RHODE ISLAND
DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
OFFICE OF THE DIRECTOR
235 Promenade Street, Providence, Rhode Island 02908

March 18, 2024

RE: DEM Comments to the Special Legislative Commission to Study and Provide Recommendations on the Issues Relating to the Reduced Catch of Quahogs in Narragansett Bay

Dear Commission Members:

On June 14, 2023, a Joint Resolution was passed, 2023 – S 1126, forming a *Special Legislative Commission to Study and Provide Recommendations on the Issues Relating to the Reduced Catch of Quahogs in Narragansett Bay* (the "Commission"). The goal of the Commission is to complete a comprehensive study of, and provide recommendations related to, the effects of 1) WWTF nitrogen reduction, 2) Hypoxia, 3) Changing aquatic life and 4) Climate change on the reduced catch of quahogs in Narragansett Bay. The Commission is required to report its findings to the General Assembly by May 31, 2024. Below is a summary of the Department of Environmental Management's (the "DEM's") positions on topics that were raised or discussed during Commission meetings:

1. Quahog Abundance

a. Commercial Quahog Landings

Annual RI quahog landings are variable and have had two peaks over the past 75 years (Figure 1). These periods of elevated quahog landings have been attributed to changes in the management of RI's quahog fishery (1950s) and improved water quality (1980s) (Gibson, 2010).

The late 1950s peak in quahog landings occurred during a period that had an extensive State-funded quahog transplant program, in which State funds were used to transplant quahogs from areas that were closed to shell fishing due to pollution into areas where commercial harvesting was permitted. In addition, during this time-period dredging was an allowed harvest method, which resulted in large quantities of quahogs being harvested but resulted in other significant adverse environmental impacts (e.g., damage to habitat and harvest of non-target species). After dredging was banned, commercial quahog landings declined and stabilized at about one million pounds of quahog meats per year during the 1970s.

The 1980s peak in RI quahog landings occurred in response to improved wastewater collection and treatment and concomitant declines in fecal coliform pollution in the Upper Bay which allowed for the opening of previously closed shellfish harvest areas in Upper Narragansett Bay. Upper Bay Conditional Area B (3,711 acres) was previously closed to shellfish harvest in December 1978 due to unsanitary conditions but was subsequently reopened as a conditionally approved area (0.5" rain closure and WWTF bypass closure) in March 1980. Similarly, Upper Bay Conditional Area A (5,925 acres, including 'Barrington Beach') was previously closed to shellfish harvest in December 1978 and subsequently reopened as a conditional area (0.5" rain closure and WWTF bypass closure) in July 1982. Since the 1980s peak, quahog landings have declined to levels between 400,000 and 1 million pounds of quahog meats per year from 2005 to the present. The 1980s to present decline in RI quahog landings is similar in magnitude and timing to that seen in other northeast states. Commercial bivalve mollusk landing in states from Maine to North Carolina fell by approximately 85% between 1980 and 2010 (Mackenzie and Tarnowski, 2018). Analyses by Gibson (2010) indicated that, due to elevated historic fishing pressure, it would take more than a decade, even at zero fishing mortality (i.e., no quahog harvest), for the Narragansett Bay quahog population to recover to pre-2000 abundance levels.

