spatial coverage to characterize the spatial extent of HAB biotoxin accumulation in shellfish.

Mussel Filtering Behavior

Kittner and Riisgard (2005) found blue mussels to continue filtering at high rates between 4°C (39°F) when acclimated to cool temperatures up to 20°C (68°F) at algae counts of 1,000-4,000 cells/ml (~1-5 ug chlorophyll /liter). Mussel filtration rate varies depending on the measurement technique, but runs from 65-100 ml/min/individual at all temperatures between 4-20°C at low phytoplankton cell counts (1,000-4,000 cell/l) (Kittner and Riisgard 2005) to 30 ml/min at 15°C (59°F) and low cell counts (<6,000 cell/ml), and dropping to 12 ml/min at high cell counts (>13,000 – 24,000 cells/l). Extrapolating their chlorophyll values, 20,000 cells/l would be approximately 25 ug/l chl a for the algae (Rhodomonas spp.) used in the feeding experiments. The saturation concentration for algae cells (concentration at which mussels decrease filtration rates because cells exceed need) is between 5,000 and 8,000 cells/ml (Riisgard et al. 2011).These rates clearance rates calculate out to approximately 5 gal/24h/mussel (~19 L/24 h/mussel = low filtration rate) to 38ga/24h/mussel (~144 L/24h/mussel).

Maximum mussel growth rate seems to be at approximately 5-6 ug/l chlorophyll *a* and 16-22°C (60-72°F) (Clausen and Riisgard 1996). This chlorophyll levels is similar to that found at the mouth of the Bay northward to approximately the bridges. Chlorophyll concentration tends to be higher than this in the upper Bay and Greenwich Bay. The maximum temperature for blue mussels in the RI area seems to be around 27°C (80°F) but animals are probably not doing well at this elevated temperature. Lethal temperature for mussels seems to be around 27-29°C (80-84°F) Water temperature at the selected sentinel sites typically has a summer maxima that is below the lethal temperature.

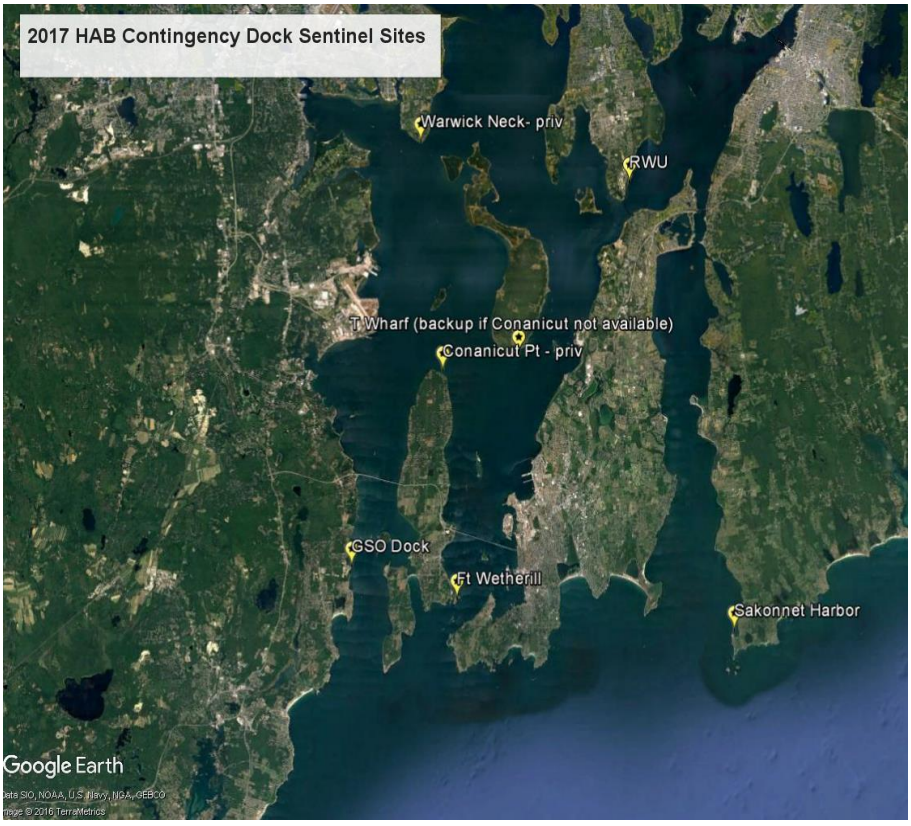
Salinity effects the filtration rate mainly at very low salinity (<10 psu) but where populations are used to low salinity, they still filter down to 6.5 psu (Riisgard et al. 2013).

The coastal range for blue mussels is migrating northward, likely due to max summer temps in the intertidal areas. Mussel population in Delaware and North Carolina are now rare, while blue mussels have extended their range northward into the Arctic (Sorte et al 2017). Declines in

the Gulf of Maine population are potentially linked to warming surface water temps, although many other co-varying stressors including increased harvest and increased predator abundance (green crabs) may also contribute to mussel declines (Sorte et al. 2017). Carrington et al. (2009) studied mortality causes in mussel beds in the rocky intertidal at two RI sites (Black Point and Bass Rock) from 2001-2003. She found losses due to maximum air temperatures (30°C (86°F)) that coincided with low tide were modest and sporadic (5% loss), while greatest overall mortality occurred due to a freezing event in Jan-Feb 2003(35-50% loss; Carrington, 2002). HAB sentinel mussels are deployed sub-tidally, so should be free from such intertidal temperature-related losses. Predation by diving birds is also a potential source of mussel loss. At RI DEM Fort Wetherill, major losses of blue mussels attached to the floating docks occur during January and February due to mussel-eating ducks like Common Eider. Caged sentinel mussels are likely to be safe from such predation. Regular checks of the sentinel mussel stack will verify that mussels are available and healthy if needed for HAB monitoring.

Based on the above information, typical filtration behavior of blue mussels that are in non-stressful environmental conditions should be acclimated to and representative of local conditions within one week or less after deployment.

Figure 1 Location of sentinel mussel sites for HAB monitoring in Narragansett Bay.



3. Management Responses to Prevent Consumption of Affected Shellfish

DEM-OWR in consultation with RIDOH Center for Food Protection will take management actions based on the biotoxin concentration in shellfish meats following the contingency levels recommended in NSSP (2017) guidance described below (Table 6):

Table 6 Shellfish meat biotoxin concentration contingency levels for PSP, DSP, ASP, and AZP (after NSSP, 2017).

