Technical Memorandum

FINAL

Water Quality Monitoring and Assessment of the Nantucket Island-Wide Estuaries and Salt Ponds Update 2018

To:

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From:

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Executive Summary

Water Quality Monitoring and Assessment of the Nantucket Island-Wide Estuaries and Salt Ponds

Update 2018

As in previous years, this annual Technical Memorandum summarizes the water quality monitoring results of the estuarine sampling undertaken through the ongoing Nantucket Island-wide Water Quality Monitoring Program. The program is multi-year collaboration between the Town of Nantucket Natural Resources Department and the Coastal Systems Program within the University of Massachusetts-Dartmouth, School for Marine Science and Technology. Water sample collection and analysis has been undertaken according to specific protocols developed at the outset of the monitoring first undertaken in 2010 such that year to year results would be cross comparable from one Nantucket estuary to another but also, so that Nantucket results would also be cross comparable to water quality data collected from other programs managed by the Coastal Systems Program (e.g. Cape Cod monitoring programs as well as Martha's Vineyard Island-wide monitoring program). The 2018 summary memo is focused specifically on the following: 1) Water Quality Results for Nantucket Harbor, Madaket Harbor, Long Pond, Hummock Pond, Miacomet Pond, Sesachacha Pond, Polpis Harbor Streams and Oyster Aquaculture Potential Sites**,** 2) Trophic State - Water Quality/Eutrophication Status and trends and 3) Recommendations for Future Monitoring**.**

The goals of the monitoring program remain unchanged from previous years, primarily to:

1. determine the present (2018) ecological health of each of the main salt ponds and estuaries within the Town of Nantucket,
2. gauge (as historical data allows, 2010-2018) the decline or recovery of various salt ponds and embayments over the long-term (also part of TMDL compliance), and
3. provide the foundation (and context) for development of potential alternatives for nutrient and resource management and quantitative measures of success.

Point (3) is critical for restoration planning should a system be found to be impaired or trending toward impairment, which requires targeted management actions for restoration or a system is improving due to Town actions which then should be improved/enhanced.

As was the case in 2010, 2012 - 2017 sampling efforts, the 2018 sampling program focused on the summer/early fall months (June - September) as this time frame is typically representative of worst case water quality conditions and the basis for habitat management decisions. Samples collected in 2018 were obtained from the same sampling station locations and the same depths as in previous years to maximize cross comparability and to gauge temporal changes. It should be noted that the Town of Nantucket did undertake water quality monitoring in 2011, however, those samples were analyzed by a lab other than the Coastal Systems Analytical Facility at the UMASS School for Marine Science and Technology and data was presented in the report on the 2012 monitoring effort.

The Town of Nantucket has been working for decades to protect and more recently restore its estuaries and their aquatic resources. At present and based on the 2010 - 2018 water quality database developed under the Island-wide unified water quality monitoring program, activities to lower nitrogen enrichment and its negative impacts to water and habitat quality have been planned and implementation is ongoing in 4 estuarine systems: Nantucket Harbor (jetties and sewers), Madaket/Long Pond (landfill and possible dredging), Sesachacha Pond (openings), Hummock Pond (refined opening protocol). In addition, all of the Town's estuaries should benefit from the recent fertilizer application by-law. As a result, it is anticipated that the efficacy of these management activities should be seen in the on-going monitoring results.

Summer 2018 appears to have sustained high water quality for the Nantucket Harbor and Madaket Harbor systems. In contrast, Hummock Pond water quality appears to have continued the decline started in 2016 which showed a decrease in overall water quality compared to 2015. The variations in TN levels results primarily from opening success. For instance, in spring 2017 the opening was only 1.5 days with high precipitation, although the spring opening in 2016 was comparable to the duration of the opening in 2015 (18 days and 15 days respectively). In contrast, Long Pond has continued to show declines in TN concentrations over historic levels with parallel improvements in water and habitat quality, although the inter-annual reductions appear to be stabilizing.

Miacomet Pond, which is now functionally a eutrophic freshwater pond, saw a slight improvement in 2017 as seen in lower TN concentrations and lower total pigments (CHLA + Pheophytin) but worsened again in 2018. Miacomet Pond in 2017 and 2018 as in 2016-2014 appears to have had phytoplankton production (e.g. chlorophyll-*a*) stimulated by both N and P inputs as pond salinities declined to present freshwater levels.

Water Quality in Sesachacha Pond appears to be directly related to the efficacy of its seasonal openings. Water quality in 2010, 2012, 2013 was significantly improved over the levels observed previously in the MEP analysis (November 2006). The lower TN levels in Sesachacha Pond (2010-2013) versus historic levels documented by the MEP indicated significant improvement of pond resources. Since there was no major shift in nitrogen loading within the Sesachacha Pond watershed during that period of improvement, it is almost certain that the amount of tidal flushing during a given artificial

breaching is driving the variability in the observed summer TN level. The rise in TN observed during the 2014 sampling suggests that a poor inlet opening may have occurred in spring 2014, as watershed loading was unchanged. Short openings in subsequent years (2015 {5 days}, 2016 {3 days}, 2017 {7 days}) suggests that inlet opening efficacy has a significant effect on pond water quality as TN concentrations from 2014 to 2017 have steadily increased to nearly the same level as when the MEP analysis was completed. However, the results indicate that the recent decline in water quality observed in Sesachacha Pond since 2014 should be readily reversible if sufficient flushing can be established.

The Trophic State of an estuary is a quantitative indicator of its nutrient related ecological health and is based on key ecological metrics: concentrations of inorganic and organic Nitrogen, water clarity (Secchi Depth), lowest measured concentrations of Dissolved Oxygen (average of lowest 20% of summer measurements), and Chlorophyll-*a* pigments (surrogate for phytoplankton biomass/blooms). Nutrient related trophic health scales generally range from Oligotrophic (healthy-low nutrient) to Mesotrophic (showing some signs of deterioration of health due to nutrient enrichment) to Eutrophic (habitats significantly impaired and degraded, high levels of nutrients and organic matter and community shifts).

Nantucket Harbor (with Madaket Harbor) is presently supporting the highest water quality of Nantucket's estuaries. In 2018, all of the Nantucket and Polpis Harbor monitoring stations were showing high water quality, slightly better than in 2017 Over the past 5 years, the main basin of Nantucket Harbor has supported high quality waters, with only a periodic small level of decline in the uppermost basin, Wauwinet basin. Summer 2017 saw a slightly lower TN level at station NAN-2A (MEP sentinel station) and 2018 lower still. Summers 2016-2018 generally showed similar water quality in this basin as 2014 which also showed improved chlorophyll-*a* and TN levels versus prior years. Nutrient management activities associated with the Harbor (additional sewer hookups, jetty improvement and oyster aquaculture) should result in even lower TN and chlorophyll levels and reduce the likelihood of large phytoplankton blooms in the future.

Polpis Harbor basins which after showing moderate impairment in 2010 and 2012 have been showing only low to no impairment in recent years, suggesting some improvement over historic conditions. Polpis Harbor showed 2018 & 2017 TN levels similar to 2010, 2012 and 2015, slightly higher than 2013 and 2014. This variation makes continued monitoring essential to clarify any trends in water quality and linkages to stream nitrogen discharges. While the overall Nantucket Harbor System is generally supporting high quality waters, the variability in the index in Wauwinet and Polpis basins should be monitored to ascertain their long-term health and to determine the effectiveness of restoration effort by the Town as it continues to move forward to meet the MassDEP TMDL for this system. Overall, Nantucket Harbor appears to be relatively stable from year to year with a gradual slight improvement with high index scores and higher level metrics that support the contention that it is approaching its TMDL threshold, as is also the case for Polpis Harbor. Planned sewering within the Nantucket watershed should complete the restoration on nitrogen mitigated impairment within this estuarine system

Madaket Harbor main basin in 2018 continued to support a high level of nutrient related water quality. It has been the more enclosed basins of Hither Creek and Long Pond with their reduced tidal flushing that have had nitrogen impairment problems. Over the 8 years of monitoring, Hither Creek (Station 1), which receives discharge from Long Pond via Madaket Ditch, has consistently supported the poorest "health" status within the Madaket Estuary. Hither Creek is clearly nitrogen enriched and showing continuing impairment based on a variety of parameters, but has clearly improved since 2010. Over the past 8 years the Trophic Index indicates that this basin has improved slightly each year, going from fair-poor water quality and improving in a step-wise manner to moderate water quality since 2014 with the exception of 2017 where TN levels rose, but stayed within the range that has developed over the past 4-5 years. The main basin of Madaket Harbor is showing relatively high water quality in each year but also shows a possible improvement from 2010 to 2012 and has been generally stable at high water quality in more recent samplings to 2018.

Long Pond is a large tributary basin to Madaket Harbor, which receives tidal flow through the artificial connection of Madaket Ditch. Given the structure of the basin and its watershed, Long Pond operates semi-independently from Madaket Harbor. Long Pond's Trophic Index scores for both monitoring stations (5 & 6) in the 8 years of monitoring (2010, 2012-2018) clearly indicate poor nutrient related water quality. However, based upon the 2018 results and the 8-year time-series, it appears that the Town's management of the landfill, has reduced the nitrogen load from this source with the associated observed lowering of TN levels. While the water quality Index for Long Pond is starting to improve in response to the lower TN levels, the basin remains moderately impaired. While continued monitoring will determine the final level of improvement, it does appear that the reduction in N loading is occurring with beneficial effects. It should be noted that the lack of major change in the Health Index for Long Pond results in part from the relative coarseness of the Index, where sometimes large index score changes are required to change the Index value. The analysis of key metrics (Chlorophyll-*a*, water clarity-Secchi and total nitrogen) individually do show improving water quality at stations 5 and 6 in 2012-2018 compared to 2010 and in the MEP threshold analysis and a recent Town supported benthic animal analysis parallels the water quality improvements.

Sesachacha Pond is a closed coastal salt pond that has its water quality managed by periodically breaching the barrier beach to open the basin to tidal exchange with the adjacent Atlantic Ocean waters. Sesachacha Pond was evaluated under the Massachusetts Estuaries Project (MEP) which recommended an additional mid-summertime opening (if logistically possible) as part of the pond management strategy to enhance flushing of the pond and improve water quality to reach the threshold without any need for infrastructure. The water quality monitoring program in 2010, 2012 and 2013 showed that the pond nitrogen levels were converging on the MEP Threshold (0.60 mg/L total nitrogen). Improved openings resulted in total nitrogen (TN) levels dropping significantly from historical levels in 2010 and 2012 with associated improvements in the levels of water clarity and chlorophyll-*a*. However, with limited openings in 2014-2017, TN has risen and has returned to near historic levels (~0.9 mg/L), with an

improvement in 2018 (0.752 mg N/L), and with continuing impaired conditions. It appears that these changes relate to the quality of the pre-summer opening. Given the 2010-2013 period when robust openings occurred, it appears that a solid opening program has the capability to improve the water quality metrics pond-wide to levels near the TMDL nitrogen threshold.

Based upon the Index alone, changes in water quality in Sesachacha Pond over the 2010-2013 period were stabilized at moderate impairment of this estuary, with more recent monitoring 2015-2017 seeing a trend toward poor water quality conditions with a slight rebound in 2018 as TN levels rose (2015-2017) then declined (2018). It appears that like other periodically opened ponds, the quality of the opening (amount of water exchanged) controls the level of water quality in the following months. A closer examination of the opening protocol and the linkage to resultant water quality is needed for management of this system.

Hummock Pond is a closed coastal salt pond that is only periodically opened to the ocean to flush out nutrients and organic matter on the ebb tide and receive low nutrient saline waters on the flood tide. Creating sustained openings that are sufficient to allow exchange of tidal waters for more than 4-5 days has been difficult for this system due to its location on the coast and the large amount of sand migration in the coastal zone which can rapidly reseal the inlet.

The present non-tidal state and level of watershed nutrient inputs have resulted in moderate to poor nutrient related water quality throughout the pond, with poor water quality conditions the present norm (2005-2007, 2010, 2012, 2013, 2014, 2015). Unfortunately, in 2016 the pond appears to have had lower water quality in its upper and mid reaches than in previous years, although the lower basin did not show this inter-annual variation. Similarly, in 2017 and 2018 water quality declined even further throughout most of the estuary, including the lower basin. This resulted from the poor spring 2017 and 2018 openings. There is generally a small gradient in water quality with moderate to poor conditions near the ocean and poor conditions in the uppermost basins, but this collapsed to generally poor water quality throughout the system in 2017 and 2018. All of the metrics are consistent with a nutrient impaired basin in all years. Based upon the monitoring results it is clear that the nutrient related health of Hummock Pond is significantly related to the success of its periodic openings and that the pond is presently significantly impaired by nitrogen enrichment.

Miacomet Pond is a closed coastal salt/fresh pond that is rarely (over a decade ago) opened to the ocean to flush out nutrients and organic matter on the ebb tide and receive low nutrient saline waters on the flood tide. As a result of the lack of tidal flow and continuous groundwater inputs, the pond is presently freshwater, with salinity levels in each of the past 7 years of monitoring of <0.5 ppt, reaching a low of 0.1 ppt, 2015-2017. The present non-tidal state and extent of watershed nutrient inputs has resulted in a decline in nutrient related water quality throughout the pond for both nitrogen and phosphorus, with poor water quality and habitat impairment the present norm. All of the metrics for Miacomet Pond are consistent with a highly nutrient impaired basin.

However, as the freshening of this basin has become complete and sustained, it likely will have to be managed as a transitional freshwater system and will need to be reassessed as such. Since Miacomet Pond may have storm over-wash in the future due to climate change related storm intensification and sea level rise, it may be necessary for management to create both a nitrogen and a phosphorus budget for this system and to conduct short-term incubations to determine which nutrient is controlling pond health under present and varying salinity conditions. It is likely that regions of the pond may be sensitive to both nitrogen and phosphorus, such that overall both nutrients need to be monitored and considered for management of Miacomet Pond, although phosphorus management is clearly needed at this time.

Table ES-1. Summary of present status and trends of water/habitat quality of estuaries of Nantucket based on present (2018) water quality monitoring data reconciled against historic data collected from 2010-2017 and MEP nutrient threshold analyses undertaken for each system except Miacomet Pond.

Summary of Present Status and Trend of Water Quality in Nantucket's Estuaries					
Estuary	**Type**	**TMDL**	**Status**	**Trend**	**Remedial Actions**
Madaket Harbor	Marine	In Place	Approaching N Target	Improving	Landfill Remediation
Long Pond	Brackish	In Place	Approaching N Target	Improving	Landfill Remediation
Nantucket Harbor - Polpis Harbor	Marine	In Place	Approaching N Target	Improving	New Jetties, Planned Sewers
Sesachacha Pond	Brackish	In Place	Moderate Improvement	Variable	Targeted opening
Hummock Pond	Brackish/Fresh	In Place??	Significantly Impaired	Variable	Targeted opening
Miacomet Pond	Fresh	None	Significantly Impaired	Unchanged	Unknown

The Technical Memorandum on the 2018 Nantucket Water Quality Monitoring Program is organized consistent with previous SMAST water quality monitoring summaries (2010 and 2012 - 2017) to allow direct comparison to data from the previous years of monitoring. The tech memo does include summary tables for each year of the program so that this can be used as a both the 2018 review and a program summary. As was the case with the 2017 summary, the 2018 summary does not include an overview of the program or the summary of the sampling approach as neither of those two sections have changed from previous years, instead they are included by reference. The 2018 summary is focused specifically on the following:

1. Results of Sampling: Summary of Water Quality Results

    Nantucket Harbor
    Madaket Harbor
    Long Pond
    Hummock Pond
    Miacomet Pond
    Sesachacha Pond
    Polpis Harbor Streams
    Oyster Aquaculture Potential Sites

2. Trophic State: Water Quality/Eutrophication Status

3. Recommendations for Future Monitoring

As in previous years, the 2018 water quality monitoring of Nantucket's fresh and saltwater systems was focused on summer-time conditions, as the warmer months typically have the lowest water quality conditions, hence are critical period for resource management. As in previous years (2010, 2012-2017), the 2018 approach utilized for the collection and analysis of water samples from each of the estuaries of Nantucket remains the same. This consistency is intended to maximize the value of the results by making the data perfectly cross-comparable to water quality monitoring data collected across the Island of Nantucket from previous years and to previous Massachusetts Estuaries Project results for Nantucket estuaries as well as more broadly to estuaries throughout the region (Cape Cod, Martha's Vineyard). In this manner, inter-ecosystem comparisons can be made to better assess system health/impairment and function and to formulate appropriate nutrient management strategies. This allows individual towns such as Nantucket to directly benefit from lessons learned throughout the wider region. It should be noted that in 2018 (as was the case in 2017), compliance monitoring samples were collected from sentinel locations in Nantucket Harbor, Sesachacha Pond and Madaket Harbor as established under the Massachusetts Estuaries Project. Those samples are required of the Town by MassDEP and are denoted by a (C) in the sample ID.

As in past years, UMD-SMAST Coastal Systems Program (CSP) scientists focused primarily on the analysis of samples collected from the field effort, data analysis and overall program coordination. The Nantucket Natural Resources Department staff

primarily focused on coordination of field efforts, field sampling and data collection on physical parameters and water quality improvement efforts.

The goals of the monitoring program remain unchanged from previous years, primarily to:

4. determine the present (2018) ecological health of each of the main salt ponds and estuaries within the Town of Nantucket,

5. gauge (as historical data allows) the decline or recovery of various salt ponds and embayments over the long-term (also part of TMDL compliance), and

6. provide the foundation (and context) for development of potential alternatives for nutrient and resource management and quantitative measures of success.

This latter point (3) is critical for restoration planning should a system be found to be impaired or trending toward impairment, which requires targeted management actions for restoration.

As was the case in 2010, 2012 - 2017 sampling efforts, the 2018 sampling program focused on the summer/early fall months (June - September). In addition to the standard estuarine sampling, in the 2016 sampling season 2 additional sampling events were completed in Sesachacha Pond to monitor the efficacy of the spring opening (breaching barrier beach) and in Hummock Pond an additional event was completed in April to represent pre-opening conditions and the regularly scheduled May sampling event was utilized to determine water quality in the pond after the pond closed. Monitoring of the openings of Sesachacha Pond and Hummock Pond were NOT continued in 2017 and 2018.

Water samples were collected from 6 estuarine systems (Figures 1, 2, 3, 4 and 5) on multiple dates ("events") following the schedule presented in Table 1a (2018), Table 1b (2017), Table 1c (2016), Table 1d (2015), Table 1e (2014), Table 1f (2013). Table 1g (2011) and Table 1h (2010). Samples collected in 2018 were obtained from the same sampling station locations and the same depths as in previous years to maximize cross comparability and to gauge temporal changes. It should be noted that the Town of Nantucket did undertake water quality monitoring in 2011, however, those samples were analyzed by a lab other than the Coastal Systems Analytical Facility at the UMASS School for Marine Science and Technology. The 2011 water quality data were presented in tabular form in Appendix A in Annual Technical Memoranda of 2012 and 2013 and are not being reproduced again herein.

As in all previous years, the physical/environmental parameters measured in the estuaries during the 2018 sampling season included: total depth, Secchi depth (light penetration), temperature, conductivity/salinity (YSI meter), general weather (rain, cloudiness, etc), wind force and direction, dissolved oxygen levels and observations of moorings, birds, shell fishing and unusual events (fish kills, algal blooms, etc). Laboratory analyses of estuarine waters included: salinity, nitrate + nitrite, ammonium, dissolved organic nitrogen, particulate organic carbon and nitrogen, chlorophyll-*a* and

pheophytin-*a* and orthophosphate. As initiated in the summer of 2015, the estuarine water quality monitoring undertaken in 2016, 2017 and 2018 included an additional 3 stream locations. During the summer 2016 season, stream station STA-3 was dropped due to no flow and a station STA-4a was added to clarify water quality conditions in the stream outflow associated with cranberry bogs up-gradient of STA-4. In 2017 a fourth stream station was added (WPH outlet) to directly measure flow and nutrient load into Western basin of Polpis Harbor. In total, 2018 stream sampling took place at 4 stations: STA-4, STA-4A, STA-6 and WPH outlet.

In 2018, 24 field duplicates (11% of the total number of samples collected {n=225}) were taken as part of the field sampling protocol for QA analysis. Data were compiled and reviewed by the laboratory for accuracy and evaluated to discern any possible artifacts caused by improper sampling technique, physical disturbance, etc. In addition, some samples were rerun to confirm prior results.

The Town of Nantucket has been working for decades to protect and more recently restore its estuaries and their aquatic resources. At present, activities to lower nitrogen enrichment and its negative impacts to water and habitat quality are ongoing in 4 estuarine systems: Nantucket Harbor (jetties and sewers), Madaket/Long Pond (landfill and possible dredging), Sesachacha Pond (openings), Hummock Pond (refined opening protocol). In addition, all of the Town's estuaries should benefit from the recent fertilizer application by-law. As a result, it is anticipated that the efficacy of these management activities should be seen in the on-going monitoring results.

As detailed below, summer 2018 appears to have sustained high water quality for the Nantucket Harbor system (2018 embayment wide TN average of 0.31 mg/L, 2017 = 0.35 mg/L, 2016 = 0.35 mg/L, 2015 = 0.37 mg/L). In contrast, Hummock Pond water quality appears to have continued the decline started in 2016 which showed a decrease in overall water quality compared to 2015 (2018, 2017 and 2016 embayment wide average TN levels remain high at 0.83, 1.01 and 0.80 mg/L (respectively vs 2015 = 0.58 mg/L). The variations in TN levels results primarily from opening success for instance in spring 2017 the opening was only 1.5 days with high precipitation, although the spring opening in 2016 was comparable to the duration of the opening in 2015 (18 days and 15 days respectively). Long Pond TN concentrations have improved over historic levels although the reduction appears to be stabilizing (0.587 mg/L in 2018). Miacomet Pond, which is now functionally a eutrophic freshwater pond, saw a slight improvement in 2017 as seen in lower TN concentrations and lower total pigments (CHLA + Pheophytin). Water Quality in Sesachacha Pond appears to be directly related to the efficacy of its seasonal openings. Water quality in 2010, 2012, 2013 (mean TN = 0.671 mg/L, Chla = 5.5 ug/L) was significantly improved over the levels observed previously in the MEP analysis. The lower TN levels in Sesachacha Pond (2010-2013) versus historic levels documented by the MEP indicated improvement of pond resources most likely due to modified breaching of the pond as recommended by the MEP analysis. Since there was no major shift in nitrogen loading within the Sesachacha Pond watershed during that period of improvement, it is almost certain that the amount of tidal flushing during a given artificial breaching is driving the variability in the observed summer TN level. The rise in TN observed during the 2014 sampling suggests that a poor inlet opening may have occurred in spring 2014, as it is unlikely a significant change in the watershed load

occurred to drive the increase in TN from one summer to the next. Short openings in subsequent years (2015 {5 days}, 2016 {3 days}, 2017 {7 days}) suggests that inlet opening efficacy has a significant effect on pond water quality as TN concentrations from 2014 to 2017 have steadily increased to nearly the same level as when the MEP analysis was completed. In recent years (2014-2017) water quality has declined (mean TN = 0.933 mg/L, Chla = 8.4 ug/L) and is again approaching MEP levels of enrichment. The amount of flushing with the openings is reflected in the significantly higher salinities in 2010-2013 versus 2014-2017, 17.9 PSU and 11.6 PSU, respectively. Higher salinities reflect more flushing which is correlated with lower TN and total chlorophyll a levels. The 2016 water quality analysis confirmed that the significant improvement in Sesachacha Pond seen previously had diminished and the Pond has declined in nitrogen related water quality over the past 4 years (2014-2017) almost certainly due to the quality of the inlet openings. The important role of the pond openings is further supported by the fact that average TN concentration in Sesachacha Pond was higher (1.00 mg/L TN) in 2016 which received a 3 day opening compared to average TN concentrations observed in 2017 (0.88 mg/L TN) given a 7 day opening. These results indicate that the recent decline in water quality observed in Sesachacha Pond since 2014 should be readily reversible if sufficient flushing can be maintained. The effect of improved pond flushing is discussed in detail in the MEP Sesachacha Pond Nutrient Threshold Report submitted to the Town of Nantucket in 2006.

Table 1a. Sampling Schedule for 2018 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond	Polpis Streams	Oyster Sites
Jan								
Feb								
Mar								
April							April 25	
May								
June	June 5	June 7	June 13	June 11	June 11	June 13	June 6,26	June 5
July	July 5	July 2	July 17	July 10	July 10	July 17	July 24	July 5
August	August 1	August 2	August 8	August 14	August 14	August 8	August 21	August 1
September	Sept. 12	Sept. 13	Sept. 5	Sept. 4	Sept. 4	Sept. 5		Sept.12
October								
November								
December								
Total Events	**4**	**4**	**4**	**4**	**4**	**4**	**5**	**4**

Table 1b. Sampling Schedule for 2017 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond	Polpis Streams	Oyster Sites
Jan								
Feb							February 8	
Mar				March 30		March 29	March 27	
April							April 27	
May	May 18	May 16	May 10	May 4	May 4	May 3	May 23	May 17
June	June 14,29	June 27	June 13	June 22	June 19		June 12	June 14
July	July 12,27	July 11	July 10	July 6,31	July 6	July 10	July 5	July 12
August	August 10,24	August 9	August 7		August 3	August 7	August 15	August 10
September	Sept. 25	Sept. 12	Sept. 27	Sept. 5	Sept. 5	Sept. 13	Sept. 11	Sept.25
October							Oct. 24	
November								
December								
Total Events	**8**	**5**	**5**	**6**	**5**	**5**	**9**	**5**

Table 1c. Sampling Schedule for 2016 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond	Polpis Streams	Oyster Sites
Jan								
Feb								
Mar							March 16	
April				April 6,25		April 11	April 20	
May	May 9	May 11	May 12	May 18	May 18	May 10	May 17	May 12
June	June 8, 23	June 7	June 6	June 15	June 15	June 13	June 14	June 27
July	July 8, 25	July 6,28	July 13	July 5,18	July 5	July 13	July 21	July 11
August	Aug 8,23	Aug 10,24	Aug 4	Aug 3	Aug 3	Aug 4		Aug 25
September	Sept 21	Sept 22	Sept 19	Sept 12	Sept 13	Sept 19		Sept 20
October								
November								
December								
Total Events	**8**	**7**	**5**	**8**	**5**	**6**	**5**	**5**

Table 1d. Sampling Schedule for 2015 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond	Polpis Streams	Oyster Sites
Jan								
Feb								
Mar								
April								
May	May 7		May 12	May 11	May 11	May 12, 27		
June	June 9, 22	June 8	June 17	June 15	June 15	June 17	June 8	June 9
July	July 8, 20	July 6	July 13	July 15	July 15	July 13	July 6	July 6
August	Aug 4,19	Aug 5	Aug 17	Aug 10	Aug 10	Aug 12	Aug 3, 31	Aug 3
September	Sept 1	Sept 3	Sept 14	Sept 10	Sept 10	Sept 9		Sept 2
October								
November								
December								
Total Events	**8**	**4**	**5**	**5**	**5**	**6**	**4**	**4**

Table 1e. Sampling Schedule for 2014 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond
Jan						
Feb						
Mar						
April						
May	May 6		May 14	May 20	May 14	May 7, 19
June	June 4, 17	June 19	June 11	June 12	June11	June 10
July	July 1, 17	July 2	July 23	July 30	July 30	July 23
August	Aug 4, 14	Aug 18	Aug 21	Aug 19	Aug 19	Aug 21
September	Sept 2, 15*	Sept 15	Sept 4	Sept 4	Sept 18	Sept 18
October						
November						
December						
Total Events	**8**	**4**	**5**	**5**	**5**	**6**

Note: * The September 15 sampling of Nantucket Harbor only involved one station (NAN-4).

Table 1f. Sampling Schedule for 2013 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond
Jan						
Feb						
Mar						
April						
May		May 28		May 22	May 22	May 21
June	June 13, 25	June 12	June 4,26	June 5	June 5	June 6
July	July 17, 30	July 16	July 10	July 9	July 9	July 2
August	Aug 13, 28	Aug 12	Aug 21	Aug 21	Aug 6	Aug 14
September	Sept 9	Sept 10	Sept 24	Sept 19	Sept 24	Sept 18
October						
November						
December						
Total Events	**7**	**5**	**5**	**5**	**5**	**5**

Table 1g. Sampling Schedule for 2012 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond
Jan						
Feb						
Mar						
April						
May	May 29					
June	June 7, 28	June 12	June 25	June 20	June 20	June 27
July	July 9, 26	July 11	July 24	July 19	July 19	July 31
August	Aug 7, 22	Aug 8	Aug 21	Aug 23	Aug 23	Aug 24
September	Sept 6	Sept 7	Sept 25	Sept 25	Sept 27	Sept 26
October						
November						
December						
Total Events	**8**	**4**	**4**	**4**	**4**	**4**

Table 1h. Sampling Schedule for 2010 Nantucket Water Quality Monitoring Program

Month	Nantucket Harbor	Madaket Harbor	Long Pond	Sesachacha Pond	Miacomet Pond	Hummock Pond	Streams
Jan							
Feb							
Mar							
April							
May	May 18	May 20	May 19	May 26	May 26	May 25	
June	June 2, 17	June 3, 15	June 17	June 24	June 24	June 29	June 28
July	July 1, 15, 30	July 16, 27	July 29	July 26	July 26	July 28	
August	Aug. 13	Aug. 12, 30	Aug. 11	Aug. 26	Aug. 26	Aug. 27	
September	Sept. 1, 14	Sept. 13	Sept. 15	Sept. 23	Sept. 23	Sept. 28	
October	Oct. 21						
November							
December							
Totals	**10**	**8**	**5**	**5**	**5**	**5**	**1**

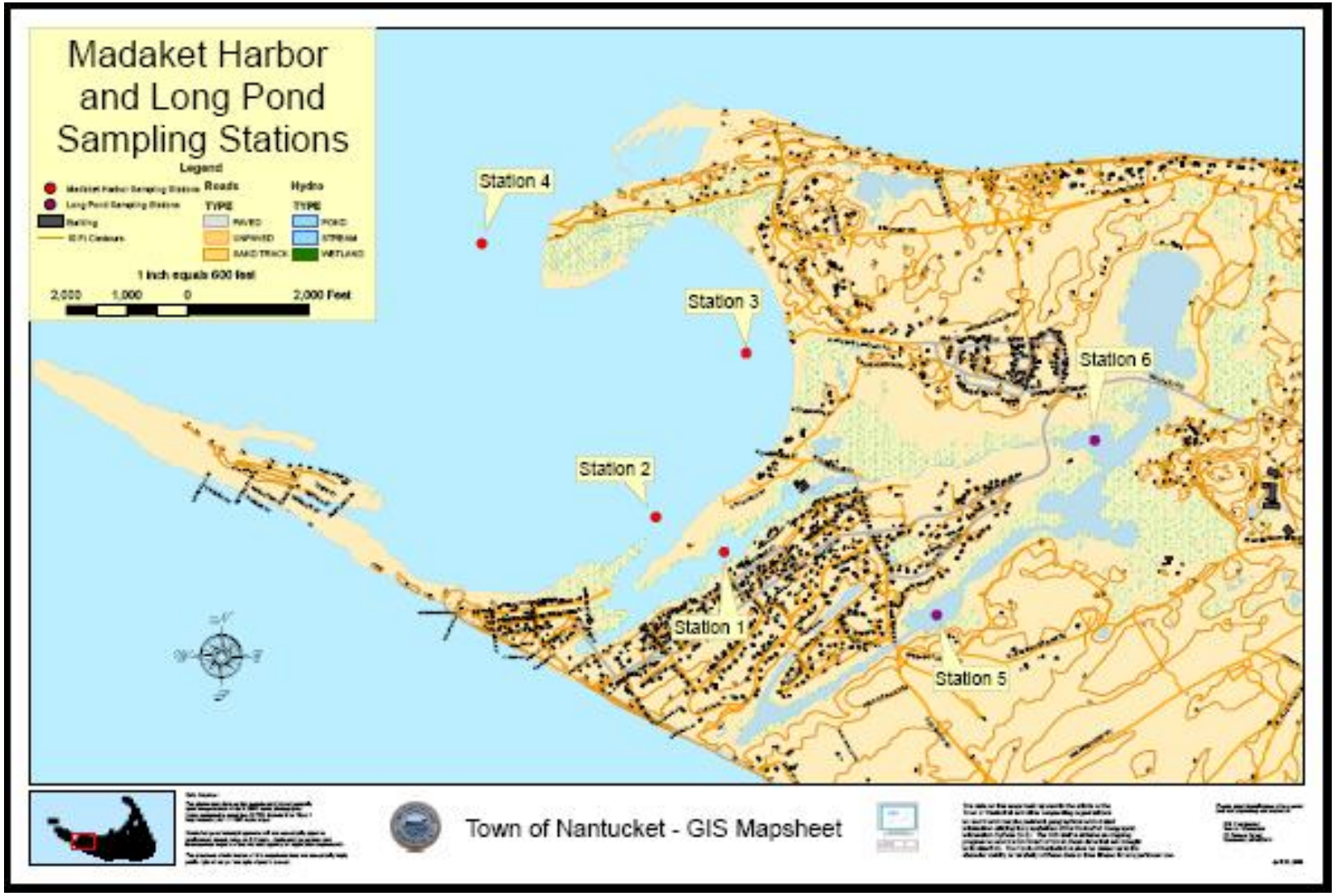

Figure 1. Madaket Harbor and Long Pond sampling stations 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018.

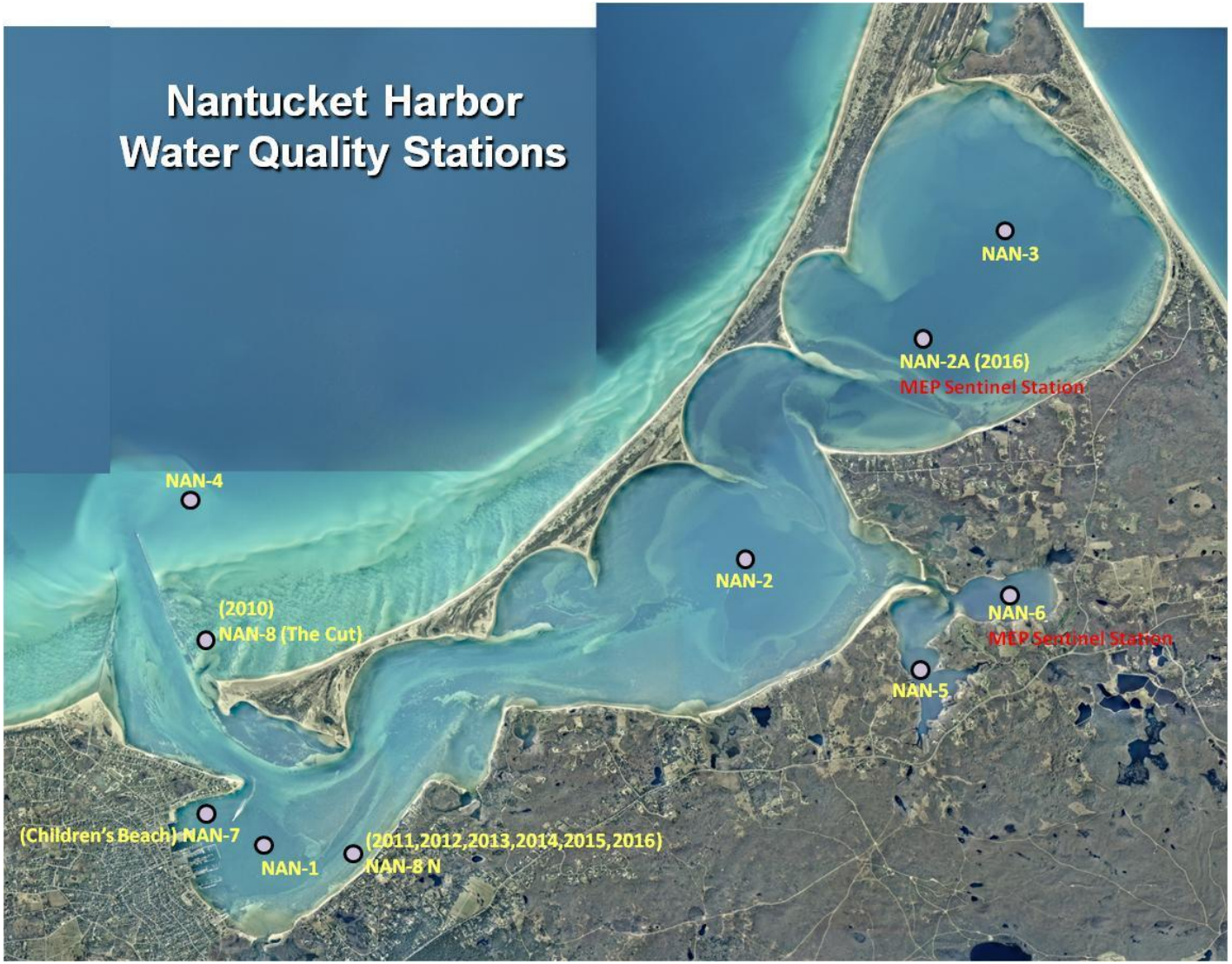

Figure 2. Nantucket Harbor sampling stations 2018. Station NAN-8 (the cut) was only sampled in 2010 and location changed in 2011 - 2018. Nantucket Harbor and Polpis Harbor each have nitrogen thresholds in the MassDEP/USEPA TMDL for this system.

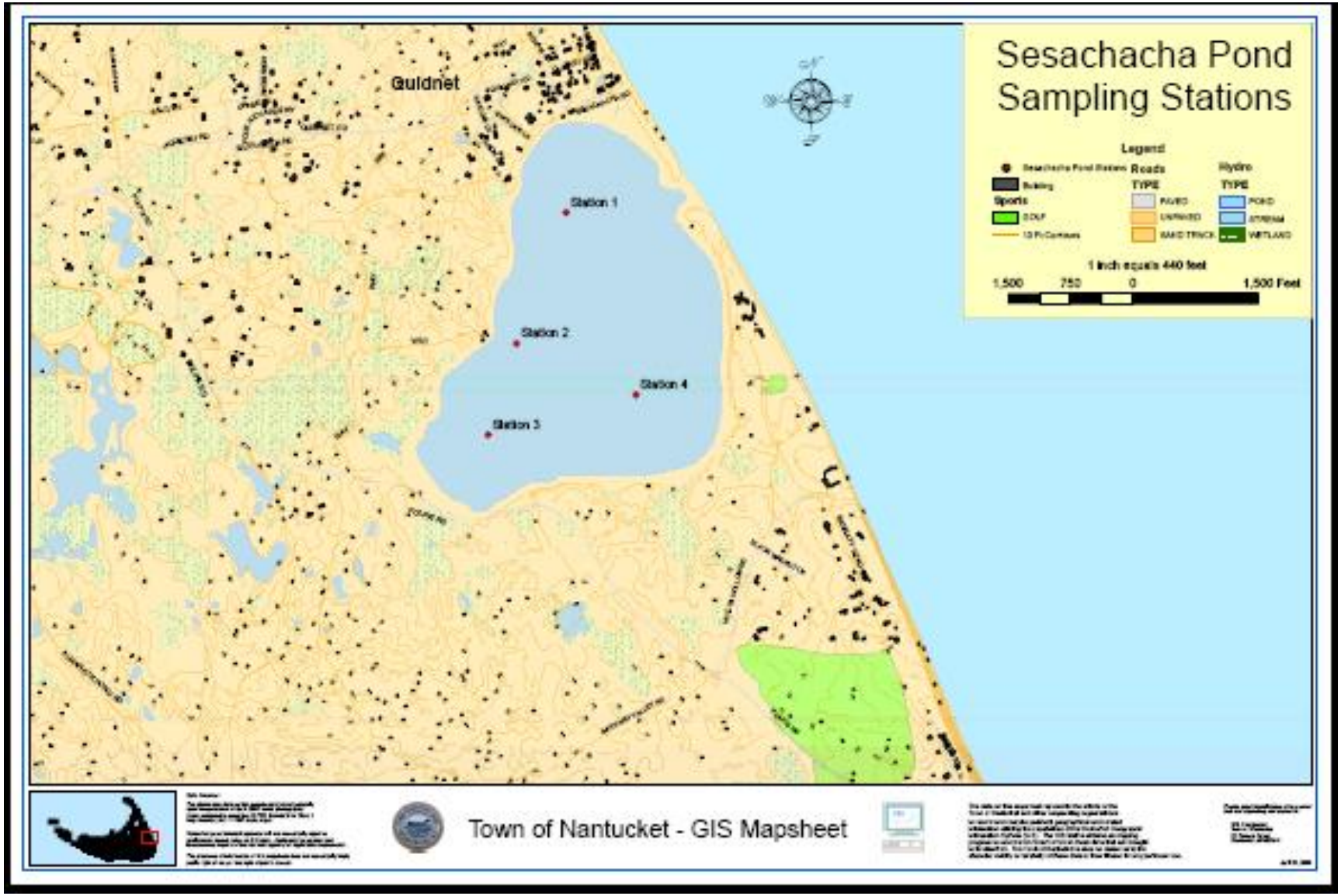

Figure 3. Sesachacha Pond sampling stations 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018. This system has a nitrogen threshold set in its site-specific MassDEP/USEPA TMDL..

Figure 4. Hummock Pond sampling stations 2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018. Station 7 is in Head of Hummock, a kettle pond connected by an artificial channel to the estuary with limited exchange from Station 7 to Station 8.

Figure 5. Miacomet Pond sampling stations 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018. Miacomet Pond is currently functioning as a fresh pond.

Figure 6. Polpis Harbor Stream Sampling locations (ST-4, 4A, 6B and WPH-outlet). Stream sites sampled in 2016 and 2017 (shown as yellow pins). WPH-outlet sampled only in 2017 and 2018. Water samples from mid depth in water exiting culverts.

Figure 6a. Polpis Harbor Stream Sampling locations (ST-4, 4A, 6B and WPH-outlet) relative to estimated direction of flow as determined by the Town of Nantucket.

Figure 6b. Polpis Harbor Stream Sampling locations (ST-4, 4A, 6B) 2016 (shown as yellow pins). Water samples from mid depth in water exiting culverts.

Figure 6c. Polpis Harbor Stream Sampling locations (ST-3,4,6B) 2015 (yellow pins). Water samples from mid depth in water exiting culverts. ST-3 was dropped in 2016 due to zero flow.

Figure 7a. Sampling locations associated with potential oyster aquaculture deployments in Nantucket Harbor (ORS-2,3,4,5,6) and Madaket Harbor (ORS-1) sampled in 2015. ORS-2,4,6 sampled in 2016, 2017 and 2018. Sites are associated with possible oyster aquaculture areas (yellow pins). ORS4 was the selected reef location and reef construction began in June 2017. Spat on shell was deployed in the Fall 2017.