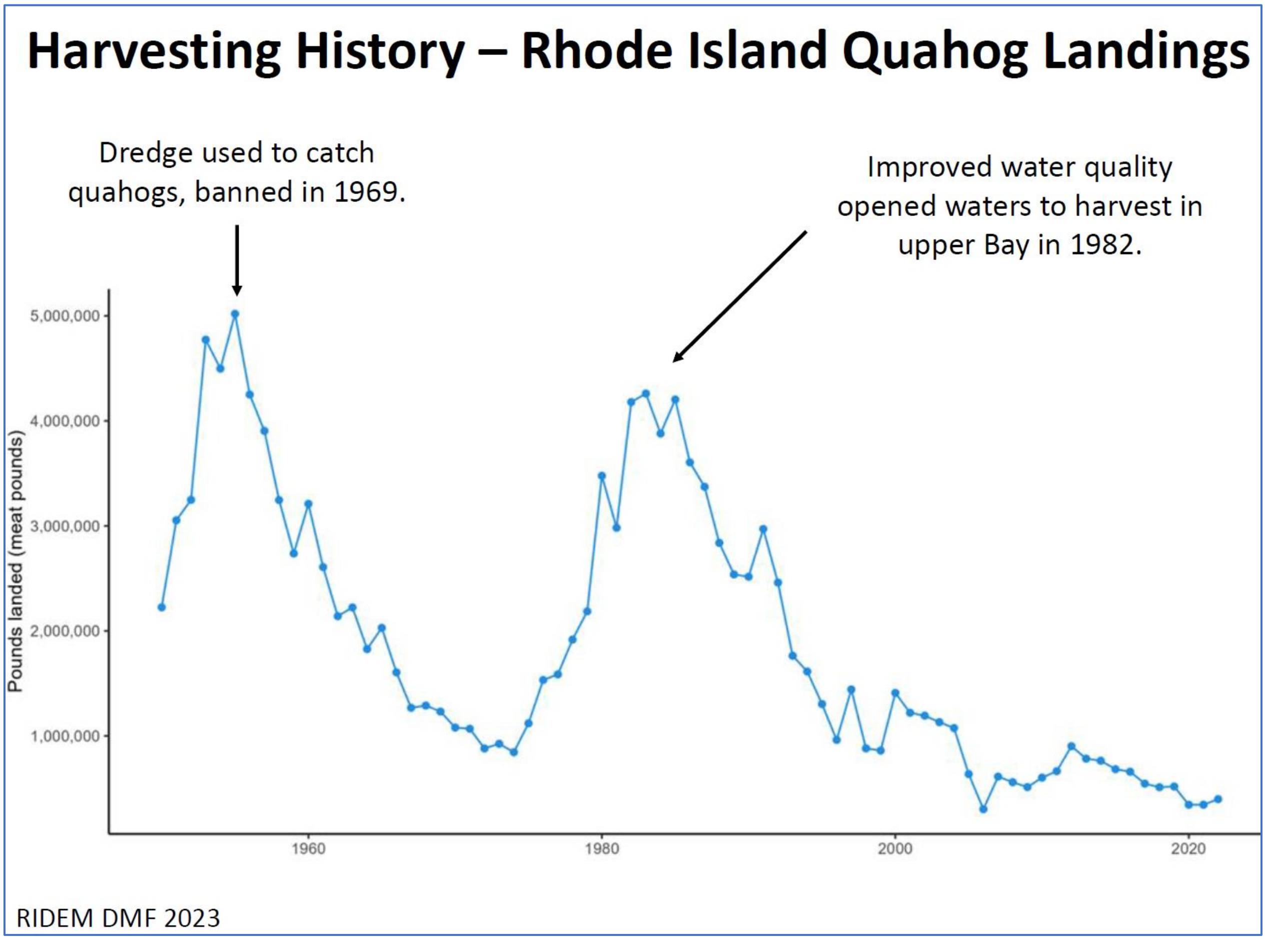

Figure 1: Annual RI commercial harvest quahog landings during 1950 to 2022. Source: RI DEM Division of Marine Fisheries.

b. Fishery Independent Quahog Abundance Assessment

The DEM Division of Marine Fisheries routinely assesses quahog abundance via dredge surveys. Results of these surveys show that the abundance of quahogs in Narragansett Bay proper (which includes the Upper Bay, Mt. Hope Bay, and the Sakonnet River) and Greenwich Bay between 1993 and 2022 were consistently at 1-3 quahogs/m^2 (Figure 2). This level of quahog abundance density may be approaching the limiting density at which recruitment is impaired (Gibson, 2010; Kraeuter et al., 2005).

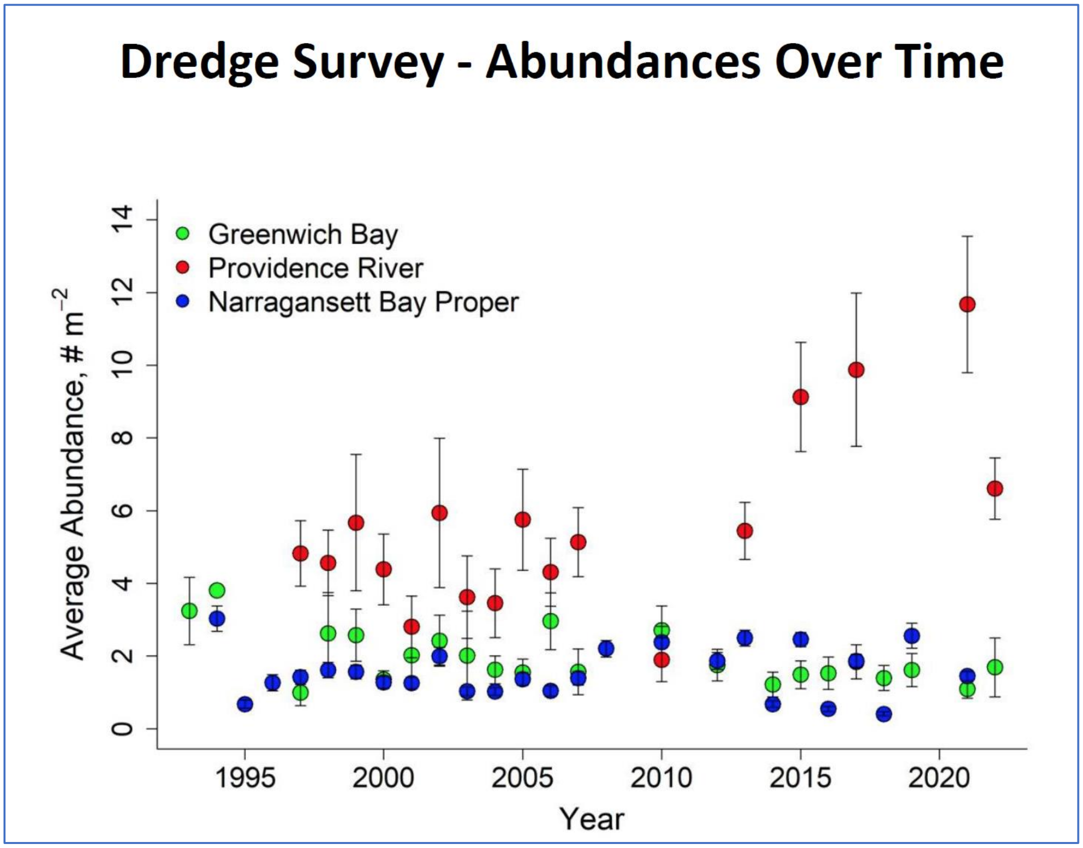

Figure 2: RI DEM dredge survey estimates of average quahog abundance (number per square meter) in Greenwich Bay, Narragansett Bay proper, and the lower Providence River during 1993 to 2022. Source: RI DEM Division of Marine Fisheries.

In contrast, quahog abundance in the lower Providence River, which was closed to shellfish harvest due to bacterial pollution from ~1945 through 2021, was found to have 4-6 quahogs/m^2 during the late 1990s and early 2000s followed by a 2-fold increase to 8-10 quahogs/m^2 during 2015 to 2021 (Figure 2). Note that improved stormwater control and wastewater treatment in the Providence area led to improved water quality and this lower Providence River shellfishing area was opened to shellfish harvest for the first time in ~75 years in May 2021. Under a carefully planned harvest schedule approximately 4.7 million (2021, 2023) to 10.6 million (2022) quahogs were commercially harvested annually from this 1,900-acre area since 2021 and quahog abundance has remained greater than 6 quahogs/m^2 (RI DEM DMF data).

2. **Quahog Fishery Management Changes**
   a. **Daily Quotas and Days Open for Harvest**

Upper Bay Area A and Area B: Upper Bay Areas A (5,925 acres) and B (3,711 acres; Figure 3) have a quahog commercial harvest daily limit of 12 bushels per person per day with no commercial harvest schedule applied to these areas. These daily harvest limits have not changed in many years and were not modified as water quality improved and fishing access increased. However, the frequency of water quality closures of the Upper Bay has decreased in the past 20 years, allowing a dramatic increase in the number of days these areas are open for shellfish harvest. In the past decade, Area A was open for shellfish harvest an average of 246 days/year from 2013-2023 compared to 164 days/year during 2000-2012. This is a 50% increase in harvest days/year (Table 1). Area B was open an average of 342 days/year during 2013-2023, a 28% increase in harvest days/year over the 267 days/year during 2000 – 2012 (Table 1). Further, in addition to being open to harvest more days/year on average, the Upper Bay is also now open for shellfish harvest more days during a wet year (for example 2018: 63.5 inches rain, Area A open 206.5 days, Area B open 365 days) than it was during a dry year prior to 2012 (example 2001: 40.2 inches rain, Area A open 165 days, Area B open 277 days).