Toxin	Concentration	Action
Saxitoxin (PSP)	0.40 – 0.79 ppm	Precautionary Closure
Saxitoxin (PSP)	>/=0.80 ppm	Mandatory Closure
Okadaic Acid (DSP)	>0.08 – 0.15 ppm	Precautionary Closure
Okadaic Acid (DSP)	>/=0.16 ppm	Mandatory Closure
Domoic Acid (ASP)	10 – <20 ppm	Precautionary Closure
Domoic Acid (ASP)	>/=20 ppm	Mandatory Closure
Azaspiracid (AZP)	>0.08 – 0.15 ppm	Precautionary Closure
Azaspiracid (AZP)	>/= 0.16 ppm	Mandatory Closure
Brevetoxin (*K. brevis*, NSP)	10 - <20 MU/100 grams (0.4 mg brevetoxin-2 equivalents/kg)	Precautionary Closure
Brevetoxin (*K. brevis*, NSP)	20 MU/100 grams (0.8 mg brevetoxin-2 equivalents/kg)	Mandatory Closure

Precautionary Closures

1. If shellfish toxin concentration ***exceed a precautionary closure level*** (Table 6), the following management actions will be taken:

a. DEM-OWR in consultation with RIDOH Center for Food Protection will decide whether to issue a precautionary closure of the affected area(s). This decision will be based on positive screening for presence of biotoxins in shellfish meats, cell counts of HAB taxa, oceanographic and meteorological data and/or the regional patterns of the HAB event. A recorded message of the biotoxin closure will be placed on DEM's hotline (222-2900), notice will be sent via the Shellfish List-Serve and on the DEM Shellfish closure webpage. In addition a press release will be issued to news outlets and made available on DEM's website.

b. DEM-Enforcement will be informed of closures to allow patrolling of closed shellfish areas and will contact local harbormasters.

c. Once notified of the closure, RIDOH Center for Food Protection will put a precautionary hold on dealer shellfish stock that was harvested from affected areas. RIDOH dealer stock will be collected by RIDOH CFP and tested for biotoxin and will be released if shellfish meat analyses

are negative for biotoxin. Shellfish that have may been illegally harvested from affected areas after the precautionary closure or that are confirmed positive for biotoxin at exceedance levels will be embargoed or destroyed by RIDOH Center for Food Protection or recalled as per each RIDOH Dealer's policy established by RIDOH CFP. In such case if shellstock is confirmed positive but biotoxin is lower than the mandatory closure levels, RIDOH CFP shall consider action on an individual basis while being protective of public health.

d. The US FDA Regional Shellfish Specialist will be notified of the biotoxin closure.

e. DEM-OWR will contact other Shellfish Programs in nearby states (MA, CT, NH, ME) to inform them of the biotoxin closure.

f. DEM DMF, will be notified of the closure to help communicate biotoxin closure information to shellfishers and shellfishing associations via their listserve, and to allow them to prepare to assess impacts of the HAB event on marine animals (birds, finfish, and marine mammals). DEM Law Enforcement and the public will also be notified of the closure via a RIDEM press release.

2. If biotoxin is detected, but is **below precautionary closure level concentration** (Table 6), monitoring of toxin in plankton and shellfish will continue until toxin levels either decline to below detection thresholds or increase to mandatory closure threshold concentration.
3. ***Re-opening Criteria to end precautionary closure****:* The decision to end a precautionary closures will be based on biotoxin levels in shellfish meats as detected by quantitative methods and declining cell counts of HAB taxa and/or the regional patterns of the HAB event. Precautionary closures will be lifted by DEM-OWR in consultation with RIDOH Center for Food Protection upon receipt of results from a FDA approved lab indicating toxins are below FDA threshold.

Mandatory Closures

If shellfish meat biotoxin concentration ***exceed a mandatory closure level*** (Table 6), the following management actions will be taken:

1. DEM-OWR, after consultation with RIDOH Center for Food Protection, will close the affected area(s) to shellfish harvesting. A recorded message of the biotoxin closure will be placed on DEM's hotline (222-2900), notice will be sent via the Shellfish List Serve and on the DEM Shellfish closure webpage. In addition a press release will be issued to news outlets and made available on DEM's website.
2. DEM-Enforcement will be informed of the closure(s) to allow patrolling of closed shellfish areas.

3. Targeted plankton and shellfish meat sampling activities will continue and, if necessary, additional samples will be collected from other locations to ensure a safe product for consumers.

4. Once notified of the closure, RIDOH Center for Food Protection will contact dealers and require that shellfish that have been harvested from affected areas prior to the closure but are still held at the dealer be tested. Shellfish will be released if shellfish meat analyses are confirmed negative for biotoxin. Shellfish that have been illegally harvested from affected areas after the mandatory closure or that are confirmed positive for biotoxin at exceedance levels will be embargoed or destroyed by RIDOH Center for Food Protection or recalled as per each RIDOH established Dealer's policy by RIDOH Center for Food Protection Shellfish Program. In such case as shellstock confirmed positive but biotoxin is lower than the mandatory closure levels, RIDOH CFP shall consider action on an individual basis while being protective of public health.
5. The US FDA Regional Shellfish Specialist will be notified of the biotoxin closure.
6. DEM-OWR will contact other Shellfish Programs in nearby states (MA, CT, NH, ME) to inform them of the biotoxin closure.
7. DEM DMF will be notified of the closure to help communicate biotoxin closure information to shellfishers and shellfishing associations via their listserve, and to allow them to prepare to assess impacts of the HAB event on marine animals (birds, finfish, and marine mammals). DEM Law Enforcement and the public will also be notified of the closure via a RIDEM press release.

8. ***Re-opening Criteria to end mandatory closure:*** **For ASP (domoic acid)**: DEM-OWR, with the advice and consent of RIDOH Center for Food Protection, may reopen the area(s) closed to shellfish harvesting after quantitative analysis of shellfish meat sampling from a FDA approved laboratory has confirmed either the absence of toxin, or the presence of toxin at levels below the precautionary closure standards (Table 6) in two (2) sets of shellfish meat samples collected seven (7) days apart. Experience during 2016 and 2017 ASP closures demonstrated the effectiveness of this reopening criteria. Once affected shellfish growing area(s) are opened, the routine HAB phytoplankton monitoring procedures will be resumed. **For PSP, DSP, NSP and AZP**: DEM-OWR, with the advice and consent of RIDOH Center for Food Protection, will reopen the area(s) closed to shellfish harvesting after quantitative analysis of shellfish meat sampling from a FDA approved laboratory has confirmed either the absence of toxin, or the presence of toxin at levels below the precautionary closure standards (Table 6) in three (3) sets of shellfish meat samples

collected at least fourteen (14) days apart. Once affected shellfish growing area(s) are opened, the routine HAB phytoplankton monitoring procedures will be resumed.

Figure 2 Conceptual flow chart summarizing RI HAB and biotoxin monitoring and contingency plan.