Figure 7b. Oyster Aquaculture Sampling location Madaket Harbor (ORS-1) 2015 (yellow pin). Site is associated with possible oyster aquaculture areas but was not sampled in 2016, 2017 or 2018.

Summary of 2018 Water Quality Results for Nantucket Sampling

Estuarine Water Quality: While there were some localized areas supporting inter-annual variation in water quality (Hummock Pond {-}, Miacomet Pond {-}, Nantucket Harbor {+}[1], see below), the overall trends in water quality observed in 2018 follow and expand the pattern observed in previous years. As in previous years, water samples collected from June through September in the estuarine systems indicate that organic nitrogen (dissolved + particulate) dominates the Total Nitrogen pool (99%-89% in 2018, 86%-99% in 2017 depending on the estuary vs. 92-98% in 2016 and 96% in 2015 alone), while bio-available nutrients in the form of nitrite+nitrate (NOx) and ammonium (NH_4) (combined DIN) in estuarine waters account for 1% - 10% in both 2018 and 2017 compared to 2% - 10% of the TN pool in 2016 and 4% of Total Nitrogen pool in 2015 (Tables 3a-h and Figures 15,16). Only the uppermost reach of Hummock Pond (salinity 2 ppt) had a slightly higher proportion inorganic nitrogen, likely due to its nearly freshwater status. The observed distribution of the nitrogen fractions comprising total nitrogen are typical for estuarine systems throughout New England, where nitrogen is the nutrient responsible for eutrophication and therefore the critical nutrient for management.

It is the uptake of bio-available nitrogen, entering via groundwater to estuarine waters, primarily by phytoplankton that is transforming inorganic to organic nitrogen forms and under nitrogen enrichment is the mechanism through which water quality becomes impaired. Where tidal flushing is effective, much of this produced particulate matter along with dissolved nutrients is washed out of the system resulting in good water clarity as evidenced by the greater Secchi depth readings in the main basins of Nantucket Harbor and Madaket Harbor in 2017 (Table 3a), as noted in prior years as well (Tables 3b-h). Consistent with the water clarity and TN levels, corresponding chlorophyll-*a* pigment concentrations are lowest (1-5 ug/L) at the outer stations (nearest the tidal inlet) of these well flushed systems (Table 3a-h, Figures 8,9). The observed level of variation is common and underscores the need for long-term monitoring to detect water quality trends.

Nantucket Harbor and Madaket Harbor are both well flushed basins but tended to have slightly higher water quality with relatively low phytoplankton biomass (chlorophyll-*a*) in 2017 and 2018compared to 2016 (all stations in Madaket Harbor and most stations in Nantucket Harbor). In Nantucket Harbor, station Nan-5 showed a lower level of total pigment in 2017 compared to 2016, but returned to 2016 levels in 2018, however, the difference was slight and the levels in all years were relatively low (7.2 to 4.8 ug/L). In Madaket Harbor the total pigment levels in 2017 were consistently higher compared to most other years except 2010 which showed higher chlorophyll levels than all years monitored to date. This is consistent with the water clarity observed in 2017 (Nantucket Harbor station 3 secchi depth 2015 = 1.45 m, 2016 = 2.34 m, 2017 = 2.30m, 2018 = 2.00 m, Madaket Harbor MH-2 secchi 2.2 meters in 2015, 1.7 meters in 2016, 1.68 meters in 2017 and 2.81 m in 2018) as turbidity is primarily the result of organic particulates, e.g. phytoplankton. The parallel measurements of total nitrogen (TN) are generally consistent with the chlorophyll-*a* results, showing a positive relationship between changes in TN levels with changes in chlorophyll-*a* levels (see below). This is particularly apparent in Nantucket Harbor (station 5 and 6, Polpis as well as station 2

[1] {+} indicates improved conditions in 2017; {-} indicates declining conditions in 2017.

mid harbor and the sentinel station 2A) and provides additional evidence that nitrogen is controlling the level of eutrophication in these systems.

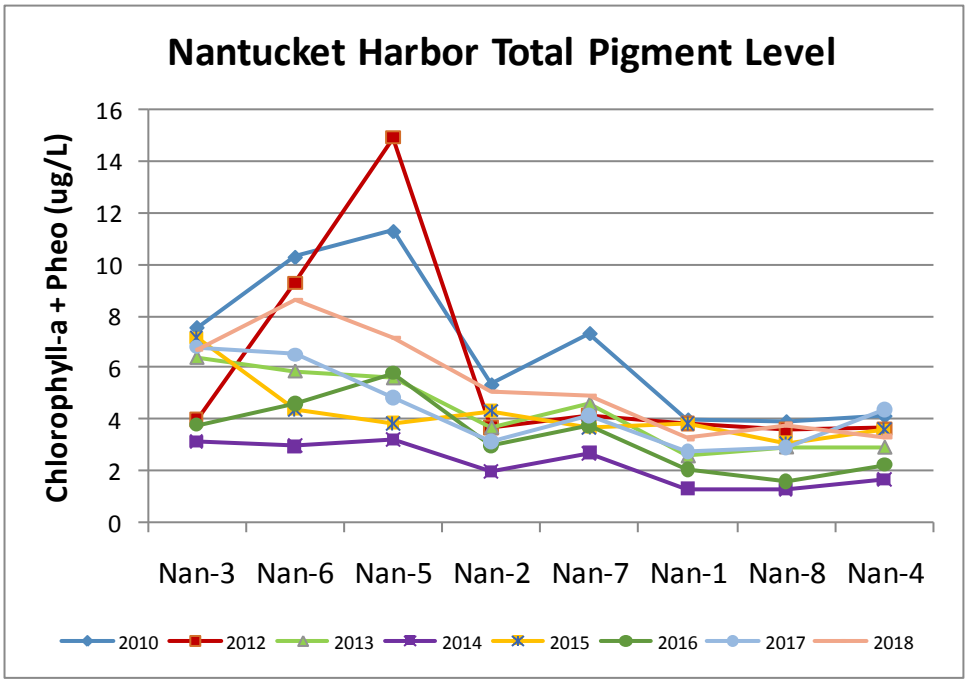

Figure 8. Average Chlorophyll-*a* (CHLA) concentrations by station in the well flushed Nantucket Harbor system during the summer 2018 sampling season. Stations Nan-5 and 6 are in Polpis Harbor the rest relate to the main basin. Note that 2018 levels were slightly above average within the upper basins (Nan-5 slightly higher in 2018 compared to 2017 and 2016, Nan-6 slightly higher in 2018 compared to 2017 and 2016) and relatively constant throughout the Harbor at a level consistent with low-moderate nitrogen enrichment. The large blooms of 2012 and 2010 have not reoccurred in recent years.

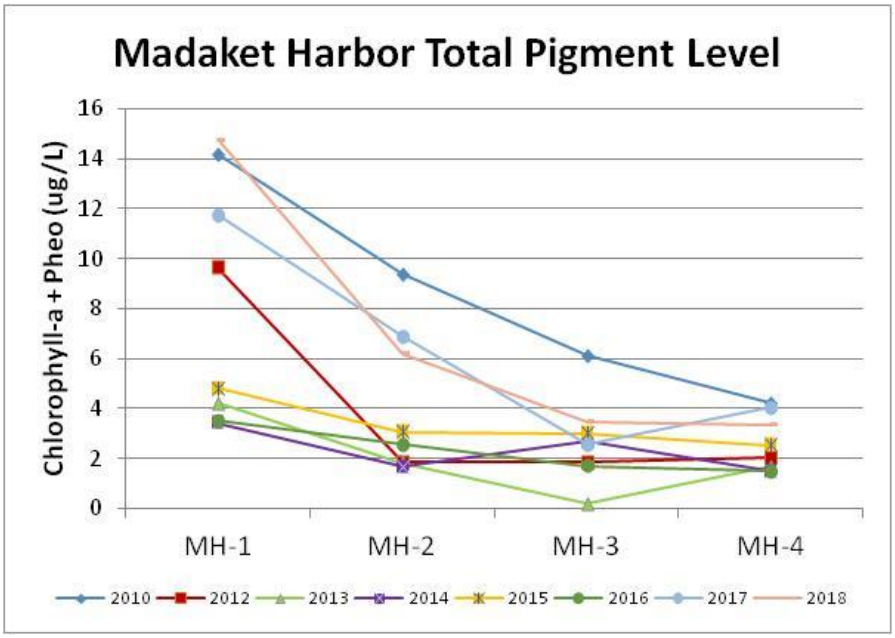

Figure 9. Average Chlorophyll-*a* (CHLA) concentrations by station in the well flushed Madaket Harbor system during the summer 2010-2017 sampling seasons. Stations MH-2,3,4 are in the main open basin and consistently show moderate to low chlorophyll a pigments, MH-1 is the

MEP sentinel station in Hither Creek and recorded the highest levels to date. The 2010 blooms had not been as prevalent in follow-on years however in 2017 and 2018 total pigment levels were notably higher at stations MH-1 and MH-2.

Where tidal flushing is more restricted in Long, Hummock, Miacomet and Sesachacha Ponds, the moderate levels of water clarity were consistent with the moderate to high chlorophyll-*a* concentrations that have a higher (2x-3x) average compared to the open basins of Nantucket and Madaket Harbors. Sesachacha and Long Pond generally had similar total chlorophyll-*a* levels 2015-2018, significantly lower than Miacomet and Hummock Ponds, possibly related to the total annual water exchange in each system. Average chlorophyll-*a* concentrations in 2018 and 2017 in the poorly flushed basins of Long Pond were 11.0 and 16.5 ug/L (max. 23.5 ug/L) and in Sesachacha Pond, 13.9 and 9.0 ug/L (max. 27.7 ug/L). Nantucket's poorest flushed basins: Hummock and Miacomet Ponds had the highest plankton levels in 2018 and 2017 with Hummock Pond averaging 19.4 ug/L and 22.5 ug/L, respectively (max. 77.3 ug/L) and Miacomet Pond averaging 25.0 ug/L and 9.7 ug/L, respectively (max. 112.8), (Table A, Figures 10, 11,12,13). These general patterns were also observed in Sesachacha, Long, Hummock, Miacomet Ponds monitoring results for 2015 and 2016 (6.7 and 11.1 ug/L, 6.1 and 9.3 ug/L, 15.52 and 48.7 ug/L) with highest total chlorophyll levels generally being observed in the freshwater Miacomet Pond basin, and upper Hummock Pond and Sesachacha and Long Ponds which generally show lower blooms but show higher levels during periods when they freshen due to poor openings. In Hummock Pond chlorophyll-*a* levels were noticeably higher in 2018 and 2017 compared to 2016 and 2015, likely due to less effective openings in recent years (a persistent bloom of *Dolichospermum* was also observed for a significant portion of the 2017 sampling period). The low flushing of Hummock Pond in 2018 and 2017 can be seen in the low salinity (4.9 and 3.5 PSU) compared to 2016 and 2015 (6.5 and 5.8 PSU, respectively).

The multi-year results clearly show that 2010 was the poorest water quality year, 2010-2018, in each of Nantucket's estuaries. Over the past 4 years, chlorophyll-*a* levels in Long Pond, Hummock Pond, Miacomet Pond and Sesachacha Pond have declined compared to historic levels (MEP) and 2010 but do show inter-annual variation (e.g. all ponds higher in 2017 compared to 2016) due to differences in opening duration, rainfall, temperature, etc. However, Sesachacha Pond and Long Pond have showed much improved water quality compared to their long term status during the MEP assessment. Sesachacha Pond historic chlorophyll-*a* levels were generally >20 ug/L, frequently >60 ug/L, with blooms as high as 100 ug/L, while Long Pond has seen improvements apparently due to decreasing nitrogen inputs. It is becoming clear that that Hummock Pond and Sesachacha Pond water quality is tightly linked to the success of their periodic openings. Sesachacha Pond showed significantly improved conditions in 2012 and 2013 with successful openings, but has showed recent decline, 2014-2018. However, conditions remain improved over historic levels. The 2012-2013 conditions approached the TMDL target TN levels to restore nitrogen impaired habitats, with the recent trend in pigment levels (2014-2018) in concert with renewed decline in TN levels in 2016, 2017 and 2018. The increase in total pigment levels appears to be related to duration of spring openings in respective sampling years: 2018 { 3 day spring opening}, 2017 {7 day spring opening}, 2016 {3 day spring opening}, 2015 {5 day spring opening}). Given that opening duration may not accurately reflect flushing success in all cases, salinity was analyzed as the response to tidal flushing. In this case it appears that the low nitrogen/chlorophyll years (2012 & 2013) also had the highest salinities on record (24.7 and 17.0 PSU), whereas in 2018

salinity was 13.2 PSU and the recent water quality decline is under salinity conditions of 11.3-11.6 PSU. Note that the MEP indicates that a salinity of 22 PSU should be associated with high water quality in Sesachacha Pond, consistent with the monitoring program results.

It is important to note that creating sustained openings in Sesachacha Pond is difficult due to the dynamic coastal processes which move to refill and close the tidal channel almost immediately. However, when openings have been successful there was a dramatic improvement in pond water quality. It appears from all of the accumulated information that it is unlikely that the Town will be able to reproducibly have good openings despite planning openings based on weather and tides, therefore a combination of openings and nitrogen management will likely be needed for a stable restoration.

As previously noted in past summary reports, the temporal data indicate that both Sesachacha Pond and Hummock Pond can be significantly restored by effective pond openings and that salinity is a good metric from which to gauge opening "success" (higher resultant salinity = lower TN). As more data is available, it will be possible to derive predictions of the water quality response from opening metrics which can then be used by the Town in refining what is a difficult process of pond openings. In the case of Sesachacha Pond, where openings are through a barrier beach subject to very active coastal processes, if openings cannot be made more effective, it may be necessary to consider nutrient load reducing strategies in the watershed or in situ processes to improving water quality, such as use of oysters to lower TN levels. This in situ approach of using the filtering capacity of oysters to improve water quality is being considered by a number of towns on Cape Cod (Falmouth, Orleans, Mashpee) as well as across Buzzards Bay (Westport).

After the high chlorophyll-*a* levels in 2010, 2012, Long Pond has maintained its phytoplankton levels at a moderate to high level. However, in 2017 the total chlorophyll levels increased noticeably which were not repeated in 2018 where levels declined significantly to those of 2015, while 2016 remains as the lowest levels of record, a pattern mirrored in the TN results. The initial decline (post-2012) was noted in the previous 3 monitoring years and is possibly a result of activities at the landfill leading to declining nitrogen inputs to pond waters. Interestingly, while station LONG 5 in 2017 showed a dramatic increase, station LONG 6 closest to the outflow point from Long Pond to Madaket Ditch,(while higher than most previous years) still showed similar chlorophyll levels as in past years, consistent with the observed algae bloom (Diatoms) in the lower portion of Long Pond furthest away from the outflow that was captured during the June and July sampling dates (personal communication, Kaitlyn Shaw). 2018 was a return to the long-term total chlorophyll-*a* pattern, and had the lowest TN levels on record. As previously recommended in 2016 and 2015, a detailed assessment of the current landfill effect on groundwater quality flowing to Long Pond is now underway for making predictions as to the likely extent of improvement possible. It should be noted, however, that a benthic infaunal survey was undertaken in November 2017 by scientists from the Coastal Systems Program, UMD-SMAST, at the request of the Town of Nantucket. Sediment samples were collected using the same protocols as employed by the Massachusetts Estuaries Project thereby allowing direct cross comparison of 2017 and 2003 results when infauna was last surveyed by the MEP as part of the Long Pond habitat assessment. The 2017 infaunal survey results indicated a significant improvement in habitat quality mirroring the decline in water column TN levels and indicating that Long Pond was approaching its nitrogen TMDL threshold set by MassDEP and USEPA under the Clean Water Act.[2]

[2] Technical Memorandum: Updated Benthic Infauna Survey of Long Pond, Nantucket. 2018. B.L. Howes, S.J.

Comparison of the 2003 and 2017 Long Pond benthic animal habitat surveys with the preceding 3-5 years of water quality (TN & chlorophyll-*a*) data indicated some clear shifts in the habitat quality of the Long Pond Basin. In contrast, the semi-isolated Head of Long Pond showed less certain shifts in benthic habitat quality. Specifically, nitrogen related water quality has significantly improved within the main basin of Long Pond in the 2002-2004 and 2013-2017 monitoring records. TN levels associated with the 2003 and 2017 benthic surveys declined from 0.883 mg TN L^{-1} to 0.719 mg TN L^{-1} at Town Station 6 (LOPO-4) and from 0.971 mg TN L^{-1} to 0.725 mg TN L^{-1} at Town Station 5 (LOPO-5). Given the structure and brackish water environment of the main basin of Long Pond the benthic habitat has clearly improved from 2003 to 2017, paralleling the water quality improvement. The assessment of improved benthic animal habitat is based on the loss of most stress indicator species, increase in major species (from 10 to 12), increase in average number of species from 5 to 9, the increase in diversity from 1.19 to 1.78 and the recolonization of the benthic habitat at station 8 from no species/organisms in 2013 to 13 species in 2017. For a wetland dominated brackish system the benthic animal habitat seems to be transitioning to high quality, although diversity remains a bit low.

In addition to infauna surveys, nutrient testing of landfill effluent was initiated in 2017 by the Public Works department and CDM-Smith who already monitor the wells. These efforts are being used to update the nutrient load values to Long Pond based on new nitrogen concentrations and groundwater information and should be integrated into the detailed assessment of the effect of the landfill activities on Long Pond water and habitat quality. Presently, Long Pond is generally showing signs of improving. It does, however, continue to be nitrogen enriched and moderately impaired based upon the suite of water quality metrics.

In contrast to the improvements seen in Long Pond, Miacomet Pond which is not open to tidal flows, remains very fresh (avg. salinity 0.1-0.2 PSU), continues to show high chlorophyll-*a* levels in 2018 (27.8 ug/L seasonal average), although 2017 and 2016 levels were generally lower). Miacomet Pond is still clearly supporting poor water quality conditions with high TN, TP and total chlorophyll-*a* levels (system average 0.741 mg TN/L and 0.070 mg TP/L, respectively in 2018) and high total chlorophyll-*a* levels (25 ug/L), poor water clarity and moderate oxygen depletion, all indicators of a nutrient impaired basin. Additionally, given how fresh Miacomet Pond has become, phosphorous as a driver of nutrient impairment must be considered.

The upper portion (Hum-8 and Hum-5) of Hummock Pond showed overall total pigment and chlorophyll-*a* levels in summer 2018 and 2017 higher than 2016 and 2015 and most other years in general. This is a significant shift as 2016 levels were lower than 2010, 2012, 2013 and showed moderate levels in the mid reaches but with stations in the lower portion (Hum-1 and Hum-3) closer to the barrier beach having slightly lower total pigment levels compared to most years. However, in 2018 and 2017 total chlorophyll-*a* levels basin wide were almost three time those of the previous 2 years (22.1 and 24.2 ug/L vs. 7.5 and 9.2 ug/L), In 2018 and 2017, the lower stations (Hum-1 and 3) were noticeably higher than 2010 levels which were previously considered the highest of all years monitored by the island-wide water quality monitoring program. The 2014 results

remain the lowest levels measured over the 2010-2017 monitoring period and while 2016 was slightly higher than 2015 in the upper reaches of the system, chlorophyll levels in 2016 were still moderate-high as a metric of eutrophication. In 2018 and 2017, chlorophyll levels were indicative of eutrophication. While three years (2014, 2015 and 2016) represent the beginning of a restoration trend, the lower levels in these three years are consistent with an improved opening protocol implemented in 2014 that was not able to be repeated in 2018 and 2017. The new opening protocol stemmed from the Town and the Nantucket Land Council supporting a project specifically to refine the opening protocol for Hummock Pond to maximize the amount of tidal flushing achieved by each opening. The April 2014 opening of Hummock Pond was moderately successful and was followed by a more effective opening that Fall (October 2014) which lowered TN levels in the pond and raised its salinity. In 2015, the revised opening protocol allowed for a 15 day spring opening and a 17 day fall opening further flushing the pond. This was followed by a 18 day spring opening in 2016 in advance of the summer sampling season. It is almost certain that the sequence of good openings in past years was the cause of the relatively low total pigment and TN conditions in the lower half of Hummock Pond in 2016. By comparison, in 2017 a spring opening was initially achieved but it lasted less than 1 day and was followed by another opening which only lasted 1.5 days in duration. The lack of an effective spring opening of Hummock Pond is likely the main contributor to the decreased nutrient related water quality observed in 2017 and 2018, consistent with the lower overall pond (Stations 1-7) salinity (2018 = 5.0 PSU; 2017= 3.5 PSU; 2016=6.5 PSU indicative of less flushing in 2017.

As flushing in the uppermost portions of Hummock Pond tend to be limited, total pigment (and component chlorophyll-a) showed to be significantly higher (3x) at Hum-8 in 2017 and 2018 (45.0 and 50.7 ug/L, respectively) compared to 2016. Head of Hummock (sta. 8) consistently has a lower salinity and higher total chlorophyll and TN levels than the adjacent stations consistent with the Head of Hummock not being tidally well connected to the main basin of Hummock Pond through its narrow shallow channel. Total pigment and chlorophyll-*a* generally remains the lowest at each monitoring station in 2014 with 2015 and 2016 being the next lowest when compared to prior years. In April 2016 and 2015, Hummock Pond was opened and water levels and water quality were monitored before and after the opening. Both the April 2016 and 2015 openings appeared to be more effective than the fall 2014 opening as seen in the enhanced water quality during the 2016 and 2015 summers. Not surprisingly, in 2016 at station Hum-8 which showed elevated total pigment levels compared to 2015, average TN levels in the summer of 2016 were also higher than in summer 2015 (1.19 mg/L and 0.576 mg/L respectively) and in 2017 and 2018 which showed the highest total pigment levels (44.9 and 50.7 ug/L) with associated TN levels of >1.20 mg N/L. It appears that the lack of a significant spring opening allowed phytoplankton to build to bloom levels throughout the upper tidal reaches in both 2017 and 2018 compared to prior years. Additionally, in 2016 at station Hum-7 which showed similar total pigment levels compared to 2015, average TN levels in the summer of 2016 were nearly the same as in summer 2015 (0.674 mg/L and 0.621 mg/L respectively). In 2017 and more so in 2018, total pigment levels at Hum-7 were noticeably higher (13.9 and 21.8 ug/L) than in 2016 and 2015 (5.9 and 7.1 ug/L respectively) and with associated higher TN levels in 2017 and 2018 of 0.789 and 0.889 mg N/L, respectively. In general, it appears that the water quality in Hummock Pond does respond well to longer inlet openings as achieved in the spring of 2016 (18 days) and spring of 2015 (15 days). However as indicated by the elevated

2017 and 2018 nutrient and total pigment results, the pond is very sensitive to the duration of openings. Further improvements are anticipated if openings can be made longer than 18 days or loads to Hummock Pond reduced. It should be noted that each consecutive year of good tidal exchanges lowers the overall TN level the following year until a new equilibrium is reached (likely 3-5 years). This has been observed in periodically opened ponds on Martha's Vineyard (e.g. Edgartown Great Pond) and it stems from the fact that lowering TN levels requires time to build back up from watershed inputs and sediment recycling than if the TN levels remain high year around.

Table A - 2018 Minimum, Maximum and Average CHLA and Total Pigment values for the closed ponds of Nantucket.

2018 System	min CHLA (ug/L)	max CHLA (ug/L)	avg CHLA (ug/L)	min Total Pig (ug/L)	max Total Pig (ug/L)	avg Total Pig (ug/L)
Miacomet Pond	0.14	151.81	20.92	8.13	153.58	27.85
Sesachacha Pond	1.33	24.06	10.57	1.36	28.35	13.58
Long Pond	5.87	11.37	9.25	8.72	16.09	11.19
Hummock Pond	3.35	77.26	16.71	6.86	80.37	22.06

Table B - 2017 Minimum, Maximum and Average CHLA and Total Pigment values for the closed ponds of Nantucket.

2017 System	min CHLA (ug/L)	max CHLA (ug/L)	avg CHLA (ug/L)	min Total Pig (ug/L)	max Total Pig (ug/L)	avg Total Pig (ug/L)
Miacomet Pond	2.46	33.87	8.29	4.82	44.30	12.65
Sesachacha Pond	4.92	23.68	8.92	5.23	23.99	10.48
Long Pond	0.57	31.04	11.51	5.24	36.70	14.19
Hummock Pond	2.89	65.26	19.93	2.91	88.96	24.72

Table C - 2016 Minimum, Maximum and Average CHLA and Total Pigment values for the closed ponds of Nantucket.

System	min CHLA (ug/L)	max CHLA (ug/L)	avg CHLA (ug/L)	min Total Pig (ug/L)	max Total Pig (ug/L)	avg Total Pig (ug/L)
Miacomet Pond	2.88	43.05	11.82	5.44	58.35	15.52
Sesachacha Pond	2.92	10.51	5.60	3.54	10.54	6.68
Long Pond	1.52	6.80	4.14	2.55	9.67	6.12
Hummock Pond	0.86	44.86	5.11	1.62	46.18	7.52

Table D - 2015 Minimum, Maximum and Average CHLA and Total Pigment values for the ponds of Nantucket with limited or only periodic tidal exchange.

System	min CHLA (ug/L)	max CHLA (ug/L)	avg CHLA (ug/L)	min Total Pig (ug/L)	max Total Pig (ug/L)	avg Total Pig (ug/L)
Miacomet Pond	2.80	204.83	41.26	9.55	204.86	48.71
Sesachacha Pond	3.08	11.23	6.79	6.56	18.79	11.10
Long Pond	2.56	11.37	5.44	4.40	19.54	9.30
Hummock Pond	1.00	19.71	4.50	2.92	43.41	9.24

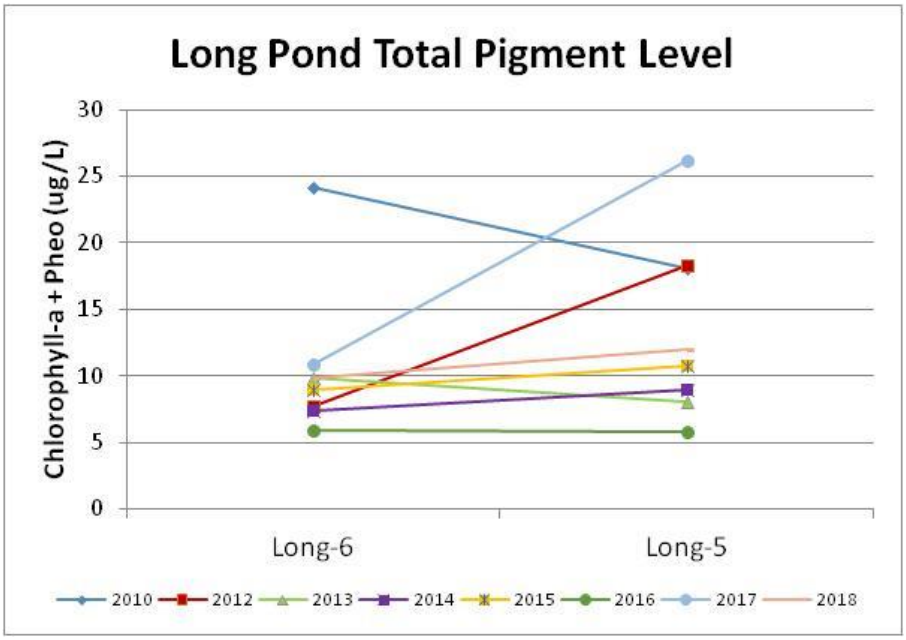

Figure 10. Average Total Pigment (Chlorophyll-a +Pheophytin) concentrations by station in the Long Pond portion of the Madaket Harbor system during the summer 2018 sampling season compared to 2010, 2012, 2013, 2014, 2015, 2016 and 2017.

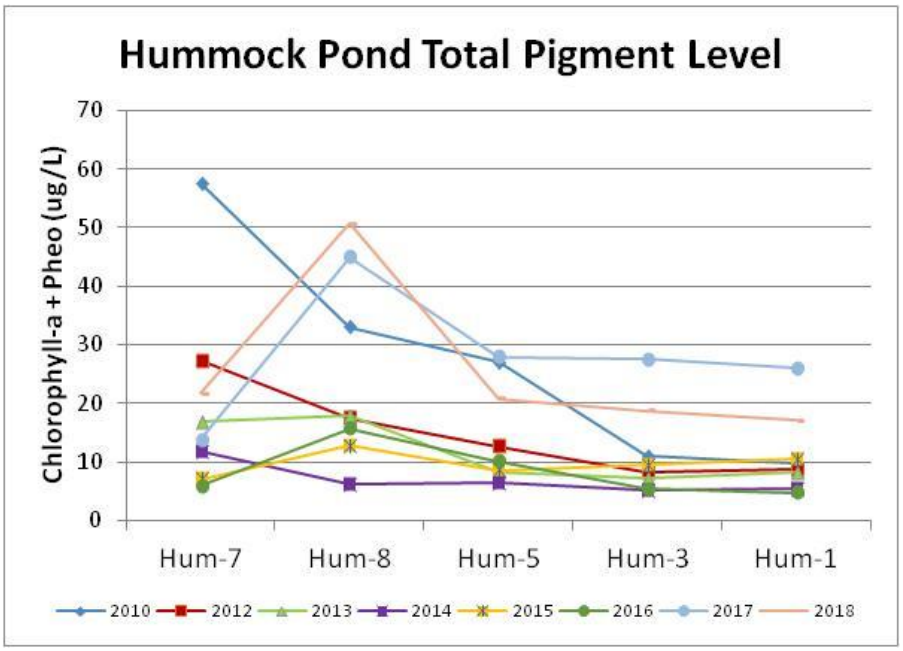

Figure 11. Average Total Pigment (Chlorophyll-a +Pheophytin) concentrations by station in the seasonally opened Hummock Pond system, during the summer 2018 sampling season compared to 2010, 2012, 2013, 2014, 2015, 2016 and 2017.

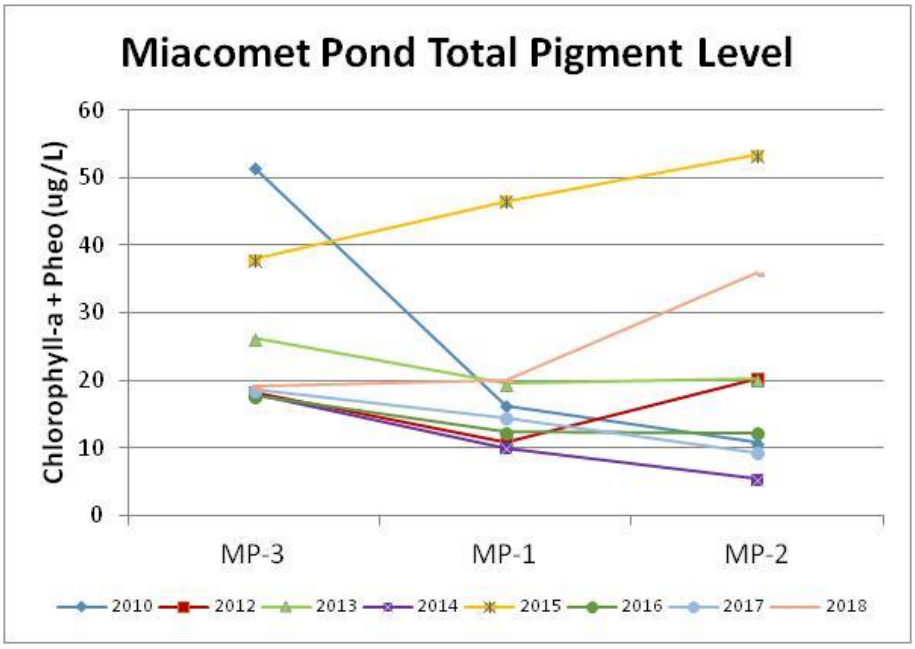

Figure 12. Average Total Pigment (Chlorophyll-a +Pheophytin) concentrations by station in the Miacomet Pond system during the summer 2018 sampling season compared to 2010, 2012, 2013, 2014, 2015, 2016 and 2017. Miacomet Pond is not opened to the Atlantic Ocean and now contains freshwater (≤0.2 PSU).

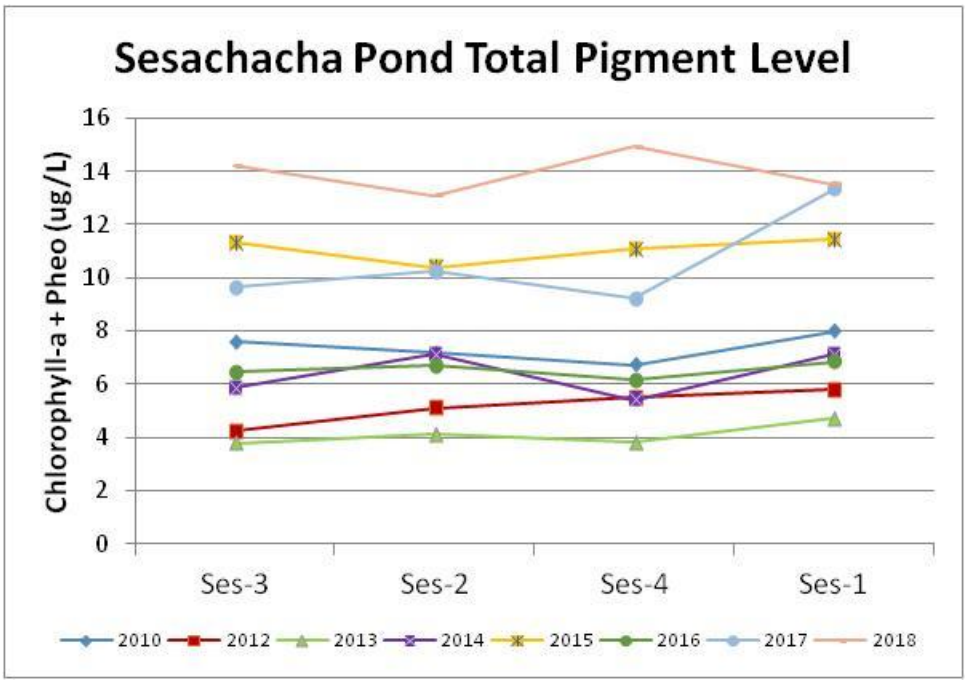

Figure 13. Average Total Pigment (Chlorophyll-a +Pheophytin) concentrations by station in the seasonally opened Sesachacha Pond system during the summer 2018 sampling season compared to 2010, 2012, 2013, 2014, 2015, 2016 and 2017.

Average Total Nitrogen values for all of Hummock Pond (MEP TN threshold = 0.50 mg/L, HUM-3) were higher in 2018 than 2017 with a commensurate increase in total phytoplankton pigment throughout the pond. By comparison, in 2016 total pigment appeared slightly lower in the bottom half of the pond and slightly higher in the upper half compared to 2015. Total nitrogen in the full main stem averaged 0.832 mg/L in 2018 and 0.932 mg/L in 2017 whereas in prior years [2016, 2015, 2014, 2013, 2012, 2010] average TN values were [0.797, 0.583, 0.715, 0.900, 0.923, 0.944 mg/L] respectively. However, the pattern for Hummock Pond is somewhat deceptive given the strong TN gradient from the upper station (Hum 7) and the lower stations (Hum 1 & 3). The lower stations, most influenced by the breaches, showed the largest improvement 2014-2016, with 2016 showing the lowest TN levels to date approaching the TMDL threshold level. The gradient was also seen in 2017 and 2018 (lower stations better than upper stations), however, given the short breach, TN levels remained significantly higher than in 2016 with the associated effect of high total pigment and chlorophyll levels. This inter-annual variation follows the pattern of improved flushing observed in fall 2014, 2015 and 2016 under effective openings, and decreased water quality under the poor flushings from spring 2014 and spring 2017. Relative to the 2012-2018 and 2010 data sets, results indicate that within Hummock Pond, less so Long Pond and Miacomet Pond, there is a general gradient of nutrient (N and inorganic P) and chlorophyll concentrations from high levels in the upper, more enclosed and poorly flushed reaches of the estuaries to lower concentrations closer to the outlets where flushing is more effective (Figure 15,16). The gradient appears to be a bit flatter in 2016 for both Long Pond and Miacomet Pond but more pronounced in 2017 and 2018. Based on average TN values in Hummock Pond, water quality in 2017 and 2018 appears lower compared to 2016 and well above the nitrogen threshold needed for restoration.

In contrast, Miacomet Pond (No MEP threshold set) which has had no restoration activities or openings in recent decades showed TN levels in 2018 (0.741 mg/L) comparable to 2017 (0.711 mg/L) and 2016 (0.742 mg/L) and significantly lower TN levels than in 2015 (1.203 mg/L) and the previous 4 years of monitoring [1.202, 0.982, 0.962, 0.919, 0.886 mg/L]. Not surprisingly, average total pigment values in 2018 (25.0 ug/L) were higher than 2017 and 2016 (14.11 and 14.10 ug/L respectively). It is not clear what has caused the recent reductions (2017 and 2016), but as a freshwater pond, Miacomet is highly influenced by freshwater inflows and may be responding to lower freshwater inflows associated with the drought in 2016, but this is purely speculative and would need site-specific confirmation. It should be noted that although Miacomet Pond's TN levels were observed to be lower in both 2018, 2017 and 2016 compared to previous years, the levels are still quite elevated and the pond is clearly impaired by excess nutrients (N & P). The high levels of TN in these poorly flushed estuaries clearly contrast with the levels of TN and pigment in Nantucket's well flushed estuaries (Nantucket and Madaket Harbors). The effect of reduced flushing is to increase the sensitivity of an estuary to nutrient inputs as water exchange rates are diminished.

In addition to TN, the measured TP levels in Miacomet Pond in 2018 (MP-1: 60 ug/L; MP-2 61 ug/L; MP-3: 103 ug/L) were higher than in 2015 and 2016 which were also similarly high (MP-1: 45-85 ug/L; MP-2 68-80 ug/L; MP-3: 65-136 ug/L; Tables 3a & 3c). If Miacomet Pond is to be managed as a freshwater pond then phosphorus needs to be considered (with nitrogen) as a concern. Since no fresh pond or lake nutrient TMDLs have been developed on Cape Cod or Nantucket, SMAST's 2001 survey of 190 lakes and ponds on Cape Cod was used by the Cape Cod Commission to develop potential region-specific nutrient thresholds.[3] This review used an EPA method that relies on a statistical review of the available data within an eco-region to develop the thresholds.[4] This review suggested a target TP concentration range for Cape Cod ponds between 7.5 and 10 µg/L to sustain high quality pond habitats. Potential target threshold ranges were also developed for total nitrogen (0.16 to 0.31 mg/L), and chlorophyll-a (1.0 to 1.7 µg/L). These concentrations closely approximated the EPA eco-region reference criteria available at the time for the region.[5] These Cape Cod-specific thresholds can be used as guidance targets for Miacomet Pond, they have not been formally adopted as regulatory standards by MassDEP. However, it is clear even from the limited TP data available that phosphorus levels within Miacomet Pond are consistent with an impaired freshwater pond, which is supported by the high TN and chlorophyll-a levels.

Miacomet Pond in 2017 and 2018 as in 2016-2014 likely had phytoplankton production (e.g. chlorophyll-*a*) stimulated by both N and P inputs as pond salinities declined to present levels. As TP and PO_4 samples were collected in parallel with the nitrogen fractions in the 2018-2014 surveys of Miacomet Pond, it was possible to assess eutrophication from N and P. N/P ratios can be compared to the idealized Redfield

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[3] Eichner, E.M., T.C. Cambareri, G. Belfit, D. McCaffery, S. Michaud, and B. Smith. 2003. Cape Cod Pond and Lake Atlas. Cape Cod Commission. Barnstable, MA.

[4] U.S. Environmental Protection Agency. 2000. Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs. First Edition. EPA-822-B00-001. US Environmental Protection Agency, Office of Water, Office of Science and Technology. Washington, DC.

[5] U.S. Environmental Protection Agency. 2001. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Lakes and Reservoirs in Nutrient Ecoregion XIV. EPA 822-B-01-011. US Environmental Protection Agency, Office of Water, Office of Science and Technology, Health and Ecological Criteria Division. Washington, DC.

Ratios (C:N:P, 106:16:1) to get a first approximation of the degree to which N or P maybe structuring the pond. Interestingly, particulate C/N ratios remain relative consistent from the head to the lowest basin of the pond closest to the ocean (MP3 - MP1 - MP2, C/N ratio in 2017 of 7.5, 7.7, 8.4, in 2016 of 7.3, 6.9, 8.6 and in 2015 6.5, 6.8, 6.5 respectively, Redfield C/N ratio is 6.62). This supports the contention that phytoplankton comprise almost all of the particulate matter in the pond. The nutrient data showed significant variation between the pond basins, with total N/P ratios lower at the head and increasing to the middle and lower portions (MP3 to MP1 - MP2, for a total N/P ratio in 2018 of 12.1, 29.0, 31.3 were lower at the head, but similar within the main basin compared to 2017 of 20.1, 35.4, 40.9, in 2016 of 26.8, 37.9, 21.8, and 2018 was very similar to 2015 ratios at these stations of 16.9, 36.9, 34.4 respectively, Redfield N/P ratio is 16). In freshwater basins, Ratios significantly greater than 16 (i.e. >20) indicate that phosphorus additions likely result in increased eutrophication and that Phosphorus should be a focus of pond management. This is the case throughout Miacomet Pond in 2018, 2017 and 2016, for the middle and lower pond. It is also important to note that orthophosphate concentration are quite low in the main basin (MP-1, MP-2) generally <0.2 uM, such that adding phosphorus to this basin in mid summer would likely stimulate phytoplankton growth. In contrast, the upper station (MP-3 generally supports 2x-3x higher phosphate levels. It is likely that regions of the pond may be sensitive to both nitrogen and phosphorus, such that overall both nutrients need to be monitored and considered for management of Miacomet Pond, although phosphorus management is clearly needed at this time.

As previously recommended, to refine this approximation of the limiting nutrient for Miacomet Pond, nutrient ratios from the monitoring effort should be coupled to controlled bioassays (bottle tests, mesocosms) with different levels of P and N amendments to the natural phytoplankton community. These types of bioassays were employed by the Coastal Systems Program for an assessment of other low salinity ponds, Oyster Pond in Falmouth and Cockeast Pond in Westport, specifically to better determine the degree of N or P limitation for nutrient management purposes. Comparison of algal bioassay results and chemical nutrient concentrations in lakes has suggested that a mass N:P ratio above 20 indicates P limitation, a ratio below 10 indicates N limitation and values between 10 and 20 indicate that either of the nutrients may be limiting." (Petri Ekholm, Finnish Environment Institute, 2008). That there is variation in N/P ratios in the different basins of the pond suggests that some regions could be either N limited or P limited (or both). A more detailed examination of N and P cycling is warranted to ascertain which is playing a bigger role in the nutrient cycling of the pond system as a whole. At present, this pond continues to appear to have shifted from a eutrophic brackish water system to a eutrophic freshwater ecosystem and should potentially be managed as such, taking into consideration which nutrient is dominant (N vs. P). However, management must include that periodic overwash from storms could upset the ecological balance of this system if it were managed purely as a freshwater system. All of the estuarine stations in Nantucket’s estuaries are clearly nitrogen limited, based upon various assessments including the MEP.