Table 1: Comparison of number of days Upper Bay Area A and Upper Bay Area B were open for shellfish harvest during 2000-2012 compared to 2013-2023. Source: RI DEM Office of Water Resources.

Period	Area A days open (annual average)	Area B days open (annual average)
2000 to 2012	163.9	267.2
2013 to 2023	246.0	341.6
Change (days)	+ 82.0	+ 74.4
Change (%)	+ 50.0 %	+ 27.8 %

Providence River Shellfish Management Area: The Providence River Shellfish Management Area (Area E), which consists of 1,922 acres (Figure 3), was created in 2021 when the classification of this water was upgraded from prohibited to conditionally approved for shellfish harvest due to improvements made to the capture of combined sewage overflows and improved stormwater and wastewater treatment. This shellfish management area has a 6 bushel per person per day quahog possession limit, with up to two daily possession limits per boat allowed. Commercial harvest in this area is annually reviewed thus far, with most management changes based on days to access the area. This has resulted in the lower Providence River being open for commercial shellfish harvest for 15 days in 2021, 16 days in 2023, and 28 days in 2022.

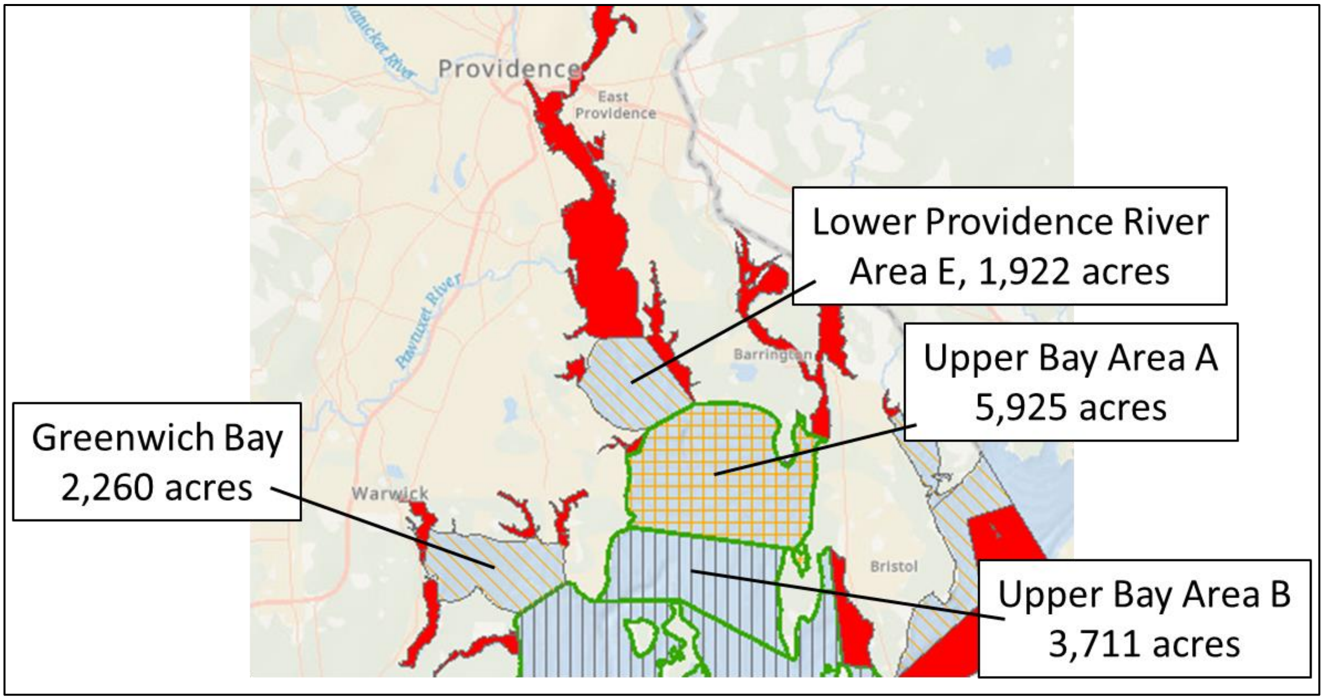

Figure 3: Map of Upper Narragansett Bay showing important quahog harvesting areas and number of acres open to shellfish harvest in each area. Red shaded areas are closed to shellfish harvest due to bacterial pollution and/or presence of WWTF outfall dilution zones. Source: RI DEM Office of Water Resources (dem.ri.gov/shellfish).

b. State-funded Transplant Program

Quahog transplants were historically an important tool used in the management and augmentation of the commercially fished quahog resource in Narragansett Bay. These quahog transplants occurred annually and were large (Figure 4); they averaged 31,500 bushels (approx. 2.5 million pounds) of quahogs transplanted annually during 1954-1974 (Pratt, 1988). Examples of these quahog transplants (details in Pratt, 1988) include: during 1964: 32,538 bushels (2.6 million pounds/year using 80 lbs. per bushel; Pratt,1988) of quahogs transplanted from the Providence River to areas off Melville and Rocky Point: during 1971-1975: transplants of ~2,000 bushels annually (approx. 160,000 pounds/year) transplanted from the Providence River to the Wickford Harbor seasonal (winter harvest) area. During 1977 to 1992 an annual average of 200,000 pounds of quahogs were transplanted from closed coves of Greenwich Bay into the Greenwich Bay shellfish management area for winter harvest. From 1993 to 2001 approximately 100,000 pounds of quahogs per year were transplanted to the Fox Island / Bissel Cove area. These controlled relay programs were successful by both augmenting the quahog spawning stock during the summer after the transplant and by providing the industry with additional resource to harvest during the winter season. Since approximately 2010 this quahog transplant program has been discontinued due to a lack of dedicated state funding, and the frequency and magnitude of quahog transplants has declined dramatically (Figure 4). Examples of smaller, recent transplants include the transplant of 52,650 pounds of quahogs from the Providence River to Greenwich Bay and Winnapaug Pond in 2020 and the transplant of 58,000 to 65,000 pounds of quahogs from Greenwich Cove to Greenwich Bay in 2022 and 2023. The magnitude of state-funded quahog transplant activity has declined dramatically since 2010 and the volume of quahogs transplanted annually in recent years (approximately 44,000 pounds annually) is a minor fraction of the volume transplanted historically.