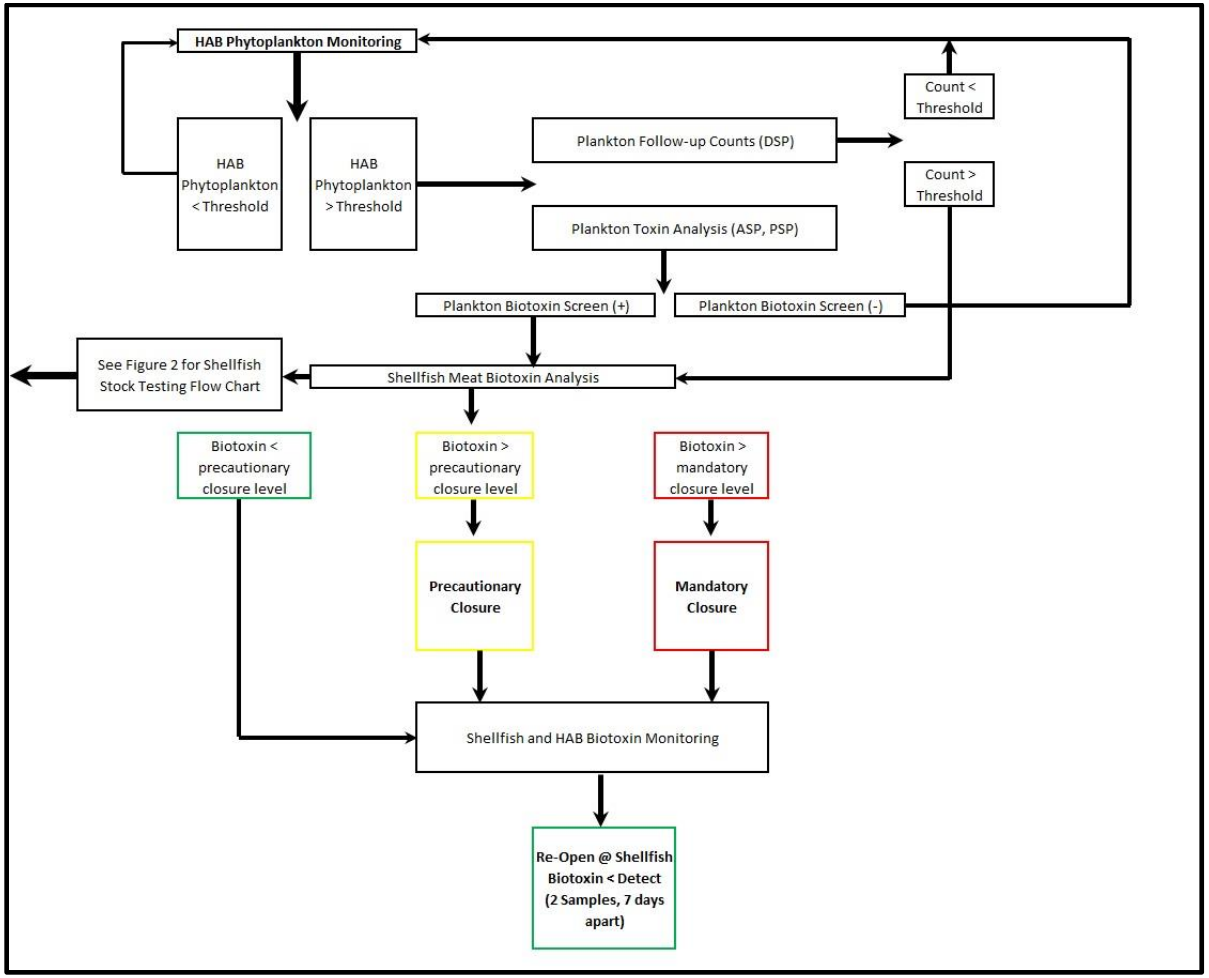
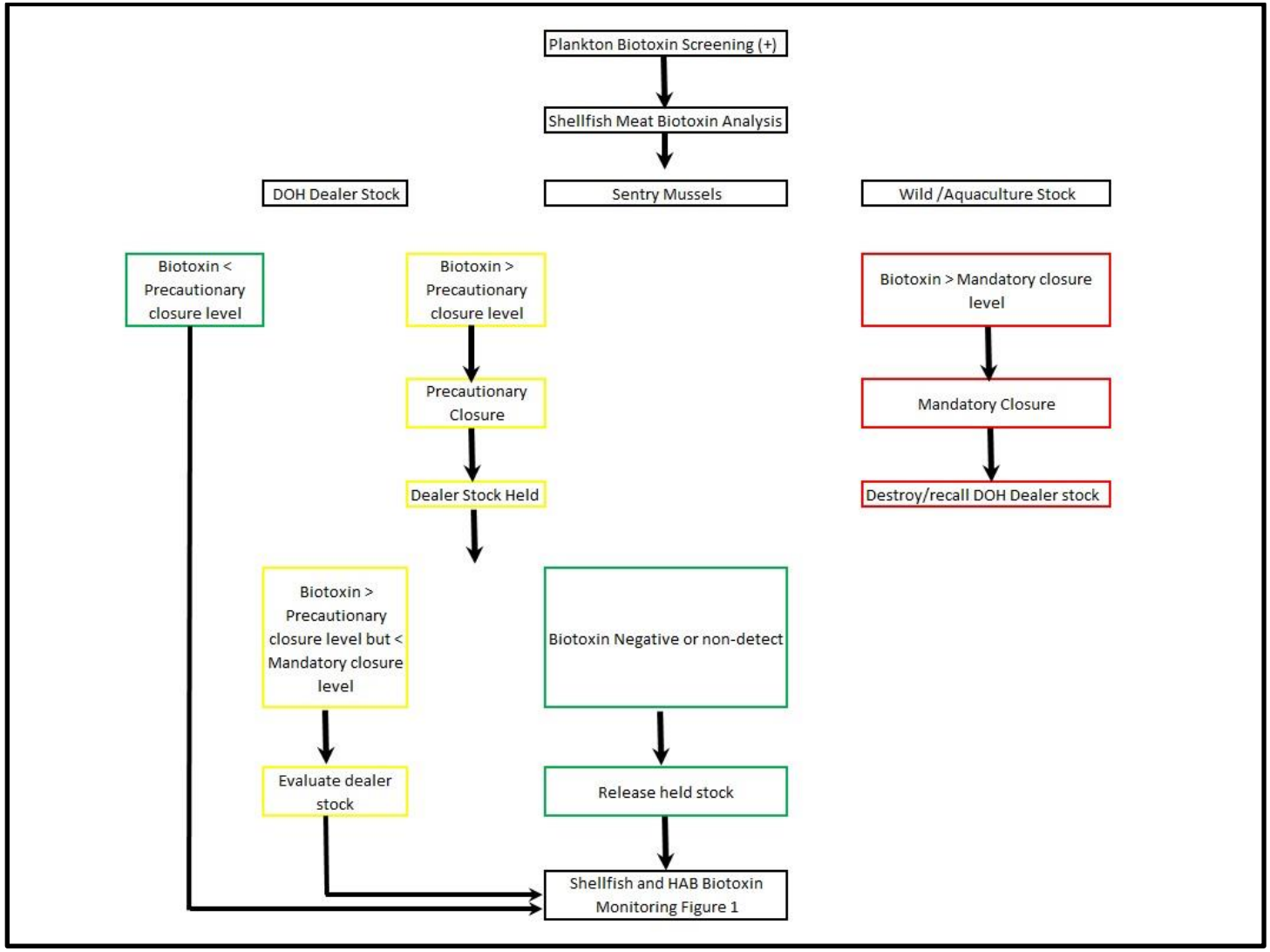


Figure 3 Conceptual flow chart summarizing RIDOH Center for Food Protection Shellstock contingency plan.



Literature Cited:

Anderson, DM. 1997. Bloom dynamics of toxic *Alexandrium* species in the northeastern US. Limnol. Oceanogr. 42: 1009-1022.