Table E - Below shows various nitrogen to phosphorous ratios from Miacomet Pond during the summer 2018 sampling season.

Station Id. (2018)	N/P organic	PC/PN particulate	DIN/DIP inorganic	TN/TP total
MP-3	25.7	7.2	2.1	12.1
MP-1	34.7	6.3	7.5	29.0
MP-2	33.1	6.1	17.1	31.3

Table F - Below shows various nitrogen to phosphorous ratios from Miacomet Pond during the summer 2017 sampling season.

Station Id. (2017)	N/P organic	PC/PN particulate	DIN/DIP inorganic	TN/TP total
MP-3	34.7	7.5	3.4	20.1
MP-1	39.6	7.7	7.0	35.4
MP-2	43.9	8.4	12.4	40.9

Table G - Below shows various nitrogen to phosphorous ratios from Miacomet Pond during the summer 2016 sampling season.

Station Id. (2016)	N/P organic	PC/PN particulate	DIN/DIP inorganic	TN/TP total
MP-3	33.4	7.3	2.9	26.8
MP-1	41.2	6.9	5.8	37.9
MP-2	21.8	8.6	8.8	21.8

Table H - below shows various nitrogen to phosphorous ratios from Miacomet Pond during the summer 2015 sampling season.

Station Id	N/P organic	PC/PN particulate	DIN/DIP inorganic	TN/TP total
MP-3	16.9	6.5	10.2	16.1
MP-1	36.9	6.8	10.3	34.3
MP-2	34.4	6.5	13.1	32.3

Similar to observations of Hummock Pond, Total Nitrogen values also show inter-annual variations in Long Pond (MEP secondary threshold, Long Pond basin average 0.80 mg/L). TN levels in 2018 (0.587 mg/L) were lower than in 2017 (0.787 mg/L) but similar to 2015 and 2016; 2016-2012 and 2010 of 0.640, 0.677, 1.14, 0.795, 0.94,1.75 mg/L. In Sesachacha Pond (MEP threshold < 0.60 mg/L, SES-1) 2018 (0.752 mg N/L) was lower than 2017 (0.882 mg N/L) but within the range of 2016-2012 and 2010: 1.000, 0.904, 0.922, 0.669, 0.704, 0.639 mg/L. Like Hummock and Miacomet Ponds, Long Pond and Sesachacha Ponds are poorly flushed with Miacomet Pond not having been opened in over a decade and Long Pond having a poor hydraulic connection to Hither Creek / Madaket Harbor via Madaket Ditch. In the case of Sesachacha Pond, the TN levels also appear to be related to the success of the periodic openings. The similar TN levels in 2017, 2016 and 2015 (0.960, 1.00 mg/L and 0.904 mg/L respectively) are predicted from the similar Spring opening durations (5 days Spring 2015, 3 days Spring 2016, 7 days Spring 2017) and are higher than the previous years which had better openings and associated lower subsequent TN levels (≤0.704 mg/L). It is worth noting that the very high historic levels (1.20 mg/L) and 2010 levels were under less robust opening conditions, prior to the Town's new awareness of the importance of openings as a pond management tool. It should be noted that Sesachacha Pond TN levels in 2018, 2017 and 2016 (and 2015) are still lower than during the MEP assessment and suggest that achieving the TMDL may be possible by refined openings, saving infrastructure costs. Additionally, it appears nutrient related water quality is worsening as a function 2014-2017 poor openings with some improvement in 2018. As previously mentioned above, in the case of Sesachacha Pond, where openings are through a barrier beach subject to very active coastal processes, if openings cannot be made more effective (e.g. like 2010, 2012, 2013), it may be necessary to consider nutrient load reducing strategies in the watershed or in situ processes to improving water quality, such as use of oysters to lower TN levels, as is being considered by a number of towns on Cape Cod (Falmouth, Orleans, Mashpee) as well as across Buzzards Bay (Westport). Average TN levels in all 4 ponds are significantly higher than average values in the "offshore" stations NAN 4 and MH4 which average 0.288 [0.283, 0.297, 0.277, 0.317, 0.344, 0.302] and 0.306 [0.219, 0.328, 0.254, 0.278, 0.297, 0.285] mg/L, respectively (Tables 3a, 3b, 3c, 3d, 3e,3f, 3g, Figures 1, 2). It should be noted that the average offshore TN concentration for station MH4 is 0.295 mg/L if the 8/5/2015 sampling date (TN concentration = 0.427 mg/L) is not included in the calculation. It appears that sample data for that one sampling date is aberrant, which is supported by statistical analysis of the complete data set (2010-2018).

Long Pond (MEP secondary threshold = 0.80 mg/L) showed significantly lower TN levels (~40%) in 2018 and 2012 versus 2010. Levels at Station 5 declined from 2012 to 2013 and held steady or improved in 2013, however there was an increase in average TN levels from 2013 to 2014 at station 5 (1.48 mg/L in 2014 vs. ~0.70 mg/L in 2013). TN concentrations at station 5 returned to 2013 levels in 2015 (0.697 mg/L). In 2016 TN concentrations at station 5 declined again reaching the lowest level on record, 0.650 mg/L. In 2018, data indicate that TN levels declined to 0.587 mg/L, however, the duration of this shift in TN levels is unknown at present. The general decline from historic levels, 2010 to 2016 in TN levels at station 5 needs to be tracked closely by the monitoring program, as MEP modeling suggests that conditions will improve significantly in Long Pond as the landfill TN load diminishes. Similarly, Station 6 also shows declining TN levels from historic to 2010 to 2016 samplings. Station 6 TN concentrations in 2016 declined to the lowest on record, 0.629 mg/L even lower than

2015, 0.656 mg/L, with 2014 being 0.788 mg/L and historic levels being 0.84 mg/L. In 2017, TN levels at station LONG6 increased to 0.712 mg/L, consistent with the observed increase at station LONG5. Based on the previous declines in TN concentrations observed in 2016 and 2015 and the increase and then decrease at both stations in 2017 and 2018, it appears that there is inter-annual variation that must be accounted for in Long Pond. Continued monitoring of stations 5 and 6 is warranted to confirm the downward trend in TN concentrations observed in past years. Overall, the monitoring results, both long term and over recent years, show a clear decline in TN from historic to 2018 levels, with TN levels at both stations in both 2015 and 2016 and 2018 being less than half of previous observations. However, the slight increase measured in 2017 should be tracked and more specific investigation into the nutrient load reductions related to work at the landfill is being undertaken through use of the MEP modeling tool to determine if the general downward trend is landfill related.

The long-term lowering of the TN levels, particularly at station 6, is consistent with on-going Town activities at the landfill (mining and capping), as 2018, 2016, 2015, 2014 and 2013 TN levels follow a downward trend and chlorophyll-*a* levels in Long Pond are significantly lower than in 2010 and 2012 and generally similar to what was measured in 2013, 2014 and 2015 but with 2016 levels being the lowest on record. While TN levels measured in 2017 did appear higher and at odds with the decreases measured over the past few years, the TN decline was again seen in the 2018 data, supporting the longer term TN reduction. Therefore, the monitoring program should continue to track the improvements in water quality at station 5 and 6 and the Town may want to continue to measure nutrient water quality in the wells down gradient of the land fill (as initiated by the Town DPW assisted by CDM-Smith) to better quantify any continuing positive effect the land fill actions maybe having on Long Pond and to better project the potential magnitude of the reduction in load and the time required until the full effect is realized. Additionally, at present the MEP water quality model is being rerun with the new landfill loads based on all the upgrades completed to date to see how the modeling results match the water quality observations from the past few years. Results of updated scenario runs using the MEP developed modeling tool and new loads will support adaptive management approaches ultimately steering decision makers to the most cost effective solutions for restoration.

As in all previous years, in Sesachacha Pond (MEP threshold <0.60 mg/L, SES-1), there is no noticeable nutrient or chlorophyll gradient among any of the 4 Stations (Figure 13 and 15, Tables 3a,b,c,d,e,f,g). The well horizontally mixed nature of this salt pond results from it only having periodic tidal exchange such that it operates more like a kettle pond than a tidal estuary. However, it should be noted that while TN and chlorophyll-*a* concentrations in Sesachacha Pond where generally higher in 2014 compared to 2013, TN levels in 2015 remained high (0.904 mg/L and 0.922 mg/L respectively), which continued through the 2016 field season. The slight rise in TN in 2016 (1.00 mg/L) is consistent with its limited opening. TN levels in 2017 appeared to drop from 2016 levels (0.884 mg/L vs. 1.00 mg/L) and again in 2018 to 0.752 mg N/L. This does not seem unusual considering the duration of the spring 2017 opening compared to the spring 2016 opening. The spring 2017 opening lasted 7 days whereas the spring 2016 opening was only 3 days in duration. The spring 2018 opening of 3 days did lower TN levels slightly 2017 levels, however, average chlorophyll levels in 2018 were higher than past years, likely due to small window for exchange with low nutrient Atlantic Ocean water. It is Interesting to note that while total pigment in 2015

was higher than what was observed in 2014 (11.07 ug/L versus 6.37 ug/L respectively), TN levels were similar in both years, and the slightly higher TN in 2016 supported a similar total pigment as 2014 (6.56 ug/L and 6.37 ug/L respectively). TN levels while lower in 2018 were similar to 2017, average total pigment levels (13.9 and 10.6 ug/L) compared to 2016 (5.4 ug/L), but similar to what was observed in 2015 (11.07 ug/L). Given the diverse factors which can alter pigment levels (wind, light, temperature, nutrients, water clarity) the difference is similar to that seen in other systems throughout the region. That there was a noticeable increase from 2013 to 2014 and consistency between 2014, 2015, 2016 and 2018 with a temporary increase in 2017 is good reason to continue regular monitoring of the system, particularly to determine changes in the effectiveness of annual pond openings that are the likely driver for increased or decreased water quality in a given year. However, TN levels remain well above the nitrogen threshold in the TMDL, and the 2014, 2015 and 2016 TN increase is a cause for concern, particularly after the few prior years of much lower TN levels (~0.6 mg/L). It appears the short duration spring openings in 2015 and 2016 are having a negative effect on pond water quality, however the longer (7-day) opening and the associated reduction in TN concentrations is a clear sign that longer openings achievable under the right conditions (wind direction, wind speed, wave state, lunar phase, pond stage) are effective for reducing nutrient levels in the pond.

Consistent with previous years monitoring results, in 2017 and 2018 Madaket Harbor (MEP threshold 0.45 mg/L, MH-1: Hither Creek) showed a clear nitrogen gradient (and associated metrics) from Station 1 (0.57 and 0.41 mg/L) in Hither Creek (which receives discharge from Long Pond via Madaket Ditch), and is relatively poorly flushed, out to Station 2 (0.39 and 0.29 mg/L) in the Harbor, with further decreases out to the off-shore Station 4 (0.20 mg/L, Figure 9 and 15, Table 3a). In 2018, the TN levels continued their decline from prior years and it appears that this system may have achieved its TMDL target set by MassDEP/EPA. Similarly, in Nantucket Harbor in 2018, there is a very small nutrient gradient from Wauwinet at the Head of the Harbor (Nan-3, 0.33 mg/L) and the more enclosed Polpis stations out to the entrance at Stations 8 (0.25 mg/L) and 4 (0.19 mg/L). There is also a total chlorophyll gradient with the highest concentrations at the 2 Polpis Stations (5 and 6, 7.2 and 8.6 ug/L respectively) and Wauwinet basin (6.7 ug/L), decreasing in the main Harbor and out to the off-shore Station 4 (3.3 ug/L). These levels within the main open basins are indicative of high quality habitat and nutrient related water quality.

Average 2018 [2017-2013, 2012, 2010] TN level in Madaket Harbor (Stations 1-3, not including Station 4, offshore) was 0.308 [0.433, 0.343, 0.422, 0.390, 0.404, 0.485, 0.462] mg/L, compared to the off-shore Station 4, 0.181, [306, 0.219, 0.328, 0.254, 0.278, 0.297, 0.285] mg/L. As mentioned above, due to the lack of a significant temporal trend, the best estimate of the offshore TN concentration for station MH4 is the average of all years (2010 to 2017, 0.281 mg/L).

Average 2018 TN in Nantucket Harbor {MEP threshold = 0.35 mg/L at NAN-2A and 0.355 at NAN-6} (all stations except Station 4, offshore) remain quite low averaging 0293 in 2018 and 0.353 mg/L in 2017 compared to 2010, 2012, 2013, 2014, 2015, 2016, with the offshore boundary station 4 averaging only 0.288 mg/L in 2017, slightly lower compared to offshore Madaket Harbor station MH-4 at 0.306 mg/L (Tables 3a, 3b). It should be noted that the 2010 value includes station NAN-8 (the cut) whereas the 2017, 2016, 2015, 2014, 2013 and 2012 value includes station NAN-8N which was

relocated into the Town Basin within the Harbor (refer to Figure 2 for station location). Additionally, as specified in the nutrient TMDL developed by the MassDEP based on the MEP nutrient threshold analysis, an additional monitoring station was added in head of Nantucket Harbor (NAN-2A) to represent the water quality at the MEP sentinel station. In 2018 and 2017, the TN concentration at station NAN-2A was 0.337 and 0.377, respectively. In 2016 the TN level at station NAN-2A was 0.415 mg/L. The MEP TN threshold concentration were exceeded at these sentinel locations, 0.350 versus 0.337 and 0.377 mg/L, and for the sentinel station in Polpis Harbor (NAN-6) 0.355 mg/L versus 2018/2017 TN level = 0.327/0.405 mg/L. Generally, conditions in Nantucket Harbor were not significantly different in 2018 and 2017 compared to 2016, but did tend to be lower overall.

Estuarine Temporal Analysis: As the Nantucket Water Quality Program has collected 8 years of field data, it is possible to begin assessing long term trends. While this usually requires a decade of monitoring, we can conduct an initial analysis on "whole estuary results". In this analysis all of the stations and events are averaged to yield an overall TN or total chlorophyll a value for an estuary for each year so that the complete time series can be evaluated. This approach can yield new information when examining factors that affect entire estuaries, like increases or decreases in nitrogen loading or changes in tidal flushing. Smaller single year events, e.g. rainfall, show up as variability, as they are not long-term trends.

Temporal analysis of Hummock Pond underscores the inter-annual variability within its main basin for key water quality indicators, TN and total chlorophyll-a, due primarily to the amount of flushing achieved through its spring opening (Figure 14a). While the openings in 2014-2016 brought the overall TN levels significantly down from prior years, the spring 2017 and 2018 openings were insufficient to maintain these lower levels and TN level rose to the prior highs of 2014-2016 (note 2018 opening was slightly more effective than 2017). As such there is no consistent trend, but the results clearly indicate that TN levels can be lowered significantly in this basin through pond openings, when "successful", almost to levels restorative of currently impaired habitats. However, given the variability in openings the Town may consider a hybrid approach of openings plus either in pond nitrogen reduction (shellfish) or watershed source control for long-term restoration of this system.

As stated above, Sesachacha Pond, like Hummock Pond, has its water quality primarily controlled by the amount of flushing achieved during its spring openings. The variability introduced by the quality of openings makes temporal analysis difficult. However, it appears that Sesachacha Pond TN levels have clearly increased in recent monitoring years (Figure 14b). The increase is significant (t test, $p<0.05$) with the initial years 2010-2013 (TN=0.671 mg/L) significantly lower than 2014-2017 (TN=0.933 mg/L), with the groupings determined by the quality of the openings. While the pond during this period moved toward historic low water quality levels, the high quality openings in 2010-2013 indicate that pond openings can play a primary role in restoring water and habitat quality within the pond (threshold = 0.600 mg/L), although this may have to be done in concert with other nitrogen management alternatives, e.g. shellfish, source reduction, etc. During 2017 nitrogen levels once again began to decline over the previous 2 years and further declined in 2018 to levels near 2010 (0.752 vs 0.704 mg N/L) again indicating that restoration of this system should probably include a tidal flushing

component to reduce infrastructure costs and to ensure that this provides productive estuarine habitat.

In contrast to Hummock Pond and Sesachacha Pond, Long Pond is open to tidal exchange, although somewhat restricted as seen in its mean salinity (2017 = 14 PSU and 2018 16 PSU; mean stations 5 & 6). Madaket Ditch provides a conduit for outflow of nutrient rich water from Long Pond and inflowing low nitrogen water from Madaket Harbor. Early on, the Nantucket Water Quality Monitoring Program reported a decline in TN levels potentially resulting from Town improvements to the landfill in the Long Pond watershed. Initially, it was not clear if the observed decline 2010-2013 would be sustained, continue to decline or return to previous (MEP) levels. It now appears that TN levels have declined significantly with 2018 being the lowest on record (0.59 mg N/L) and may be stabilizing at a lower level, around 0.60 mg N/L, Figure 14c). However due to inter-annual variations which may be related to on-going activities at the landfill and/or ecological transitions within the pond itself, it is not yet clear what the “new” steady state TN level will be. However, continued monitoring should clarify this latter point within a few years, unless new nitrogen sources or sinks develop within the watershed.

The large estuarine basins of Madaket Harbor and Nantucket Harbor both support high quality habitats consistent with their low TN and chlorophyll-a levels. The nearshore region of Madaket Harbor (stations 1-3) is the recipient for ebbing waters from Long Pond via Madaket Ditch. Temporal analysis indicates that TN levels at these nearshore stations has declined slightly over the monitoring period (Figure 14d). While there is some inter-annual variation in TN levels, the decline is statistically significant. At this point the only explanation available for this observed decline is that the TN load to Madaket Harbor from Long Pond has been decreasing. As more information from the landfill has become available the Town has decided to re-run the MEP Watershed-Embayment Model for this system as previously mentioned above to verify the expected improvements to Hither Creek (sentinel station) and Madaket Harbor, as well as Long Pond itself. At present, it is important to determine the new steady state TN level in Long Pond, as it appears to be approaching the level set in the MassDEP/USEPA TMDL for this system.

Similarly, the main basins of Nantucket Harbor are also showing a possible temporal decline in TN, although the amount is obscured by the inter-annual variability (r^2=0.30) and the very small changes (Figure 14e). At present, the time-series changes cannot be demonstrated statistically and therefore only indicate that analysis should continue. However, it does not appear that TN levels are decreasing. It should be noted that only a very small TN reduction was anticipated from the reconstruction of the jetties, but as additional planned sewering is undertaken, it should be possible to detect the TN reduction. As stated above, this temporal analysis is preliminary and is being undertaken to guide future analysis.

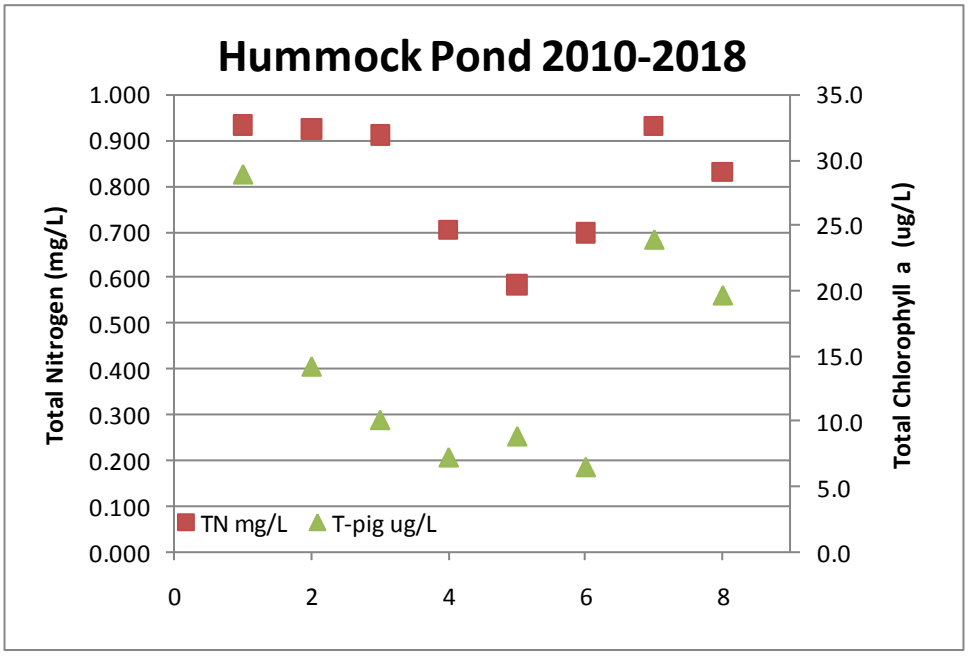

Figure 14a. Hummock Pond main basin annual averages for TN and total chlorophyll a from 2010, 2012-2017 (shown as year 0, 2, 3, 4, 5, 6, 7). No significant temporal trends were detected. Does not include the semi-isolated Head of Hummock Pond.

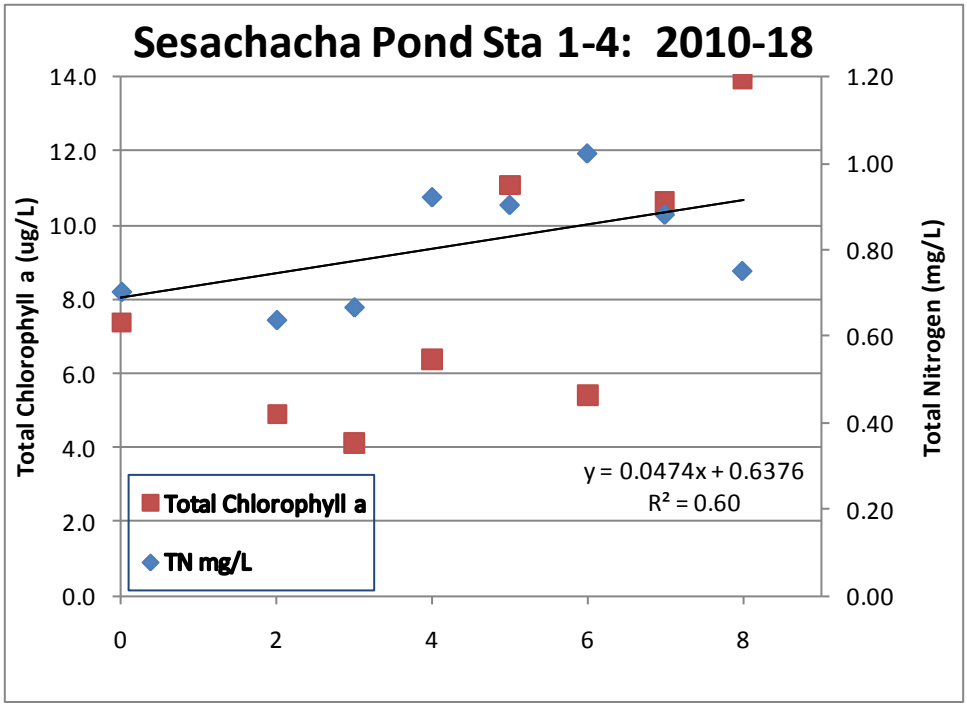

Figure 14b. Sesachacha main basin annual averages for TN and total chlorophyll a from 2010, 2012-2017 (shown as year 0, 2, 3, 4, 5, 6, 7). Total nitrogen appears to have been increasing over the monitoring period as openings have declined. 2010-2013 (TN=0.671 mg/L) is significantly ($p<0.05$) lower than 2014-2017 (TN=0.933 mg/L).

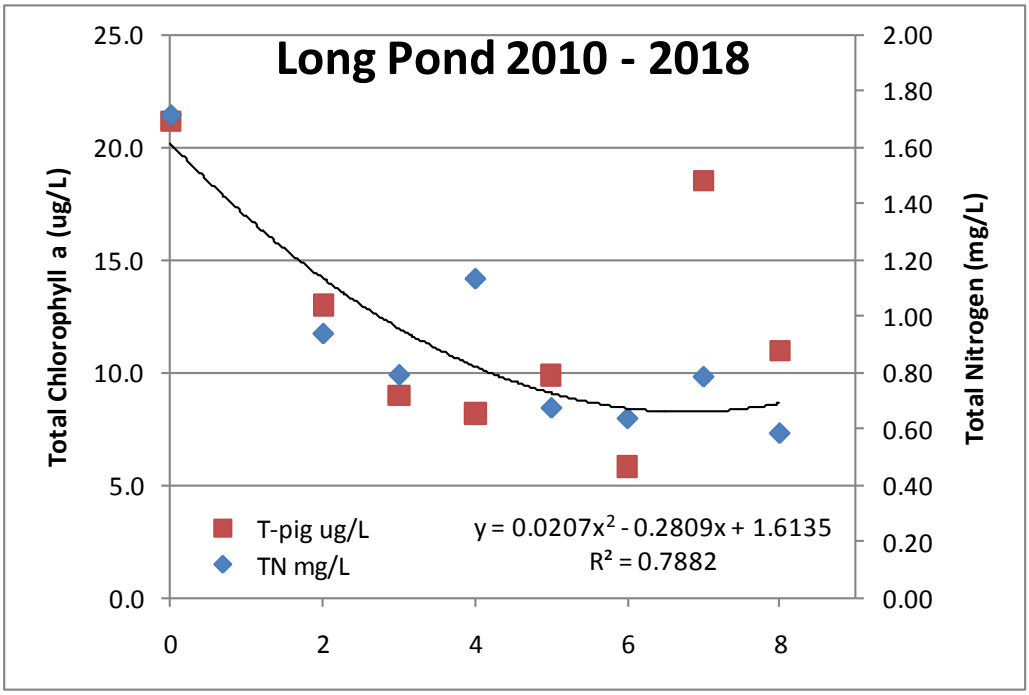

Figure 14c. Long Pond main basin annual averages for TN and total chlorophyll a from 2010, 2012-2017 (shown as year 0, 2, 3, 4, 5, 6, 7). Total nitrogen has declined over the monitoring period and appears to be stabilizing.

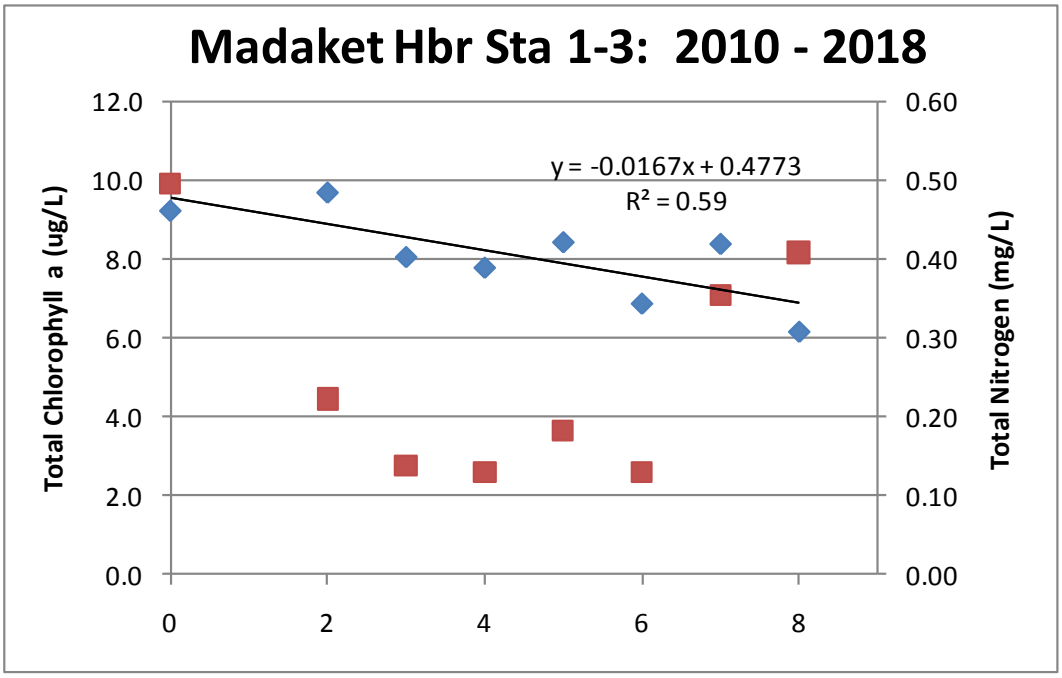

Figure 14d. Nearshore Madaket Harbor main basins annual averages for TN and total chlorophyll a from 2010, 2012-2017 (shown as year 0, 2, 3, 4, 5, 6, 7). Total nitrogen appears to have been declining over the monitoring period. While the trend is significant ($p<0.05$), the variability makes an accurate determination of average annual decline difficult in this initial analysis. The offshore station is not included.

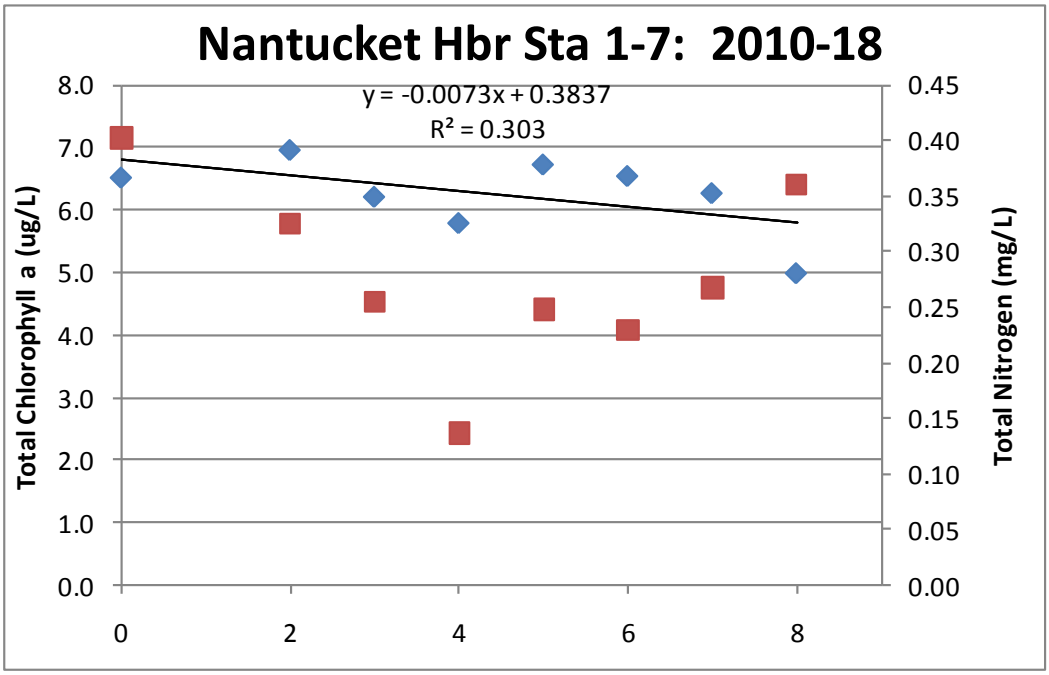

Figure 14e. Nantucket Harbor main basins annual averages for TN and total chlorophyll a from 2010, 2012-2017 (shown as year 0, 2, 3, 4, 5, 6, 7). Total nitrogen appears to have been declining over the monitoring period, but the variability makes determination of the magnitude difficult at this time. The variability and small potential decline can be seen in the low R2. The offshore station is not included.

Streams: Stream flow data has is not currently available for 2018 field season, but will be included at the appropriate time. Stream sampling in 2017 followed sampling completed in 2016 with the addition of one stream sampling location (WPH OUTLET, Figure 6). WPH Outlet was added by the Town of Nantucket as it is thought that a portion of the flow from the up-gradient bogs is discharged to West Polpis Harbor as depicted in Figure 6a. 2016 stream sampling locations were reduced from 6 stream locations to 3 (STA. 4, 4A and 6B), all of which discharge to Polpis Harbor. Stations 4 and 6B represent two distinct surface water inflows to Polpis Harbor with flow passing station 6B entering West Polpis Harbor and flow passing station 4 going to East Polpis Harbor from the up-gradient bogs, with the above mentioned caveat regarding station WPH OUTLET which may be directing a bit of cranberry bog flow to West Polpis Harbor. Station 4A (selected by the Conservation Foundation) is located up-gradient of station 4 and captures nutrient conditions prior to influence from a network of cranberry bogs.

TN concentrations at the three discharge points measured in 2017 (stations 6B, WPH OUTLET, 4) were relatively high and consistent (1.107 mg/L, 1.037 mg/L and 1.021 mg/L respectively). By comparison, the TN levels in the 2 streams to Polpis Harbor sampled in 2016 ranged from 0.856 mg/L in Stream 4 to 0.922 mg/L in Stream 6B (Table 3a). In spite of the high TN concentrations in these 2 streams and the TN loads that these streams transport to Polpis Harbor, tidal flushing and dilution with lower concentration Nantucket Harbor waters is sufficient to maintain TN levels in the main body of Nantucket Harbor at relatively low levels (Table 3a,b,c,d,e,f,g; Figure 6, 6a). The 2016 stream sampling sites were a subset of the streams sampled in 2010 with the results coupled with 2017 data and discussed below. It should be noted that the stream

stations were not sampled in 2012, 2013 or 2014, however, with increasing interest in lowering TN concentrations in Polpis Harbor, in 2015 it was decided to re-establish sampling of streams discharging to this tributary sub-embayment and continue sampling these sites with the idea that in the future a detailed evaluation of stream related flows and loads to east and west Polpis Harbor would warranted.

Average 2017 [2016, 2015, 2014, 2013, 2012, 2010] TN concentrations in East Polpis Harbor, 0.405 [0.400, 0.404, 0.378, 0.401, 0.438, 0.484] mg/L and West Polpis Harbor 0.429 [0.420, 0.422, 0.389, 0.385, 0.431, 0.419] appear to have been very stable from 2017-2012. These basins are fed by the high TN levels in Streams 4, WPH OUTLET and 6B and diffuse groundwater inflows and support TN levels slightly higher than the levels in the main Harbor, but still significantly lower than the levels in the streams (Table 2a, Figure 6, 6a). It should be noted that the two stations in Polpis Harbor (NAN-5 {Polpis west} and NAN-6 {Polpis east}) do show essentially the same TN concentration compared to levels observed in 2016 and 2015. TN levels remain above the nitrogen threshold for these basins, although total pigment was still relatively low in 2017 and similar to levels measured in 2016. Total pigment at Polpis Station NAN-5 was slightly lower in 2017 compared to 2016 (4.82 ug/L vs. 5.80 ug/L) and levels at NAN-6 were slightly higher in 2017 compared to 2016 (6.51 ug/L vs. 4.61 ug/L). These values are consistent with the nearly equal TN concentrations observed in 2017 and 2016. Chlorophyll levels in 2015 were higher than 2014 possibly reflecting the slightly higher TN and warmer summer conditions in 2015 compared to 2014. Overall, TN concentration in Nantucket Harbor was the same in 2017 (0.353 mg/L) compared to 2016 and slightly lower in 2016 (0.354 mg/L) compared to 2015 (0.381 mg/L) and slightly higher compared to summer 2014 (0.324 mg/L). As such it is important to continue summer water quality monitoring and watershed based nutrient management and to provide a multi-year base for determining TMDL compliance as management actions are being implemented. Evaluation of the streams should be continued keeping stream volumetric flow and stream sampling such that nitrogen loads to Polpis Harbor can be monitored and related to the Polpis Harbor TN levels. Determining the coupling of stream inputs to Harbor TN levels may support development of a nitrogen management alternative for this basins. However, given the complexity of flow from the bogs seemingly split between east Polpis and west Polpis Harbor, a more detailed study of this surfacewater flow systems and its associated loads might be needed to refine any potential management action.

Stream sampling in 2015, 2016 and 2017 included both nitrogen concentration and flow measurements and was included in the overall monitoring program to determine linkages, as they may exist, between stream loads and Polpis Harbor TN levels, particularly as related to the MEP TN threshold in Polpis Harbor (NAN-6 is considered the MEP sentinel station, with a TN threshold concentration of 0.355 mg/L for restoration). In 2017, samples were collected from 4 stations (stations 6B, WPH OUTLET, 4, 4A) on two distinct streams flowing into different parts of Polpis Harbor (e.g. east vs. west). This differs slightly from 2016 when samples were collected from a total of 3 stations in 2 streams (ST4, ST4A, ST6B) but in 2015 the same stations (ST4, ST6B) were sampled along with ST3 to gauge TN load discharging to Polpis Harbor. In 2017, station WPH OUTLET was added because it was suspected that a portion of the flow from upgradient cranberry bogs was splitting towards west Polpis Harbor as opposed to passing by station 4 and all entering east Polpis Harbor. In 2016, ST3 was replaced by ST4A (upgradient of ST4) because there was little flow at ST3 in 2015 and

no measureable flow in the summer of 2016 (though not checked consistently by the Town in 2016). Sampling at station 4A was continued in 2017, however, there is a possibility that this maybe discontinued in 2018 due to the limited flow passing through that stream sampling location. As in 2016, stream sampling in 2017 showed high TN concentrations at stations 4 and 4A (1.021 mg/L and 0.984 mg/L respectively) and higher than the same stations in 2016. By comparison, stream sampling in 2016 showed high TN concentrations at ST4 and 4A (0.856 mg/L and 0.776 mg/L respectively) but were lower than in 2015 (ST4 in 2015 = 1.060 mg/L), based on data presented in Table 2a,b,c. Interestingly, stream sampling site ST4 and ST6B were sampled once (June) in 2010 and showed TN concentrations of 1.200 and 2.139 mg/L respectively. The 2010 concentrations were consistent with the high concentrations observed in 2015 but in 2016 TN levels at both these stations (4 and 6B) were similar (0.856 mg/L and 0.922 mg/L) and lower than in 2015 or 2010. Similarly, in 2017 TN levels at both these stations (4 and 6B) were essentially the same (1.021 mg/L and 1.107 mg/L respectively). It should be noted that TN concentrations at WPH OUTLET were similar to measured concentrations at station 4, as would be expected (1.037 mg/L vs. 1.021 mg/L) since the flow passing WPH OUTLET is supposedly from the same up-gradient source, the cranberry bogs. The variation in TN levels from year to year may be associated with a combination of changes in long-term groundwater variations as well as cranberry bog management and warrants continued monitoring of stream flow and nutrient concentrations discharging to Polpis Harbor. Management of these flows and nutrient loads may provide a non-infrastructure approach to achieving the MassDEP/USEPA TMDL TN threshold for Polpis Harbor at the sentinel station (NAN-6).

By measuring both the nutrient concentrations and the volumetric discharge the nutrient load can be determined. As in the previous year, Town of Nantucket staff measured the volumetric flow of water flowing at each sampling location in parallel with the water quality sample collection during the summer 2017 field season. The Town provided to CSP the critical stream flow values (m^3/d) to be coupled with the parallel measurements of total nitrogen concentration data to calculate TN load (kg/day) from these streams to Polpis Harbor in summer 2017. The flow determined for each sampling day was then used to determine load for a representative month.

Combining the high TN concentrations with relatively large flows measured in 2017 at ST4, WPH OUTLET and ST6B, it is clear that a large TN load is being transported to Polpis Harbor on a monthly basis, if there is sufficient flow. For the period June-October, the load passing through sampling location 4, WPH OUTLET and 6B was calculated to be 198 kg, 152 kg and 156kg respectively (based on values presented in Table G). It is important to note that given some of the large loads presented for winter and spring sampling dates as opposed to the lower loads during the summer when rainfall is typically much lower than in the winter and spring, a more robust quantification of flows and loads is warranted given the potential influence of these discharges on the sentinel station in Polpis Harbor. Given this first approximation of the TN loads entering Polpis Harbor via streams, it would clearly be worth continuing measuring flow and nitrogen sampling in coming years of monitoring, particularly since flows and loads in 2017 and 2016 appeared higher than in 2015. A perfect comparison is difficult as the sampling periods were not exactly the same in these initial years.

Table G. 2017 flows and nitrogen and phosphorus loads determined for two streams at sampling stations 4 and 6B. Station 4A is upgradient of station 4 in the same stream.

Date	Sample ID	Measured Flow (m3/d)	TN Load (kg/day)	TN Load (kg/month)	TP Load (kg/day)	TP Load (kg/month)	Representative Month
2/8/2017	ST4	343	0.2366	6.63	0.0127	0.36	**February**
3/27/2017	ST4	969	0.7292	22.60	0.0364	1.13	**March**
4/27/2017	ST4	2911	1.9522	58.57	0.1272	3.82	**April**
5/23/2017	ST4	ND	ND	ND	ND	ND	**May**
6/12/2017	ST4	1584	1.6539	49.62	0.0930	2.79	**June**
7/5/2017	ST4	171	0.1499	4.65	0.0060	0.19	**July**
8/15/2017	ST4	3743	3.2070	99.42	0.0981	3.04	**August**
9/11/2017	ST4	685	0.7796	23.39	0.0422	1.27	**September**
10/24/2017	ST4	580	0.6899	21.39	0.0963	2.99	**October**
2/8/2017	ST4A	70	0.0627	1.75	0.0006	0.02	**February**
3/27/2017	ST4A	159	0.0915	2.84	0.0005	0.02	**March**
9/11/2017	ST4A	710	1.0488	31.46	0.0279	0.84	**September**
2/8/2017	ST6B	159	0.1037	2.90	0.0035	0.10	**February**
3/27/2017	ST6B	489	0.2556	7.92	0.0087	0.27	**March**
4/27/2017	ST6B	856	0.5221	15.66	0.0243	0.73	**April**
5/23/2017	ST6B	1737	3.4664	107.46	0.0551	1.71	**May**
6/12/2017	ST6B	208	0.4185	12.56	0.0086	0.26	**June**
7/5/2017	ST6B	1798	2.0030	62.09	0.1830	5.67	**July**
8/15/2017	ST6B	0	0.0000	0.00	0.0000	0.00	**August**
9/11/2017	ST6B	1676	1.4075	42.22	0.0645	1.94	**September**
10/24/2017	ST6B	1121	1.2595	39.05	0.3695	11.45	**October**
5/23/2017	WPH OUTLET	5811	5.1762	160.46	0.2565	7.95	**May**
6/12/2017	WPH OUTLET	1182	1.3769	41.31	0.0625	1.88	**June**
8/15/2017	WPH OUTLET	976	0.7176	22.25	0.0248	0.77	**August**
9/11/2017	WPH OUTLET	1994	2.2316	66.95	0.1279	3.84	**September**
10/24/2017	WPH OUTLET	612	0.6896	21.38	0.0947	2.94	**October**

Table H. 2016 flows and nitrogen and phosphorus loads determined for two streams at sampling stations 4 and 6B. Station 4A is upgradient of station 4 in the same stream.