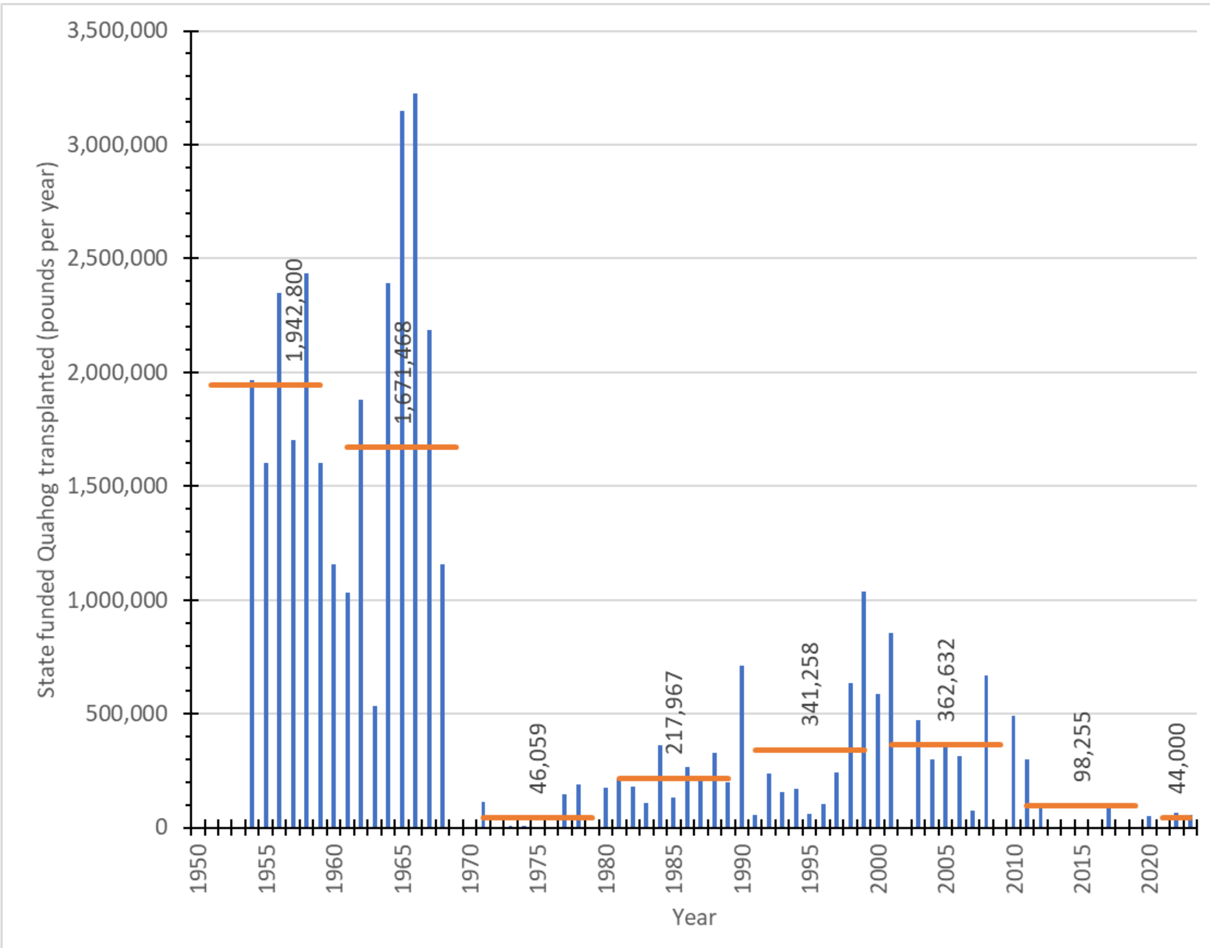

Figure 4: Estimated annual weight (pounds per year) of quahogs transplanted during 1950 to 2023. Decadal average pounds transplanted per year shown as orange horizontal lines. Source: Pratt, 1988, Pratt et al., 1992, Rice et al., 2000, and RI DEM.

Currently, quahog transplant funding is provided only by fines levied on municipal Wastewater Treatment Facilities ("WWTFs") as a result of violation of their DEM-issued discharge permits which result in shellfish harvest closure. Quahog transplants from the 1950s through about 1990 were funded by legislative allocations of $5,000 to $25,000 annually (in 1960's dollars). Pratt (1988) and Pratt et al. (1992) summarized the annual allocation of state funding devoted to quahog transplant in RI waters through approximately 1990. The amount of state funding for quahog transplants has declined dramatically since the 1980s (Figure 5). State funding for transplants regularly exceeded $75,000 per year and occasionally exceeded $250,000 annually (in 2023 dollars) prior to 1980. Funding for more recent transplants has been sporadic and relatively small (on the order of $25,000 per year).

Quahog relays, or transplants, were an important part of the fishery's management when much of the upper Bay was closed to shellfish harvest due to pollution. While large-scale transplants are no longer viable because there are less closed areas in the upper Bay, several evaluations of declining quahog catch have identified regular and sustained quahog transplants as an important tool for rebuilding the Narragansett Bay quahog fishery (Ganz, 1987, Saila and Keller, 1992, Rice et al., 2000; Gibson, 2010). Analyses have indicated that up to 10% of the standing stock of quahogs could be sustainably relayed (transplanted) from areas closed due to bacterial pollution to areas that are open for harvest (Rice et al., 2000). Recent transplants have been to shellfish management areas, especially Greenwich Bay, to augment the winter fishery. Note that there is only one spawner sanctuary in the Bay, the Greenwich Bay spawner sanctuary, and transplants to this sanctuary have not been carried out in the last decade. Establishment of new spawner sanctuaries in the Bay and regular transplants to these carefully sited shellfish spawner sanctuaries may be an effective method of enhancing quahog larvae production and retention for increased quahog recruitment in important commercial harvest areas of the Bay (McManus et al., 2019).