Anderson, DM and 4 co-authors. 2001. Monitoring and Management Strategies for Harmful Algal Blooms in Coastal Waters. APEC #201-MR-01.1, Asia Pacific Economic Program, Singapore, and Intergovernmental Oceanographic Commission Technical Series No. 59, Paris, 274 pages.

Bates, S. and 16 co-authors. 1989. Pennate Diatom *Nitzschia pungens* as the Primary Source of Domoic Acid, a Toxin in Shellfish from Eastern Prince Edward Island, Canada. Can. 1. Fish. Aquat. Sci. 46: 1203-1215.

Borkman, D.G., Smayda, T.J., Tomas, C.R., York, R., Strangman, W. and Wright, J. 2012. Toxic *Alexandrium peruvianum* (Balech and de Mendiola) Balech and Tangen in Narragansett Bay, Rhode Island (USA). Harmful Algae 19: 92-100.

Borkman, D.G., Smayda, T.J., Schwarz, E.N., Flewelling, L.J. and Tomas, C. R. 2014. Recurrent vernal presence of the toxic *Alexandrium tamarense* / *Alexandrium fundyense* (Dinoflagellata) species complex in Narragansett Bay USA. Harmful Algae 32: 73-80.

Borkman, D.G., Hannus, L., Scott, E., Liberti, A., Rodrique, K., Leibovitz, H. 2017. Novel toxigenic *Pseudo-nitzschia* blooms in Narragansett Bay, Rhode Island. Abstract presented at the 9th US Symposium on Harmful Algae Blooms, Baltimore, MD. (https://www.9thushab.com/abstracts-1).

Crespo, B.G., Keafer, B.A., Ralston, D.K., Lind, H., Farber, D., Anderson, D.M., 2011. Dynamics of *Alexandrium* fundyense blooms and shellfish toxicity in the Nauset Marsh system of Cape Cod (Massachusetts, USA). Harmful Algae 12, 26–38

Deshpande, SS. 2002. Handbook of Food Toxicology. CRC Press, Boca Raton, FL. 920 pp.

Hargraves, PE and Maranda, L. 2002. Potentially Toxic or Harmful Microalgae from the Northeast Coast. Northeast Naturalist 9: 81-120.

Hattenrath, TK, et al. 2013. The emergence of *Dinophysis acuminata* blooms and DSP toxins in shellfish in New York waters. Harmful Algae 26 (2013) 33–44.

Jauffrais, T. and 7 coauthors. 2012. Azaspiracid accumulation, detoxification and biotransformation in blue mussels (*Mytilus edulis*) experimentally fed *Azadinium spinosum*. Toxicoin 60(4): 585-595.

Jewett, E.B., Lopez, C.B., Dortch, Q., Etheridge, S.M, Backer, L.C. 2008. Harmful Algal Bloom Management and Response: Assessment and Plan. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Karentz, D. and T.J. Smayda 1984. Temperature and the seasonal occurrence pattern of 30 dominant phytoplankton species in Narragansett Bay over a 22-year period (1959-1980). Marine Ecology Progress Series 18: 277-293.

Karentz, D.K. and T.J. Smayda 1998. Temporal patterns and variations in phytoplankton community organization and abundance in Narragansett Bay during 1959-1980. Journal of Plankton Research 20: 145-168.

Maranda, L, Anderson, DM, Shimizu, Y. 1985. Comparison of toxicity between populations of *Gonyaulax tamarensis* of eastern North American waters. Estuar. Coast. Shelf. Sci. 21: 401-410.

Maranda, L. and Shimizu, Y. 1987. Diarrhetic Shellfish Poisoning in Narragansett Bay. Estuaries and Coasts 10(4):298-302.

NSSP. 2015, 2017, 2019. National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish. Biennial revisions available at the ISSC website: https://www.issc.org/nssp-guide.

Preece, EP and 3 co-authors. 2016. A review of microcystin detections in estuarine and marine waters: Environmental implications and human health Harmful Algae 61: 31-45.

Salas, R. and eight co-authors. The role of *Azadinium spinosum* (Dinophyceae) in the production of azaspiracid shellfish poisoning in mussels. Harmful Algae 10(6): 774-783.

Sieburth, J.M., Johnson, P.W. & Hargraves, P.E. (1988). Ultrastructure and ecology of *Aureococcus anophagefferens* gen et sp. nov. (Chrysophyceae): the dominant picoplankter during a bloom in Narragansett Bay, Rhode Island, summer 1985. *Journal of Phycology* 24(3): 416-425.

Smayda, T.J. 1957. Phytoplankton studies in lower Narragansett Bay. Limnology and Oceanography 2: 342-359.

Smayda, T.J. 1997. What is a bloom? A commentary. Limnology and Oceanography 42: 1132-1136.

Tester, PA, Stumpf, RP, Vukovich, FM, Fowler, PK and Turner, JT. 1991. An expatriate red tide bloom: Transport, distribution, and persistence. Limnol. and Oceanogr. 36(5): 1053-1061.

Tillman, U and four co-authors. 2009. Azadinium spinosum gen. et sp. nov. (Dinophyceae) identified as a primary producer of azaspiracid toxins. European Journal of Phycology 44: 63-79.

Trainer, VL and Hardy, FJ. 2015. Interactive monitoring of marine and freshwater harmful algae in Washington State for public health protection. Toxins 7: 1206-1234.

Twiner, M.J and three co-authors. 2008. Azaspiracid shellfish poisoning: A review on the chemistry, ecology, and toxicology with an emphasis on human health impacts. Marine Drugs 6: 39-72.

UK Food Standards Agency. 2014. Managing Shellfish Toxin Risks: Guidance for Harvesters and Processors. UK 34 pp.

Figure 4 DEM-OWR Shellfish Program HAB monitoring sites in Upper Narragansett Bay. Sites sampled by DEM-OWR and DEM-DMF personnel.