Sample ID	Date	Measured Flow (m3/d)	TN Load (kg/day)	TN Load (kg/month)	TP Load (kg/day)	TP Load (kg/month)	Representative Month
STA4	3/16/2016	6044	3.455	107.11	0.457	14.15	March
STA4	4/20/2016	2544	1.464	43.92	0.228	6.85	April
STA4	5/17/2016	1479	1.139	35.32	0.124	3.86	May
STA4	6/14/2016	451	0.425	12.74	0.056	1.69	June
STA4	7/21/2016	0	0.000	0.00	0.000	0.00	July
STA4A	3/16/2016	734	0.405	12.55	0.009	0.29	March
STA4A	4/20/2016	361	0.199	5.96	0.004	0.12	April
STA4A	5/17/2016	183	0.115	3.56	0.003	0.08	May
STA4A	6/14/2016	214	0.163	4.90	0.004	0.12	June
STA4A	7/21/2016	31	0.029	0.90	0.001	0.03	July
STA6B	3/16/2016	452	0.215	6.67	0.013	0.40	March
STA6B	4/20/2016	449	0.176	5.27	0.013	0.38	April
STA6B	5/17/2016	1154	0.644	19.98	0.038	1.17	May
STA6B	6/14/2016	2418	3.045	91.36	0.645	19.34	June
STA6B	7/21/2016	75	0.071	2.21	0.027	0.84	July

Table I. 2015 flows and nitrogen loads determined for three streams. Stations 4 and 6B were also sampled in 2016.

Sample ID	Date	Measured Flow (m3/d)	TN Load (kg/day)	TN Load (kg/month)	Representative Month
ST3	6/8/2015	259	0.301	9.0	June
ST3	7/6/2015	189	0.294	9.1	July
ST3	8/3/2015	83	0.078	2.4	August
ST3	8/31/2015	21	0.010	0.3	September
ST4	6/8/2015	2157	2.135	64.1	June
ST4	7/6/2015	999	0.981	30.4	July
ST4	8/3/2015	0	0.000	0.0	August
ST4	8/31/2015	104	0.107	3.2	September
ST6B	6/8/2015	457	0.385	11.5	June
ST6B	7/6/2015	444	0.799	24.8	July
ST6B	8/3/2015	92	0.074	2.3	August
ST6B	8/31/2015	88	0.083	2.5	September

The effect of stream inputs requires further analysis, because while flows and loads from stream sites ST4 and 6B were measurably higher in 2017 compared to 2016 and 2015, TN concentrations at stations Nan-5 and Nan-6 in Polpis Harbor were not significantly different from concentrations measured in 2016. Additionally, TN levels were lower in 2016 compared to 2015. Moreover, in regard to stream sampling location ST4 and ST4A (up-gradient of ST4 but selected by the Conservation Foundation to represent water before influence of the bogs), for the months of February and March in 2017 where there was data for both stations, TN load at ST4A compared to ST4 ranged from 12% to 25% (2016 TN load at ST4A compared to ST4 ranged from 12% to 38% of the measured load at ST4) indicating substantial “pick-up” of groundwater occurs between these stations. Equally important, in 2017 TN load for the period June through October from ST4 accounted for 27% more load when compared to load leaving ST6B (June-October load at ST4 = 198 kg vs. ST6B = 156 kg). Additionally, load from WPH OUTLET which enters west Polpis Harbor along with loads from ST6B is an equally significant input to that portion of the Polpis Harbor system (June-October load at WPH OUTLET = 152 kg vs. ST6B = 156 kg). The WPH OUTLET load maybe greater than that measured at STA6B simply because there was no data for July from the WPH OUTLET location. As previously mentioned in 2016, it would be important to more accurately quantify flows and loads from WPH OUTLET, ST4 and the up-gradient bog system as this surfacewater source may be the main driver of TN levels at Nan-5 and 6 in Polpis Harbor. Given these complexities, a detailed investigation of flow and loads throughout the network of bogs up-gradient of ST4 and WPH OUTLET is warranted to refine management of nutrients entering Polpis Harbor from its associated sub-watershed. Further study would be helpful to determine whether the cranberry bogs will benefit from best management practices to limit their influence in contributing nitrogen to Polpis Harbor. As such, it may be preferable that such an investigation be completed by the bog owner: The Nantucket Conservation Foundation in collaboration with the bog manager who would have detailed information on bog operating practices critical to ensure sample timing and bog management practices are coordinated.

Additional estuarine stations (ORS-2,3,4,5,6) were added in 2015 to the sampling stations in Nantucket Harbor and Madaket Harbor (ORS-1) specifically to monitor water quality in the vicinity of potential sites for deployment of oyster aquaculture. A subset of the 2015 stations (ORS-2,4,6) were sampled again in 2016 and 2017. These stations had never been sampled prior to 2015 so it is not possible to compare 2017, 2016 and 2015 results to past years, however, 2017, 2016 and 2015 results for stations ORS-2,4,6 can serve as the beginning of establishing a baseline for gauging changes in future years. 2017 TN levels at ORS-2,4,6 (0.329 mg/L, 0.414 mg/L, 0.460 mg/L) were very similar to 2016 levels (0.339 mg/L, 0.382 mg/L, 0.472 mg/L) and lower then in 2015 at ORS-2,4,6 (0.338 mg/L, 0.415 mg/L, 0.551 mg/L). Station concentrations are generally consistent with the water quality from nearby long term monitoring stations. In the future a detailed interpretation of the data collected at these stations will be possible once more data becomes available.

Table 2a. Summary of Stream Water Quality Parameters (ST4, ST6, WPH OUTLET) and stations associated with potential oyster aquaculture locations (ORS,2,4,6), **2018** Nantucket Sampling Program. STA4A was added in 2016 to further interpret flow and load results from STA4, however, in 2017 there were dates when there was no flow at STA4A and in 2018 samples were not collected from STA4A.

Date	Location	Sample ID	Lab Salinity ppt	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
4/25/2018	NANTUCKET STREAMS	ST4	0.10	0.028	0.042	0.004	0.003	0.007	0.305	0.268	0.335	0.019	0.325	0.332	NS	NS	NS
6/6/2018	NANTUCKET STREAMS	ST4	0.10	0.032	0.056	0.016	0.008	0.024	0.545	0.488	0.467	0.028	0.573	0.597	NS	NS	NS
6/26/2018	NANTUCKET STREAMS	ST4	0.10	0.037	0.067	0.008	0.013	0.021	0.548	0.488	0.358	0.030	0.578	0.599	0.93	1.52	2.45
7/24/2018	NANTUCKET STREAMS	ST4	0.10	0.023	0.678	0.004	0.006	0.010	0.475	0.416	1.305	0.102	0.577	0.587	4.80	1.05	5.85
8/21/2018	NANTUCKET STREAMS	ST4	0.10	0.026	0.376	0.007	0.016	0.023	0.608	0.541	15.878	0.986	1.593	1.617	7.13	5.19	12.32
4/25/2018	NANTUCKET STREAMS	ST6	0.00	0.023	0.032	0.008	0.011	0.019	0.281	0.257	0.501	0.024	0.305	0.324	NS	NS	NS
6/6/2018	NANTUCKET STREAMS	ST6	1.00	0.026	0.060	0.015	0.006	0.022	0.471	0.423	1.034	0.041	0.512	0.534	NS	NS	NS
6/26/2018	NANTUCKET STREAMS	ST6	0.00	0.070	0.112	0.014	0.000	0.014	0.522	0.459	1.665	0.095	0.617	0.630	0.52	1.82	2.34
7/24/2018	NANTUCKET STREAMS	ST6	0.00	0.091	0.261	0.015	0.006	0.021	0.367	0.333	6.480	0.370	0.736	0.758	0.32	0.43	0.75
8/21/2018	NANTUCKET STREAMS	ST6	0.10	0.015	0.244	0.005	0.002	0.007	0.184	0.163	5.825	0.250	0.434	0.441	0.07	1.40	1.47
4/25/2018	NANTUCKET STREAMS	WPH OUTLET	0.50	0.026	0.279	0.021	0.004	0.026	0.288	0.269	0.451	0.031	0.319	0.344	NS	NS	NS
6/6/2018	NANTUCKET STREAMS	WPH OUTLET	0.10	0.034	0.063	0.015	0.007	0.022	0.522	0.466	0.542	0.033	0.555	0.577	NS	NS	NS
6/26/2018	NANTUCKET STREAMS	WPH OUTLET	0.10	0.039	0.065	0.011	0.009	0.020	0.528	0.470	0.432	0.034	0.562	0.582	0.86	1.48	2.34
8/21/2018	NANTUCKET STREAMS	WPH OUTLET	NS	0.025	0.149	0.067	0.015	0.082	0.243	0.278	2.108	0.317	0.560	0.641	31.42	17.03	48.45

Date	Location	Sample ID	Lab Salinity ppt	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
6/5/2018	Old North Wharf - Oyster	ORS2	31.30	0.009	NS	0.020	0.0004	0.020	0.140	0.160	0.650	0.095	0.235	0.255	2.79	1.78	4.56
7/5/2018	Old North Wharf - Oyster	ORS2	29.60	0.018	NS	0.012	0.0004	0.013	0.145	0.157	0.692	0.106	0.251	0.264	2.65	0.89	3.54
8/1/2018	Old North Wharf - Oyster	ORS2	31.40	0.020	NS	0.003	0.0004	0.003	0.175	0.179	0.464	0.082	0.257	0.261	3.44	0.03	3.47
9/12/2018	Old North Wharf - Oyster	ORS2	31.20	0.031	NS	0.012	0.0004	0.013	0.144	0.157	0.326	0.054	0.198	0.211	1.77	0.56	2.33
6/5/2018	Shimmo - Oyster	ORS4	29.70	0.007	NS	0.000	0.0004	0.001	0.109	0.110	0.625	0.101	0.210	0.211	2.90	2.20	5.10
8/1/2018	Shimmo - Oyster	ORS4	30.90	0.023	NS	0.007	0.0004	0.007	0.179	0.186	0.632	0.126	0.305	0.312	1.88	0.29	2.17
9/12/2018	Shimmo - Oyster	ORS4	30.60	0.028	NS	0.028	0.0004	0.028	0.204	0.233	0.497	0.090	0.294	0.322	2.65	1.04	3.69
7/5/2018	Shimmo - Oyster	ORS4	29.00	0.023	NS	0.018	0.0037	0.022	0.162	0.184	0.747	0.132	0.294	0.316	4.92	1.28	6.19
6/5/2018	Polpis - Oyster	ORS6	30.50	0.012	NS	0.008	0.0004	0.008	0.163	0.171	0.780	0.124	0.287	0.295	2.67	2.21	4.89
7/5/2018	Polpis - Oyster	ORS6	28.80	0.030	NS	0.012	0.0004	0.013	0.130	0.142	1.366	0.215	0.345	0.358	6.96	1.71	8.66
8/1/2018	Polpis - Oyster	ORS6	30.70	0.027	NS	0.010	0.0004	0.010	0.191	0.201	0.792	0.167	0.358	0.369	3.60	1.39	4.99
9/12/2018	Polpis - Oyster	ORS6	31.30	0.030	NS	0.006	0.0004	0.007	0.223	0.230	4.674	0.544	0.767	0.774	28.10	0.03	28.12

Table 2b. Summary of Stream Water Quality Parameters (ST4,ST4A,ST6B) and stations associated with potential oyster aquaculture locations (ORS,2,4,6), **2017** Nantucket Sampling Program. STA4A was added in 2016 to further interpret flow and load results from STA4, however, in 2017 there were dates when there was no flow at STA4A.

Date	Location	Sample ID	Lab Salinity ppt	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
2/8/2017	NANTUCKET STREAMS	ST4	0.10	0.037	0.051	0.007	0.005	0.012	0.629	0.549	0.777	0.050	0.679	0.691	1.35	0.93	2.280
3/27/2017	NANTUCKET STREAMS	ST4	0.10	0.038	0.055	0.012	0.009	0.020	0.703	0.620	0.364	0.029	0.732	0.753	1.01	0.14	1.153
4/27/2017	NANTUCKET STREAMS	ST4	0.10	0.044	0.064	0.011	0.005	0.016	0.631	0.555	0.282	0.023	0.655	0.671	0.53	0.79	1.325
5/23/2017	NANTUCKET STREAMS	ST4	0.10	0.036	0.063	0.007	0.014	0.020	0.967	0.846	0.808	0.046	1.013	1.033	0.77	1.31	2.087
6/12/2017	NANTUCKET STREAMS	ST4	0.10	0.059	0.086	0.016	0.014	0.029	0.958	0.846	0.736	0.057	1.015	1.044	1.19	0.99	2.184
7/5/2017	NANTUCKET STREAMS	ST4	0.10	0.035	NS	0.011	0.004	0.015	0.806	0.704	0.629	0.039	0.845	0.875	0.63	0.89	1.522
8/15/2017	NANTUCKET STREAMS	ST4	0.10	0.026	0.053	0.007	0.002	0.010	0.742	0.644	1.649	0.095	0.837	0.857	3.05	0.03	3.073
9/11/2017	NANTUCKET STREAMS	ST4	0.10	0.062	0.085	0.021	0.002	0.023	1.079	0.945	0.569	0.036	1.115	1.138	1.53	0.46	1.987
10/24/2017	NANTUCKET STREAMS	ST4	0.10	0.166	0.227	0.007	0.006	0.013	1.142	0.990	0.505	0.035	1.177	1.190	0.02	0.36	0.374
2/8/2017	NANTUCKET STREAMS	ST4A	0.10	0.009	0.018	0.011	0.009	0.020	0.851	0.747	0.450	0.028	0.879	0.899	0.09	2.68	2.767
3/27/2017	NANTUCKET STREAMS	ST4A	0.10	0.003	0.012	0.011	0.008	0.019	0.514	0.457	0.451	0.043	0.556	0.575	0.24	0.33	0.566
9/11/2017	NANTUCKET STREAMS	ST4A	0.10	0.039	0.079	0.025	0.009	0.034	1.387	1.219	0.533	0.056	1.444	1.478	0.10	0.85	0.949
2/8/2017	NANTUCKET STREAMS	ST6B	0.10	0.022	0.030	0.010	0.007	0.017	0.603	0.531	0.557	0.032	0.635	0.652	0.39	0.55	0.942
3/27/2017	NANTUCKET STREAMS	ST6B	0.10	0.018	0.027	0.019	0.037	0.055	0.444	0.428	0.400	0.023	0.467	0.522	0.26	0.20	0.458
4/27/2017	NANTUCKET STREAMS	ST6B	0.00	0.028	0.040	0.013	0.008	0.021	0.553	0.492	0.664	0.036	0.589	0.610	0.50	0.82	1.316
5/23/2017	NANTUCKET STREAMS	ST6B	0.00	0.032	0.057	0.013	0.015	0.028	1.930	1.679	0.672	0.037	1.967	1.996	0.55	1.35	1.894
6/12/2017	NANTUCKET STREAMS	ST6B	0.00	0.041	0.062	0.016	0.015	0.031	1.927	1.679	1.124	0.054	1.981	2.013	0.65	0.95	1.600
7/5/2017	NANTUCKET STREAMS	ST6B	0.00	0.102	NS	0.003	0.005	0.008	0.581	0.505	13.568	0.516	1.097	1.114	0.63	2.03	2.667
8/15/2017	NANTUCKET STREAMS	ST6B	0.10	0.025	0.068	0.007	0.003	0.010	0.355	0.313	1.457	0.067	0.422	0.442	14.21	0.03	14.232
9/11/2017	NANTUCKET STREAMS	ST6B	0.00	0.039	0.054	0.016	0.003	0.019	0.787	0.691	0.640	0.033	0.821	0.840	0.04	0.38	0.416
10/24/2017	NANTUCKET STREAMS	ST6B	0.00	0.330	0.525	0.019	0.004	0.023	1.063	0.931	1.009	0.038	1.101	1.124	0.00	0.90	0.901
5/23/2017	NANTUCKET STREAMS	WPH OUTLET	1.00	0.044	0.074	0.006	0.007	0.013	0.823	0.716	0.902	0.055	0.878	0.891	0.30	1.29	1.590
6/12/2017	NANTUCKET STREAMS	WPH OUTLET	2.00	0.053	0.102	0.018	0.013	0.031	1.074	0.947	0.908	0.060	1.134	1.165	1.99	0.99	2.975
8/15/2017	NANTUCKET STREAMS	WPH OUTLET	0.70	0.025	0.047	0.019	0.004	0.023	0.627	0.557	1.079	0.062	0.689	0.735	0.60	0.03	0.623
9/11/2017	NANTUCKET STREAMS	WPH OUTLET	0.10	0.064	0.087	0.020	0.006	0.026	1.052	0.924	0.707	0.041	1.093	1.119	0.20	0.75	0.958
10/24/2017	NANTUCKET STREAMS	WPH OUTLET	0.10	0.155	0.216	0.011	0.008	0.019	1.063	0.927	0.793	0.046	1.109	1.127	0.06	0.70	0.762

Table 2b cont'd. Summary of Stream Water Quality Parameters (ST4,ST4A,ST6B) and stations associated with potential oyster aquaculture locations (ORS,2,4,6), **2017** Nantucket Sampling Program. STA4A was added in 2016 to further interpret flow and load results from STA4, however, in 2017 there were dates when there was no flow at STA4A.

Date	Location	Sample ID	Lab Salinity ppt	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
5/17/2017	Old North Wharf - Oyster	ORS2	31.90	0.009	NS	0.016	0.003	0.019	0.213	0.231	0.450	0.083	0.296	0.314	2.08	0.87	2.95
6/14/2017	Old North Wharf - Oyster	ORS2	30.30	0.004	NS	0.013	0.001	0.014	0.220	0.234	0.283	0.049	0.269	0.283	3.98	0.75	4.73
7/12/2017	Old North Wharf - Oyster	ORS2	NS	0.023	NS	0.035	0.003	0.038	0.206	0.244	NS	NS	NS	NS	NS	NS	NS
8/10/2017	Old North Wharf - Oyster	ORS2	31.00	0.014	NS	0.014	0.001	0.015	0.262	0.277	0.296	0.043	0.305	0.334	1.87	0.03	1.89
9/25/2017	Old North Wharf - Oyster	ORS2	29.70	0.021	NS	0.063	0.013	0.076	0.242	0.318	0.302	0.052	0.294	0.370	1.59	0.81	2.40
5/17/2017	Shimmo - Oyster	ORS4	30.70	0.009	NS	0.014	0.012	0.027	0.387	0.414	0.296	0.049	0.436	0.463	1.02	0.87	1.89
6/14/2017	Shimmo - Oyster	ORS4	29.70	0.012	NS	0.022	0.007	0.029	0.284	0.313	0.318	0.059	0.343	0.372	1.55	1.19	2.74
7/12/2017	Shimmo - Oyster	ORS4	30.10	0.019	NS	0.035	0.003	0.038	0.257	0.295	0.326	0.054	0.311	0.386	1.57	1.50	3.07
8/10/2017	Shimmo - Oyster	ORS4	30.30	0.017	NS	0.014	0.003	0.017	0.462	0.479	0.306	0.051	0.514	0.548	1.02	0.35	1.37
9/25/2017	Shimmo - Oyster	ORS4	29.10	0.027	NS	0.047	0.027	0.074	0.225	0.299	0.310	0.050	0.276	0.350	1.30	0.76	2.06
5/17/2017	Polpis - Oyster	ORS6	30.20	0.009	NS	0.011	0.000	0.011	0.230	0.241	0.417	0.074	0.304	0.315	1.56	0.86	2.43
6/14/2017	Polpis - Oyster	ORS6	30.00	0.009	NS	0.010	0.001	0.011	0.322	0.333	0.306	0.054	0.376	0.387	1.68	1.07	2.75
7/12/2017	Polpis - Oyster	ORS6	30.20	0.021	NS	0.046	0.006	0.052	0.393	0.445	0.542	0.101	0.494	0.598	3.33	0.90	4.23
8/10/2017	Polpis - Oyster	ORS6	30.10	0.020	NS	0.026	0.002	0.028	0.307	0.335	0.344	0.061	0.368	0.424	0.38	0.34	0.73
9/25/2017	Polpis - Oyster	ORS6	28.70	0.027	NS	0.069	0.011	0.080	0.271	0.351	0.529	0.079	0.350	0.430	1.82	1.52	3.35

Table 2c. Summary of Stream Water Quality Parameters (ST4,ST4A,ST6B) and stations associated with potential oyster aquaculture locations (ORS,2,4,6), **2016** Nantucket Sampling Program. Station STA3 from 2015 was discontinued due to zero flow (should be checked in out years to confirm flow) and STA4A was added to further interpret flow and load results from STA4.

Date	Embayment	Sample ID	Lab Salinity ppt	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
3/16/2016	Stream to Polpis	STA4	0.1	0.044	0.076	0.012	0.001	0.014	0.529	0.543	0.323	0.029	0.558	0.572	0.42	0.45	0.87
4/20/2016	Stream to Polpis	STA4	0.1	0.045	0.090	0.008	0.001	0.009	0.538	0.547	0.299	0.028	0.566	0.575	0.49	0.54	1.03
5/17/2016	Stream to Polpis	STA4	0.2	0.071	0.084	0.014	0.001	0.015	0.715	0.730	0.464	0.041	0.756	0.770	0.44	0.70	1.15
6/14/2016	Stream to Polpis	STA4	0.1	0.064	0.125	0.022	0.004	0.026	0.862	0.888	0.552	0.054	0.915	0.942	0.40	1.15	1.55
7/21/2016	NS	STA4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
3/16/2016	Stream to Polpis	STA4A	0.1	0.007	0.013	0.012	0.001	0.013	0.515	0.528	0.259	0.023	0.539	0.552	0.11	0.45	0.55
4/20/2016	Stream to Polpis	STA4A	0.1	0.005	0.012	0.010	0.002	0.012	0.512	0.524	0.295	0.027	0.539	0.551	0.28	0.46	0.74
5/17/2016	Stream to Polpis	STA4A	0.1	0.006	0.014	0.014	0.000	0.014	0.584	0.597	0.523	0.031	0.615	0.628	3.89	2.26	6.15
6/14/2016	Stream to Polpis	STA4A	0.0	0.010	0.019	0.022	0.006	0.028	0.704	0.733	0.310	0.030	0.734	0.763	1.10	1.85	2.94
7/21/2016	Stream to Polpis	STA4A	0.1	0.016	0.027	0.023	0.010	0.032	0.856	0.888	0.441	0.050	0.906	0.938	0.20	0.92	1.13
3/16/2016	Stream to Polpis	STA6B	0.0	0.021	0.028	0.013	0.003	0.016	0.434	0.450	0.309	0.026	0.460	0.476	0.15	0.40	0.55
4/20/2016	Stream to Polpis	STA6B	0.0	0.018	0.028	0.010	0.002	0.012	0.361	0.373	0.257	0.019	0.379	0.392	0.39	0.57	0.96
5/17/2016	Stream to Polpis	STA6B	0.0	0.025	0.033	0.014	0.002	0.015	0.516	0.531	0.351	0.028	0.543	0.558	0.38	0.69	1.07
6/14/2016	Stream to Polpis	STA6B	0.0	0.118	0.267	0.023	0.008	0.031	0.891	0.922	7.398	0.338	1.229	1.259	0.35	2.01	2.36
7/21/2016	Stream to Polpis	STA6B	0.0	0.173	0.361	0.020	0.008	0.028	0.604	0.632	7.724	0.317	0.921	0.949	0.005	0.39	0.40

Date	Embayment	Sample ID	Lab Salinity ppt	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
5/12/2016	Old North Wharf - Oyster	ORS2	31.5	0.006	NS	0.004	0.000	0.004	0.144	0.148	0.222	0.036	0.180	0.184	0.61	0.38	0.99
6/27/2016	Old North Wharf - Oyster	ORS2	32.0	0.014	NS	0.008	0.009	0.017	0.195	0.213	0.430	0.074	0.269	0.287	1.57	0.73	2.30
7/11/2016	Old North Wharf - Oyster	OR2	31.1	0.018	NS	0.007	0.003	0.010	0.248	0.258	0.589	0.104	0.352	0.362	3.66	0.66	4.32
8/25/2016	Old North Wharf - Oyster	ORS2	32.1	0.014	NS	0.004	0.002	0.006	0.098	0.104	0.478	0.081	0.178	0.184	1.43	0.55	1.98
9/20/2016	Old North Wharf - Oyster	ORS2	32.0	0.021	NS	0.006	0.007	0.013	0.425	0.438	0.331	0.087	0.512	0.525	0.59	0.60	1.19
5/12/2016	Shimmo - Oyster	ORS4	30.8	0.008	NS	0.004	0.008	0.012	0.147	0.159	0.252	0.038	0.185	0.197	0.48	0.32	0.80
6/27/2016	Shimmo - Oyster	ORS4	31.6	0.016	NS	0.012	0.001	0.013	0.202	0.214	0.836	0.162	0.364	0.377	3.83	0.82	4.65
7/11/2016	Shimmo - Oyster	OR4	29.7	0.022	NS	0.012	0.006	0.018	0.289	0.307	0.647	0.117	0.406	0.424	1.35	1.16	2.51
8/25/2016	Shimmo - Oyster	ORS4	31.5	0.019	NS	0.008	0.003	0.010	0.128	0.138	0.727	0.125	0.253	0.263	1.50	1.41	2.91
8/25/2016	Shimmo - Oyster	ORS4	31.4	0.019	NS	0.012	0.002	0.014	0.139	0.153	0.656	0.112	0.251	0.265	1.14	1.25	2.40
9/20/2016	Shimmo - Oyster	ORS4	31.4	0.019	NS	0.007	0.006	0.013	0.287	0.300	0.840	0.165	0.452	0.465	3.13	0.52	3.64
5/12/2016	Polpis - Oyster	ORS6	30.5	0.008	NS	0.005	0.000	0.005	0.157	0.162	0.337	0.050	0.207	0.212	0.59	0.64	1.23
6/27/2016	Polpis - Oyster	ORS6	32.0	0.024	NS	0.008	0.001	0.009	0.280	0.289	0.566	0.101	0.381	0.390	1.80	1.05	2.86
7/11/2016	Polpis - Oyster	OR6	30.9	0.021	NS	0.061	0.002	0.063	0.298	0.360	0.769	0.137	0.435	0.498	2.96	1.43	4.39
8/25/2016	Polpis - Oyster	ORS6	32.1	0.027	NS	0.018	0.002	0.020	0.173	0.194	--	--	0.844	--	4.49	4.61	9.09
9/20/2016	Polpis - Oyster	ORS6	31.4	0.026	NS	0.006	0.006	0.011	0.334	0.345	1.947	0.185	0.519	0.530	3.01	0.36	3.37

Table 2d. Summary of Stream Water Quality Parameters (ST3,ST4,ST6B) and stations associated with potential oyster aquaculture locations (ORS1,2,3,4,5,6), **2015** Nantucket Sampling Program.

Sample ID	Date	Embayment	Avg. PO4 (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
ST3	6/8/2015	ND	0.011	0.012	0.056	0.068	0.369	0.437	9.117	0.724	1.093	1.160	2.334	4.934	7.267
ST3	7/6/2015	STREAMS TO POLPIS	0.012	0.007	0.052	0.059	0.369	0.429	19.465	1.126	1.495	1.554	0.884	2.088	2.971
ST3	8/3/2015	STREAMS TO POLPIS	0.021	0.004	0.049	0.052	0.330	0.382	10.349	0.557	0.886	0.939	0.025	0.757	0.782
ST3	8/31/2015	STREAMS TO POLPIS	0.010	0.010	0.050	0.059	0.229	0.289	4.055	0.211	0.440	0.499	0.476	5.067	5.543
ST4	6/8/2015	ND	0.037	0.010	0.001	0.011	0.942	0.953	0.539	0.037	0.979	0.990	0.612	1.536	2.148
ST4	7/6/2015	STREAMS TO POLPIS	0.044	0.010	0.000	0.010	0.935	0.945	0.454	0.037	0.972	0.982	0.261	0.652	0.913
ST4	8/3/2015	STREAMS TO POLPIS	0.168	0.026	0.002	0.028	0.975	1.003	4.852	0.243	1.218	1.246	0.109	0.482	0.591
ST4	8/31/2015	STREAMS TO POLPIS	0.077	0.020	0.001	0.021	0.905	0.926	1.596	0.098	1.003	1.024	1.104	1.266	2.370
ST6B	6/8/2015	STREAMS TO POLPIS	0.024	0.011	0.000	0.011	0.649	0.660	3.694	0.182	0.831	0.842	1.310	2.059	3.369
ST6B	7/6/2015	STREAMS TO POLPIS	0.166	0.007	0.001	0.007	0.790	0.797	22.908	1.003	1.793	1.801	0.329	0.745	1.074
ST6B	8/3/2015	STREAMS TO POLPIS	0.012	0.014	0.001	0.015	0.322	0.337	11.321	0.469	0.791	0.806	0.200	0.519	0.719
ST6B	8/31/2015	STREAMS TO POLPIS	0.026	0.077	0.014	0.091	0.411	0.502	9.627	0.443	0.854	0.945	3.178	7.018	10.196

Sample ID	Date	Embayment	Avg. PO4 (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Avg. Total Pig (ug/L)
ORS1	6/9/2015	MADAKET	0.037	0.015	0.005	0.020	0.287	0.307	0.849	0.119	0.406	0.426	3.376	4.160	7.536
ORS1	7/6/2015	MADAKET HITHER CREEK	0.025	0.000	0.014	0.014	0.373	0.388	1.072	0.231	0.604	0.618	6.118	4.891	11.009
ORS2	6/9/2015	OLD NORTH WHARF	0.014	0.019	0.000	0.019	0.200	0.219	0.563	0.090	0.290	0.309	2.855	2.202	5.057
ORS2	7/6/2015	OLD NORTH WHARF	0.016	0.004	0.007	0.011	0.287	0.298	0.532	0.086	0.373	0.384	1.733	1.453	3.186
ORS2	8/3/2015	OLD NORTH WHARF	0.019	0.017	0.011	0.028	0.254	0.282	0.350	0.059	0.313	0.341	0.661	1.806	2.467
ORS2	9/2/2014	OLD NORTH WHARF	0.026	0.020	0.001	0.021	0.225	0.246	0.407	0.072	0.297	0.318	1.523	1.940	3.463
ORS3	6/9/2015	MONOMOY CREEKS	0.024	0.014	0.036	0.050	0.294	0.344	0.473	0.077	0.371	0.421	1.563	2.419	3.983
ORS3	7/6/2015	MONOMOY CREEKS	0.028	0.029	0.047	0.076	0.429	0.504	0.522	0.082	0.511	0.587	1.212	1.491	2.703
ORS4	8/3/2015	PIMENYS POINT	0.012	0.015	0.002	0.016	0.369	0.385	0.373	0.064	0.433	0.449	0.909	1.193	2.102
ORS4	9/2/2014	SHIMMO	0.026	0.056	0.003	0.059	0.214	0.273	0.596	0.109	0.323	0.382	2.712	2.476	5.188
ORS5	8/3/2015	DUCKS HOLM	0.009	0.012	0.003	0.015	0.460	0.475	0.351	0.063	0.522	0.537	0.904	0.849	1.753
ORS5	9/2/2014	DUCKS HOLM	0.014	0.013	0.000	0.013	0.302	0.315	0.493	0.089	0.391	0.404	1.237	2.264	3.501
ORS6	8/3/2015	POLPIS	0.020	0.013	0.000	0.013	0.533	0.546	0.683	0.112	0.645	0.658	1.589	2.614	4.204
ORS6	9/2/2014	POLPIS	0.035	0.050	0.000	0.050	0.299	0.349	0.561	0.094	0.393	0.443	1.451	2.696	4.147

Trophic State of the Estuaries of Nantucket Island

The Trophic State of an estuary is a quantitative indicator of its nutrient related ecological health and is based on key ecological metrics: concentrations of inorganic and organic Nitrogen, water clarity (Secchi Depth), lowest measured concentrations of Dissolved Oxygen (average of lowest 20% of measurements), and Chlorophyll-*a* pigments (surrogate for phytoplankton biomass/blooms). Nutrient related trophic health scales generally range from Oligotrophic (healthy-low nutrient) to Mesotrophic (showing some signs of deterioration of health due to nutrient enrichment) to Eutrophic (habitats significantly impaired and degraded, high levels of nutrients and organic matter and community shifts). The Trophic Health Index Score used here is a standard numerical scale based on criteria for open water embayments and uses the above mentioned measured parameters to create a habitat quality scale (Howes et al. 1999, http://www.savebuzzardsbay.org). For the estuaries within the Town of Nantucket, a trophic index score was calculated for each sampling location for each year (2010 and 2012- 2018) using the summer monitoring results. The Index scores were calculated in 2 ways, one which included the low dissolved oxygen for each year in the index ("with DO", Table 8) and one which excluded the oxygen metric ("without DO", Table 9). The reason for this dual approach is that in some estuaries, such as those on Nantucket, there are only periodic depletions in bottom water dissolved oxygen, generally related to meteorological events acting on nutrient enriched basins. While these short-term depletions have important ecological consequences, they are difficult to capture in programs that sample 4 or 5 dates per summer. In these cases, inclusion of the oxygen can bias the Index upwards (i.e. higher quality) because of the greater probability of capturing high versus low oxygen events (i.e. missing periodic low oxygen events). This bias was found in the previous analysis of the 2010 dataset, as well as for other estuaries in s.e. Massachusetts. However, this is not always the case and there was no substantive “biasing high” between the "with DO" and "without DO" Index scores based on the 2013 and 2014 data and again in 2016 and 2017 none-the-less, the index analysis by both methods is presented for informational purposes herein (Tables 8a-g and 9a-g). It should be noted that to the extent the bias does exist in a given year, it relates only to the oxygen data, the other water quality parameters do not change as rapidly as dissolved oxygen and therefore the sampling program adequately captures accurate concentrations of nutrient related metrics (DO changes by the hour). Further analysis of the *with DO* and *without DO* index values for all stations and monitoring years indicates that there is very little difference in the determined index value between the methods (RPD <10%; generally <5%). The exception was in Miacomet Pond and Head of Hummock Pond which have significant DO depletions in some years and therefore higher variability between the methods (RDP up to 20%). Given that inclusion of oxygen data did not generally change the bay health rank, the index calculated by including DO appears to be most appropriate based upon 8 years of data, but both approaches are developed each year and presented herein.

For the present analysis the standard Index (with DO) was used for assessment and the Health Status was determined for each site based on the data collected during the sampling events. The ranges of Index scores that fall within a particular Health Status determination are given at the bottom of both Tables 7 and 8 with the Index values and description for each monitoring station. Figures 20-24 show the distribution of Health Status throughout each estuary based on each of the 8 years of monitoring (2010, 2012-2018). For the location maps, only the “with DO” index is shown as in 3 of the

past 5 years the inclusion of DO made no substantive difference in the index value and in 2015 the difference was minor. Therefore, the Index maps shown for the “with DO” index are comparable to other estuaries in the region for assessing Trophic Status. Numerical results in the tables are color coded in the figures for ease of interpretation. The colors of each triangle represent the Bay Health Index status of each site and follow the designation scheme below:

Color	**Health Status**
Blue	High Quality
Blue/Yellow	High-Moderate
Yellow	Moderate
Yellow/Red	Moderate/Fair
Red	Fair/Poor

The integrated water quality scores, as represented by the Index were generally consistent among all 8 years of monitoring. Although change at some sites was observed, change was gradual and large inter-annual changes were typically related to major management actions. This relative stability is typical as nutrient related health does not generally change rapidly unless a significant alteration has occurred to the watershed nitrogen loading or to tidal flushing of a basin (e.g. Hummock Pond, Long Pond). However, 4 systems do appear to show a potential shift in nitrogen related health over the past 8 years, Hither Creek, lower Hummock Pond and Long Pond and after 8 years, slight improvements in Nantucket Harbor seem to be emerging (see below). Based upon the results it is possible to assess the nutrient related health of the basins within each of the 5 estuarine systems within the Nantucket Water Quality Monitoring Program. The following assessments rely mainly on the Index "with DO" scores as it appears to accurately represent current conditions:

Madaket Harbor

Madaket Harbor main basin in 2018 continued to support a high level of nutrient related water quality. It has been the more enclosed basins of Hither Creek and Long Pond with their reduced tidal flushing that have had nitrogen impairment problems. Water quality generally changes gradually, unless there has been a major change in loading or flushing. Within the Madaket Harbor/Long Pond watershed there has been a significant change in the nitrogen sourced at the Town Landfill. The Landfill has recently been undergoing management actions that reduce nitrogen loading to the groundwater, hence to upper Long Pond. It appears that the long-term gradual reduction in TN levels within the upper portions of this complex estuary is consistent with a lowering of watershed nitrogen loading. Over the 8 years of monitoring, Hither Creek (Station 1), which receives discharge from Long Pond via Madaket Ditch, has consistently supported the poorest “health” status within the Madaket Estuary (Table 8, 9, Figure 20). Hither Creek is clearly nitrogen enriched and showing continuing impairment based on a variety of parameters, but has clearly improved since 2010. Over the past 8 years the Index indicates that this basin has improved slightly each year, going from fair-poor water quality and improving in a step-wise manner to moderate water quality since 2014. The exception was 2017 where TN levels rose, but stayed within the range that has developed over the past 4-5 years, TN level declined to pre-2017 levels in 2018 and it is expected that this variability will be reduced in coming years as the system reaches a new equilibrium with the new lower landfill TN loading rate. The main basin of Madaket Harbor is showing relatively

high water quality in each year but also shows a possible improvement from 2010 to 2012 and has been generally stable at high water quality in more recent samplings to 2018. It appears that Station 2, near the outlet to Hither Creek can receive low quality waters on the ebb tide from Hither Creek and that can modify water quality at this nearshore location (e.g. 2010). But with improvements in the water quality in Hither Creek, its effect on water quality at Station 2 in nearshore Madaket Harbor has been insufficient to effect the Harbor waters, which have maintained high quality status since 2012. The offshore sites (3 & 4) support high quality waters resulting from low nitrogen inputs and very high rates of water exchange. The 8 year positive trend in health index is at least partially the result of the reduced loading from the landfill to upper Long Pond and an improvement in the ebbing waters through Madaket Ditch. This trend is consistent with the upper basin feeding Madaket Ditch. In 2014-2018 the previously observed gradient in water quality metrics between the 2 Long Pond stations is only periodically detectable, lessening concern over a potential tidal restriction. While a further analysis of the mechanism underlying this periodic gradient would be useful, it is not needed at this time, tracking the phenomenon through the on-going monitoring program should be sufficient. If the improvement in Hither Creek becomes stabilized at the lower end of its range (0.8 – 0.6 mg/L) and 2018 was 0.59 mg N/L, it is possible that the TMDL for Madaket Harbor may require somewhat less nitrogen load reduction, making the success of other nitrogen management actions (other than associated with the landfill and any needed septic system work in Madaket) more certain. However, at this point it is likely that additional nitrogen management will be required to meet the TMDL in Hither Creek as it remains of moderate quality, although it appears the reduced load discharging from Madaket Ditch has resulted in somewhat lower TN levels already. It should be noted that the “fair/poor" quality water designation in Long Pond relates primarily to Long Pond being not supportive of eelgrass. But the MEP and TMDL for Long Pond is based on infaunal animals living in the bottom sediments (i.e. not eelgrass) so the water quality index should not cause concern. However, additional analysis is required to determine if landfill activities will be sufficient to meet the TMDL for Long Pond (see below). Additional study to clarify the drivers of the improvement (controllable such as the landfill improvements or fertilizer management) will further assist in determining the magnitude of septic system management as posited through the MEP analysis. This further analytical effort is in progress in parallel with the Town’s actual and potential management actions.

Long Pond

Long Pond is a large tributary basin to Madaket Harbor, which receives tidal flow through the artificial connection of Madaket Ditch. Given the structure of the basin and its watershed, Long Pond operates semi-independently from Madaket Harbor (Figure 20). Unlike Madaket Harbor which is marine, Long Pond is a brackish water system resulting from mixing of groundwater inflows and salt water entering through its restricted tidal channel (2018 salinity = 16 PSU). Long Pond’s Bay Health scores for both stations (5 & 6) in the 8 years of monitoring (2010, 2012-2018) clearly indicate poor nutrient related water quality. It is nearly certain that the water quality of Hither Creek is partially dependent on the nitrogen load from Long Pond via Madaket Ditch during the ebb tide. However, it should be noted that the TMDL targets restoration of sediment animal communities (infauna) which do not require the same high water quality as eelgrass.

Based upon the 2018 results and the 8 year time-series, it appears that the Town’s management of the landfill, has reduced the nitrogen load from this source with the associated observed lowering of TN levels. The connection is strengthened by the

parallel timing of the landfill work and the lowering of TN in the adjacent waters, which are only a short travel time from the landfill. While still small, the water quality Index for Long Pond is starting to improve in response to the lower TN levels although the basin remains impaired. TN levels in 2015-2017 and 2018 were almost half that of historical and 2010 measurements although they still show inter-annual variations. While continued monitoring will determine the final level of improvement, it does appear that the reduction in N loading is occurring with beneficial effects. If TN levels stabilize at 2018 levels, the TN target in the TMDL will be achieved and in 2 years a habitat and DO survey should be conducted to remove Long Pond from the MassDEP list of impaired waters. It should be noted that the lack of major change in the Health Index for Long Pond results in part from the relative coarseness of the Index, where sometimes large index score changes are required to change the Index value. The analysis of key metrics (Chlorophyll-*a*, water clarity-Secchi and total nitrogen) individually do show improving water quality at stations 5 and 6 in 2012-2018 compared to 2010 and in the MEP threshold analysis (see analysis and figures above).

Nantucket Harbor

Nantucket Harbor with Madaket Harbor are presently supporting the highest water quality of Nantucket's estuaries. In 2018, all of the Nantucket and Polpis Harbor stations were showing high water quality, slightly better than in 2017 Over the past 5 years, the main basin of Nantucket Harbor has supported high quality waters, with only a periodic small level of decline in the uppermost basin, Wauwinet basin (Figure 21). Wauwinet basin (station 3) had the highest average total nitrogen values for the Harbor System in 2013 (0.415 mg/L) and 2015 (0.436 mg/L) consistent with its designation as the surrogate for the sentinel station for the main basin and its documented past eelgrass loss. It should be noted that in summer 2016, SMAST added station 2A and established it as the official MEP sentinel station for which the nitrogen threshold was established (refer to Figure 2, TN 0.399 mg/L), along with station 3 in order to meet TMDL compliance monitoring criteria. Summer 2017 saw a slightly lower TN level at station NAN-2A (0.368 mg/L) and 2018 lower still (0.337 mg/L). Summers 2016-2018 generally showed similar water quality in this basin as 2014 which showed improved chlorophyll-*a* and TN levels versus prior years. The main driver of the poorer 2015 water quality was a phytoplankton bloom in the upper Harbor, which was relatively large for Nantucket Harbor but only moderate for more enriched estuaries in the region. While it is unclear if blooms will become more commonplace in the future, the levels in 2016 reflected more historic conditions and 2017/2018 again higher levels, clearly these blooms need to be tracked. However, other activities associated with the Harbor (additional sewer hookups, jetty improvement and oyster aquaculture) should result in even lower TN and chlorophyll levels and reduce the likelihood of large phytoplankton blooms in the future.