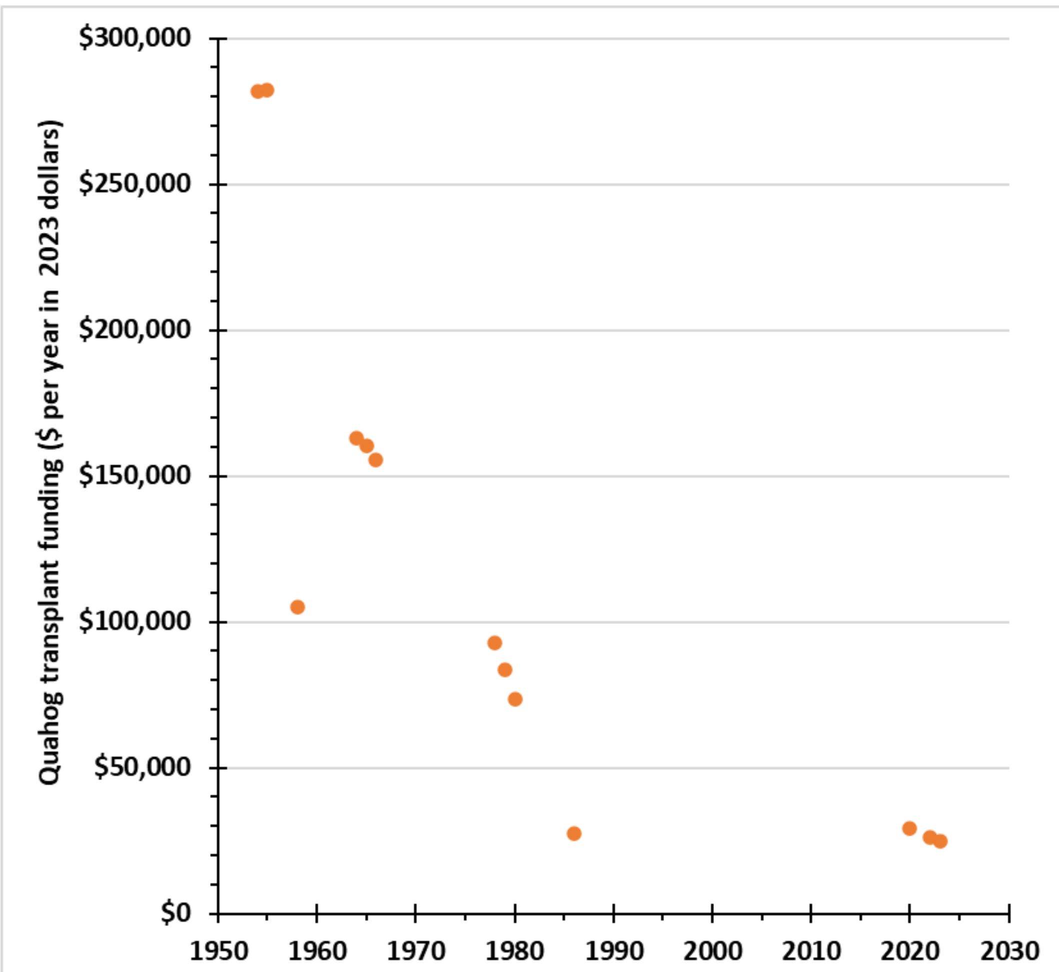

Figure 5: Estimated annual state expenditures (adjusted to 2023 dollars) for RI quahog transplants during 1950 to 2023. Source: Pratt, 1988, Pratt et al., 1992 and RI DEM.

3. WWTF Loadings

a. Nitrogen Loading

Since the early 1980s it has been documented that the health of Narragansett Bay north of Prudence Island and Greenwich Bay is negatively impacted by excessive nitrogen, which stimulates excessive phytoplankton and seaweed growth, decreases water clarity, and results in loss of seagrass habitat, poor benthic habitat, and low dissolved oxygen levels. The Comprehensive Conservation and Management Plan for Narragansett Bay summarized prior research and identified several management actions to reduce nitrogen and reduce chronic excess phytoplankton chlorophyll, improve water clarity, and increase dissolved oxygen (US EPA 1992; NBEP, 2012). To address these negative impacts to Upper Bay aquatic life from excessive nitrogen loadings, a goal of reducing RI WWTF loadings by 50% was adopted in the spring of 2004 by the Governor's Narragansett Bay and Watershed Planning Commission and signed into law during the 2004 legislative session (RIGL § 46-12-2(f)). Estimated nutrient reduction required to achieve acceptable Narragansett Bay eutrophication and dissolved oxygen improvements were based on studies conducted at the University of Rhode Island's Marine Ecosystems Research Laboratory (MERL; see Oviatt et al., 1986).

Based on these studies, 11 Rhode Island and 6 Massachusetts WWTFs were identified for seasonal (May through October) nitrogen reductions to make progress towards reducing acute summer hypoxia impacts in the Upper Bay. Changes were implemented through modification of the WWTF's discharge permits so that theses WWTFs have total nitrogen discharge limits ranging from 3.0 – 8.0 mg/L in effect from May to October. In addition, to prevent the accumulation of nitrogen in the Providence River/Upper Bay, although they don't have numeric nitrogen limits WTTFs must operate their facilities to reduce nitrogen discharges to the maximum extent practicable from November through April. Winter reductions vary greatly between WWTF facilities (Codiga, 2020). Between 2013 and 2016, the May – October nitrogen loads from the 11 RI and 6 MA WWTFs have been reduced 62-73% when compared to the early 2000s (pre-nitrogen reduction; Figure 6). These reductions coupled with other watershed loading changes which have reduced riverine N-loading resulted in an estimated 50% reduction in summer WWTF and riverine N-loading to Upper Narragansett Bay.