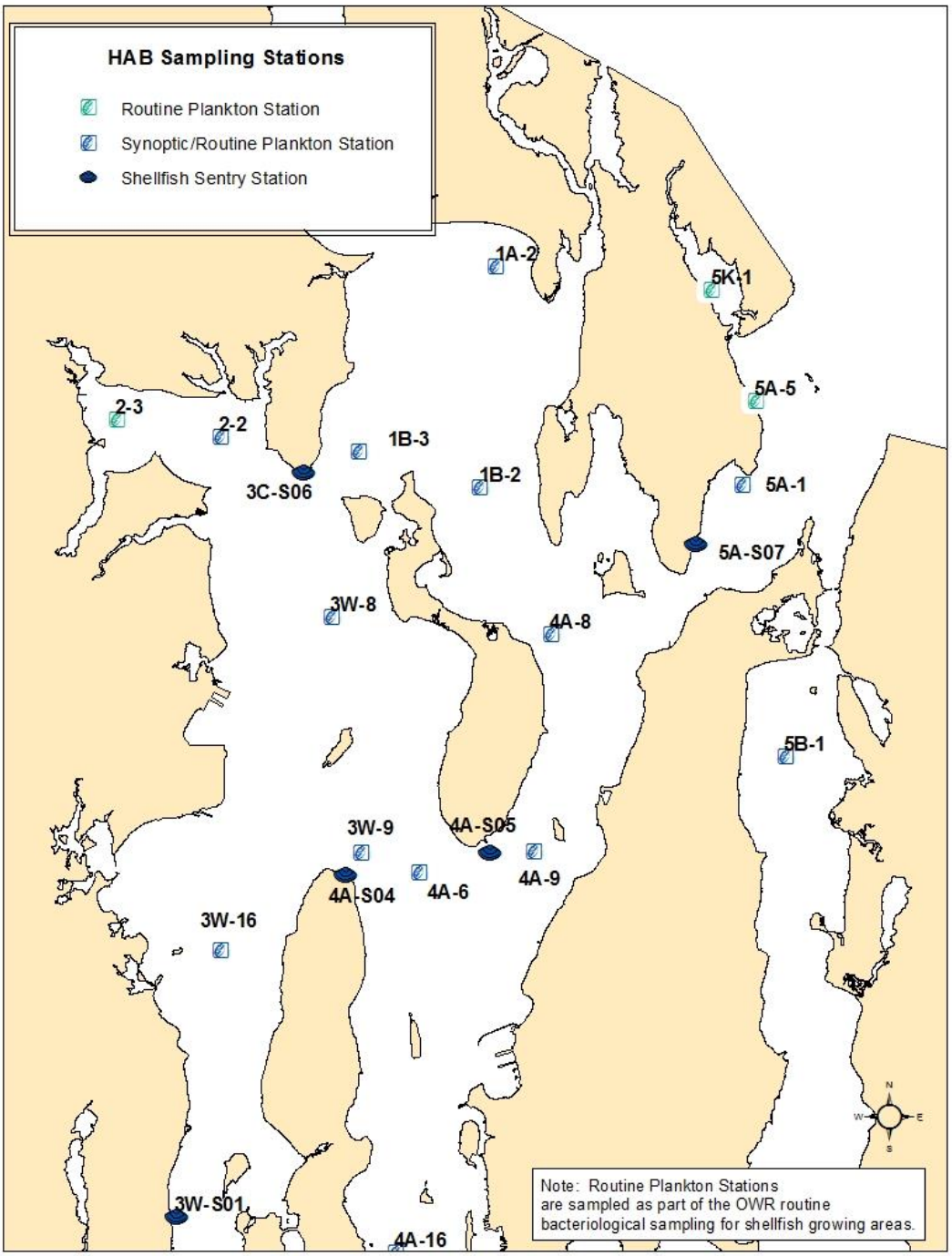


Figure 5 DEM-OWR Shellfish Program HAB monitoring sites in Lower Narragansett Bay. Sites sampled by DEM-OWR and DEM-DMF personnel.

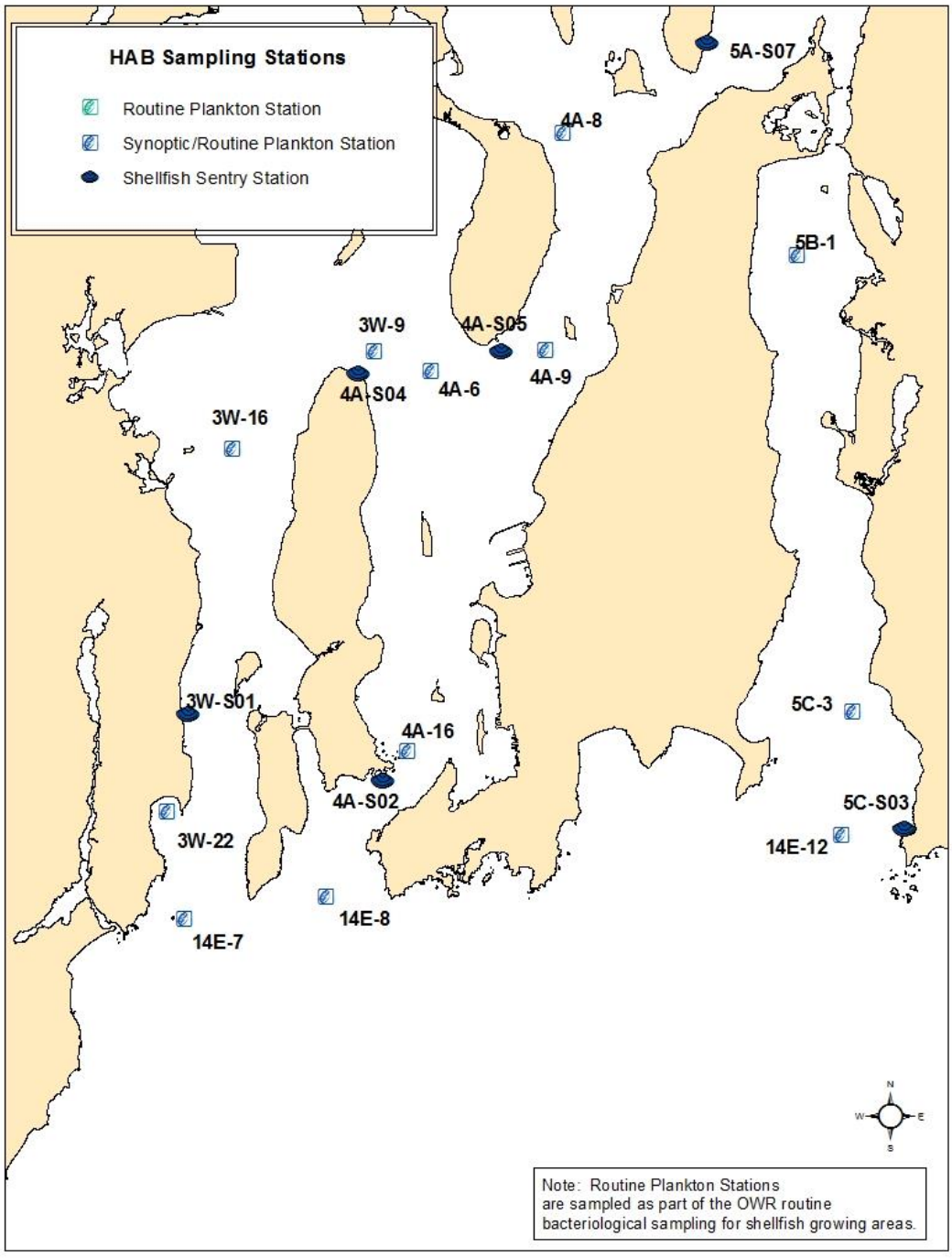


Figure 6 DEM-OWR Shellfish Program HAB monitoring sites in coastal salt ponds and along southern RI coast. Sites sampled by DEM-OWR and DEM-DMF personnel.