A similar pattern was seen in the enclosed sub-basins of Polpis Harbor (East and West) as in the main basins of Nantucket Harbor. Polpis Harbor basins which after showing moderate impairment in 2010 and 2012 have been showing only low to no impairment in recent years, suggesting some improvement over historic conditions. As in Wauwinet, Polpis Harbor showed 2018 & 2017 TN levels similar to 2010, 2012 and 2015, slightly higher than 2013 and 2014. This variation makes continued monitoring essential to clarify any trends in water quality and linkages to stream nitrogen discharges. Polpis Harbor did not show a phytoplankton bloom in 2015 and supported only moderate-low phytoplankton biomass in 2015-2017 and 2018 (average <6 ug/L)

and appears to have attained generally high water quality status from moderate status in 2010 and 2012. While the overall Nantucket Harbor System is generally supporting high quality waters, the variability in the index in Wauwinet and Polpis basins should be monitored to ascertain their long-term health and to determine the effectiveness of restoration effort by the Town as it continues to move forward to meet the MassDEP TMDL for this system. Overall, Nantucket Harbor appears to be relatively stable from year to year with a gradual slight improvement with high index scores and higher level metrics that support the contention that it is approaching its TMDL threshold, as is also the case for Polpis Harbor. Equally important, although variable, it appears that slight positive changes have been occurring in recent years.

Sesachacha Pond

Sesachacha Pond is a closed coastal salt pond that has its water quality managed by periodically breaching the barrier beach to open the basin to tidal exchange with the adjacent Atlantic Ocean waters. This management action serves to flush out nutrients and organic matter on the ebb tides and receive saline waters on the flood tides. Sesachacha Pond was evaluated under the Massachusetts Estuaries Project and a nitrogen threshold (0.60 mg/L) was established for restoration of this system. Additionally, the MEP analysis recommended an additional mid-summertime opening (if logistically possible) as part of the pond management strategy to enhance flushing of the pond and improve water quality to reach the threshold without any need for infrastructure. The water quality monitoring program in 2010, 2012 and 2013 showed that the pond nitrogen levels were converging on the 0.60 mg/L total nitrogen threshold established by the MEP. Total nitrogen (TN) levels dropped significantly from historical levels of 1.20 mg/L to ~0.68 mg/L in 2010 and 2012 and 0.67 mg/L in 2013, with associated improvements in the levels of water clarity and chlorophyll-*a*. However, with limited openings in 2014-2017, TN has risen and has returned to near historic levels, ~0.9 mg/L but with an improvement in 2018 (0.752 mg N/L), associated with continuing impaired conditions. It appears that these changes relate to the quality of the pre-summer opening. Given the 2010-2013 period when robust openings occurred, it appears that a solid opening program has the capability to improve the water quality metrics pond-wide to levels near the TMDL nitrogen threshold.

Based upon the Index alone, changes in water quality in Sesachacha Pond over the 2010-2013 period were stabilized at moderate impairment of this estuary, with more recent monitoring 2015-2017 seeing a trend toward poor water quality conditions with a rebound in 2018 (Figure 22) as TN levels rose (2015-2017) then declined (2018). Additional higher level assessment of Sesachacha Pond initiated based on the 2010 monitoring results was conducted and confirmed that the pond was improving by 2013, but was impaired in 2014 consistent with the monitoring results. The 2015-2018 data underscores the reversal of improvement with phytoplankton biomass (as chlorophyll) averaging >10 ug/L at all stations over the summer of 2018, 2017 and 2015 and 6-10 ug/L in 2016, consistent with nitrogen enrichment. The high chlorophyll values are consistent with the elevated TN values in 2014-2018. It appears that like other periodically opened ponds, the quality of the opening (amount of water exchanged) controls the level of water quality in the following months. Fortunately, the data indicate that attaining pond openings of the quality of 2012 and 2013 (done under Town supervision) in the future may be sufficient to attain the TMDL for this system. In addition the impaired but improved conditions in 2018, while high in TN, did not show bottom water D.O. depletion, but with high chlorophyll-a, consistent with the MEP

threshold target of 0.60 mg N/L. A closer examination of the opening protocol and the linkage to resultant water quality is needed for management of this system.

Hummock Pond

Hummock Pond is a closed coastal salt pond that is only periodically opened to the ocean to flush out nutrients and organic matter on the ebb tide and receive low nutrient saline waters on the flood tide. Creating sustained openings that are sufficient to allow exchange of tidal waters for more than 4-5 days has been difficult for this system due to its location on the coast and the large amount of sand migration in the coastal zone which can rapidly reseal the inlet.

Hummock Pond is opened at a sufficient frequency to sustain salinity levels in the 4-8 ppt range, with only small inter-annual differences (2012 slightly higher than 2010). The pond supports a small but clear salinity gradient from Station 1 nearest the ocean to Station 7 in the uppermost basin (Head of Hummock). The present non-tidal state and watershed nutrient inputs have resulted in moderate to poor nutrient related water quality throughout the pond, with poor water quality conditions the present norm (2005-2007, 2010, 2012, 2013, 2014, 2015). Unfortunately, in 2016 the pond appears to have had lower water quality in its upper and mid reaches than in previous years, although the lower basin did not show this inter-annual variation. Similarly, in 2017 and 2018 water quality declined further throughout most of the estuary, including the lower basin. This resulted from the poor spring 2017 and 2018 opening which is reflected in the very low salinities throughout summer 2017 (3.5 PSU) and 2018 (4.8 PSU). There is generally a small gradient in water quality with moderate to poor conditions near the ocean and poor conditions in the uppermost basins, but this collapsed to generally poor water quality throughout the system in 2017 and 2018 (Figure 23). The uppermost basin, Station 7, is approaching fresh/brackish conditions (4 ppt and 3.7 in 2018) and is currently supporting mainly freshwater plant and animal habitats. This basin is particularly eutrophic with phytoplankton blooms periodically exceeding 70 ug/L (offshore waters are ~2 ug/L), although 2017 & 2016 showed levels ~15 ug/L and 21 ug/L in 2018 (consistent with is decline in salinity). This basin appears to have been artificially connected to the adjacent estuary and is the recipient of much of the freshwater inflow. It is one of the most highly eutrophic basins within the Town of Nantucket with oxygen depletions to 3 mg/L. Due to the restricted tidal exchange even the lower basin of Hummock Pond supports moderate to high average chlorophyll levels ~10 ug/L (2010, 2012, 2015). All of the metrics are consistent with a nutrient impaired basin in all years. It should be noted that the lower third of the Hummock Pond Estuary is currently supporting impaired benthic animal habitat even though conditions are the "best" in the overall impaired system.

Based upon the monitoring results it is clear that the nutrient related health of Hummock Pond is significantly related to the success of its periodic openings. As a result, the Town and Nantucket Land Council undertook an analysis to refine the opening protocol and gauge its effectiveness. The April 2013 opening was the first “experimental” opening and it appeared to result in significant loss of TN and inflow of salt water. The individual metrics and the Health Index for summer 2014 and 2015 appear to support that tidal flushing was improved as nutrient related health was highest in 2014 and 2015 of the years monitored. It also appears that the continued successful inlet openings from April 2014 into 2015 have resulted in additional improvements in water quality from 2014 to 2015, with 2015 showing the lowest TN levels in records back to 2005, although

it is still above its threshold value to support high quality habitat. Unfortunately, this pattern was not seen in the 2016-2018 water quality data, which showed further decline in the upper and mid reaches, and even the lower basin. This opening program and associated monitoring around the openings and in the summer will need to be used to set metrics for a "successful" opening, to produce a simplified assessment protocol for opening success and to document and further refine the opening protocol for the Town's on-going program. To date this joint effort has shown the potential for significant benefits to Hummock Pond water quality and associated natural resources at low cost to the Town, but successful openings appear to vary from year-to-year.

Miacomet Pond

Miacomet Pond is a closed coastal salt pond that is rarely (over a decade ago) opened to the ocean to flush out nutrients and organic matter on the ebb tide and receive low nutrient saline waters on the flood tide. As a result of the lack of tidal flow and continuous groundwater inputs, the pond is presently freshwater, with salinity levels in each of the past 7 years of monitoring of <0.5 ppt, reaching a low of 0.1 ppt, 2015-2017. The present non-tidal state and extent of watershed nutrient inputs has resulted in a decline in nutrient related water quality throughout the pond for both nitrogen and phosphorus, with poor water quality and habitat impairment the present norm (Figure 24). This can be seen, for example, in the high chlorophyll levels (2010: 12-50 ug/L); 2012: 10-20 ug/L; 2013: 20-26 ug/L; 2014: 23-70 ug/L; 2015: 38-53 ug/L) several times greater than the levels found in the high quality basins of Nantucket and Madaket Harbors with a maximum in 2018 (25 ug/L) following highs in 2017 and 2016 (mean = ~14 ug/L). It appears that 2015 also had very high chlorophyll levels which were seen in several of Nantucket's estuaries, with conditions returning to more typical levels in 2016 and 2017. All of the metrics for Miacomet Pond are consistent with a highly nutrient impaired basin. However, as the freshening of this basin has become complete and sustained, it likely will have to be managed as a transitional freshwater system and will need to be reassessed as such. As salt ponds freshen and become fresh ponds the nutrient causing eutrophication can shift to phosphorus from nitrogen or become both nitrogen and phosphorus (seasonally varying nutrient limitation). Since Miacomet Pond may have storm over-wash in the future due to climate change related storm intensification and sea level rise, it may be necessary for management to create both a nitrogen and a phosphorus budget for this system and to conduct short-term incubations to determine which nutrient is controlling pond health under present and varying salinity conditions. None-the-less, phosphorus should be a part of pond management, with phosphorus limitation to phytoplankton growth throughout Miacomet Pond in 2018 and 2016/2017, although only for the middle and lower pond in 2015. It is also important to note that orthophosphate concentrations are quite low in the main basin (MP-1, MP-2) generally <0.2 uM, such that adding phosphorus to this basin in mid-summer would likely stimulate phytoplankton growth. In contrast, the uppermost reach generally supports 2x-3x higher phosphate levels. It is likely that regions of the pond may be sensitive to both nitrogen and phosphorus, such that overall both nutrients need to be monitored and considered for management of Miacomet Pond, although phosphorus management is clearly needed at this time.

Another challenge in managing Miacomet Pond is that it will be difficult for the Pond to maintain itself as a purely freshwater system as storm over-wash and rising sea level (as well as increasing storm intensity and frequency related to climate change) will tend to periodically cause seawater intrusion into its lower basin. An analysis of future

conditions for Miacomet Pond as sea level rises may be in order in the near future, as remediation is considered. But at present the system is a highly nutrient impaired aquatic system with poor water quality. It would be prudent for the Town to continue the development of a management plan that takes into account not only the nutrient related impairment of Miacomet Pond, but also accommodates the likely shifting between fresh and salt water over the long term.

Recommendations for Future Monitoring (2018)

(1) As mentioned in previous years summaries of estuarine water quality across Nantucket, due to the critical importance of dissolved oxygen to the ecological health of an estuarine basin, additional data should be collected using high frequency automated sensors when the low frequency sampling of the monitoring program suggests that a problem may exist in a specific basin. At this point, Polpis Harbor and Wauwinet basin in Nantucket Harbor and Hither Creek and Long Pond in the Madaket Harbor System should be considered for this analysis at some time in the future (e.g. summer 2019/2020). It may also be timely to complete a higher level nutrient limitation assessment of Miacomet Pond (if one hasn't already been completed) as that large “salt pond” has been transitioning to a freshwater ecosystem and has been showing consistently poor water quality and low trophic status indicative of an impaired habitat. However, procedural steps should also be implemented to strengthen the oxygen data base from the on-going monitoring program. In addition, Long Pond appears to be maintaining a lowering of its nitrogen levels over the past 3 years (even though 2017 TN levels are slightly higher than 2016), since the MEP full assessment of ecological health. At present, it appears that the Town activities at the Landfill have lowered the annual nitrogen input from this source lowering TN levels in Long Pond to ~0.6 mg N/L. However, it is not known how long it will take for the full reduction to occur (as it appears to be continuing into 2018) or what the new TN load from the landfill will be. In addition, the extent of ecological improvement in Long Pond has not been fully assessed toward meeting the restoration targets under the Clean Water Act, although the lowering of nitrogen levels is a very positive result as also shown in the benthic infaunal survey (November 2017).

Approaches to address these 2 issues are:

a) Deploying in situ oxygen meters (sondes) on the bottom of specific estuaries at several strategic locations for the summer months when periodic hypoxic or anoxic events in bottom waters can occur.

b) Long Pond is currently being reassessed with the MEP watershed-embayment management model to determine if the new low TN levels are likely sustainable. This effort uses Town evaluation of the current TN load to the pond from the landfill. The monitoring results from 2012 - 2018 appear to show a significant reduction in TN over historical conditions and 2010, however, there is still some inter-annual variability as seen in the 2014-2018 results. At present, TN levels are the lowest on record. The landfill analysis would allow prediction of how low TN levels should decline and should guide the level of improvement expected in animal communities that was seen in 2017. It appears the Long Pond may be near compliance with its TMDL and the Clean Water Act.

(2) Results from monitoring streams discharging to Nantucket Harbor (specifically Polpis Harbor) for which sampling was conducted only in 2015, 2016 and 2017 indicated that the nitrogen load from these streams can be significant relative to TN levels within Polpis Harbor, but that flow is highly seasonal due to lower stream flow volumes in summer. With increasing interest in lowering TN concentrations in Polpis Harbor to meet the MEP established TN threshold, it is appropriate to extend stream sampling into the 2018 sampling season given the high concentrations of total nitrogen observed in 2017, 2016 and 2015 that are discharging to this tributary sub-embayment. Moreover, given the complexity of the flow leaving the cranberry bogs up-gradient of station 4 and the apparent split of the flow between east and west Polpis Harbor, a detailed flow and load investigation should be undertaken. This is particularly important as the load entering west Polpis Harbor past station WPF OUTLET appeared to be nearly equal to the load entering the same portion of the system past station 6B (however sources of load to both discharge points are different). The team is awaiting the 2018 flow measurements for this analysis.

The stream monitoring coupled to the estuarine monitoring will allow a determination of the linkage of stream discharge to TN levels in Polpis Harbor. Moreover, in regard to stream sampling location ST4 and ST4A, TN load at ST4A compared to ST4 in 2017 ranged from ~12% to 25% (2016, ~12% to 38%) of the measured load at ST4, clearly indicating a load difference with associated concentrations being measurably higher at station 4A (1.478 mg/L) compared to station 4 (1.021 mg/L). In 2016 the average TN concentrations were fairly similar (0.856 versus 0.776 mg/L). It is clear that there is significant “pick-up” of flow and load to the stream occurring between the upper and lower station, which dominates the stream discharge to the Harbor. The source of this nitrogen should be investigated. In 2017 TN load for the period June through October from ST4 accounted for 27% more load when compared to load leaving ST6B (June-October load at ST4 = 198 kg vs ST6B = 156 kg). Additionally, load from WPH OUTLET which enters west Polpis Harbor along with loads from ST6B is an equally significant and possibly greater input to that portion of the Polpis Harbor system (June-October load at WPH OUTLET = 152 kg vs ST6B = 156). The WPH OUTLET load maybe greater than that measured at STA6B simply because there was no data for July from the WPH OUTLET location. The initial data from 2016 indicated that TN load from ST4 accounts for 61% to 70% of the combined load from streams ST4 and ST6B. Given the 2017 and the 2016 results, it would be important to determine the watershed areas contributing flow and load to ST4, ST6B and WPH OUTLET and to a lesser extent from the upgradient bog system relative to reducing loads to Polpis Harbor. A more detailed investigation is warranted in collaboration with the bog owner.

(3) Miacomet continues to show poor trophic conditions, high TN concentrations (though slightly lower in 2017 at stations MP-1 and MP-2) through its basins (stations 1, 2, and 3 in 2018: 0.797, 0.864. 0.562 mg/L, 2017: 0.641, 0.584, 0.909 mg/L, 2016: 0.772, 0.669, 0.783 mg/L, respectively). Although TN levels were slightly lower in 2018 and 2017 at the middle and lower stations and lower in 2016 than in 2015, 2017 and 2018 levels are still indicative of a highly enriched condition, as also indicated by the high total pigment concentrations (CHLA + pheophytin) in 2018 (19-36 ug/L), 2017 (10-20 ug/L) and 2016. In light of yet another year of poor water quality in Miacomet Pond, nitrogen and phosphorus budgets should be developed for Miacomet Pond and a quantitative analysis of N versus P as the driving nutrient of eutrophication (if this has

not been completed to date). Assessing the degree to which Miacomet Pond is N or P limited and if the limitation tends more to one or the other constituent seasonally will be critical to developing an effective management plan for this freshwater system coupled with results from the 604b study prepared by Water Resources Services in conjunction with the Town of Nantucket, Nantucket Pond Coalition and Nantucket Land Council to address N/P limitation using groundwater wells.

(4) Pond Openings and Linkage to Water Quality. Hummock Pond appears to have its nutrient related health significantly controlled by the success of its periodic openings. As a result, the Town and Nantucket Land Council undertook an analysis of openings in 2013-2014 to refine the opening protocol and gauge its effectiveness. Critical elements of the protocol were described in a technical memorandum developed by the Coastal Systems Program which summarized two openings that were monitored to gauge effectiveness. The opening protocol developed from this detailed work should continue to be rigorously implemented as monitoring clearly shows that if specific conditions are taken into consideration during a given opening, the ensuing opening tends to be effective and have a clear positive impact on water quality. To date Hummock Pond water quality has been shown to significantly improve under the revised opening protocol by the Town. However, poor openings in 2017 have negated those improvements. Even so, the monitoring indicates that both Sesachacha and Hummock Ponds respond rapidly to changes in the level of annual flushing. It appears that only ~3 years of good flushing conditions can significantly improve pond water and habitat quality. It also appears that pond openings may have to be coupled with other nitrogen management alternatives to provide sufficient and long-lasting restoration.

Monitoring of the pond opening should be continued to evaluate the need for a mid-summer opening (as was recommended by the MEP for the Sesachacha Pond system) in this system and to improve the present protocol and to set metrics for evaluating a "successful" opening in real time. Summer openings are hindered by restrictions due to piping plover nesting, so it will be important to address this issue as possible over the coming year. As previously stressed, monitoring openings should include wind and tidal conditions during a given opening, pond water level before during and after the opening, water quality before opening and after closure, size of opening {depth and width} and number of days that tidal flows (in and out) occurred. It should be noted that timing and construction of a proper pond opening is a difficult task to accomplish successfully, especially through a large barrier beach like that separating Sesachacha Pond from the ocean waters. The concept is to first document what has worked and what has not to help make the efforts by the Town more beneficial. Future openings in 2018 should continue to be monitored, as for Hummock Pond, to build a database of the details of an effective opening in both Sesachacha Pond (and Hummock Pond). The Ponds Opening Protocol should continue to be refined, with the goal of making future openings more beneficial to the associated pond's water quality and producing simplified approaches to reduce the effort required for a successful opening. If it is determined that effective openings can not be achieved for either closed pond but in particular Sesachacha Pond, due to the dynamic nature of the barrier beaches being breached, then the town will have to focus on reducing load to the ponds from the watershed or consider in situ approaches for improving water quality. Oyster aquaculture as appropriate is being investigated by towns on Cape Cod.

Acknowledgements

This work is in collaboration with the Town of Nantucket through its Natural Resources Department and the Marine Department. Special thanks go to Kaitlyn Shaw, Town of Nantucket Water Resources Specialist and the Monitoring Program Coordinator, Assistant Biologist Leah Cabral and to Jeff Carlson, Director - Natural Resources Department, for the extra efforts that they have provided to ensure sampling success and the maintenance of a high quality monitoring program. In addition, the Nantucket Land Council (Cormac Collier) provided support for assessment of Hummock Pond openings and the development of the new opening protocol, with additional support from Land Council staff. It is through the dedication of these groups and the efforts of other environmental stewards in the Town of Nantucket that Nantucket's estuaries are being protected and in some cases already moving toward restoration.

Table 3a. Summary of Water Quality Parameters, **2018** Nantucket Sampling Program. Values are Station Averages of all sampling events, June-September for sampling sites. Station NAN2A represent an MEP sentinel location for monitoring in Nantucket Harbor. NAN-2A is in a new station that was first sampled in 2016 and is in a different location than NAN-2. It should be noted that in 2018, TP was only evaluated in the stream sites, Sesachacha Pond, Hummock Pond, Long Pond and Miacomet Pond because of the expected low salinity values in those closed ponds and the possibility that the Miacomet system maybe phosphorous limited rather than nitrogen limited. Further study should investigate the possibility of P-limitation and TP paired with salinity should continue to be monitored during the summer 2019 field season.

Summer 2018 Embayment	Sample ID	Secchi average (meters)	Secchi Depth % of WC	20% Low Field DO Sat (mg/L)	20% Low Field DO Sat (% sat)	Salinity (ppt)	Avg. PO4 (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Chla/T-Pig Ratio	Avg. Total Pig (ug/L)
HUMMOCK POND	HUM7	1.333	35%	3.835	41%	3.74	0.0460	0.174	0.0079	0.181	0.285	0.466	2.395	0.423	0.707	0.889	13.09	8.71	0.60	21.80
HUMMOCK POND	HUM8	0.383	32%	5.139	62%	4.03	0.0813	0.060	0.0306	0.090	0.514	0.604	11.792	2.884	3.398	3.488	46.80	3.85	0.92	50.65
HUMMOCK POND	HUM5	0.708	42%	8.159	92%	4.90	0.0545	0.014	0.0101	0.024	0.403	0.427	2.162	0.376	0.779	0.804	13.63	7.17	0.66	20.80
HUMMOCK POND	HUM3	0.938	52%	6.756	82%	5.55	0.0394	0.019	0.0113	0.030	0.418	0.448	2.183	0.409	0.826	0.856	13.77	4.17	0.73	18.76
HUMMOCK POND	HUM1	0.950	38%	5.640	67%	5.81	0.0269	0.009	0.0035	0.013	0.393	0.406	2.082	0.375	0.768	0.781	13.31	3.89	0.77	17.21
LONG POND	LONG6	0.900	100%	3.266	42%	16.79	0.0239	0.004	0.0008	0.005	0.333	0.338	1.339	0.216	0.549	0.554	8.38	1.51	0.85	9.90
LONG POND	LONG5	1.000	86%	5.969	79%	15.43	0.0480	0.005	0.0005	0.006	0.317	0.323	2.051	0.297	0.614	0.620	9.81	2.19	0.82	12.00
MADAKET HARBOR	MH1	1.494	84%	5.194	68%	30.12	0.0087	0.017	0.0013	0.018	0.197	0.217	1.062	0.199	0.396	0.414	8.68	6.11	0.59	14.79
MADAKET HARBOR	MH2	1.813	100%	5.468	73%	29.81	0.0044	0.012	0.0008	0.012	0.161	0.173	0.637	0.107	0.281	0.293	4.32	1.89	0.70	6.21
MADAKET HARBOR	MH3	2.188	95%	5.706	76%	31.42	0.0060	0.008	0.0004	0.008	0.134	0.142	0.446	0.076	0.210	0.218	2.80	0.69	0.80	3.48
MADAKET HARBOR	MH4	3.875	70%	6.216	83%	31.51	0.0107	0.009	0.0004	0.009	0.114	0.123	0.364	0.058	0.172	0.181	2.89	0.48	0.86	3.37
MIACOMET POND	MP3	1.113	89%	4.869	51%	0.10	0.0589	0.016	0.0393	0.055	0.300	0.355	1.286	0.207	0.507	0.562	9.19	9.82	0.48	19.01
MIACOMET POND	MP1	1.050	62%	7.085	79%	0.41	0.0119	0.039	0.0057	0.045	0.458	0.503	1.574	0.294	0.752	0.797	15.78	4.29	0.79	20.07
MIACOMET POND	MP2	1.544	56%	5.332	58%	0.55	0.0068	0.046	0.0049	0.050	0.456	0.507	1.905	0.356	0.812	0.863	27.78	8.12	0.77	35.90
NANTUCKET HARBOR	NAN1	3.188	77%	5.771	75%	30.94	0.0167	0.006	0.0004	0.006	0.140	0.146	0.385	0.065	0.206	0.212	2.90	0.35	0.89	3.25
NANTUCKET HARBOR	NAN2	2.588	65%	5.394	80%	30.98	0.0181	0.013	0.0003	0.014	0.145	0.159	0.591	0.097	0.242	0.256	3.86	1.23	0.76	5.09
NANTUCKET HARBOR	NAN2A	2.113	59%	5.134	77%	31.00	0.0232	0.014	0.0004	0.014	0.193	0.207	0.865	0.130	0.323	0.337	7.00	1.52	0.82	8.52
NANTUCKET HARBOR	NAN3	2.000	53%	5.520	77%	31.04	0.0191	0.011	0.0004	0.011	0.178	0.189	0.923	0.136	0.314	0.325	5.61	1.04	0.83	6.65
NANTUCKET HARBOR	NAN4	2.775	62%	6.214	86%	31.02	0.0142	0.007	0.0004	0.007	0.125	0.132	0.393	0.059	0.185	0.192	2.77	0.55	0.83	3.32
NANTUCKET HARBOR	NAN5	1.713	85%	5.172	79%	30.51	0.0204	0.010	0.0004	0.011	0.186	0.196	1.012	0.144	0.330	0.341	5.78	1.39	0.81	7.17
NANTUCKET HARBOR	NAN6	2.250	87%	5.115	79%	30.71	0.0193	0.008	0.0004	0.009	0.172	0.180	1.092	0.147	0.318	0.327	7.22	1.40	0.84	8.62
NANTUCKET HARBOR	NAN7	1.675	75%	5.631	81%	30.88	0.0174	0.018	0.0003	0.018	0.145	0.163	0.556	0.090	0.235	0.253	3.78	1.14	0.77	4.92
NANTUCKET HARBOR	NAN8N	1.225	100%	5.573	76%	30.81	0.0162	0.005	0.0004	0.006	0.163	0.168	0.512	0.085	0.248	0.253	2.98	0.81	0.79	3.79
Nantucket Hrb. Stream Site	ST4	0.264	100%	2.290	24%	0.10	0.0291	0.008	0.0093	0.017	0.496	0.513	3.144	0.233	0.729	0.746	4.29	2.59	0.62	6.87
Nantucket Hrb. Stream Site	ST6	0.165	50%	6.770	70%	0.22	0.0450	0.011	0.0050	0.016	0.365	0.381	2.658	0.156	0.521	0.537	0.30	1.22	0.20	1.52
Nantucket Hrb. Stream Site	WPH OUTLET	0.275	100%	1.691	22%	0.23	0.0310	0.028	0.0089	0.037	0.395	0.432	0.757	0.104	0.499	0.536	16.14	9.26	0.64	25.40
SESACHACHA POND	SESA3	0.763	25%	6.546	79%	13.20	0.2826	0.013	0.0015	0.015	0.345	0.360	3.046	0.393	0.739	0.754	11.19	3.01	0.79	14.21
SESACHACHA POND	SESA2	0.750	19%	6.737	83%	13.20	0.2830	0.016	0.0008	0.016	0.364	0.375	3.081	0.397	0.761	0.778	9.96	3.15	0.76	13.11
SESACHACHA POND	SESA4	0.775	22%	6.868	84%	13.19	0.2568	0.007	0.0021	0.009	0.335	0.345	3.087	0.399	0.734	0.744	11.78	3.17	0.79	14.95
SESACHACHA POND	SESA1	0.794	18%	6.599	81%	13.20	0.3007	0.018	0.0020	0.020	0.321	0.341	3.082	0.394	0.715	0.734	10.77	2.75	0.80	13.52
OLD NORTH WHARF - Oyster	ORS2	1.313	100%	5.500	71%	30.88	0.0193	0.012	0.0004	0.012	0.151	0.163	0.533	0.084	0.235	0.248	2.66	0.81	0.77	3.48
SHIMMO Oyster	ORS4	1.213	100%	3.323	49%	30.05	0.0202	0.013	0.0012	0.014	0.164	0.178	0.625	0.112	0.276	0.290	3.09	1.20	0.72	4.29
POLPIS Oyster	ORS6	1.000	100%	4.337	60%	30.33	0.0246	0.009	0.0004	0.009	0.177	0.186	1.903	0.263	0.439	0.449	10.33	1.33	0.89	11.67

Table 3b. Summary of Water Quality Parameters, **2017** Nantucket Sampling Program. Values are Station Averages of all sampling events, June-September for sampling sites. Station NAN2A represent an MEP sentinel location for monitoring in Nantucket Harbor. NAN-2A is in a new station that was first sampled in 2016 and is in a different location than NAN-2. It should be noted that in 2017, TP was only evaluated in the stream sites, Sesachacha Pond (pre and post opening, Hummock Pond (pre and post opening) and Miacomet Pond because of the expected low salinity values in those closed ponds and the possibility that the Miacomet system maybe phosphorous limited rather than nitrogen limited. Further study should investigate the possibility of P-limitation and TP paired with salinity should continue to be monitored during the summer 2018 field season.

(2017) Embayment	Sample ID	Secchi average (meters)	Secchi Depth % of WC	20% Low Field DO Sat (mg/L)	20% Low Field DO Sat (% sat)	Salinity (ppt)	Avg. PO4 (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Chla (ug/L)	Avg. Phaeo (ug/L)	Chla/T-Pig Ratio	Avg. Total Pig (ug/L)
HUMMOCK POND	HUM7	1.81	48%	4.67	51%	2.11	0.134	0.095	0.004	0.098	0.392	0.490	1.551	0.254	0.646	0.789	11.470	2.438	0.825	13.908
HUMMOCK POND	HUM8	0.53	38%	6.86	75%	2.68	0.123	0.017	0.014	0.031	0.647	0.678	2.788	0.512	1.159	1.200	33.279	11.694	0.740	44.974
HUMMOCK POND	HUM5	0.66	32%	6.99	77%	3.39	0.131	0.039	0.005	0.044	0.577	0.621	2.134	0.382	0.959	1.024	23.904	4.068	0.855	27.972
HUMMOCK POND	HUM3	0.83	42%	8.36	92%	4.10	0.091	0.014	0.004	0.018	0.540	0.558	2.069	0.414	0.954	0.980	22.450	5.163	0.813	27.613
HUMMOCK POND	HUM1	0.94	38%	7.02	78%	4.40	0.079	0.090	0.007	0.096	0.598	0.695	1.719	0.317	0.915	1.078	21.228	4.847	0.814	26.075
LONG POND	LONG6	0.85	84%	6.51	79%	14.61	0.016	0.066	0.009	0.076	0.467	0.543	1.130	0.166	0.634	0.712	9.467	1.452	0.867	10.919
LONG POND	LONG5	0.71	67%	6.54	78%	13.28	0.030	0.005	0.006	0.010	0.480	0.491	2.135	0.375	0.855	0.867	23.565	2.628	0.900	26.192
MADAKET HARBOR	MH1	1.47	72%	4.91	64%	25.78	0.016	0.018	0.011	0.030	0.361	0.391	0.838	0.165	0.527	0.570	9.937	1.833	0.844	11.769
MADAKET HARBOR	MH2	1.68	100%	6.24	83%	29.96	0.014	0.015	0.003	0.018	0.279	0.297	0.452	0.080	0.359	0.386	5.666	1.210	0.824	6.877
MADAKET HARBOR	MH3	2.20	94%	6.05	77%	30.83	0.013	0.021	0.002	0.022	0.236	0.258	0.409	0.069	0.304	0.341	1.600	0.976	0.621	2.576
MADAKET HARBOR	MH4	2.83	58%	6.15	80%	30.90	0.016	0.021	0.001	0.022	0.193	0.215	0.414	0.073	0.266	0.306	3.189	0.842	0.791	4.030
MIACOMET POND	MP3	1.35	84%	5.25	59%	0.10	0.050	0.044	0.027	0.071	0.414	0.485	2.496	0.386	0.800	0.909	11.287	7.352	0.606	18.638
MIACOMET POND	MP1	1.63	87%	2.86	33%	0.24	0.004	0.004	0.002	0.006	0.461	0.467	1.140	0.170	0.633	0.641	10.636	3.784	0.738	14.420
MIACOMET POND	MP2	2.23	74%	3.08	32%	0.33	0.003	0.003	0.002	0.005	0.439	0.445	0.990	0.138	0.577	0.584	7.273	2.002	0.784	9.275
NANTUCKET HARBOR	NAN1	3.34	77%	5.77	77%	30.69	0.014	0.009	0.004	0.013	0.251	0.264	0.283	0.050	0.301	0.317	2.327	0.411	0.850	2.739
NANTUCKET HARBOR	NAN2	3.04	63%	5.69	77%	30.68	0.016	0.014	0.003	0.017	0.227	0.243	0.309	0.054	0.280	0.302	2.406	0.742	0.764	3.148
NANTUCKET HARBOR	NAN2A	2.44	43%	5.66	77%	30.80	0.018	0.030	0.004	0.033	0.249	0.283	0.490	0.086	0.335	0.377	4.412	1.062	0.806	5.474
NANTUCKET HARBOR	NAN3	2.30	40%	5.93	81%	30.84	0.018	0.024	0.003	0.028	0.248	0.276	0.500	0.084	0.332	0.366	5.788	1.014	0.851	6.803
NANTUCKET HARBOR	NAN4	2.56	53%	6.15	82%	30.77	0.014	0.007	0.002	0.010	0.211	0.221	0.353	0.064	0.275	0.288	3.822	0.545	0.875	4.367
NANTUCKET HARBOR	NAN5	2.07	82%	5.44	74%	28.88	0.018	0.021	0.004	0.025	0.283	0.308	0.738	0.112	0.395	0.429	3.828	0.994	0.794	4.821
NANTUCKET HARBOR	NAN6	2.18	80%	5.60	77%	30.34	0.015	0.019	0.003	0.022	0.264	0.286	0.766	0.112	0.376	0.405	5.400	1.112	0.829	6.512
NANTUCKET HARBOR	NAN7	1.78	81%	5.78	78%	30.59	0.016	0.016	0.004	0.019	0.227	0.246	0.463	0.080	0.307	0.333	3.285	0.852	0.794	4.137
NANTUCKET HARBOR	NAN8N	1.52	100%	5.12	68%	30.51	0.015	0.010	0.003	0.013	0.217	0.230	0.348	0.059	0.276	0.293	2.361	0.548	0.812	2.908
Nantucket Hrb. Stream Site	ST4	0.18	83%	3.11	31%	0.08	0.070	0.012	0.006	0.018	0.945	0.963	0.701	0.053	0.998	1.021	1.284	0.544	0.702	1.828
Nantucket Hrb. Stream Site	ST4A	0.25	63%	1.21	12%	0.10	0.039	0.025	0.009	0.034	1.387	1.422	0.457	0.056	1.444	1.478	0.102	0.847	0.107	0.949
Nantucket Hrb. Stream Site	ST6	0.20	53%	5.75	57%	0.02	0.107	0.012	0.006	0.018	0.943	0.961	3.051	0.142	1.084	1.107	3.107	0.857	0.784	3.963
Nantucket Hrb. Stream Site	WPH OUTLET	0.13	82%	6.90	66%	0.25	0.074	0.017	0.008	0.025	0.954	0.979	0.747	0.052	1.006	1.037	0.713	0.616	0.536	1.329
SESACHACHA POND	SESA3	0.81	28%	7.21	86%	11.33	0.236	0.004	0.003	0.006	0.502	0.508	2.459	0.309	0.811	0.819	8.173	1.486	0.846	9.659
SESACHACHA POND	SESA2	0.93	21%	4.55	52%	11.30	0.259	0.004	0.002	0.006	0.526	0.532	2.831	0.358	0.884	0.891	8.724	1.528	0.851	10.252
SESACHACHA POND	SESA4	0.93	28%	8.28	94%	11.33	0.242	0.004	0.002	0.007	0.545	0.552	2.551	0.312	0.857	0.865	7.959	1.285	0.861	9.244
SESACHACHA POND	SESA1	1.02	24%	5.42	61%	11.34	0.268	0.004	0.002	0.006	0.594	0.600	2.753	0.357	0.951	0.960	11.271	2.066	0.845	13.337
OLD NORTH WHARF - Oyster	ORS2	1.21	100%	5.14	69%	30.33	0.016	0.031	0.005	0.036	0.233	0.268	0.294	0.048	0.289	0.329	2.477	0.529	0.824	3.006
SHIMMO Oyster	ORS4	1.16	100%	3.39	46%	29.80	0.019	0.030	0.010	0.039	0.307	0.347	0.315	0.053	0.361	0.414	1.362	0.947	0.590	2.309
POLPIS Oyster	ORS6B	0.93	100%	3.70	49%	29.75	0.019	0.038	0.005	0.043	0.323	0.366	0.431	0.074	0.397	0.460	1.804	0.960	0.653	2.764

Table 3c. Summary of Water Quality Parameters, **2016** Nantucket Sampling Program. Values are Station Averages of all sampling events, May-September for sampling sites. Station NAN6, NAN 6C are duplicate samples (C = compliance sample) and represent an MEP sentinel location for monitoring in Nantucket Harbor. This also applies to Station NAN-2A and 2AC, however, NAN-2A is in a new station and in a different location than NAN-2. It should be noted that TP was only evaluated in the stream sites, Hummock Pond and Miacomet Pond because of the expected low salinity values in those closed pond and the possibility that the Miacomet system maybe phosphorous limited rather than nitrogen limited. Further study should investigate the possibility of P-limitation and TP paired with salinity should continue to be monitored during the summer 2017 field season.

Embayment (2016)	Station ID	Secchi average (meters)	Secchi Depth % of WC	20% Low Field DO Sat (mg/L)	20% Low Field DO Sat (% sat)	Salinity (ppt)	Avg. PO4 (mg/L)	Avg. TP (mg/L)	Avg. NH4 (mg/L)	Avg. Nox (mg/L)	Avg. DIN (mg/L)	Avg. DON (mg/L)	Avg. TDN (mg/L)	Avg. POC (mg/L)	Avg. PON (mg/L)	Avg. TON (mg/L)	Avg. TN (mg/L)	Avg. Total Pig (ug/L)
Hummock Pond	HUM7	1.26	0.36	1.97	23%	4.10	0.06	0.058	0.0550	0.0337	0.0887	0.39	0.48	1.08	0.19	0.58	0.67	5.91
Hummock Pond	HUM8	0.44	0.35	4.18	49%	4.70	0.06	NS	0.0393	0.0078	0.0471	0.62	0.67	2.94	0.52	1.15	1.19	15.71
Hummock Pond	HUM5	0.62	0.30	2.93	34%	6.40	0.03	0.054	0.0492	0.0029	0.0521	0.50	0.55	1.88	0.32	0.82	0.87	10.11
Hummock Pond	HUM3	0.87	0.49	6.99	83%	7.24	0.02	0.054	0.0042	0.0015	0.0056	0.45	0.45	1.20	0.20	0.65	0.65	5.34
Hummock Pond	HUM1	0.92	0.45	6.16	75%	8.17	0.02	0.050	0.0083	0.0024	0.0107	0.38	0.39	1.21	0.20	0.58	0.59	4.81
Long Pond	LONG6	0.68	0.73	4.21	56%	14.80	0.01	NS	0.0148	0.0044	0.0272	0.37	0.40	1.34	0.22	0.60	0.63	5.90
Long Pond	LONG5	0.78	0.77	2.48	32%	10.93	NS	NS	0.0020	0.0021	0.0041	0.33	0.34	1.88	0.31	0.65	0.65	5.74
Madaket Harbor	MH1C	1.75	0.76	4.27	62%	27.32	0.03	NS	0.0164	0.0113	0.0277	0.27	0.32	0.79	0.15	0.41	0.44	3.68
Madaket Harbor	MH1	1.63	0.82	3.38	46%	26.64	0.03	NS	0.0359	0.0146	0.0505	0.27	0.32	0.71	0.12	0.38	0.43	3.50
Madaket Harbor	MH2	1.60	1.00	4.94	69%	29.31	0.01	NS	0.0144	0.0062	0.0206	0.21	0.23	0.60	0.10	0.32	0.34	2.56
Madaket Harbor	MH3	2.14	1.00	5.31	72%	31.36	0.01	NS	0.0094	0.0037	0.0132	0.18	0.20	0.47	0.07	0.25	0.26	1.71
Madaket Harbor	MH4	3.06	0.79	5.92	80%	31.92	0.01	NS	0.0077	0.0040	0.0116	0.16	0.17	0.33	0.05	0.21	0.22	1.50
Miacomet Pond	MP3	0.93	0.55	5.24	59%	0.10	0.01	0.065	0.0103	0.0077	0.0180	0.39	0.38	2.33	0.37	0.76	0.78	17.75
Miacomet Pond	MP1	1.06	0.57	5.09	59%	0.10	0.00	0.045	0.0063	0.0049	0.0112	0.41	0.42	2.08	0.35	0.76	0.77	12.28
Miacomet Pond	MP2	1.33	0.54	4.86	57%	0.10	NS	0.068	0.0083	0.0086	0.0169	0.38	0.40	2.00	0.27	1.27	0.67	12.26
Nantucket Harbor	NAN3	2.34	0.46	4.61	66%	31.73	0.02	NS	0.0081	0.0034	0.0115	0.23	0.24	0.72	0.11	0.34	0.36	3.79
Nantucket Harbor	NAN6	1.98	0.80	4.81	69%	31.23	0.02	NS	0.0101	0.0034	0.0135	0.24	0.25	0.92	0.12	0.39	0.37	4.61
Nantucket Harbor	NAN6C	2.15	0.78	4.97	71%	31.52	0.02	NS	0.0091	0.0021	0.0112	0.26	0.27	1.27	0.16	0.42	0.43	4.69
Nantucket Harbor	NAN5	1.68	0.84	4.53	65%	31.07	0.02	NS	0.0073	0.0040	0.0112	0.24	0.25	1.11	0.17	0.41	0.42	5.80
Nantucket Harbor	NAN2	2.14	0.43	5.11	73%	31.81	0.02	NS	0.0089	0.0026	0.0115	0.20	0.22	0.59	0.10	0.30	0.31	2.98
Nantucket Harbor	NAN2A	2.34	0.47	4.37	62%	31.97	0.02	NS	0.0090	0.0030	0.0121	0.25	0.27	0.92	0.13	0.39	0.40	4.99
Nantucket Harbor	NAN2AC	2.30	0.56	4.26	60%	32.02	0.03	NS	0.0085	0.0023	0.0108	0.25	0.26	1.13	0.17	0.42	0.43	5.29
Nantucket Harbor	NAN7	1.91	0.81	5.12	73%	31.71	0.02	NS	0.0072	0.0030	0.0102	0.18	0.19	0.87	0.11	0.29	0.30	3.74
Nantucket Harbor	NAN1	2.31	0.64	5.14	73%	31.90	0.02	NS	0.0075	0.0035	0.0110	0.23	0.24	0.43	0.08	0.31	0.32	2.02
Nantucket Harbor	NAN8N	1.30	1.00	4.73	0.66	31.65	0.02	NS	0.0076	0.0045	0.0120	0.20	0.21	0.41	0.07	0.26	0.28	1.72
Nantucket Harbor	NAN4	2.44	0.50	5.49	77%	32.04	0.02	NS	0.0078	0.0031	0.0108	0.20	0.22	0.45	0.07	0.27	0.28	2.23
Nantucket Hrb. Stream Site	STA4	0.28	0.46	5.48	53%	0.15	0.07	0.105	0.0178	0.0027	0.0206	0.79	0.81	0.51	0.05	0.84	0.86	1.35
Nantucket Hrb. Stream Site	STA4A	0.20	1.00	2.45	23%	0.07	0.01	0.020	0.0194	0.0052	0.0246	0.71	0.74	0.42	0.04	0.75	0.78	3.41
Nantucket Hrb. Stream Site	STA6B	0.20	0.78	4.72	47%	0.00	0.11	0.220	0.0188	0.0059	0.0247	0.67	0.69	5.16	0.23	0.90	0.92	1.28
Sesachacha Pond	SESA3	ND	0.23	5.90	74%	11.59	0.22	NS	0.1232	0.0053	0.1285	0.45	0.57	3.43	0.43	0.90	1.01	6.46
Sesachacha Pond	SESA2	ND	0.16	5.76	73%	11.57	0.22	NS	0.1265	0.0061	0.1326	0.46	0.59	3.35	0.41	0.89	0.99	6.72
Sesachacha Pond	SESA4	ND	0.21	5.94	74%	11.59	0.22	NS	0.1165	0.0063	0.1228	0.47	0.59	3.35	0.42	0.91	1.00	6.18
Sesachacha Pond	SESA1	0.79	0.15	5.58	70%	11.55	0.21	NS	0.1012	0.0061	0.1072	0.46	0.57	3.55	0.44	0.90	1.01	6.85
Sesachacha Pond	SESA1C	0.75	0.14	ND	ND	11.30	0.17	NS	0.0014	0.0013	0.0027	0.48	0.49	3.13	0.39	0.88	0.88	10.22
OLD NORTH WHARF - Oyster	ORS2	1.45	1.00	4.75	67%	31.80	0.02	NS	0.0061	0.0054	0.0115	0.24	0.25	0.46	0.09	0.33	0.34	2.45
SHIMMO - Oyster	ORS4	1.09	0.88	2.53	35%	31.04	0.02	NS	0.0102	0.0038	0.0140	0.23	0.24	0.75	0.14	0.37	0.38	3.36
POLPIS - Oyster	ORS6	1.14	0.92	4.46	63%	31.60	0.02	NS	0.0232	0.0027	0.0259	0.27	0.30	1.09	0.14	0.54	0.47	4.93

Table 3d. Summary of Water Quality Parameters, **2015** Nantucket Sampling Program. Values are Station Averages of all sampling events, May-September for sampling sites. It should be noted that TP was only evaluated in Miacomet Pond because of the expected low salinity values in that closed pond and the possibility that the system maybe phosphorous limited rather than nitrogen limited.