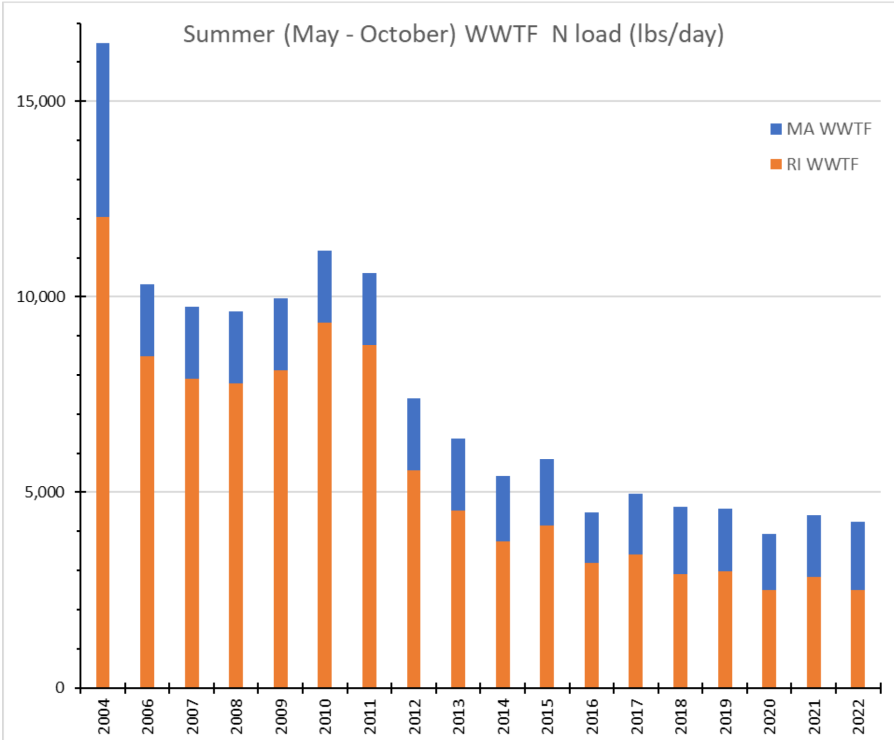

Figure 6: Estimated daily summer (May – October) nitrogen loading (in pounds per day) from RI and MA wastewater treatment facilities (WWTF) discharging to Narragansett Bay and rivers contiguous with the Bay during 2004 to 2022. Source: RI DEM Office of Water Resources.

Nitrogen rich bottom water that enters an estuary via estuarine circulation has long been known to contribute to enhanced primary production of estuaries (Riley, 1967). However, estimates of N-input to the Upper Bay from the coastal ocean south of the Bay are not as readily available as are WWTF and riverine N discharge data. Several estimates indicate that approximately 40-50% of the nitrogen supporting phytoplankton growth in the Upper Bay is transported up the East Passage into the Upper Bay from the coastal ocean. Limited nitrogen measurements and flow estimates made during the 1970s suggested that a sub-tidal mean flow of 1,040 m^3/s into the Bay delivered approximately 18% of Narragansett Bays N-budget from offshore dissolved inorganic nitrogen sources while particulate nitrogen from offshore was estimated to contribute approximately another 18% of the Bay N-budget (Kremer and Nixon, 1978, Nixon et al., 1995). Note that these estimates were made, during the 1970s, when the magnitude of WWTF and riverine N input to the Bay was elevated compared to the present day. More recent measurements based on in situ measurement of flow and N concentration at the mouth of the East Passage suggest that the amount of nitrogen delivered to the Upper Bay from offshore is much larger than earlier estimated values. Research by Dr. Chris Kincaid (URI-GSO; see 1/23/2024 presentation to the commission) indicates that sub-tidal flows into the Bay via the East Passage of up to 3,000 m^3/s were measured in 2018 – much larger than the previous 1,040 m^3/s estimate from the 1970s. Additionally, the natural topography of the Bay floor and dredged ship channels deliver a large proportion of this nitrogen rich (2 to 9 um nitrate concentration) bottom water to the Upper Bay 4-5 days after the water enters the East Passage. This offshore nitrogen supply is a dominant fraction of the nitrogen supporting Upper Bay phytoplankton blooms, with offshore nitrogen estimated to supply 40% to 50% of the nitrogen requirements of Upper Bay phytoplankton (Dr. Kincaid, presentation to the RI Legislative Commission on Quahogs, 1/23/2024).

Nitrogen discharged from WWTFs currently constitutes approximately 55% of the N-load to the Bay (NBEP 2017) and variation in weather (wet vs. dry years) and river flow is the dominant driver in interannual N- loading (Codiga et al., 2022). On an annual basis, mean bay-wide total nitrogen load from all sources after WWTF N-reduction (i.e., during 2013-2019) was 34% less than that experienced during the pre-reduction years 2005- 2012 (Codiga et al., 2022).

b. WWTF Chlorine Loading

The amount of chlorine discharged to the Bay via municipal WWTF effluent was brought up at multiple Commission meetings. Prior to 1999 RI municipal WWTFs discharged approximately 1,300 pounds of residual chlorine per day to RI waters. More efficient treatment processes incorporated at municipal WWTF in the late 1990s resulted in a dramatic decrease in municipal WWTF chlorine discharges. Subsequent reductions were achieved with alternative disinfection processes at the WWTFs (i.e., installation of dichlorination and/or UV disinfection). Today the daily residual chlorine load from municipal WWTFs is approximately 20 pounds per day, which is less than 2% of the amount released in the 1990s (Figure 7). Details of this reduction are in the document (RI DEM OWR, 2023) shared with the Quahog Commission.