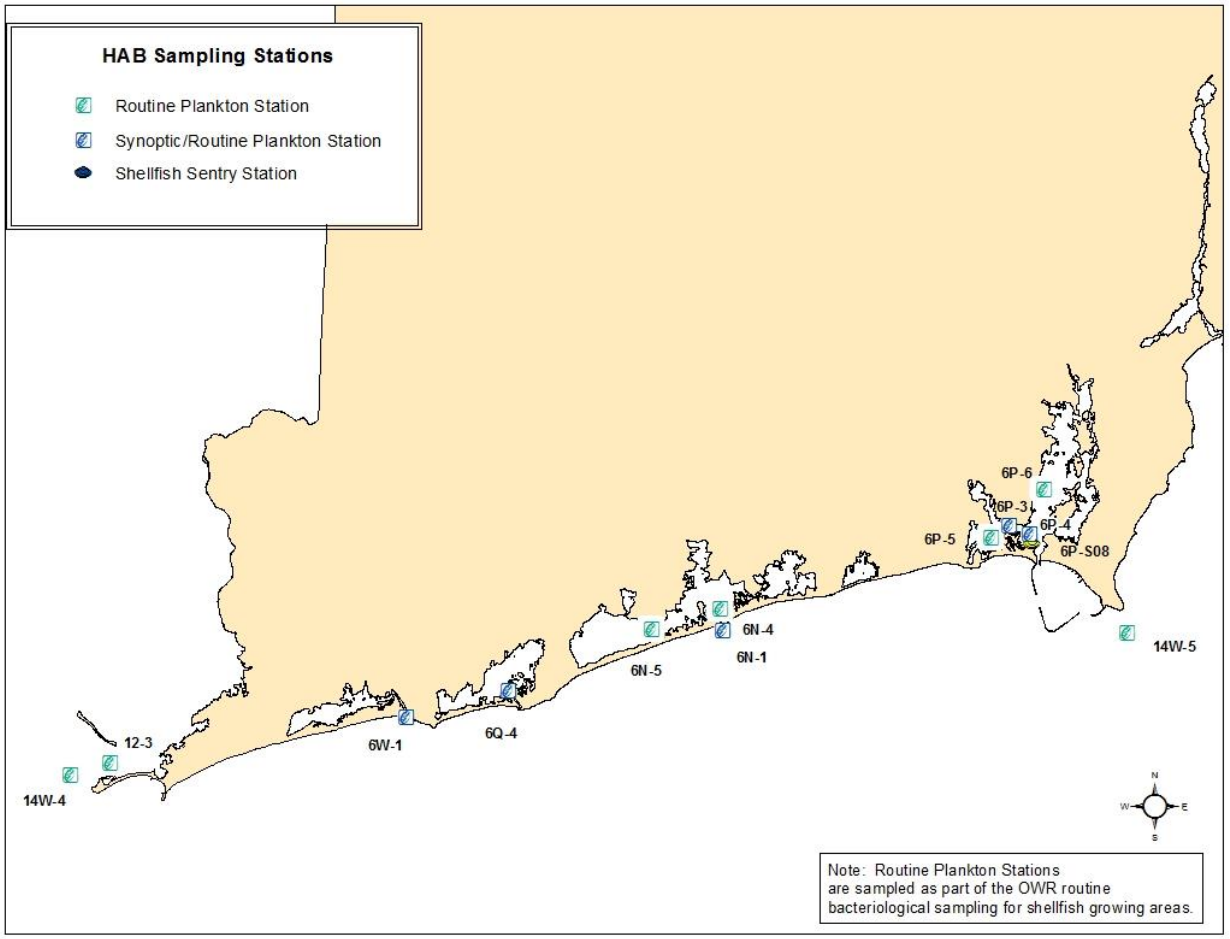
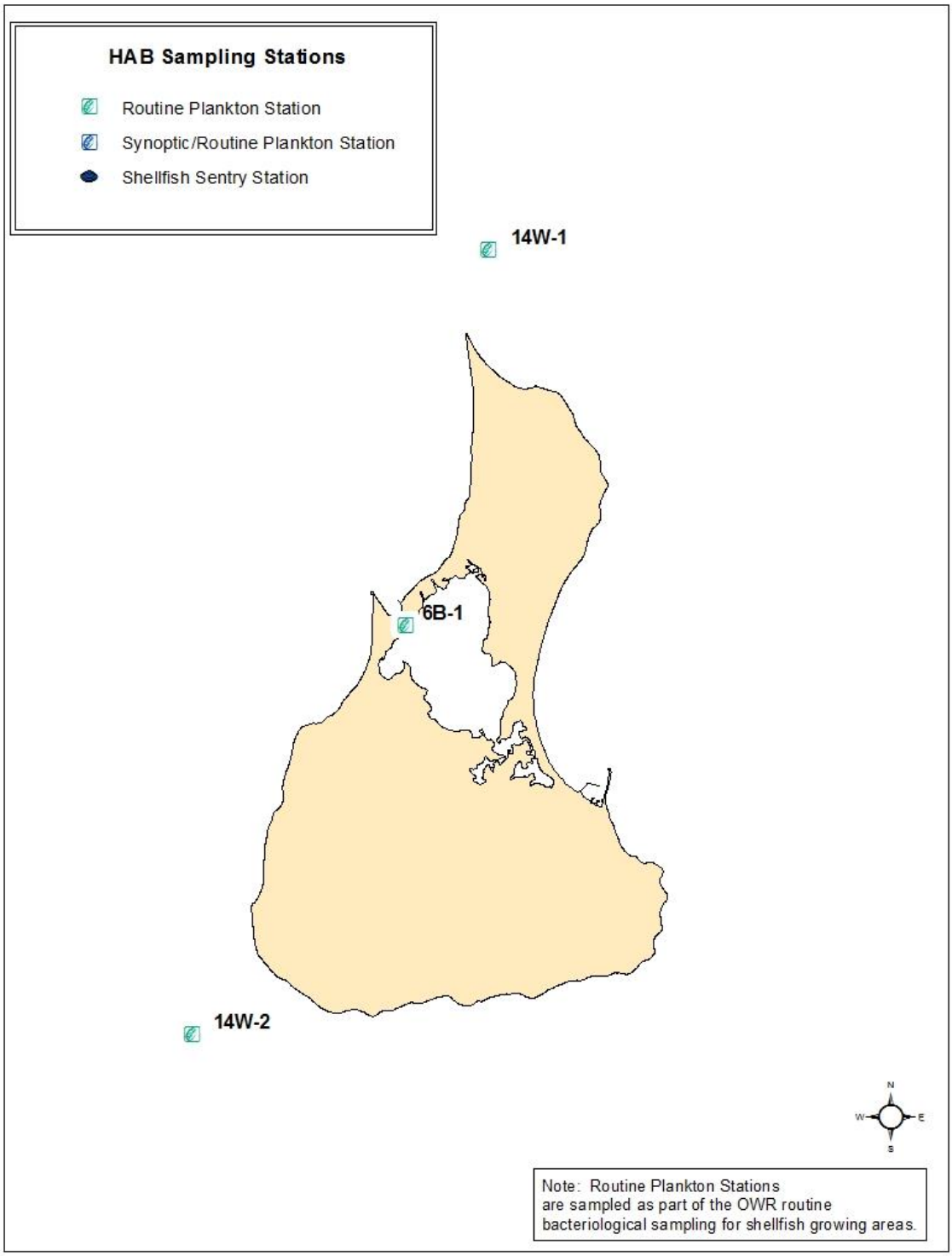


Figure 7 DEM-OWR Shellfish Program HAB monitoring sites in Block Island area. Sites sampled by Block Island Harbormaster.