2015 Sample ID	Seccchi Depth (meters)	Secchi Depth as % of WC	20% Low Field DO (mg/L)	20% Low DO Sat (%)	Salinity ppt	PO4 (mg/L)	TP (mg/L)	NH4 (mg/L)	Nox (mg/L)	DIN (mg/L)	DON (mg/L)	TDN (mg/L)	POC (mg/L)	PON (mg/L)	TON (mg/L)	TN (mg/L)	Total Pig (ug/L)
HUM1	1.50	48%	7.13	83%	7.43	0.009	--	0.004	0.003	0.007	0.350	0.357	1.097	0.182	0.532	0.539	10.50
HUM3	1.50	61%	6.82	75%	7.11	0.012	--	0.005	0.006	0.011	0.402	0.413	1.236	0.209	0.610	0.622	9.41
HUM5	1.00	57%	6.87	79%	5.45	0.019	--	0.005	0.003	0.008	0.359	0.366	1.206	0.192	0.550	0.558	8.58
HUM7	1.30	49%	5.65	87%	3.33	0.101	--	0.089	0.030	0.119	0.349	0.468	0.996	0.154	0.502	0.621	7.07
HUM8	0.70	90%	7.13	95%	3.90	0.059	--	0.005	0.011	0.016	0.366	0.381	1.230	0.195	0.560	0.576	12.82
LONG5	0.70	86%	6.60	85%	16.02	0.020	--	0.012	0.004	0.016	0.378	0.395	2.025	0.302	0.681	0.697	8.95
LONG6	0.60	76%	5.78	73%	16.01	0.025	--	0.006	0.002	0.008	0.369	0.377	1.619	0.280	0.649	0.656	10.78
MH1	1.80	77%	4.88	68%	29.28	0.021	--	0.019	0.006	0.025	0.379	0.404	0.652	0.120	0.499	0.524	4.82
MH2	1.78	100%	5.56	78%	31.76	0.010	--	0.012	0.030	0.042	0.289	0.331	0.482	0.088	0.376	0.418	3.07
MH3	2.40	97%	6.57	90%	32.00	0.010	--	0.005	0.001	0.006	0.236	0.242	0.461	0.082	0.318	0.324	3.00
MH4	2.90	63%	6.70	91%	32.13	0.015	--	0.006	0.002	0.008	0.269	0.277	0.301	0.051	0.321	0.328	2.54
MP1	0.90	50%	6.94	83%	0.10	0.008	0.084	0.025	0.013	0.038	0.592	0.630	3.870	0.666	1.259	1.297	46.52
MP2	0.70	32%	6.10	82%	0.11	0.009	0.090	0.042	0.011	0.053	0.593	0.646	3.726	0.671	1.264	1.318	53.40
MP3	1.40	54%	7.91	91%	0.10	0.017	0.136	0.021	0.057	0.077	0.396	0.473	2.878	0.518	0.914	0.992	37.91
NAN1	ND	62%	6.29	88%	32.13	0.024	--	0.010	0.002	0.012	0.246	0.258	0.437	0.072	0.318	0.330	3.84
NAN2	2.65	49%	5.95	85%	32.25	0.019	--	0.018	0.001	0.019	0.272	0.291	0.474	0.084	0.355	0.374	4.33
NAN3	1.45	27%	5.89	86%	32.37	0.026	--	0.022	0.002	0.024	0.278	0.302	0.716	0.134	0.412	0.436	7.16
NAN4	3.80	65%	6.58	91%	32.14	0.019	--	0.010	0.001	0.011	0.219	0.230	0.357	0.066	0.286	0.297	3.58
NAN5	1.65	85%	5.32	76%	31.92	0.021	--	0.018	0.001	0.019	0.296	0.316	0.578	0.107	0.403	0.422	3.86
NAN6	1.95	73%	5.64	81%	31.94	0.019	--	0.014	0.001	0.015	0.282	0.297	0.555	0.107	0.389	0.404	4.39
NAN7	1.45	76%	6.20	86%	32.00	0.019	--	0.013	0.002	0.015	0.270	0.285	0.628	0.105	0.375	0.390	3.68
NAN8N	1.00	96%	5.65	81%	31.97	0.016	--	0.007	0.002	0.009	0.227	0.236	0.435	0.077	0.304	0.313	3.08
SESA1	0.60	20%	7.06	88%	11.26	0.202	--	0.006	0.003	0.008	0.479	0.487	3.193	0.431	0.910	0.918	11.45
SESA2	0.60	14%	6.55	82%	11.27	0.202	--	0.003	0.002	0.005	0.448	0.454	3.100	0.417	0.865	0.870	10.39
SESA3	0.60	20%	6.73	89%	11.27	0.211	--	0.003	0.002	0.006	0.476	0.481	3.146	0.429	0.904	0.910	11.33
SESA4	0.60	20%	6.62	87%	11.27	0.210	--	0.003	0.003	0.007	0.507	0.514	3.028	0.405	0.912	0.919	11.10

Table 3e. Summary of Water Quality Parameters, **2014** Nantucket Sampling Program. Values are Station Averages of all sampling events, May-September for sampling sites.

Sample ID	Seccchi Depth (meters)	Secchi Depth as % of WC	20% Low DO (mg/L)	20% Low Sat (%)	Salinity ppt	PO4 (mg/L)	NH4 (mg/L)	Nox (mg/L)	DIN (mg/L)	DON (mg/L)	TDN (mg/L)	POC (mg/L)	PON (mg/L)	TON (mg/L)	TN (mg/L)	Total Pig (ug/L)
HUM1	1.37	56%	8.41	73%	6.12	0.012	0.029	0.004	0.033	0.428	0.461	1.230	0.191	0.618	0.651	5.480
HUM3	1.05	61%	8.35	75%	5.72	0.012	0.023	0.006	0.029	0.402	0.431	1.329	0.212	0.614	0.643	5.262
HUM5	1.08	58%	8.38	73%	4.75	0.014	0.014	0.003	0.017	0.401	0.418	9.925	0.235	0.636	0.653	6.534
HUM7	0.94	41%	8.44	77%	2.65	0.047	0.054	0.020	0.071	0.444	0.515	2.400	0.358	0.801	0.873	11.875
HUM8	0.79	35%	8.36	69%	3.62	0.030	0.014	0.003	0.017	0.526	0.543	1.417	0.212	0.738	0.755	6.240
LONG5	0.75	75%	7.62	53%	14.12	0.032	0.080	0.012	0.092	0.975	1.066	2.354	0.415	1.390	1.481	8.988
LONG6	0.73	75%	7.69	69%	15.06	0.014	0.040	0.011	0.051	0.420	0.472	1.841	0.316	0.737	0.788	7.342
MH1	1.74	86%	7.14	69%	28.03	0.019	0.046	0.010	0.057	0.270	0.326	0.616	0.119	0.389	0.445	3.431
MH2	2.50	100%	7.14	68%	31.01	0.010	0.024	0.002	0.026	0.243	0.269	0.433	0.079	0.321	0.347	1.674
MH3	2.26	91%	7.24	68%	31.40	0.011	0.023	0.001	0.024	0.217	0.241	0.891	0.135	0.352	0.376	2.701
MH4	2.66	57%	7.38	75%	31.53	0.012	0.016	0.007	0.020	0.174	0.194	0.340	0.059	0.233	0.254	1.489
MP1	1.38	85%	8.41	63%	0.13	0.018	0.050	0.003	0.053	0.522	0.575	1.967	0.289	0.811	0.864	9.932
MP2	1.87	63%	8.51	71%	0.12	0.009	0.035	0.002	0.036	0.568	0.604	1.170	0.180	0.748	0.784	5.326
MP3	0.87	65%	8.46	58%	0.10	0.049	0.038	0.038	0.077	0.594	0.671	4.437	0.626	1.220	1.297	18.068
NAN1	3.35	64%	7.23	77%	31.36	0.015	0.017	0.002	0.019	0.201	0.220	0.380	0.063	0.265	0.284	1.311
NAN2	3.06	52%	7.17	73%	31.42	0.017	0.021	0.003	0.024	0.210	0.234	0.493	0.080	0.290	0.314	1.977
NAN3	3.10	51%	6.98	75%	31.42	0.016	0.020	0.001	0.020	0.225	0.245	0.631	0.100	0.325	0.345	3.125
NAN4	3.00	56%	7.27	81%	31.49	0.017	0.017	0.001	0.018	0.180	0.198	0.439	0.079	0.259	0.277	1.659
NAN5	2.13	90%	7.10	69%	30.99	0.016	0.016	0.003	0.019	0.248	0.267	0.756	0.122	0.370	0.389	3.223
NAN6	2.38	85%	7.09	70%	31.08	0.016	0.013	0.002	0.015	0.258	0.272	0.626	0.105	0.363	0.378	2.963
NAN7	1.79	80%	7.26	73%	31.23	0.020	0.022	0.001	0.023	0.168	0.190	0.656	0.104	0.271	0.294	2.691
NAN8N	2.09	99%	7.16	74%	31.29	0.016	0.015	0.002	0.017	0.188	0.205	0.356	0.062	0.250	0.267	1.267
SESA1	1.17	24%	7.87	74%	12.26	0.105	0.033	0.007	0.040	0.590	0.630	1.794	0.288	0.878	0.919	7.112
SESA2	1.23	24%	7.86	70%	12.23	0.111	0.038	0.010	0.049	0.531	0.579	2.154	0.352	0.883	0.931	7.116
SESA3	1.19	32%	7.86	75%	12.23	0.106	0.030	0.009	0.039	0.603	0.642	1.871	0.296	0.899	0.938	5.852
SESA4	1.22	32%	7.83	72%	12.25	0.108	0.030	0.009	0.039	0.572	0.611	1.808	0.290	0.862	0.902	5.407

Table 3f. Summary of Water Quality Parameters, 2013 Nantucket Sampling Program. Values are Station Averages of all sampling events, May-October for estuarine and harbor sites.

2013 Station I.D.	Depth m	Secchi Depth m	Secchi Depth %WC	20% Low DO mg/L	20% Low DO %Sat	Salinity ppt	PO4 mg/L	NH4 mg/L	N0x mg/L	DIN mg/L	DON mg/L	PON mg/L	TON mg/L	TN mg/L	T-Pig ug/L
HUM-1	2.6	1.0	0.4	5.86	63%	0.9	0.029	0.030	0.018	0.047	0.554	0.169	0.722	0.769	8.2
HUM-3	2.4	1.0	0.4	5.20	56%	0.8	0.034	0.075	0.016	0.091	0.571	0.165	0.736	0.827	7.2
HUM-5	2.2	0.6	0.3	4.20	45%	0.5	0.073	0.063	0.026	0.088	0.575	0.217	0.793	0.881	8.3
HUM-7	3.5	0.6	0.2	4.08	44%	0.5	0.061	0.077	0.012	0.089	0.408	0.674	1.081	1.170	16.9
HUM-8	2.2	0.6	0.3	3.32	36%	0.4	0.079	0.042	0.018	0.061	0.672	0.331	1.004	1.064	7.9
LONG-5	1.1	0.7	0.7	5.87	75%	11.9	0.009	0.015	0.008	0.022	0.358	0.328	0.686	0.709	8.1
LONG-6	1.0	0.7	0.7	3.82	49%	12.7	0.005	0.017	0.008	0.025	0.561	0.294	0.855	0.880	9.9
MH1	2.2	1.7	0.8	4.36	61%	25.7	0.019	0.047	0.019	0.065	0.374	0.134	0.508	0.573	4.2
MH2	1.9	1.8	1.0	5.25	74%	30.6	0.012	0.021	0.004	0.025	0.215	0.083	0.298	0.323	1.8
MH3	2.0	2.0	1.0	5.25	74%	31.0	0.011	0.014	0.005	0.019	0.209	0.087	0.295	0.314	2.2
MH4	4.5	3.0	0.7	5.82	82%	31.3	0.013	0.015	0.007	0.023	0.194	0.062	0.256	0.278	1.7
MP1	1.9	1.0	0.6	5.46	66%	0.2	0.009	0.015	0.006	0.020	0.481	0.290	0.771	0.792	19.5
MP2	3.1	1.2	0.4	4.22	51%	0.3	0.014	0.029	0.022	0.051	0.429	0.555	0.985	1.036	20.2
MP3	1.6	0.9	0.6	5.20	63%	0.1	0.049	0.036	0.104	0.143	0.378	0.540	0.917	1.058	26.2
NAN1	5.5	3.2	0.6	5.10	74%	31.2	0.014	0.015	0.003	0.018	0.182	0.062	0.244	0.262	2.6
NAN2	6.0	2.9	0.5	4.80	70%	31.1	0.014	0.019	0.006	0.024	0.231	0.090	0.321	0.345	3.7
NAN3	6.2	2.6	0.4	3.48	50%	30.9	0.019	0.016	0.004	0.020	0.241	0.154	0.395	0.415	6.4
NAN4	4.9	3.1	0.6	5.66	82%	31.3	0.016	0.017	0.004	0.021	0.226	0.070	0.295	0.317	2.9
NAN5	2.3	1.9	0.8	3.90	57%	30.1	0.018	0.012	0.005	0.017	0.208	0.159	0.368	0.385	5.6
NAN6	2.7	2.0	0.8	3.26	47%	30.5	0.016	0.023	0.004	0.026	0.221	0.153	0.374	0.401	5.9
NAN7	2.5	1.9	0.8	5.02	73%	31.1	0.013	0.013	0.004	0.017	0.183	0.122	0.305	0.323	4.6
NAN8	3.2	2.1	0.9	4.96	72%	31.1	0.013	0.028	0.004	0.032	0.189	0.084	0.272	0.304	2.9
SES 1	4.9	2.1	0.4	5.83	79%	17.1	0.044	0.045	0.011	0.055	0.533	0.125	0.658	0.714	4.7
SES 2	4.3	2.4	0.6	5.2	71%	17.0	0.043	0.025	0.008	0.034	0.477	0.110	0.587	0.621	4.1
SES 3	4.5	2.5	0.6	5.6	75%	17.0	0.046	0.031	0.011	0.042	0.512	0.109	0.621	0.663	3.8
SES 4	3.9	2.6	0.7	5.6	76%	17.0	0.040	0.034	0.013	0.046	0.518	0.111	0.630	0.677	3.8

Table 3g. Summary of Water Quality Parameters, 2012 Nantucket Sampling Program. Values are Station Averages of all sampling events, May-October for estuarine and harbor sites. Stream sites were sampled once in June (see Table 1b).

Station I.D.	Secchi Depth m	Secchi Depth %WC	20% Low DO mg/L	20% Low DO %Sat	Salinity ppt	PO4 mg/L	NH4 mg/L	N0x mg/L	DIN mg/L	DON mg/L	PON mg/L	TON mg/L	TN mg/L	T-Pig ug/L
HUM-1	1.0	44%	6.27	79%	7.6	0.020	0.044	0.006	0.050	0.439	0.178	0.616	0.666	8.7
HUM-3	1.2	58%	6.20	79%	7.0	0.029	0.039	0.003	0.042	0.573	0.249	0.822	0.863	8.3
HUM-5	0.8	44%	6.56	82%	6.3	0.030	0.043	0.004	0.047	0.540	0.283	0.824	0.871	12.7
HUM-7	0.7	21%	5.76	70%	4.8	0.011	0.085	0.031	0.117	0.546	0.638	1.184	1.301	27.2
HUM-8	0.6	53%	6.51	81%	6.0	0.030	0.054	0.005	0.058	0.534	0.352	0.885	0.944	17.5
LONG-5	0.6	58%	5.49	71%	16.8	0.067	0.063	0.007	0.069	0.441	0.503	0.944	1.013	18.3
LONG-6	0.5	51%	5.13	67%	18.6	0.027	0.049	0.008	0.057	0.437	0.373	0.810	0.867	7.7
MH1	1.7	70%	6.88	98%	26.8	0.026	0.115	0.015	0.131	0.332	0.192	0.525	0.655	9.6
MH2	2.3	100%	8.16	115%	30.9	0.015	0.078	0.010	0.088	0.272	0.084	0.356	0.444	1.8
MH3	2.4	100%	7.55	104%	31.6	0.018	0.063	0.011	0.074	0.217	0.065	0.282	0.356	1.8
MH4	3.7	90%	8.35	119%	31.6	0.019	0.032	0.009	0.041	0.189	0.068	0.257	0.297	2.0
MP1	1.5	97%	7.14	79%	0.3	0.007	0.057	0.004	0.061	0.546	0.221	0.767	0.828	10.8
MP2	1.5	67%	7.24	80%	0.4	0.005	0.070	0.012	0.082	0.509	0.290	0.799	0.880	20.3
MP3	1.0	81%	7.64	92%	0.1	0.045	0.109	0.011	0.120	0.381	0.450	0.830	0.950	18.3
NAN1	3.5	73%	5.22	74%	31.6	0.020	0.045	0.011	0.056	0.210	0.070	0.279	0.335	3.8
NAN2	2.9	62%	5.91	85%	31.6	0.022	0.057	0.009	0.066	0.213	0.091	0.304	0.364	3.7
NAN3	2.4	40%	5.86	87%	31.8	0.027	0.035	0.008	0.044	0.261	0.117	0.371	0.411	4.0
NAN4	2.9	63%	6.29	90%	31.6	0.017	0.031	0.007	0.038	0.212	0.094	0.306	0.344	3.6
NAN5	1.7	76%	5.96	83%	31.5	0.019	0.046	0.007	0.053	0.233	0.133	0.366	0.419	14.9
NAN6	2.1	76%	5.50	77%	31.5	0.019	0.042	0.006	0.048	0.289	0.147	0.436	0.484	6.3
NAN7	2.0	80%	6.10	86%	31.5	0.021	0.049	0.008	0.057	0.217	0.105	0.323	0.379	4.2
NAN8	1.9	100%	5.20	74%	31.5	0.017	0.050	0.006	0.057	0.225	0.090	0.315	0.371	3.6
SES 1	2.3	51%	5.49	77%	24.7	0.064	0.042	0.010	0.051	0.497	0.130	0.627	0.678	5.8
SES 2	2.5	52%	"	"	24.7	0.065	0.087	0.014	0.101	0.405	0.120	0.525	0.627	5.1
SES 3	2.8	87%	"	"	24.7	0.063	0.053	0.007	0.060	0.417	0.107	0.524	0.584	4.2
SES 4	2.7	77%	"	"	24.8	0.062	0.060	0.010	0.070	0.456	0.142	0.599	0.668	4.5

Table 3h. Summary of Water Quality Parameters, 2010 Nantucket Sampling Program. Values are Station Averages of all sampling events, May-October for estuarine and harbor sites. Stream sites were sampled once in June (see Table 1a).

Station ID	Secchi Depth (m)	Secchi Depth as % WC	20% Low D.O. (mg/L)	20% Low % Sat	Salinity ppt	PO4 mg/L	NH4 mg/L	NOX mg/L	DIN mg/L	DON mg/L	PON mg/L	TON mg/L	TN mg/L	Total Pig (ug/L)
HUM1	1.4	54.4%	4.81	56.0%	7.3	0.013	0.021	0.002	0.023	0.425	0.168	0.592	0.616	12.30
HUM3	1.3	61.5%	4.99	59.8%	6.4	0.012	0.022	0.003	0.025	0.380	0.184	0.564	0.589	11.04
HUM5	0.9	44.2%	4.65	56.1%	5.3	0.015	0.020	0.003	0.023	0.430	0.313	0.743	0.766	27.03
HUM7	0.9	23.4%	3.89	45.0%	4.0	0.284	0.070	0.069	0.139	0.628	1.020	1.647	1.786	67.66
HUM8	0.7	51.0%	4.80	56.5%	4.4	0.025	0.031	0.008	0.039	0.584	0.360	0.944	0.983	33.02
LONG5	0.6	48.5%	4.77	62.9%	16.0	0.071	0.009	0.002	0.011	0.480	0.894	1.374	1.385	18.08
LONG6	0.6	48.8%	4.76	62.9%	15.9	0.028	0.022	0.003	0.026	0.567	1.452	2.019	2.044	24.21
MH1	1.6	67.1%	3.00	40.1%	26.8	0.024	0.045	0.005	0.050	0.316	0.260	0.576	0.626	14.20
MH2	1.9	93.9%	3.52	47.9%	29.7	0.014	0.024	0.003	0.027	0.264	0.145	0.409	0.436	9.37
MH3	2.3	100.0%	4.39	55.5%	30.8	0.011	0.024	0.002	0.026	0.213	0.084	0.297	0.324	6.14
MH4	3.8	58.3%	4.27	55.6%	31.1	0.015	0.024	0.002	0.026	0.190	0.069	0.259	0.285	4.21
MP1	1.5	86.3%	5.43	54.0%	0.7	0.003	0.030	0.002	0.032	0.557	0.265	0.822	0.854	16.29
MP2	1.9	58.5%	5.70	62.8%	0.6	0.002	0.044	0.002	0.046	0.554	0.210	0.764	0.811	11.50
MP3	1.3	83.1%	4.93	56.6%	0.1	0.031	0.048	0.056	0.104	0.499	0.490	0.990	1.093	51.52
NAN1	4.5	84.8%	3.57	48.2%	31.0	0.016	0.027	0.003	0.030	0.218	0.084	0.302	0.332	4.00
NAN2	3.4	62.8%	3.45	47.4%	31.0	0.018	0.016	0.003	0.019	0.201	0.077	0.278	0.297	5.36
NAN3	2.8	49.2%	3.72	52.4%	30.9	0.022	0.027	0.003	0.030	0.251	0.111	0.362	0.392	7.58
NAN4	3.7	84.5%	3.89	52.2%	29.8	0.015	0.027	0.002	0.029	0.203	0.070	0.273	0.283	4.15
NAN5	2.0	98.0%	3.18	44.3%	30.4	0.017	0.027	0.007	0.034	0.248	0.149	0.397	0.431	11.31
NAN6	2.2	88.7%	3.26	45.7%	30.5	0.016	0.024	0.004	0.028	0.277	0.133	0.410	0.438	10.31
NAN7	2.1	92.5%	3.60	49.8%	30.9	0.016	0.023	0.003	0.026	0.244	0.106	0.351	0.377	7.35
NAN8	2.4	100.8%	3.65	50.0%	31.1	0.018	0.031	0.002	0.033	0.204	0.076	0.280	0.313	3.93
SESA1	1.6	32.9%	4.82	56.4%	11.9	0.051	0.018	0.003	0.021	0.441	0.222	0.663	0.684	8.00
SESA2	1.4	28.6%	4.83	56.4%	11.9	0.045	0.024	0.003	0.027	0.469	0.219	0.688	0.715	7.19
SESA3	1.5	36.6%	4.83	56.2%	11.9	0.049	0.021	0.006	0.028	0.449	0.223	0.672	0.700	7.61
SESA4	1.5	38.7%	4.83	56.4%	11.9	0.046	0.024	0.003	0.027	0.470	0.221	0.691	0.718	6.73
82 WAUWINET	ND	ND	ND	ND	18.2	0.071	0.122	0.004	0.126	0.611	0.108	0.719	0.845	40.70
STREAM1	ND	ND	ND	ND	0.3	0.077	0.081	0.021	0.102	1.419	0.258	1.677	1.779	2.64
STREAM4	ND	ND	ND	ND	<0.1	0.163	0.039	0.008	0.048	1.092	0.061	1.153	1.200	1.18
STREAM6B	ND	ND	ND	ND	<0.1	0.006	0.059	0.004	0.064	1.701	0.374	2.076	2.139	16.37
STREAM6C	ND	ND	ND	ND	<0.1	0.132	0.097	0.003	0.100	0.375	0.156	0.532	0.632	7.41
STREAM8	ND	ND	ND	ND	3.3	0.015	0.045	0.005	0.050	0.398	0.118	0.516	0.565	5.29

Secchi as % of WC is the % of the water column above the secchi depth, values of 100% means that the Secchi was at or below the bottom.
Lowest 20% of D.O. records for a site over the project period.

HUM = Hummock Pond, Long = Long Pond, MH = Madaket Harbor, MP = Miacomet Pond, NAN = Nantucket Harbor, SESA = Sesachacha Pond

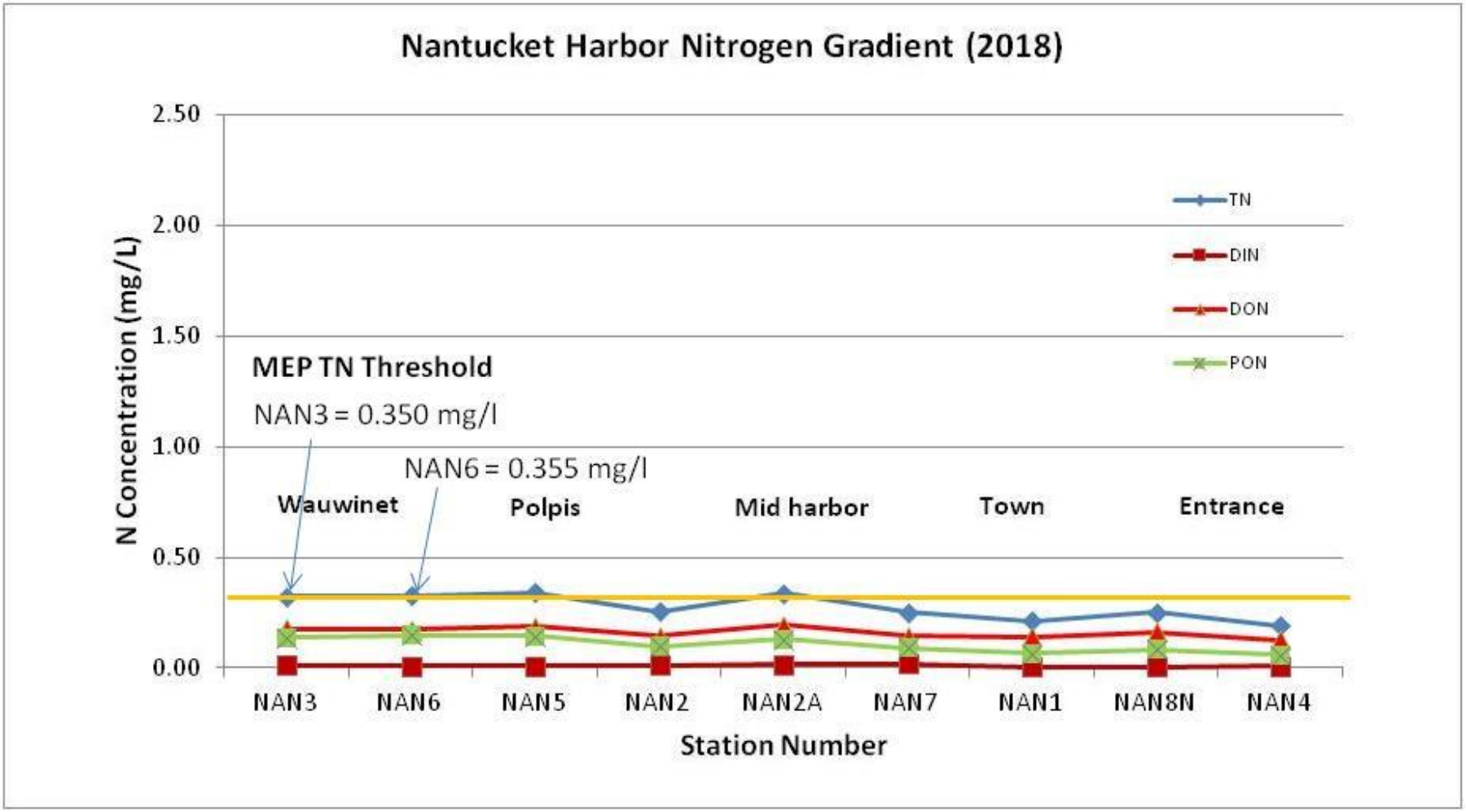

Figure 15. Nitrogen species (mg/L) in Nantucket Harbor in summer 2018 compared to historical levels presented in panels below. Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

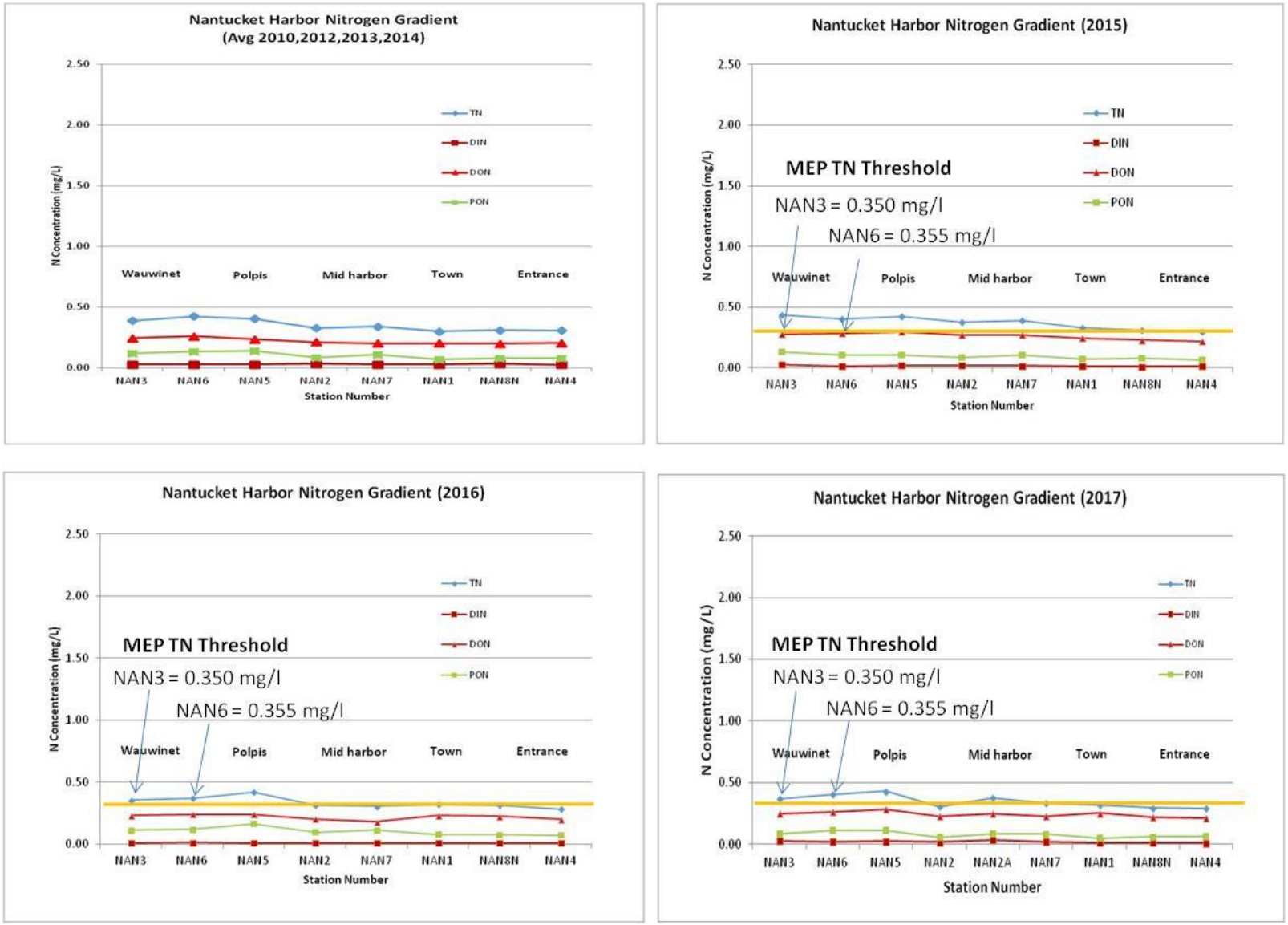

Figure 15 cont'd. Comparison of nitrogen species (mg/L) in Nantucket Harbor in summers, 2010-2014 avg. (upper left, not including 2011); 2015 (upper right); 2016 (bottom left); 2017 (bottom right). Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

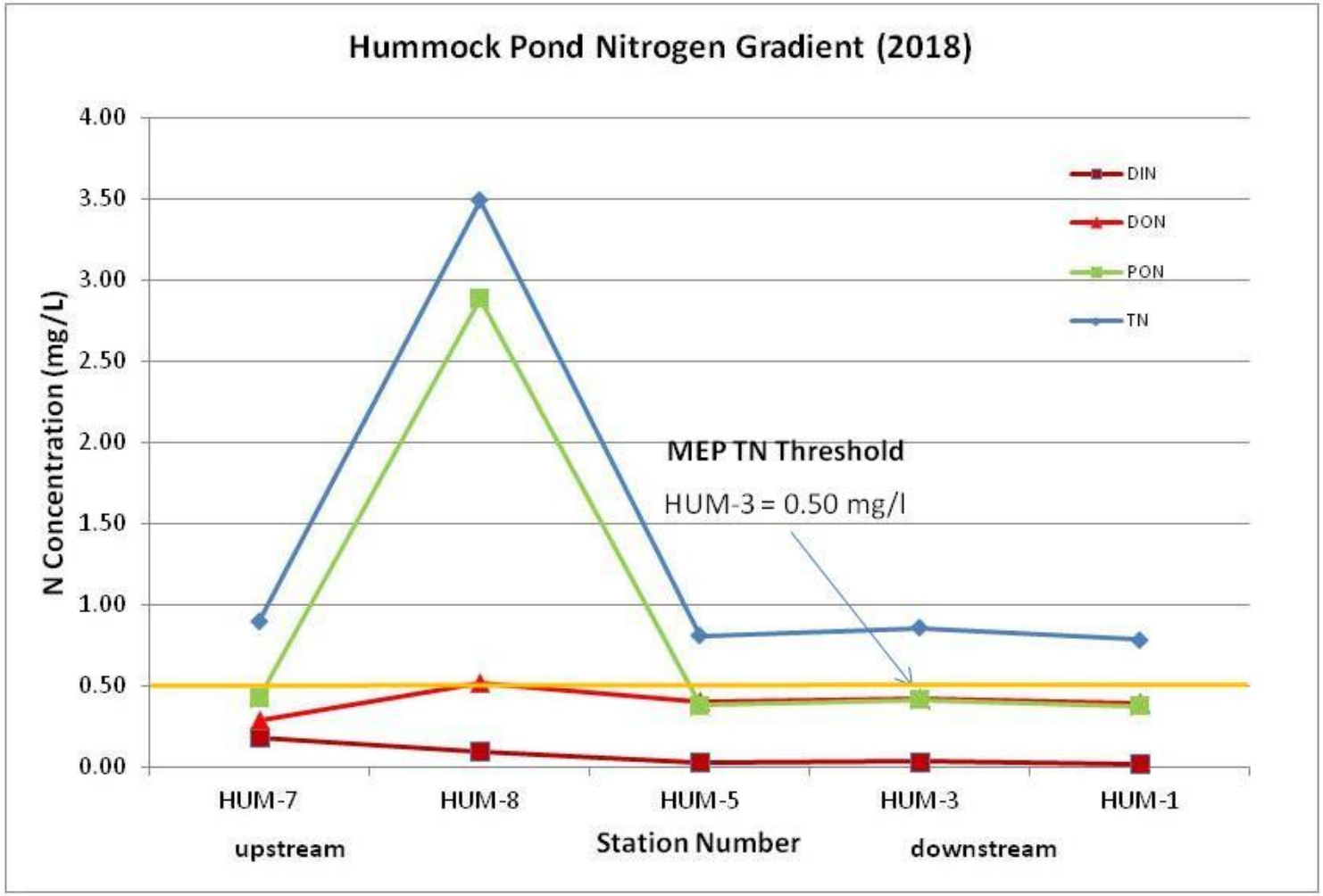

Figure 15 cont'd. Nitrogen species (mg/L) in Hummock Pond in summer 2018 compared to historical levels presented in panels below. Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

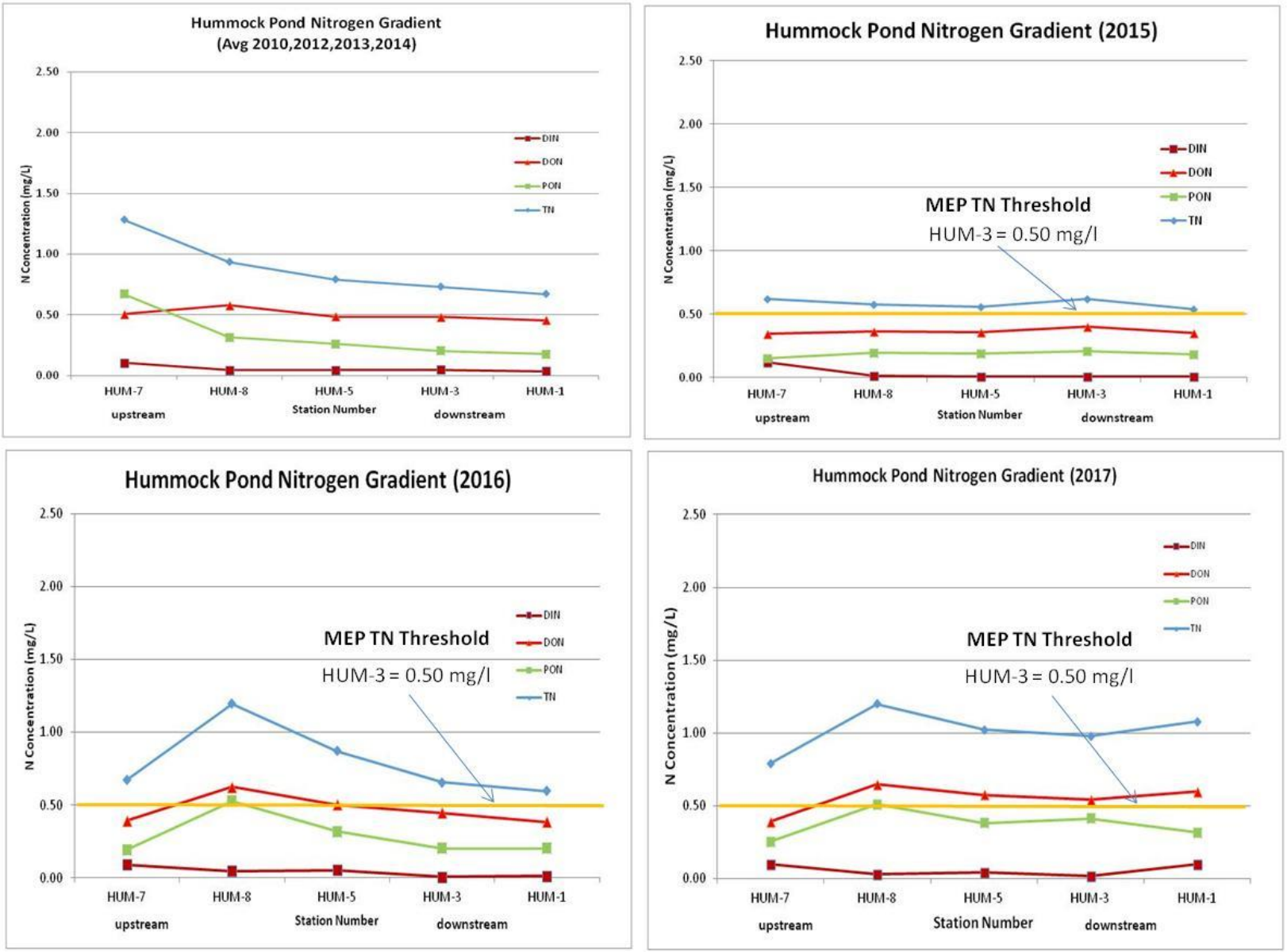

Figure 15 cont'd. Comparison of nitrogen species (mg/L) in Hummock Pond in summers, 2010-2014 avg. (upper left, not including 2011); 2015 (upper right); 2016 (bottom left); 2017 (bottom right). Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