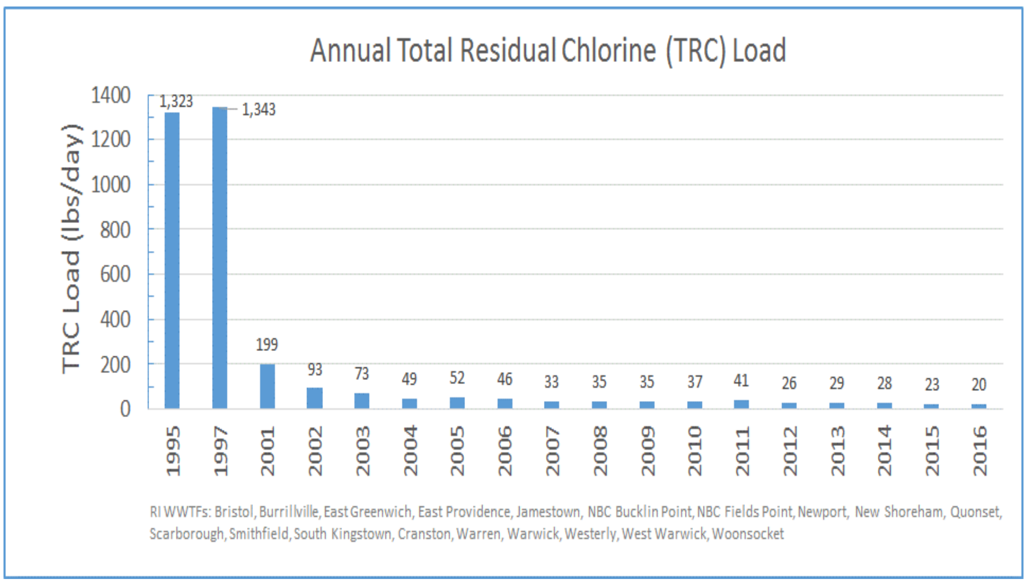

Figure 7: Estimated mean annual chlorine loading (in pounds per day) from RI wastewater treatment facilities (WWTF) discharging to Narragansett Bay and rivers contiguous with the Bay during 1995 to 2016. WWTF chlorine load during 2017-present was similar to that observed during 2010-2016. Source: RI DEM Office of Water Resources.

4. Climate Change

<u>Climate change, especially increased winter water temperature, has altered the ecology of Narragansett Bay</u> (Keller et al., 1999; Oviatt, 2004; Nixon et al., 2009). In general, the abundance and period of seasonal presence of cold-water species have declined and warm-water species have increased. Examples of these changes span all trophic levels from phytoplankton (Karentz and Smayda, 1998; Oviatt et al., 2002; Smayda et al., 2004; Canesi and Rynearson, 2016; Anderson et al., 2022; Thibodeau and Kim, 2023), zooplankton (Keller et al., 1999; Borkman et al., 2018), crustaceans (Huizenga and Oviatt, 2024), shellfish (Henry and Nixon, 2008), and finfish (Oviatt, 2004; Collie et al., 2008; Wood et

al., 2009). Predators, especially crabs, that feed on juvenile quahogs have increased in abundance as the Bay has warmed (Oviatt, et al., 2003; O'Connor, 2018). Increased predation has been suggested as a potential factor contributing to reduced quahog stocks in the Bay (Gibson, 1999). In addition to altering direct predation, these regional ecological changes (Mackenzie and Tarnowski, 2018) present at least two problems for sustaining a high biomass of quahogs in the Bay: 1) a decline in phytoplankton biomass and 2) a decline in benthic-pelagic coupling that formerly was an efficient mechanism for delivery of phytoplankton biomass from the water column to the benthos.

Declining phytoplankton biomass: Beginning in the 1980s, abundance of cold-water phytoplankton in the Bay has been declining (Smayda et al., 2004; Davis, 2013) and the abundance levels and seasonal bloom patterns of eurythermal phytoplankton species have also changed (Borkman and Smayda, 2009). Similarly, timing and abundance of zooplankton in Narragansett Bay have changed, with summer dominant species expanding their seasonal abundance into the winter (Borkman et al., 2018). Variability in the timing, magnitude, and duration of the winter-spring bloom in Narragansett Bay has been documented since the 1960s (Smayda, 1998). This variability includes at least a 10-fold variation in winter-spring phytoplankton bloom peak phytoplankton abundance and the failure of the winter spring bloom to form in some years (Smayda, 1998, Oviatt et al., 2002). In addition, there has been a post-1980s shift in the annual abundance peak of dominant phytoplankton species from a winter-spring to a summer peak (Smayda, 1998; Borkman and Smayda, 2009; Nixon et al., 2009). These shifts in phytoplankton bloom timing and magnitude have resulted in a long-term decline in phytoplankton biomass in the Bay (Li and Smayda, 1998; Nixon et al., 2009; Thibodeau and Kim, 2023) that began in the 1980s – well before recent N-reduction.

Declining benthic-pelagic coupling: Changes in phytoplankton abundance and bloom timing have contributed to a decline in the frequency, magnitude, and duration of the winter-spring diatom bloom that historically allowed the development of high biomass phytoplankton blooms during winter. In cool winters characteristic of the past, winter-spring phytoplankton biomass was not grazed in the water column but was deposited on the bottom of the Bay (Townsend et al., 1994; Keller et al., 1999). This deposited biomass served as food for benthic organisms, including quahogs, later in the spring when these organisms resumed feeding in response to the seasonal increase in water temperature. Experimental studies have indicated that approximately 75% of phytoplankton production is transferred from the water column to the benthos during cold winter conditions (0-4° C) while about half that amount, 36% of phytoplankton production, is transferred to the benthos during warm (4-8° C) winters. The frequency of warm winters with mean winter water temperature of greater than 4° C has increased from 20% of the time during the 1960s through 1980s, to 20-40% of the time during the 1990s through the 2010s. Each winter thus far in the 2020s (2020 through 2023) has had a winter water temperature of greater than 4° C (data from URI GSO Narragansett Bay Plankton Time Series). These warming-related changes appear to have contributed to a shift in quahog seasonal growth patterns that was first detected in the early 2000s (Henry and Cerrato, 2007; Henry and Nixon, 2008). Climate change induced declines in primary production and a decrease in benthic-pelagic coupling and deposition of phytoplankton biomass to the bottom have been documented in Narragansett Bay since the 1990s (Oviatt et al., 2002; Fulweiler et al., 2007; Nixon et al., 2009; Fulweiler and Hess, 2017).