Appendix A

Contact Information for Key Personnel

KEY STATE AGENCY CONTACTS

FIRST	LAST	ORGANIZATION	EMAIL	PHONE (OFFICE/CELL)
Nicole	Alexander Scott	RIDOH /Director	Nicole.AlexanderScott@health.ri.gov	(o)401-222-2232
Keith	Amoroso	RIDOH/Food Protection	keith.amoroso@health.ri.gov	401-222-7728
Andrea	Bagnall Degos	RIDOH /Communications	Andrea.BagnallDegos@health.ri.gov	(o)401-222-6054
Jim	Ball	RIDEM/ER	james.ball@dem.ri.gov	(o)401-222-1360 x7129
Robert	Ballou	RIDEM/DMF	robert.ballou@dem.ri.gov	(o)401-222-4700 x4420
Kurt	Blanchard	RIDEM/DLE	kurt.blanchard@dem.ri.gov	(o) 401-222-2284
David	Borkman	RIDEM/OWR	david.borkman@dem.ri.gov	(o)401-222-4700 x 2777412
Tom	Campbell	RIDEM/ER	thomas.campbell@dem.ri.gov	(o)401-222-1360 x7128
Carl	Cottle	NBEP Prudence Island	carl.cottle@dem.ri.gov	401-683-8132 or 401-683-4236
Ben	Goetsch	CRMC	bgoetsch@crmc.ri.gov	(o)401-783-3370
Terry	Gray	RIDEM/BEP	terry.gray@dem.ri.gov	(o)401-222-4700 x7100
Joe	Haberek	RIDEM/OWR	joseph.haberek@dem.ri.gov	401.222.4700 ext. 2777715
Michael	Healey	RIDEM/PR	michael.healey@dem.ri.gov	(o)401-222-4700 x 7273
Dean	Hoxsie	RIDEM/DLE	dean.hoxsie@dem.ri.gov	(o) 401-222-2284
Paul	Jordan	RIDEM/GIS	Paul.jordan@dem.ri.gov	(o)401-222-2776 x 4315
Kohl	Kanwit	Maine	kohl.kanwit@maine.gov	(o)207-633-9535
Ewa	King	RIDOH/Division of Laboratories	Ewa.King@health.ri.gov	(o)401-222-1999
Henry	Leibovitz	RIDOH/Division of Laboratories	henry.leibovitz@health.ri.gov	(o)401-222-5578
Conor	McManus	RIDEM/DMF	Conor.Mcmanus@dem.ri.gov	(o)423-1943
Jason	McNamee	RIDEM/DMF	jason.mcnamee@dem.ri.gov	(o)401-222-2771 x 2414
Chris	Nash	NH DES	chris.nash@des.nh.gov	(o)603 559-1509
Scott	Olszewski	RIDEM/DMF	scott.olszewski@dem.ri.gov	(o)401-423-1934
Kerry	Patterson	RIDOH/Water Microbiology	Kerry.Patterson@health.ri.gov	(o)401-222-5588
Evan	Philo	RIDOH/Center for Environmental Sciences	evan.philo@health.ri.gov	(o)401-222-5553
Katherine	Rodrigue	RIDEM/DMF	katherin.rodrigue@dem.ri.gov	(o)401-423-1944
DOH Lab	SanitaryMicro	RIDOH	DOH.SanitaryMicro@health.ri.gov	(o)401-222-5588
Greg	Sawyer	MassDEP	gregory.sawyer@massmail.state.ma.us	(o)508-742-9769
Thomas	Shields	MassDEP	thomas.shields@state.ma.us	(o)508-990-2860 x 126
Phana	Tum	RIDOH/Food Protection	Phana.Tum@health.ri.gov	(o)401-222-2749

FIRST	LAST	ORGANIZATION	EMAIL
Jim	Arnoux	Ningret Pond	BachBeachoysterfarm@gmail.com
	Behan Family Farms	Ninigret Pond	behanfamilyfarms@gmail.com
Stesha	Campbell	Point Judith Pond	stesha_campbell@yahoo.com
Steve	Crandall	Foster Cove Ninigret Pond	stevecrandall@cox.net
David	Deffley	Trims Pond Block Island	daviddeffley@yahoo.com
	East Beach Oyster Farm	Ninigret Pond	eastbeachoysterfarm@gmail.com
John	ELiason	Upper Bay	
Jeffrey	Gardner	Winnapaug Pond	watchhilloysters@gmail.com
David	Ghiglioti	V.P., RI Shellfisherman Assoc.	dlghig@aol.com
Jeff	Grant	RI Marine Fisheries Council	jeffgrant19@cox.net
Richard	Guimond	Sakonnet Harbor	foggyjoe@att.net
Tom	Hoxsie	Point Judith Pond	tomhoxsie@yahoo.com
William	Huggins	Point Judith Pond	hugginss@verizon.net
Curt	Jackson	The Cove	curtjack70@aol.com
Jody	King	Shellfisherman	qhaug@juno.com
Robert	Krause	Ninigret Pond	
Steve	Land	New Shoreham Harbor Master	harbors@new-shorehma.com
Chris	Littlefield	Harbor Pond Block Island	clittlefield@tns.org
Mike	McGiveney	President, RI Shellfisherman Assoc.	mclamdigger@aol.com
Richard	Melanson	Sakonnet River	sak_oyster@yahoo.com
Nick	Papa	Ninigret Pond	npapa1084@gmail.com
Perry	Phillips	Trims Pond Block Island	perry_phillips@my.uri.edu
Antonio	Pinheiro	West Passage Dutch Harbor	antoniodpinheiro@gmail.com
Brian	Pinsky	Ninigret Pond/Potter Pond	bpinsky1@gmail.com
Catherine	Puckett	Trims Pond / Great Salt Pond	oysterwench@aol.com
Perry	Raso	Matunuck Oyster	perry@rhodyoysters.com
Robert	Rheault	ECSGA Executive Director	bob@ECSGA.org
Dave	Roebuck	Salt Pond Oysters	dave@saltpondoysters.com
Gerry	Schey	Shellfisherman/Whelks-	gtschey@cox.net
Peter	Sebring	Ushers Cove, Nanaquaket Pond Narragansett Bay	atlantic@AtlanticAquaculture.com
Adam	Silkes	East Passage/West Bay/Rome Point	adam@americanmussel.com
William	Silkes		Bill@americanmussel.com
	Sipperly		dlsipp@netzero.net
	Soares		hoosh8388@yahoo.com
Richard	Sousa	Blue Bill Cove	sousarg@me.com
M.	Sousa		sousarg@me.com
Kenneth	Thompson	Narragansett Bay	windfallshellfish@hotmail.com
	Walrus & Carpenter Oysters	Dutch Island	jules@walrusandcarpenteroysters.com
Chris	Warfel		cwarfel@entech-engineering.com
Opton-Himmel	Watch Hill Oysters		watchhilloysters@gmail.com
John	West	Pt Judith Pond	westnest5@verizon.net
	Whilden	Fox Island	whilden1@yahoo.com
	York Dental Lab	Pt Judith Pond	bfranford@YorkDentalLab.com
	York Dental Lab		bpinsky1@gmail.com
		Ninigret Oysters	ninigretoysters@verizon.net
		Rhody Oysters	perry@rhodyoysters.com