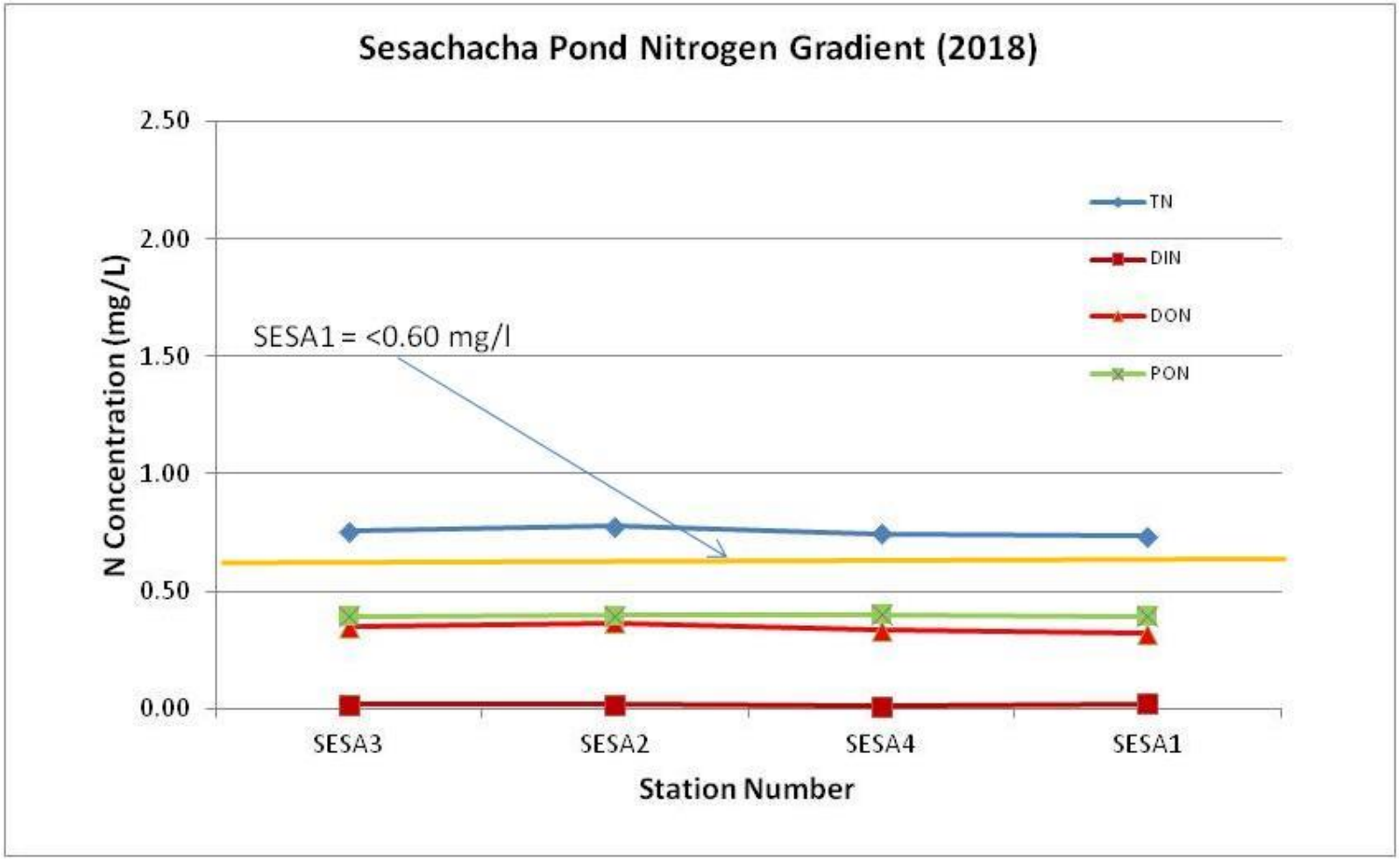

Figure 15 cont'd. Nitrogen species (mg/L) in Sesachacha Pond in summer 2018 compared to historical levels presented in panels below. Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

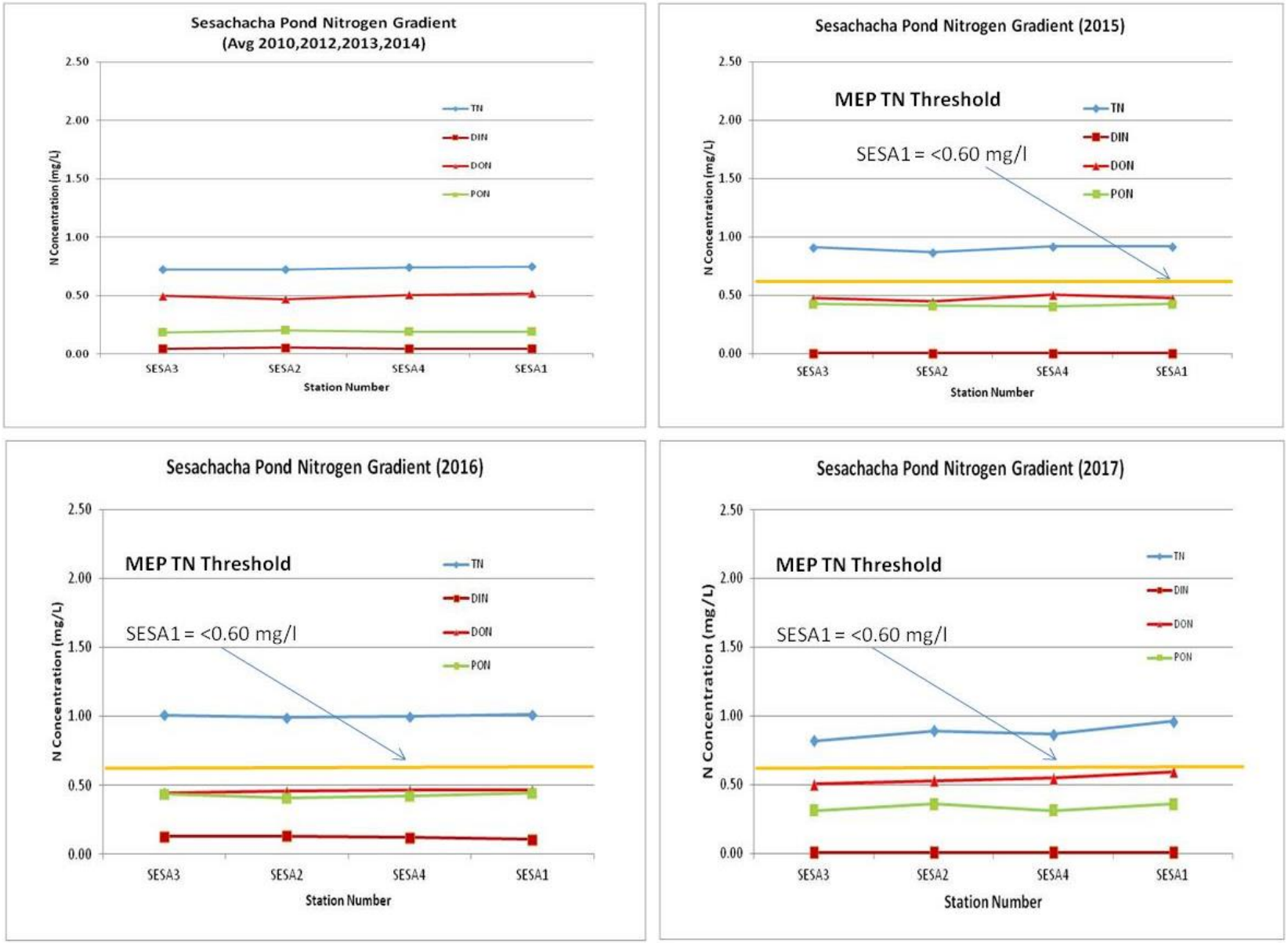

Figure 15 cont'd. Comparison of nitrogen species (mg/L) in Sesachacha Pond in summers, 2010-2014 avg. (upper left, not including 2011); 2015 (upper right); 2016 (bottom left); 2017 (bottom right). Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph).

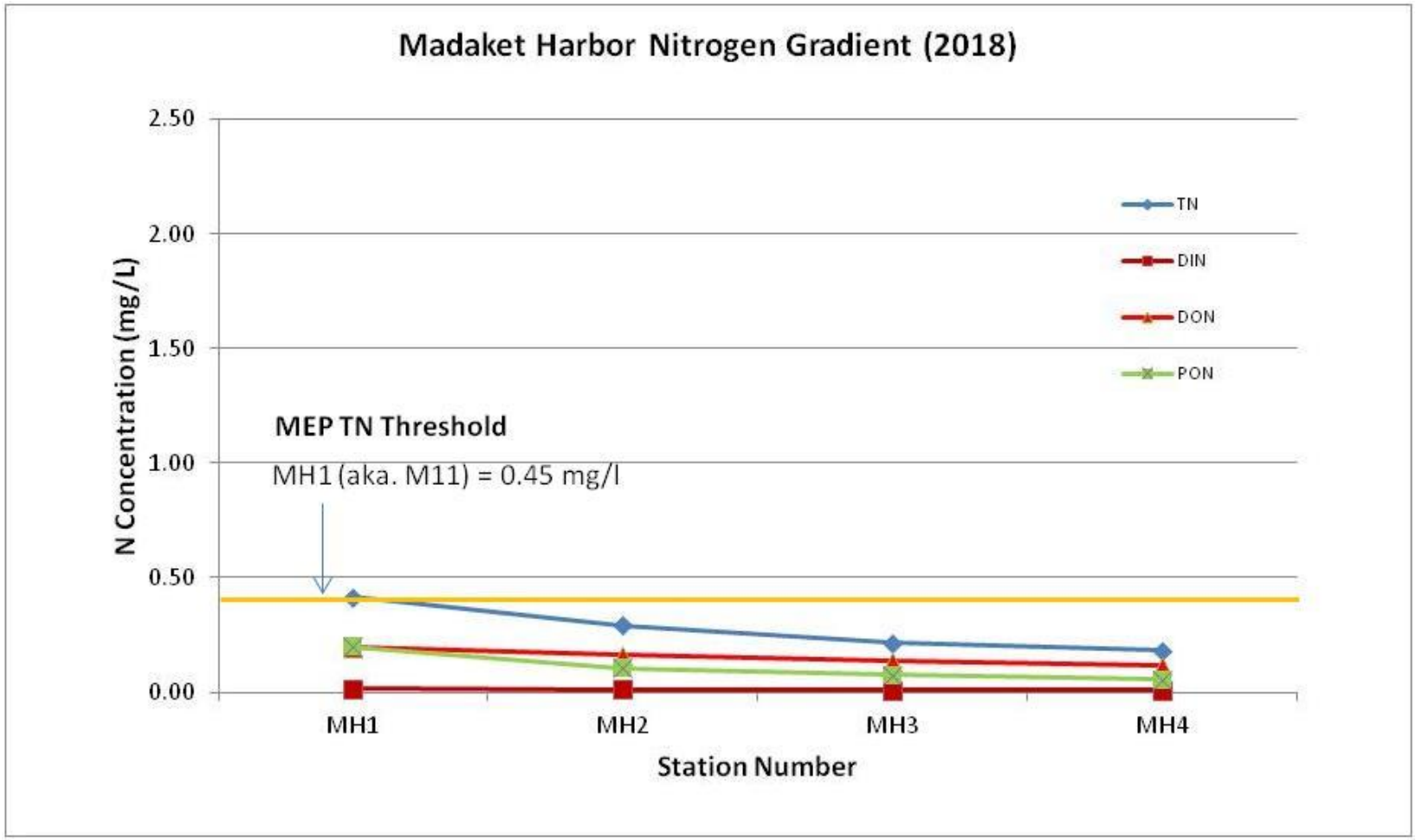

Figure 15 cont'd. Nitrogen species (mg/L) in Madaket Harbor in summer 2018 compared to historical levels presented in panels below. Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

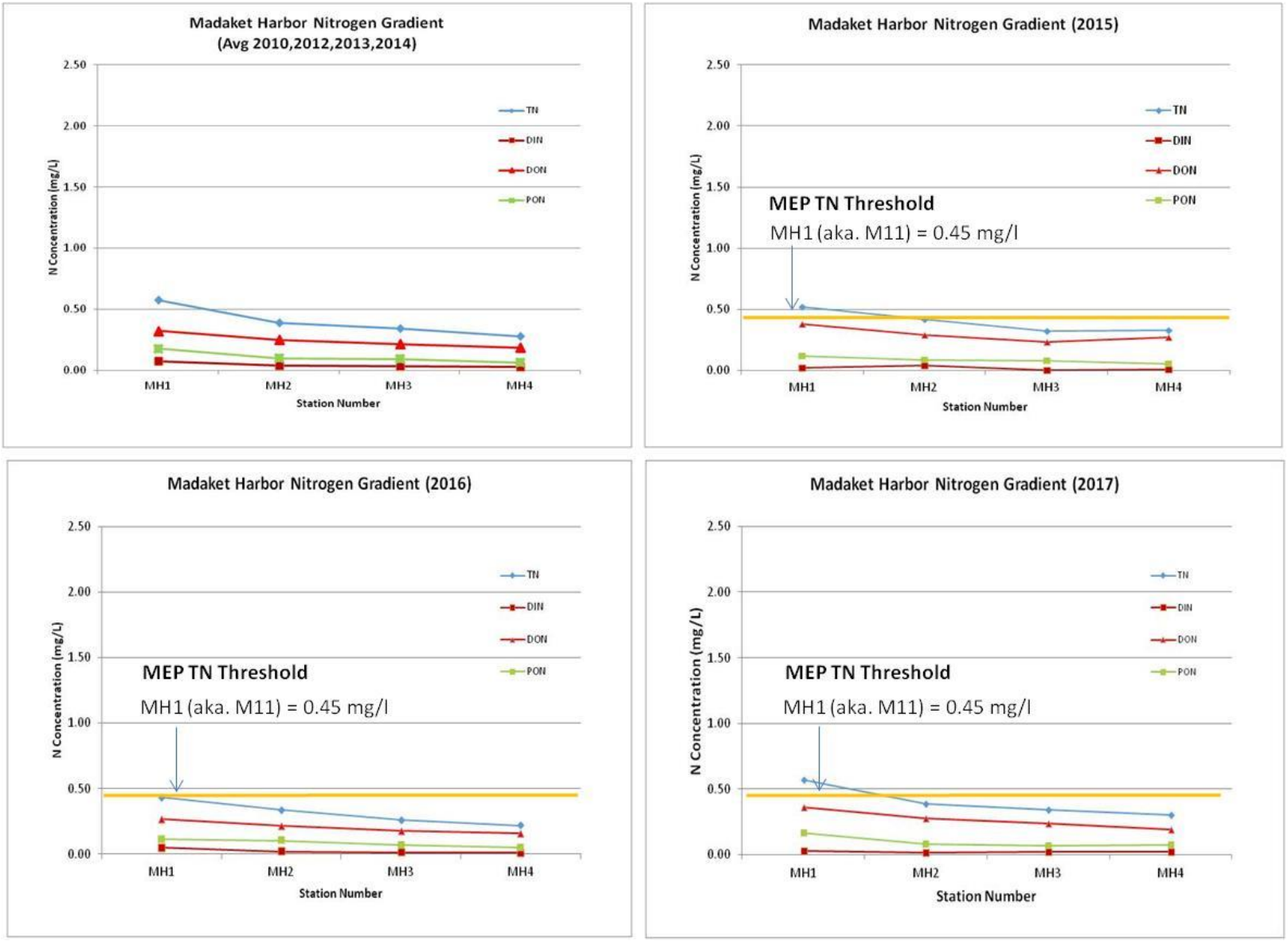

Figure 15 cont'd. Comparison of nitrogen species (mg/L) in Madaket Harbor in summers, 2010-2014 avg. (upper left, not including 2011); 2015 (upper right); 2016 (bottom left); 2017 (bottom right). Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

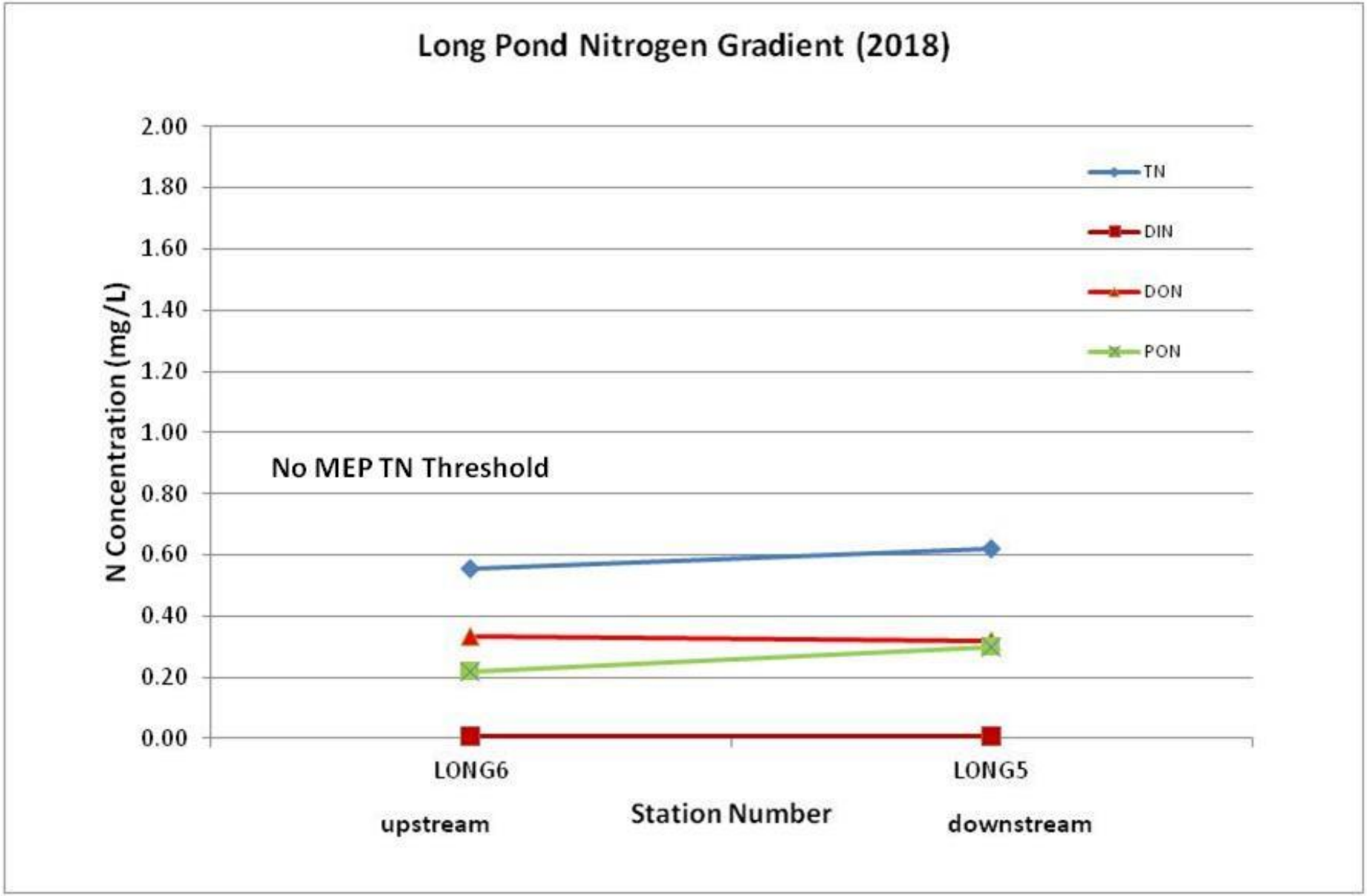

Figure 15 cont'd. Nitrogen species (mg/L) in Long Pond discharging to Madaket Harbor in summer 2018 compared to historical levels presented in panels below. Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

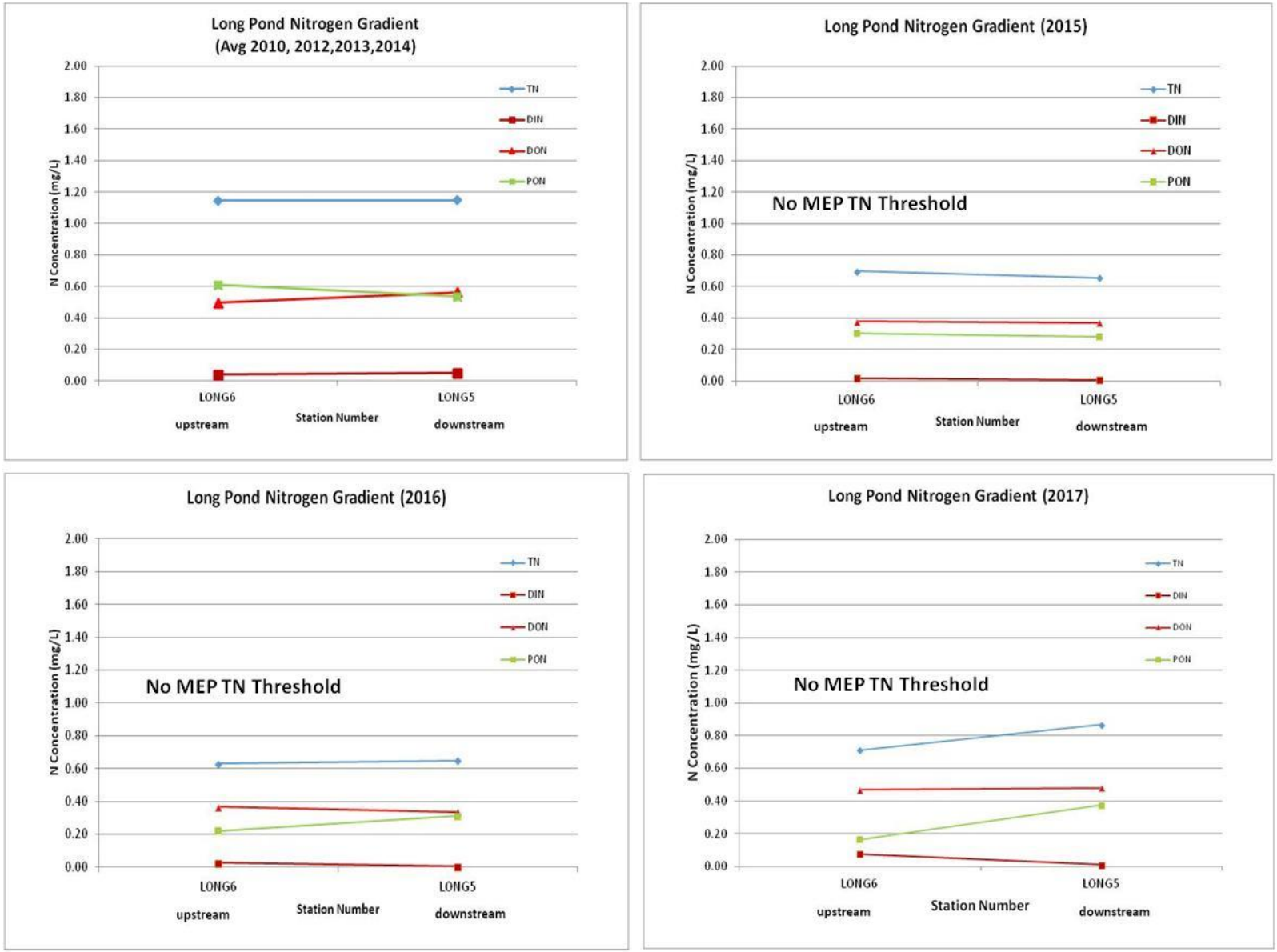

Figure 15 cont'd. Comparison of nitrogen species (mg/L) in Long Pond (Madaket Harbor System) in summers, 2010-2014 avg. (upper left, not including 2011); 2015 (upper right); 2016 (bottom left); 2017 (bottom right). Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

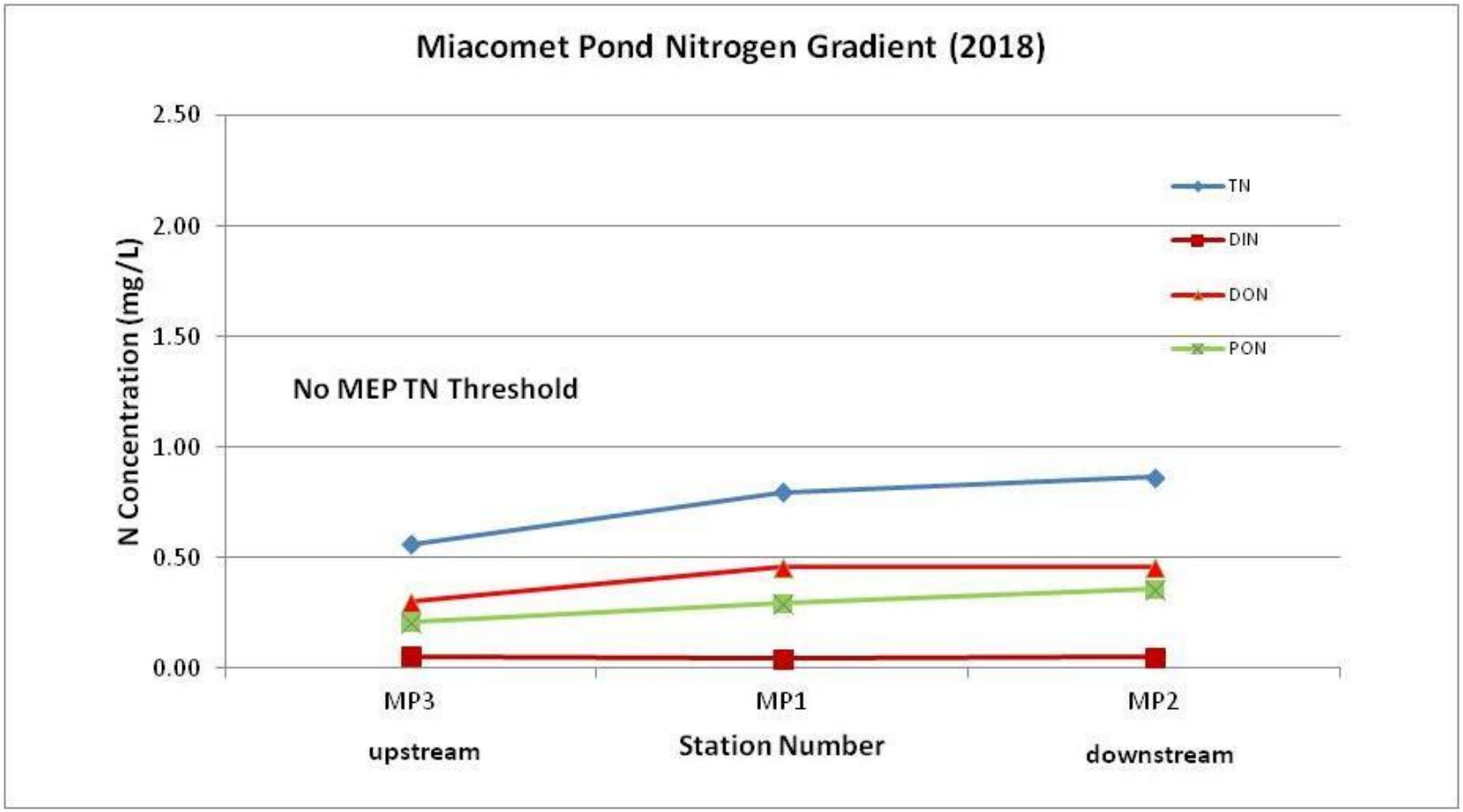

Figure 15 cont'd. Nitrogen species (mg/L) in Miacomet Pond in summer 2018 compared to historical levels presented in panels below. Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

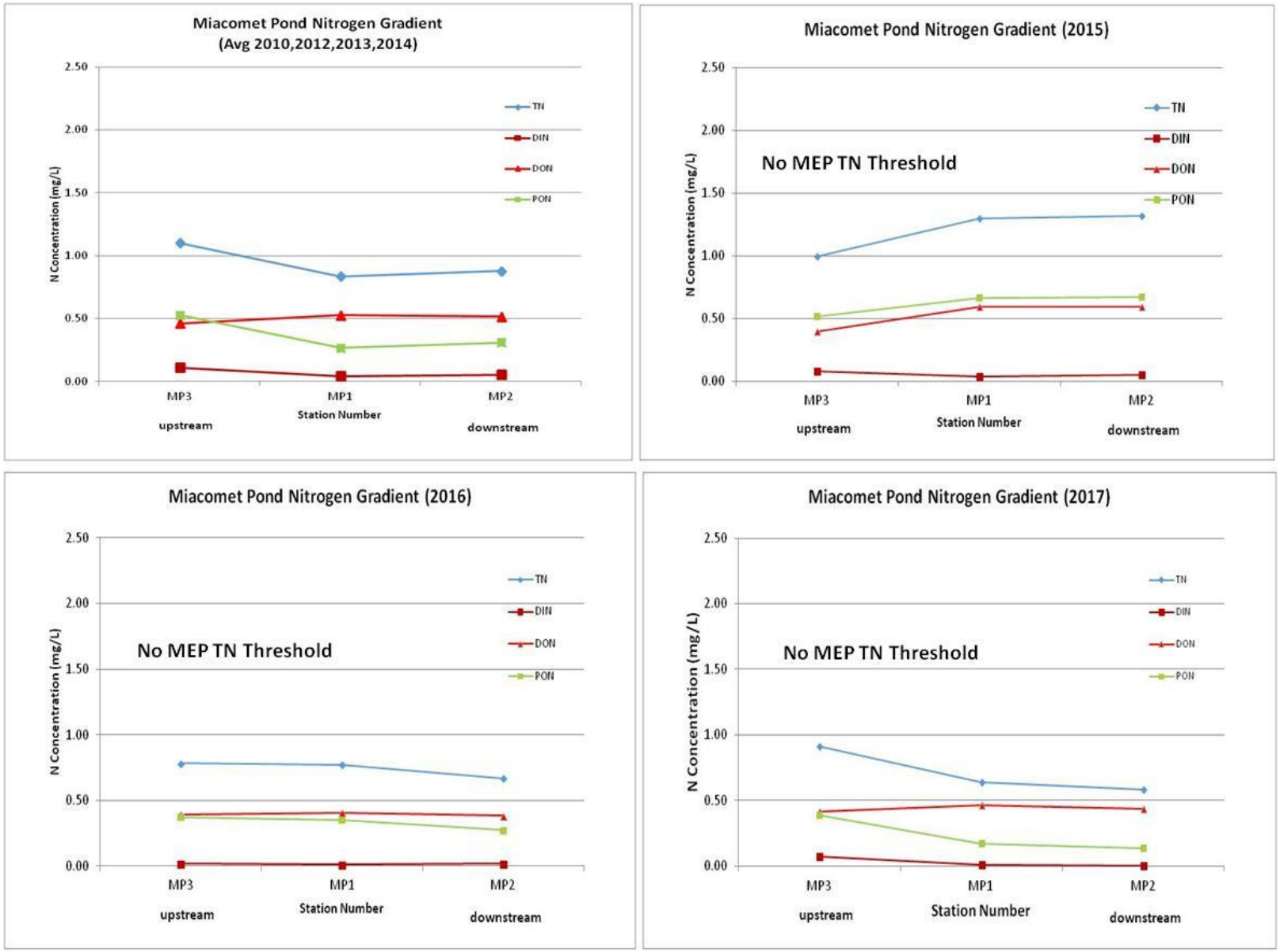

Figure 15 cont'd. Comparison of nitrogen species (mg/L) in Miacomet in summers, 2010-2014 avg. (upper left, not including 2011); 2015 (upper right); 2016 (bottom left); 2017 (bottom right). Total nitrogen is the sum of the inorganic and organic fractions (top line in each graph). All figures are to same scale.

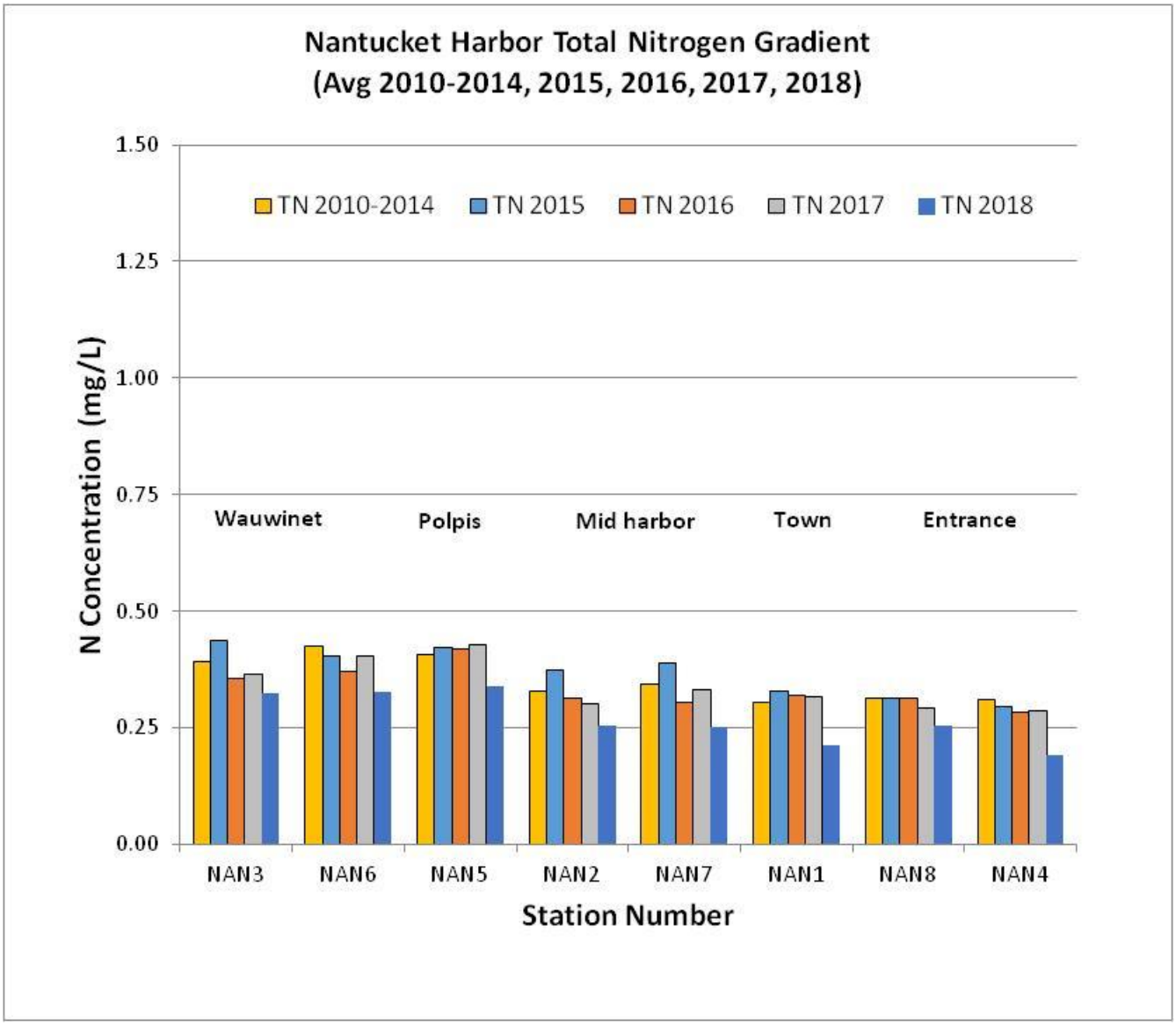

Figure 16. Summer 2018 TN concentrations compared to 2015, 2016, 2017 and average of 2010-2014 not including 2011.

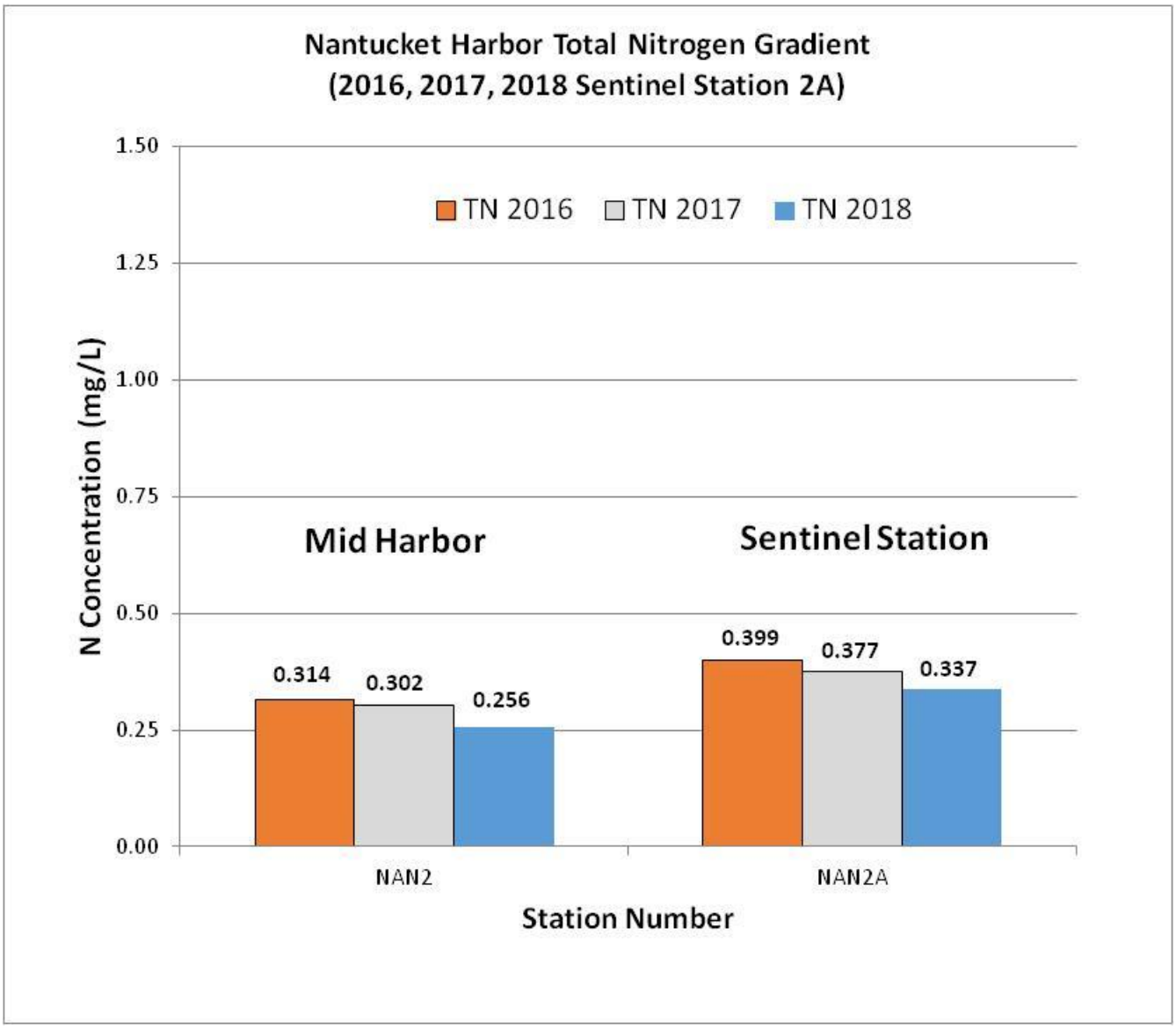

Figure 16 cont'd. Summer 2018 TN concentrations compared to summer 2016, 2017 results for both mid harbor station NAN2 and sentinel station NAN2A. Sampling at NAN2A was initiated in summer 2016.

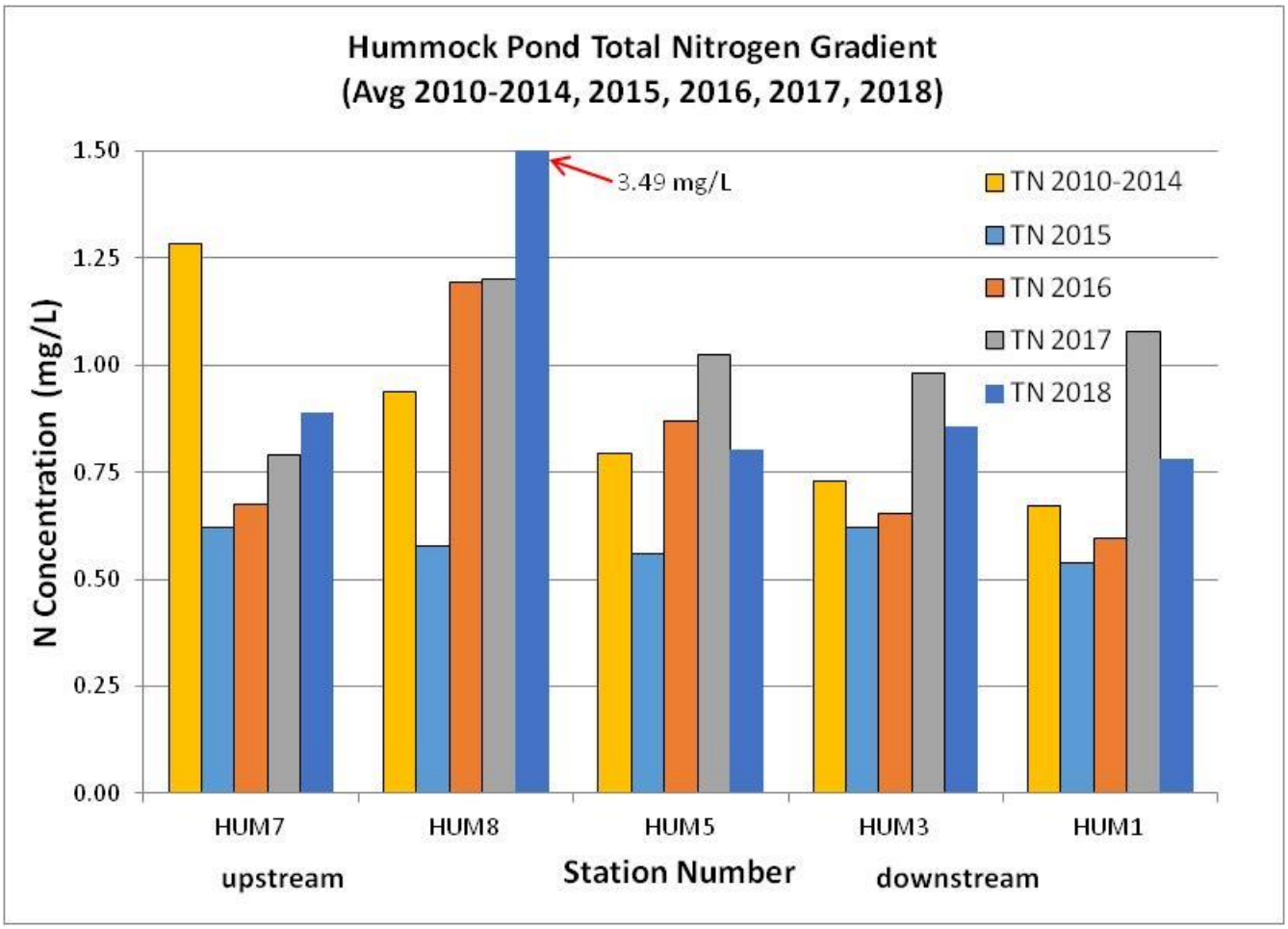

Figure 16 cont'd. Summer 2018 TN concentrations compared to 2015, 2016, 2017 and average of 2010-2014 not including 2011.