The hypothesis that a chronic and modest increase in WWTF winter nitrogen loading will increase winter-spring phytoplankton abundance and increase quahog landings (Oviatt et al., 2022) ignores the fact that winter-spring phytoplankton bloom initiation, duration, and magnitude and mechanism that led to efficient benthic pelagic coupling in Narragansett Bay in the past are under multifactorial control. Riverine N-input is the dominant source of N to the Bay, with riverine N- loading that is about 1.7X the loading of WWTFs that discharge directly to the Bay (NBEP, 2017) and variation in wet vs dry weather is the main determinant of interannual N-loading to the Bay (Codiga et al, 2022). Consistent with this, extreme winter storm conditions that were associated with improved quahog landings in Narragansett Bay as described in Oviatt et al (2022) were acute major storm events that, in addition to delivering a pulse of N to the Bay, also altered freshwater delivery and stratification that are essential for the accumulation of winter-spring phytoplankton bloom biomass. In addition, warming has resulted in a decrease in the efficiency of benthic-pelagic coupling and delivery of winter-spring phytoplankton biomass to the benthos. As shown in the literature and in presentations to the Commission (Drs. Oviatt and Fulweiler presentations to the Commission on 11/15/2023), estuaries are dynamic, especially during a period of climate warming and alteration of a single factor, such as WWTF N-loading, is not likely to return an estuarine ecosystem to a previous state (Duarte et al., 2008). The proposed, but uncharacterized in magnitude, increase in winter WWTF N-loading to the Bay is not likely to result in a sustained return to conditions that promote efficient benthic-pelagic coupling and delivery of phytoplankton biomass to the benthos unless it is accompanied by changes in a suite of variables such as decreased winter water temperature, changes in water column stratification, and reductions in winter zooplankton grazing pressure.

5. Ocean Acidification

Concentration of CO_2 in the atmosphere has increased from approximately 315 parts per million ("ppm") in 1960 to approximately 420 ppm in 2023. Much of this CO_2 has been absorbed by the global ocean, resulting in an increase in ocean acidity that can result in dissolution of the calcium carbonate shells of marine organisms (Orr et al., 2005). In addition, seasonal hypoxic conditions can contribute to further increased acidity in estuarine bottom water (Wallace et al., 2014). Lab studies (Grear et al., 2020) and surveys conducted in Narragansett Bay during 2013 and 2017 to 2019 (Pimenta et al., 2023) demonstrated that hypoxic bottom conditions in upper Narragansett Bay were persistent in the late summer and autumn and that upper Bay bottom water was acidic enough to cause weakening of larval quahog shells due to dissolution (Pimenta et al., 2023;Grear et al., 2020; presentation by Dr. Jason Grear 1/23/2024). The long-term trend in increasing atmospheric CO_2 and increasing temperature, which decreases the oxygen saturation concentration of water resulting in further decreases in dissolved oxygen, are expected to contribute to increased bottom water acidity and greater potential for calcium carbonate shell dissolution, especially for larval and juvenile shellfish, in the upper Bay in the future.

6. Summary and Recommended Actions

Based on the above, it is clear that over the past decade more efficient wastewater treatment and stormwater controls have increased the rain closure thresholds for Area A and Area B, which resulted in a dramatic increase in the number of days per year that those areas are open for quahog harvest. It is also clear that improved wastewater treatment, including nitrogen reductions, have yielded benefits to the Bay (e.g., increased summer dissolved oxygen (Codiga et al., 2022), improved seagrass (Bradley et al., 2022), improved benthic habitat (Harkins, 2023), increased water clarity (NBEP, 2017), etc.). Although nitrogen is necessary for initiation and maintenance of phytoplankton blooms, increasing WWTF nitrogen discharges alone without accompanying changes in other variables, outside of the control of the State (e.g., freshwater input, wind direction and speed, water temperature), is not likely to result in the regular formation of large winter-spring diatom blooms. Therefore, increasing the WWTF nitrogen discharges is unlikely to increase the sustainable quahog yield, while likely to result in decrease water quality (e.g., lower dissolved oxygen, decreased water clarity, and reduced habitat quality). For these reasons, any permits that propose to increase WWTF nitrogen limits would not be supported by DEM and would be challenged by the Environmental Protection Agency.

Rhode Island quahog landings have been declining for many years and the DEM has previously made specific recommendations for the fishery's management (Gibson, 2010). Building on those recommendations, DEM has identified the following actions that would help bolster and sustain the States quahog fishery:

- Provide funding for regular quahog relays or transplants to shellfish management areas for stock augmentation.
- Establish additional spawner sanctuaries in the Bay and fund regular transplants to these spawner sanctuaries to enhance larval production.
- Develop a long-term quahog restoration plan for the Upper Bay. This plan could be modelled after work done in Long Island (see Gobler et al., 2022) and would include stock augmentation and reduced fishing effort in selected areas of the Bay to promote an increase in quahog density and an increase in quahog reproductive potential. Coupled biological-physical models of the Bay bolstered by field surveys should be used to identify areas of the Upper Bay that are the best candidates for restoration efforts to promote quahog larvae production and retention.
- Review current quahog harvest regulations and evaluate whether designation of Area A and Area B as shellfish management areas is appropriate.
- Study the possibility of funding, building, and operating a shellfish hatchery with the capacity to raise quahogs (and potentially other shellfish) for stock augmentation and shellfish restoration efforts. This study should include identification of potential hatchery location, construction costs, annual operation costs (including staffing), and potential funding streams to maintain long-term hatchery operation.
- Fund fixed site buoy network and nutrient monitoring to document changing environmental conditions in shellfish growing areas, which will provide data to support an analytical assessment of trends in water temperature, oxygen, pH, nutrient concentration, phytoplankton pigments on quahog growth and condition in the Upper Bay.
- Fund experimental and field studies to evaluate:
    - WWTF nitrogen loading and climate change impacts on Upper Bay ecology, especially formation of high biomass winter-spring bloom phytoplankton formation and effects on benthic-pelagic coupling.
    - The impact of reduced rain closure frequency and increased number of harvest days/year on the quahog stocks of the Upper Bay.
    - Quahog condition (pre- and post-spawning) in historically important harvest areas of the Bay. Regular evaluations of quahog condition should be completed to develop a time series of quahog condition that is suitable for quantitative analysis of effects of climate variability, nutrient loading, and other factors on quahog condition.
    - The distribution and fate of quahog early life stages in the Bay. Studies of the distribution and abundance of quahog larvae, quahog reproductive output, factors

associated with larval settlement selection and success. Studies identifying linkages between N-loading, temperature and quahog reproductive success, growth should be funded.

DEM looks forward to working with all relevant stakeholders to ensure that this critical resource is maintained in the State and is available to discuss any of the above recommendations.

Sincerely,

Terrence Grey, P.E.

Director

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