ACADEMIC and FEDERAL HAB Scientists

FIRST	LAST	ORGANIZATION	EMAIL
Steve	Archer	Bigelow Labs	sarcher@bigelow.org
Katherine	Hubbard	Florida DMF	katherine.hubbard@myfwc.com
Neal	Churchill	MassDEP	Neil.Churchill@MassMail.State.Ma.us
Quay	Dortch	NOAA Federal	quay.dortch@noaa.gov
Marc	Suddleson	NOAA Federal	marc.suddleson@noaa.gov
Christian	Petitpas	UMass	cjadlowic@umassd.edu
Don	Anderson	Woods Hole	donanderson@whoi.edu
Michael	Brosnahan	Woods Hole	mbrosnahan@whoi.edu
McGillicuddy	Dennis	Woods Hole	dmcgillicuddy@whoi.edu
Bruce	Keafer	Woods Hole	bkeafer@whoi.edu
Dave	Kulis	Woods Hole	dkulis@whoi.edu
Mindy	Richlen	Woods Hole	mrichlen@whoi.edu

RIDOH Shellfish Dealers Contact Information

Name	City	State	Cert No.	HARVEST AREAS
ALL AMERICAN MEAT & SEAFOOD	N. KINGSTOWN	RI	349-SS	MULTIPLE
AMERICAN MUSSEL HARVESTERS	NORTH KINGSTON	RI	234-SS	MULTIPLE
ANDRADE'S CATCH	BRISTOL	RI	248-SS	MULTIPLE
ANTHONY'S SEAFOOD	MIDDLETOWN	RI	410-SS	MULTIPLE
ATLANTIC CAPES FISHERIES	BRISTOL	RI	242-SP	MULTIPLE
BEHAN FAMILY FARMS	ASHAWAY	RI	489-SS	
BRIDGEPORT SEAFOOD	TIVERTON	RI	37-SS	MULTIPLE
CASTIGLIEGO LTD	BRISTOL	RI	79-RS	MULTIPLE
CHAMPLIN'S SEAFOOD	NARRAGANSETT	RI	27-SS	MULTIPLE
CLIPPER SEAFOOD	NARRAGANSETT	RI	66-SS	MULTIPLE
DIGGERS CATCH SEAFOOD	E. PROVIDENCE	RI	504-SS	MULTIPLE
GARDNER'S WHARF	WICKFORD	RI	273-SS	MULTIPLE
JONATHAN ISLAND OYSTER CO	NARRAGANSETT	RI	506-SS	
LI'S SEAFOOD	CRANSTON	RI	495-RS	MULTIPLE
MAR SEAFOOD	WARWICK	RI	359-SS	MULTIPLE
METRO LOBSTER & SEAFOOD	WARWICK	RI	422-SS	MULTIPLE
NARRAGANSETT BAY LOBSTER	NARRAGANSETT	RI	433-SS	MULTIPLE
NARRAGANSETT BAY SHELLFISH	WARWICK	RI	474-SS	MULTIPLE
NEWPORT LOBSTER	MIDDLETOWN	RI	421-SS	MULTIPLE
OCEAN STATE LOBSTER	NARRAGANSETT	RI	454-RS	MULTIPLE
OCEAN STATE SHELLFISH COOP	NARRAGANSETT	RI	476-SS	MULTIPLE

QUALITY SEAFOOD	JOHNSTON	RI	439-SS	MULTIPLE
QUINTS SEAFOOD	BRISTOL	RI	004-SS	MULTIPLE
R & D SEAFOOD	WOONSOCKET	RI	89-RP	MULTIPLE
RESTAURANT DEPOT	CRANSTON	RI	503-RS	MULTIPLE
RHODE ISLAND CLAM	E. GREENWICH	RI	430-SS	MULTIPLE
ROCKY RHODE OYSTER	W. KINGSTOWN	RI	509-SS	
SAKONNET OYSTER CO	LITTLE COMPTON	RI	423-SS	
SALT POND OYSTER	NARRAGANSETT	RI	467-SS	
SCALES AND SHELLS	NEWPORT	RI	497-SS	MULTIPLE
SHELLFISH FOR YOU	WESTERLY	RI	371-SS	
T & C LOBSTER	NARRAGANSETT	RI	426-SS	MULTIPLE
THE LOCAL CATCH	NARRAGANSETT	RI	482-SS	MULTIPLE
TONY'S SEAFOOD	WARREN	RI	397-SP	MULTIPLE
TWIN SHELLFISH	WARWICK	RI	451-SS	MULTIPLE
VENUS OYSTERS	WAKEFIELD	RI	501-SS	
WALRUS AND CARPENTER OYSTERS	NARRAGANSETT	RI	505-SS	
WALRUS AND CARPENTER OYSTERS	CHARLESTOWN	RI	486-SS	
WILFRED'S SEAFOOD	WOONSOCKET	RI	77-SS	MULTIPLE
WINDFALL SHELLFISH	BRISTOL	RI	425-SS	
BLOCK ISLAND OYSTER FARM	NEW SHOREHAM	RI	491-SHL	
BRISTOL OYSTER BAR	BRISTOL	RI	498-SHL	MULTIPLE
KELLYS SEAFOOD	BRISTOL	RI	487-SHL	MULTIPLE
MATUNUCK OYSTER FARM	WAKEFIELD	RI	449-SHL	
PLUM POINT OYSTERS	N. KINGSTOWN	RI	462-SHL	

Appendix B

RIDOH Laboratory Submission Form

Affix Laboratory Sample Label Here

Submission and Data Collection for Toxic Plankton and Shellfish Monitoring Program

Field Data

Submitter Department / Office:		**Lab Submission Date/Time:**	
Sampling Station #		Description of Location:	
Sample Type (Plankton or Shellfish Type*):		Latitude:	Longitude:
Sampling/Harvest Date:	Time:	Collector Name:	
Depth:	Temp (°C): TOP: BOT:	Diss.Oxygen (mg/L): TOP: BOT:	Cooler Iced: Y or N
Tide:	Wind Direction:	Salinity (ppt): TOP: BOT:	Net Sieve Size (µm):
Volume Seawater Filtered Through Net (L):		Concentrated Sample Volume (mL):	

***Use one of the following: mussel, oyster, softshell clam, surf clam, quahog, whelk**

Laboratory Data

Lab Analysis Requested:
Plankton: ☐ SM29 Counting Scotia (check one): ☐ FC10 - ASP ☐ FC35-PSP ☐ FC34-DSP
Shellfish: ☐ Scotia ☐ FC08 HPLC - ASP

Sample Refrigerated Y or N	Plankton Counting		Scotia Result Present / Absent		HPLC Concentration (mg/L)	
Refrigerator Temp °C: Time:	Date	Analyst	Date	Analyst	Date	Analyst

Microscopic Results:				Tally 1	Tally 2
Alexandrium spp.	1-	2-			
Pseudonitzschia spp.	1-	2-			
Dinophysis	1-	2-			

Organism	**Count**	**Comment**

Relinquished By:_____ Received By:_____ Date/Time:_____

Relinquished By:_____ Received By:_____ Date/Time:_____

Relinquished By:_____ Received By:_____ Date/Time:_____

Relinquished By:_____ Received By:_____ Date/Time:_____

Form Updated: 2/28/2016