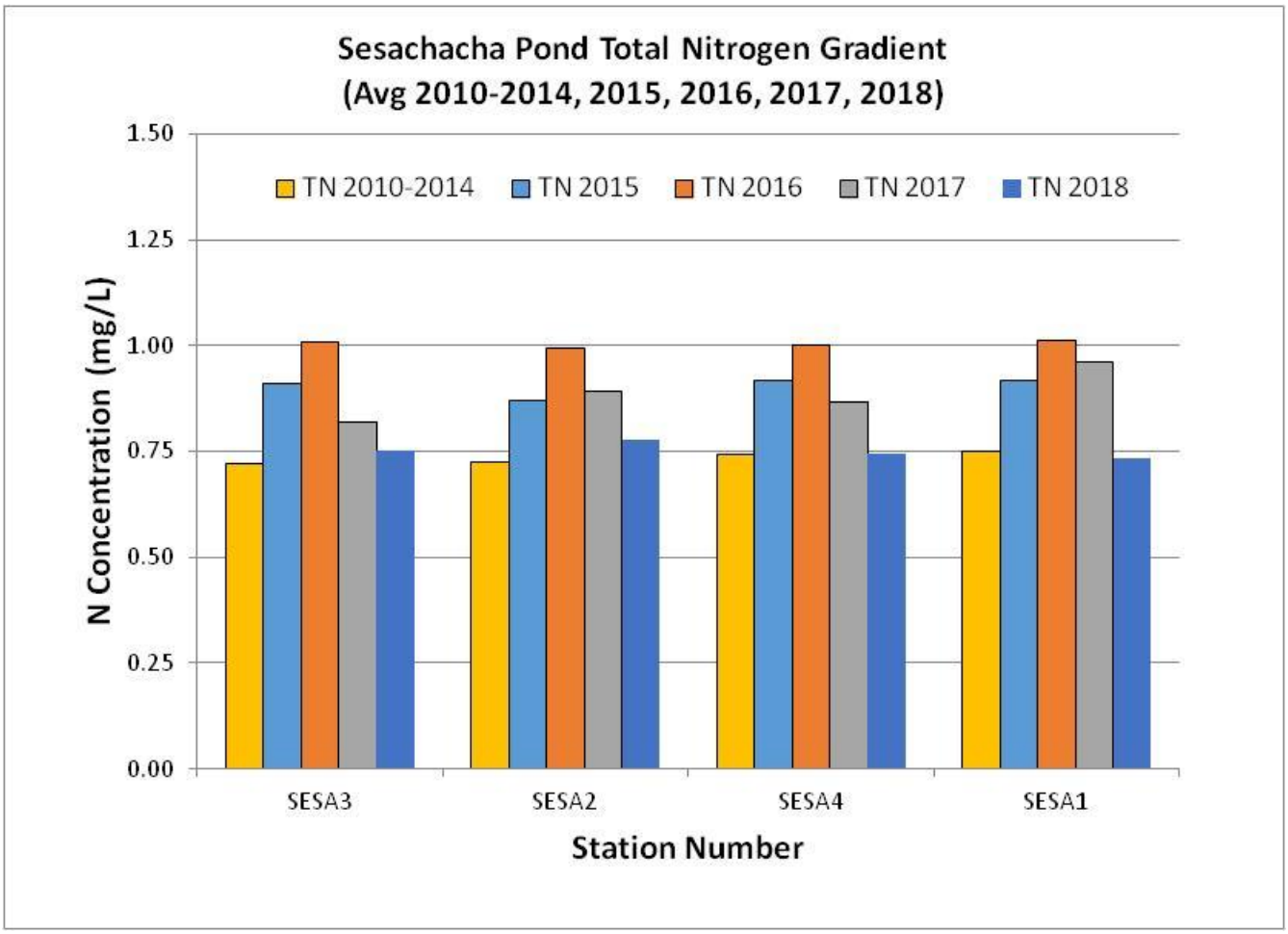

Figure 16 cont'd. Summer 2018 TN concentrations compared to 2015, 2016, 2017 and average of 2010-2014 not including 2011.

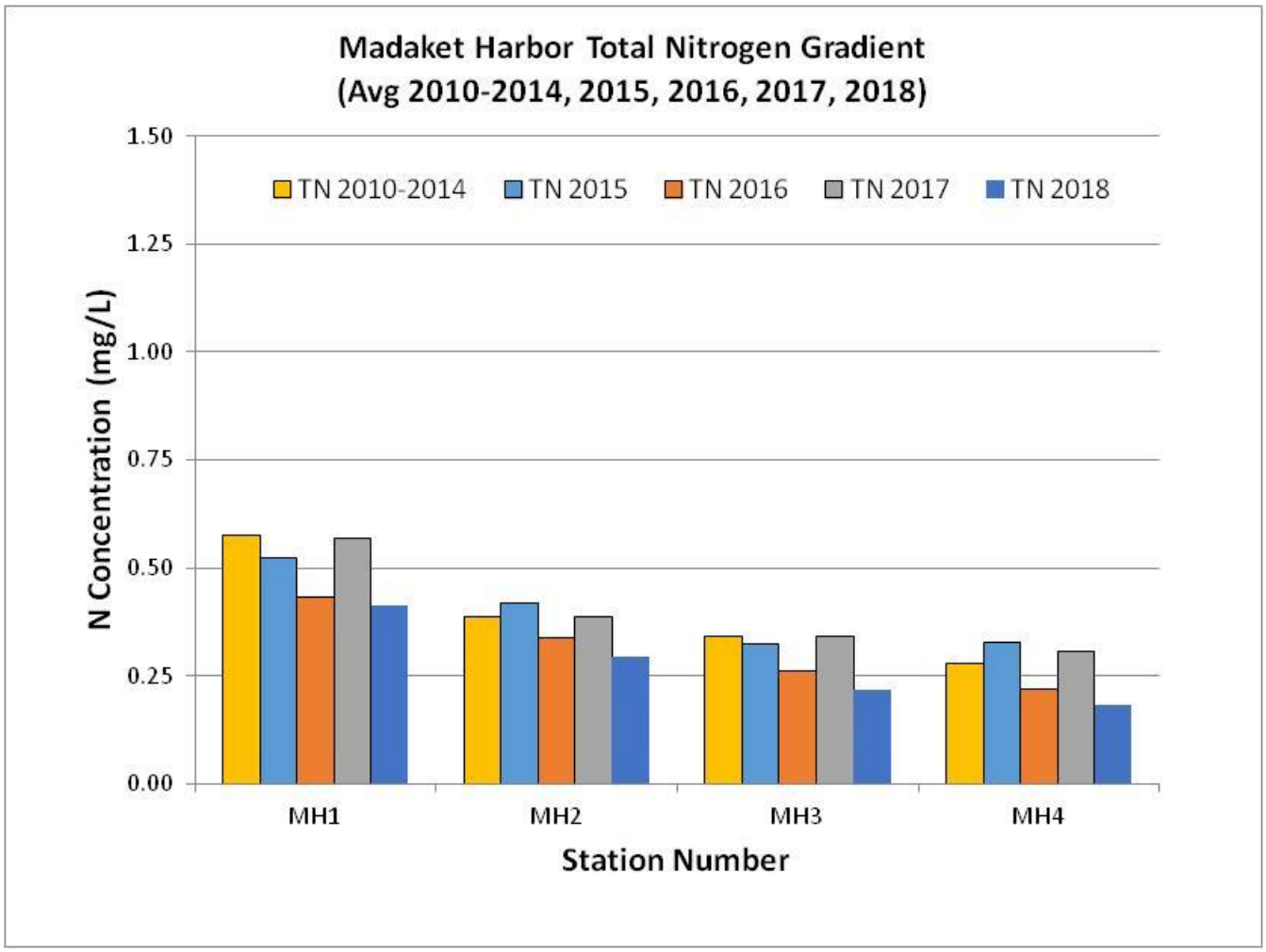

Figure 16 cont'd. Summer 2018 TN concentrations in Madaket Harbor compared to 2015, 2016, 2017 and average of 2010-2014 not including 2011.

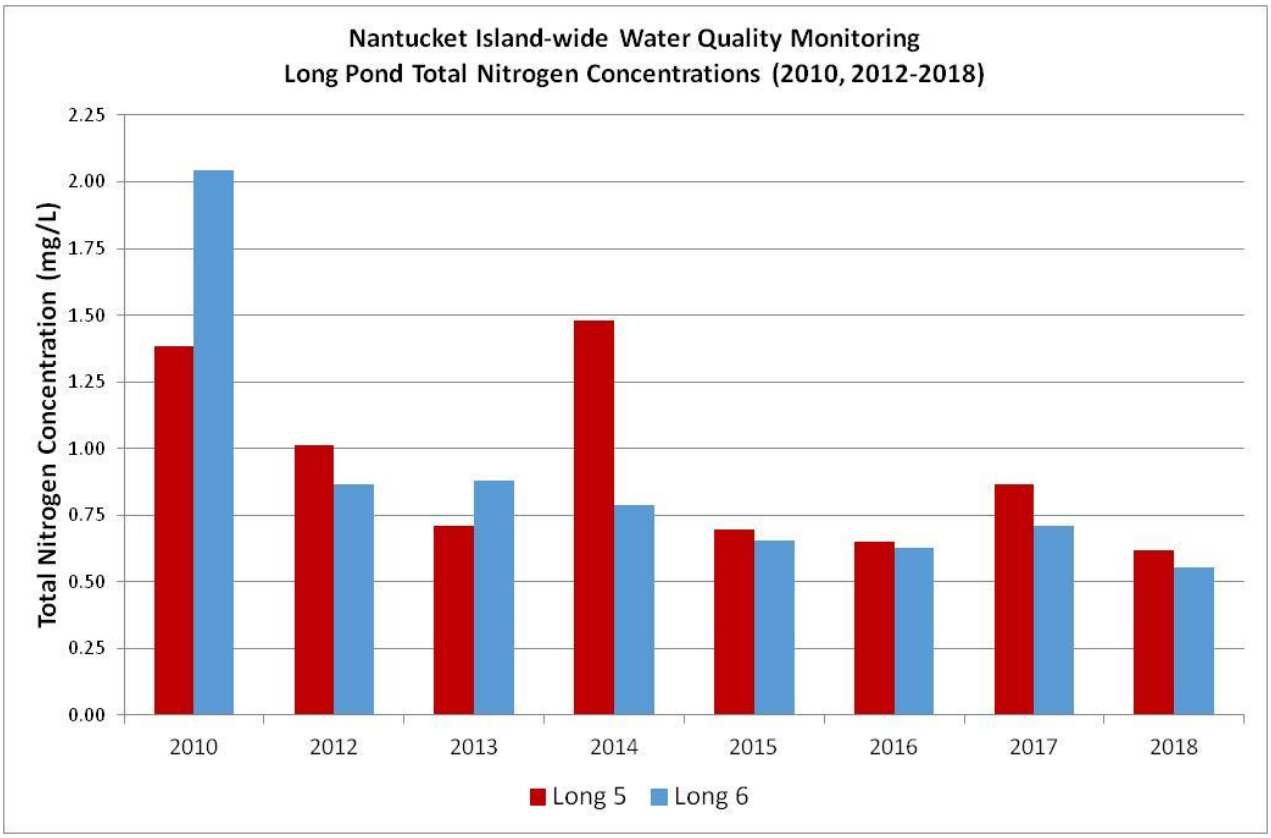

Figure 16 cont'd. Summer 2018 TN concentrations compared to 2010, 2012-2017 not including 2011.

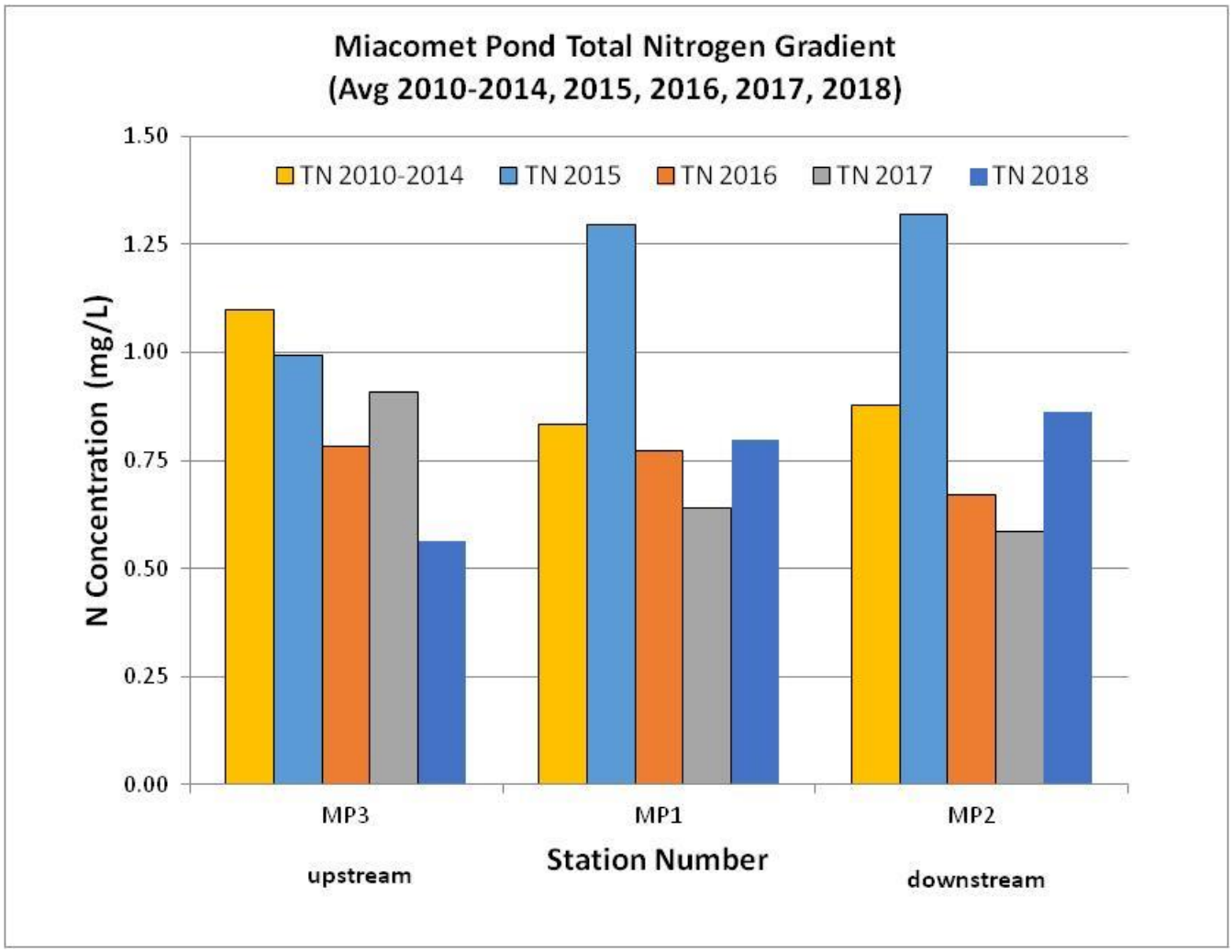

Figure 16 cont'd. Summer 2018 TN concentrations compared to 2015, 2016, 2017 and average of 2010-2014 not including 2011.

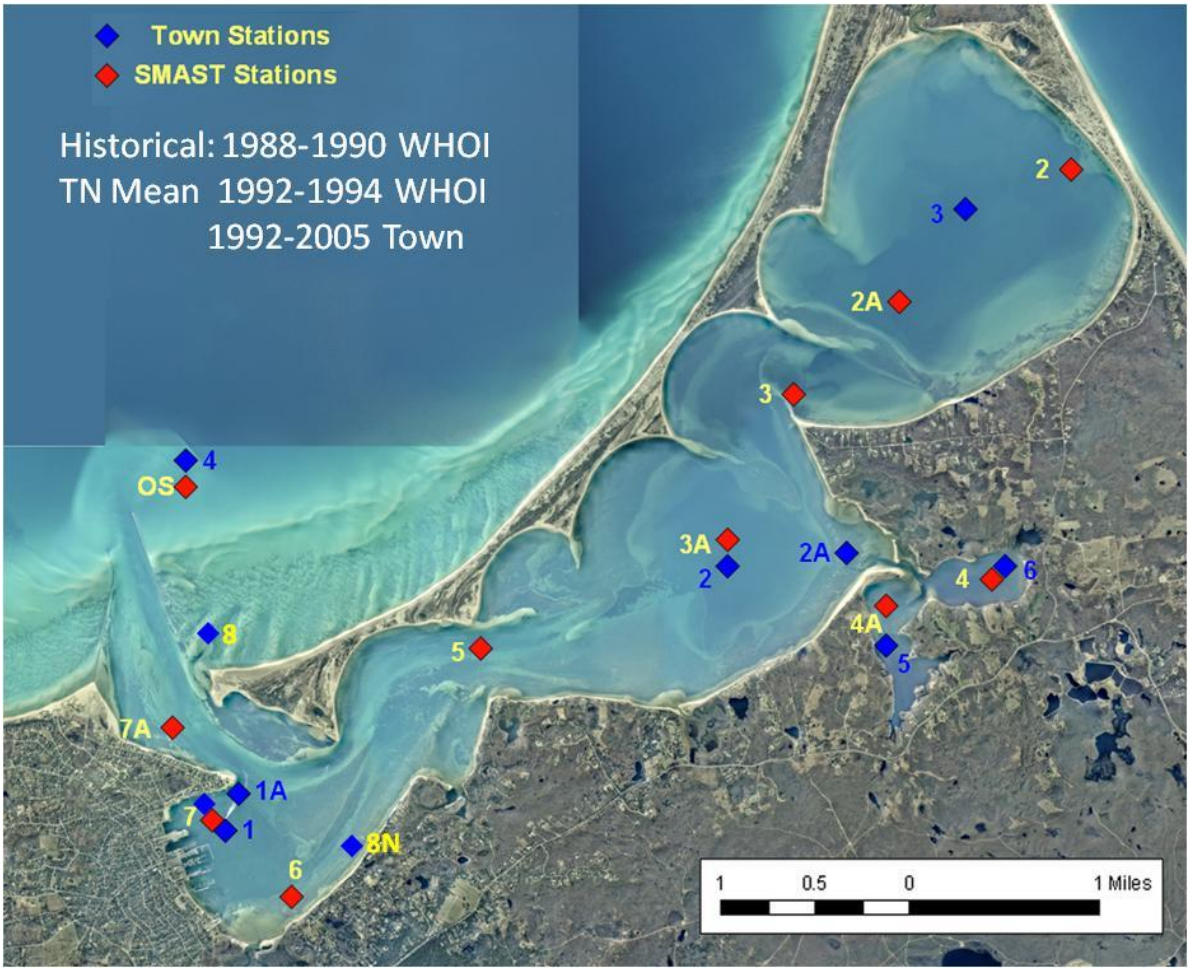

Figure 17. Estuarine water quality monitoring station locations in the Nantucket Harbor estuary system. Station labels correspond to those provided in Table 3 below. Red diamonds indicate locations of MEP monitoring stations. Blue diamonds are locations of Town sampling. Station 8 sampled in 2010, station 8N sampled in 2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018.

Sub-Embayment	Monitoring Station	Historical MEP Mean TN (mg/L)	s.d.	2010 Town ID	2010 Mean TN (mg/L)	2012 Mean TN (mg/L)	2013 Mean TN (mg/L)	2014 Mean TN (mg/L)	2015 Mean TN (mg/L)	2016 Mean TN (mg/L)	2017 Mean TN (mg/L)	2018 Mean TN (mg/L)
Head of the Harbor - Upper	2	0.408	0.188	NA	NS	NS	NS	NS	NS	NS	NS	NS
Head of the Harbor - Mid	Town 3	0.401	0.115	3	0.392	0.411	0.415	0.345	0.436	0.355	0.366	0.325
Head of the Harbor - Lwr	2A	0.339	0.07	NA	NS	NS	NS	NS	NS	0.415	0.377	0.337
Pocomo Head	3	0.335	0.081	NA	NS	NS	NS	NS	NS	NS	NS	NS
Quaise Basin	3A+Town 2	0.336	0.112	2	0.297	0.364	0.345	0.314	0.374	0.314	0.302	0.256
East Polpis Harbor	4+Town 6	0.362	0.105	6	0.438	0.484	0.401	0.378	0.404	0.371	0.405	0.327
West Polpis Harbor	4A+Town 5	0.388	0.119	5	0.431	0.419	0.385	0.389	0.422	0.42	0.429	0.341
Abrams Point	5	0.335	0.06	NA	NS	NS	NS	NS	NS	NS	NS	NS
Monomoy	6	0.297	0.086	NA	NS	NS	NS	NS	NS	NS	NS	NS
Mooring Area	7+Town 1, 1A	0.326	0.106	1, 7	0.332, 0.377	0.335, 0.379	0.323, 0.323	0.294, 0.284	0.390, 0.330	0.304, 0.319	0.317, 0.333	0.212, 0.253
Nantucket Sound	OS+Town 4	0.239	0.041	4	0.283	0.344[1]	0.3171	0.277	0.297	0.283	0.288	0.192

[1] It is almost certain that this does not represent the TN level in the inflow to Nantucket Harbor on the flood tide, but rather the 2012 data is influenced by mixing with TN enriched out-flowing waters. An attempt to control for this issue was implemented in the 2013 monitoring program.

Table 4. Comparison of MEP mean TN with Town data (values mg/L) from Nantucket Harbor. MEP data collected in the summers of 1988 - 1990 and 1992 - 1994 by the Woods Hole Oceanographic Institution, and between 1992 and 2005 by the Town of Nantucket Marine Department and by the Nantucket Marine and Coastal Resources Department in summers 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018.

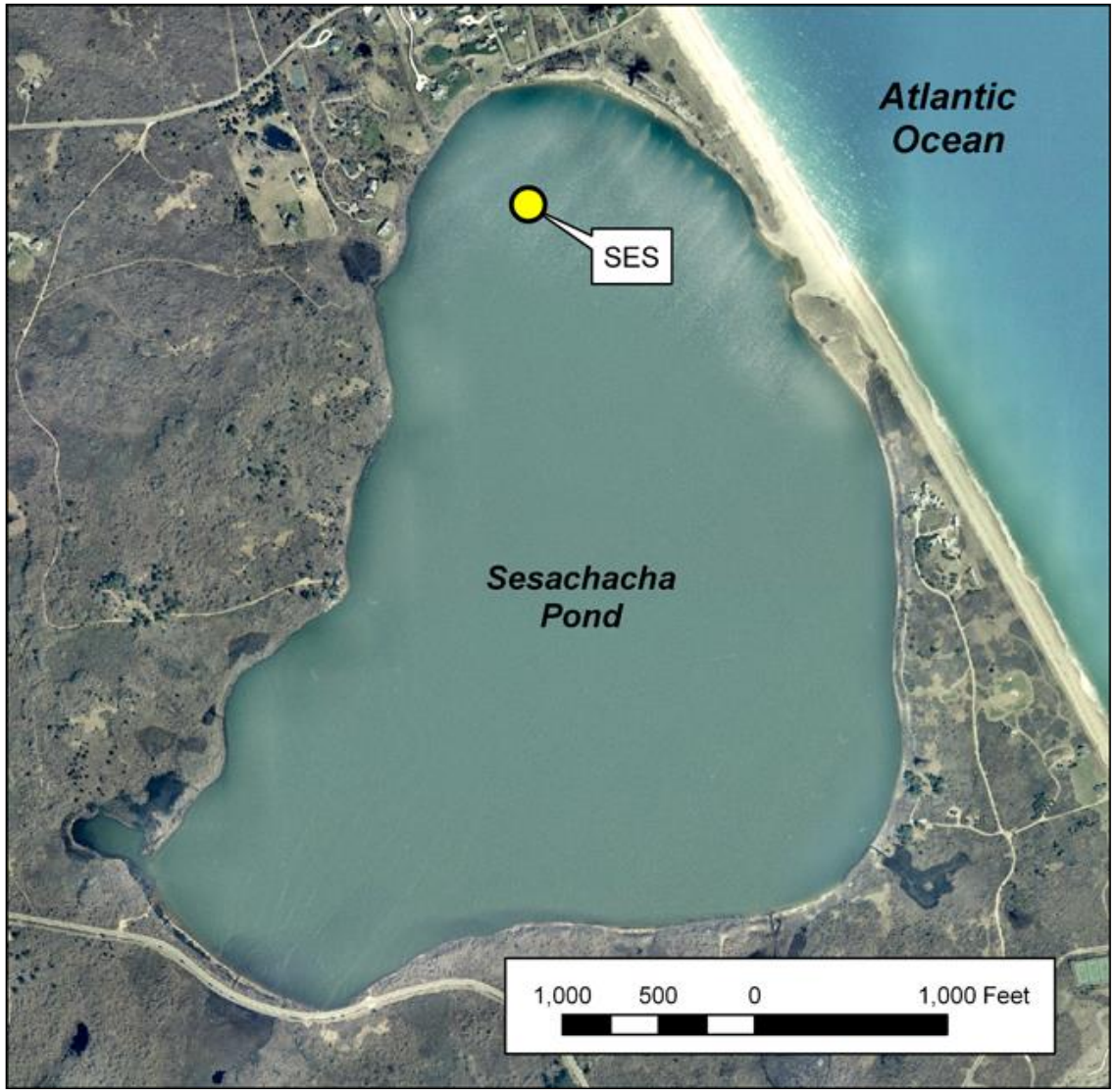

Figure 18. 2005 aerial photo showing MEP monitoring station location in Sesachacha Pond that was used in the water quality analysis for the Massachusetts Estuaries Project. Station SES corresponds to SESA-1 in Tables 2a,b and Station 1 in Figure 3.

Sampling Station Location	Historical MEP Mean TN (mg/L)	s.d.	2010 Mean TN (mg/L)	2012 Mean TN (mg/L)	2013 Mean TN (mg/L)	2014 Mean TN (mg/L)	2015 Mean TN (mg/L)	2016 Mean TN (mg/L)	2017 Mean TN (mg/L)	2018 Mean TN (mg/L)
Sesachacha Pond	1.197	0.078	0.684 (0.704)	0.678 (0.639)	0.714 (0.669)	0.919 (0.922)	0.918 (0.904)	1.01 (1.003)	0.960 (0.884)	0.734 (0.752)

Table 5. Comparison of MEP mean values of TN with Town TN data (all values are mg/L) from Sesachacha Pond. MEP data were collected in the summers of 1992 through 2005. Town data were collected in the summers of 2010, 2012, 2013 and 2014 by the Town of Nantucket Marine and Coastal Resources Department. Values in 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018 represent the average at Station 1, with the average of stations 1-4 in ( ).

Figure 19. Estuarine water quality monitoring station locations in the Madaket Harbor and Long Pond Systems.

Sub-Embayment	Monitoring Station	Historical MEP Mean TN (mg/L)	s.d.	2010 Mean TN (mg/L)	2012 Mean TN (mg/L)	2013 Mean TN (mg/L)	2014 Mean TN (mg/L)	2015 Mean TN (mg/L)	2016 Mean TN (mg/L)	2017 Mean TN (mg/L)	2018 Mean TN (mg/L)
Madaket Harbor	MEP M1	0.336	0.098								
Madaket Harbor	Town 4			0.285	0.297	0.278	0.254	0.328	0.219	0.306	0.081
Madaket Harbor	MEP M2	0.395	0.083								
Madaket Harbor	Town 2			0.436	0.444	0.323	0.347	0.418	0.338	0.386	0.293
Madaket Harbor	MEP M3	0.415	0.09								
Madaket Harbor	Town 3			0.324	0.356	0.314	0.376	0.324	0.26	0.341	0.218
Hither Creek	MEP M4	0.581	0.193								
Hither Creek	MEP M5	0.78	0.178								
Madaket Harbor	MEP M6	0.347	0.067								
Madaket Harbor	MEP M10	0.422	0.127								
Hither Creek	MEP M11+Town 1	0.62	0.215	0.626	0.655	0.573	0.445	0.524	0.434	0.57	0.414
Long Pond	MEP LOPO1	1.058	0.404								
Long Pond	MEP LOPO2+Town 5	0.971	0.369	1.385	1.013	0.709	1.481	0.697	0.649	0.867	0.62
Long Pond	MEP LOPO3	0.924	0.234								
Long Pond	MEP LOPO4+Town 6	0.894	0.278	2.044	0.867	0.88	0.788	0.656	0.629	0.712	0.554
North Head Long P.	MEP LOPO5	0.954	0.271								

Table 6. Comparison of MEP mean values of TN with Town TN data (all values are mg/L) from Madaket Harbor and Long Pond. MEP data were collected by SMAST in the summers of 2002 through 2004. Town data were collected in the summers of 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018 by the Town of Nantucket Marine and Coastal Resources Department.

Hummock Pond and Miacomet Pond Station ID's	2018	2017	2016	2015	2014	2013	2012	2010	2005/2007	
	TN (mg/L)	TN (mg/L)	TN (mg/L)	TN (mg/L)	TN (mg/L)	TN (mg/L)	TN (mg/L)	TN (mg/L)	TN (mg/L)	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	S.D.
HUM1	0.781	1.078	0.594	0.539	0.651	0.769	0.666	0.616	0.751**	0.374
HUM3	0.856	0.980	0.654	0.622	0.643	0.827	0.863	0.589	0.630**	0.388
HUM5	0.804	1.024	0.868	0.558	0.653	0.881	0.871	0.766	ND	ND
HUM7	0.889	0.789	0.673	0.621	0.873	1.170	1.301	1.786	1.283**	0.969
HUM8	**3.488**	1.200	1.194	0.576	0.755	1.064	0.944	0.983	ND	ND
MP1	0.797	0.641	0.772	1.297	0.864	0.792	0.828	0.854	0.842*	0.191
MP2	0.863	0.584	0.669	1.318	0.784	1.036	0.880	0.811	0.855*	0.213
MP3	0.562	0.909	0.783	0.992	1.297	1.058	0.950	1.093	0.280*	0
									***2005**	
									****2007**	

Table 7. Comparison of TN concentrations collected in 2005 (Miacomet Pond) and 2007 (Hummock Pond) by Nantucket Marine and Coastal Resources Department with Town TN data collected at both sites the summer of 2010, 2012, 2013, 2014, 2015, 2016, 2017 and 2018. All values are mg/L. Note the very high TN in 2018 is associated with a phytoplankton bloom in July and August (total chlorophyll a reaching of 88 ug/L)

EMBAYMENT	2018 Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2018 EUTRO Index	Health Status
HUM1	28.6	64.1	100.0	0.0	0.0	38.5	Moderate-Fair
HUM3	27.7	88.5	67.0	0.0	0.0	36.6	Moderate-Fair
HUM5	10.3	100.0	75.7	0.0	0.0	37.2	Moderate-Fair
HUM7	49.6	2.7	0.0	0.0	0.0	10.5	Fair-Poor
HUM8	0.0	53.4	19.1	0.0	0.0	14.5	Fair-Poor
LONG5	31.7	83.4	100.0	0.0	0.0	43.0	Moderate
LONG6	25.2	7.1	100.0	11.7	0.9	29.0	Fair-Poor
MH1	56.7	64.9	89.5	54.5	0.0	53.1	Moderate
MH2	68.7	74.5	100.0	99.6	39.6	76.5	High
MH3	80.4	79.0	100.0	100.0	87.6	89.4	High
MH4	100.0	89.4	100.0	100.0	90.3	95.9	High
MP1	34.8	83.9	49.3	0.0	0.0	33.6	Moderate-Fair
MP2	58.7	45.3	44.3	0.0	0.0	29.7	Fair-Poor
MP3	38.4	29.3	40.5	22.1	0.0	26.0	Fair-Poor
NAN1	100.0	78.3	100.0	100.0	93.3	94.3	High
NAN2	90.8	85.3	100.0	100.0	56.0	86.4	High
NAN2A	78.2	81.0	99.1	81.3	13.3	70.6	High
NAN3	74.8	80.4	100.0	85.0	30.0	74.0	High
NAN4	95.2	94.5	100.0	100.0	91.6	96.3	High
NAN5	65.2	84.4	100.0	78.4	27.7	71.1	High
NAN6	82.1	83.2	100.0	83.2	12.4	72.2	High
NAN7	63.8	86.8	89.0	100.0	58.9	79.7	High
NAN8N	44.3	79.0	100.0	100.0	80.7	80.8	High
SESA1	17.4	86.9	84.9	0.0	0.0	37.8	Moderate-Fair
SESA2	13.9	89.3	93.3	0.0	0.0	39.3	Moderate
SESA3	14.9	84.4	97.1	0.0	0.0	39.3	Moderate
SESA4	15.9	91.8	100.0	0.0	0.0	41.5	Moderate

Table 8a. 2018 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org)

EMBAYMENT	2017 Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2017 EUTRO Index	Health Status
HUM1	27.7	83.1	16.3	0.0	0.0	**25.4**	**Fair-Poor**
HUM3	19.8	100.0	89.1	0.0	0.0	**41.8**	**Moderate**
HUM5	5.6	80.3	50.3	0.0	0.0	**27.2**	**Fair-Poor**
HUM7	68.7	30.3	15.4	0.0	0.0	**22.9**	**Fair-Poor**
HUM8	0.0	78.1	65.5	0.0	0.0	**28.7**	**Fair-Poor**
LONG5	10.7	81.9	100.0	0.0	0.0	**38.5**	**Moderate-Fair**
LONG6	21.6	83.9	26.8	0.0	0.0	**26.5**	**Fair-Poor**
MH1	55.5	57.9	67.6	17.1	0.0	**39.6**	**Moderate-Fair**
MH2	63.8	89.5	88.2	67.5	31.1	**68.0**	**High-Moderate**
MH3	80.7	81.0	79.5	89.1	100.0	**86.1**	**High**
MH4	96.4	85.1	79.4	100.0	75.5	**87.3**	**High**
MP1	61.9	0.0	100.0	0.0	0.0	**32.4**	**Moderate-Fair**
MP2	81.4	0.0	100.0	5.2	6.2	**38.6**	**Moderate-Fair**
MP3	50.4	48.4	29.6	0.0	0.0	**25.7**	**Fair-Poor**
NAN1	100.0	80.6	100.0	90.6	100.0	**94.2**	**High**
NAN2	100.0	80.6	92.0	99.8	96.0	**93.7**	**High**
NAN2A	87.2	81.4	62.3	76.5	50.1	**71.5**	**High**
NAN3	83.6	87.0	70.7	77.6	32.0	**70.2**	**High**
NAN4	90.2	87.8	100.0	100.0	68.8	**89.4**	**High**
NAN5	76.9	76.3	75.6	54.9	60.6	**68.8**	**High**
NAN6	80.1	80.3	80.3	61.5	35.6	**67.6**	**High-Moderate**
NAN7	67.7	81.7	86.0	87.9	73.3	**79.3**	**High**
NAN8N	57.7	66.3	100.0	100.0	100.0	**84.8**	**High**
SESA1	32.9	51.7	100.0	0.0	0.0	**36.9**	**Moderate-Fair**
SESA2	26.9	33.3	100.0	0.0	0.0	**32.0**	**Moderate-Fair**
SESA3	18.4	94.0	100.0	0.0	2.9	**43.1**	**Moderate**
SESA4	27.0	100.0	100.0	0.0	6.5	**46.7**	**Moderate**

Table 8b. 2017 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

Station ID	Secchi SCORE	Low 20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2016 EUTRO Index	Health Status
HUM7	46.1	0.0	19.8	3.3	43.7	**22.6**	**Poor**
HUM8	0.0	24.2	47.3	0.0	0.0	**14.3**	**Poor**
HUM5	2.0	0.0	42.9	0.0	0.0	**9.0**	**Poor**
HUM3	23.1	90.3	100.0	0.0	52.1	**53.1**	**Moderate**
HUM1	26.6	76.8	100.0	3.5	60.8	**53.5**	**Moderate**
LONG6	7.8	40.7	71.2	0.0	43.8	**32.7**	**Mod-Fair**
LONG5	15.9	0.0	100.0	0.0	46.1	**32.4**	**Mod-Fair**
MH1C	66.5	54.4	70.4	48.5	83.1	**64.6**	**High-Moderate**
MH1	61.9	18.4	44.3	58.7	87.2	**54.1**	**Moderate**
MH2	60.9	66.7	83.2	83.6	100.0	**78.9**	**High**
MH3	79.0	71.8	100.0	100.0	100.0	**90.2**	**High**
MH4	100.0	86.2	100.0	100.0	100.0	**97.2**	**High**
MP3	26.9	47.8	89.0	0.0	0.0	**32.8**	**Mod-Fair**
MP1	35.5	47.0	100.0	0.0	0.0	**36.5**	**Mod-Fair**
MP2	49.2	42.7	91.9	0.0	0.0	**36.8**	**Mod-Fair**
NAN3	84.6	62.5	100.0	73.2	80.7	**80.2**	**High**
NAN6	74.2	66.6	100.0	56.3	64.2	**72.3**	**High**
NAN6C	79.3	70.6	100.0	47.7	62.9	**72.1**	**High**
NAN5	64.0	59.4	100.0	50.4	45.2	**63.8**	**High-Moderate**
NAN2	79.1	74.9	100.0	89.9	100.0	**88.8**	**High**
NAN2A	84.6	54.7	100.0	56.2	57.8	**70.7**	**High**
NAN2AC	83.5	50.9	100.0	45.9	52.8	**66.6**	**High-Moderate**
NAN7	72.0	73.4	100.0	93.5	81.8	**84.1**	**High**
NAN1	83.9	74.6	100.0	87.2	100.0	**89.1**	**High**
NAN8N	47.9	61.9	100.0	100.0	100.0	**82.0**	**High**
NAN4	87.1	81.2	100.0	100.0	100.0	**93.7**	**High**
STA4	0.0	35.6	83.3	0.0	100.0	**43.8**	**Moderate**
STA4A	0.0	0.0	75.4	0.0	89.4	**33.0**	**Mod-Fair**
STA6B	0.0	21.0	75.4	0.0	100.0	**39.3**	**Mod-Fair**
SESA3	100.0	75.4	3.7	0.0	36.3	**43.1**	**Moderate**
SESA2	100.0	73.5	2.4	0.0	33.0	**41.8**	**Moderate**
SESA4	100.0	76.7	5.7	0.0	39.9	**44.5**	**Moderate**
SESA1	17.1	69.5	11.6	0.0	31.4	**25.9**	**Poor**
SESA1C	13.9	100.0	100.0	0.0	0.0	**42.8**	**Moderate**
ORS2	54.8	63.5	100.0	79.2	100.0	**79.5**	**High**
ORS4	37.0	0.0	99.8	64.0	90.5	**58.3**	**Moderate**
ORS6	40.0	55.3	73.3	12.7	58.8	**48.0**	**Moderate**

Table 8c. 2016 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

EMBAYMENT	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2015 EUTRO Index	Health Status
HUM1	37.7	81.3	100.0	15.7	0.0	46.9	moderate
HUM3	37.2	73.6	100.0	0.0	5.1	43.2	moderate
HUM5	34.3	79.2	100.0	11.3	12.8	47.5	moderate
HUM7	62.7	81.4	7.1	23.3	28.7	40.6	moderate
HUM8	35.7	67.8	94.8	8.9	0.0	41.5	moderate
LONG5	22.0	82.4	93.1	0.0	9.2	41.4	moderate
LONG6	16.7	70.4	100.0	0.0	0.0	37.4	moderate/fair
MH1	63.3	51.7	74.5	24.2	60.6	54.9	moderate
MH2	81.4	72.2	52.4	61.2	98.1	73.1	High
MH3	80.0	89.5	100.0	83.3	99.9	90.5	High
MH4	99.0	98.5	100.0	82.2	100.0	95.9	Highe
MP1	19.0	75.1	56.6	0.0	0.0	30.1	Fair-Poor
MP2	17.9	79.8	42.1	0.0	0.0	28.0	Fair-Poor
MP3	24.5	95.0	25.8	0.0	0.0	29.1	Fair-Poor
NAN1	97.1	96.4	100.0	83.5	79.5	91.3	High
NAN2	92.0	89.1	86.6	68.7	69.6	81.2	High
NAN3	60.1	93.7	77.1	49.3	14.7	61.6	Moderate
NAN4	100.0	94.3	100.0	97.4	85.2	95.4	High
NAN5	67.6	79.2	85.7	52.2	79.2	72.8	High
NAN6	74.8	84.8	97.5	56.9	68.4	76.5	High
NAN7	68.7	91.8	96.4	61.7	83.1	80.4	High
NAN8N	79.7	83.5	100.0	89.3	97.8	90.1	High
ORS1	100.0	26.4	91.5	22.6	6.3	49.3	Moderate
ORS2	48.0	49.5	85.2	83.1	86.2	70.4	High
ORS3	0.0	33.8	34.6	40.4	91.0	40.0	Moderate
ORS4	0.0	35.0	57.4	60.6	83.8	47.4	Moderate
ORS5	21.6	56.5	99.9	35.8	100.0	62.8	High-Moderate
ORS6	0.0	53.3	64.6	19.0	72.5	41.9	Moderate
SESA1	25.5	88.1	100.0	0.0	0.0	42.7	Moderate
SESA2	9.6	88.5	100.0	0.0	0.0	39.6	Moderate
SESA3	9.6	98.4	100.0	0.0	0.0	41.6	Moderate
SESA4	7.8	93.5	100.0	0.0	0.0	40.3	Moderate
High Quality = >69; High-Moderate = 61-69; Moderate = 39-61; Moderate-Fair = 31-39; Fair-Poor = <31							

Table 8c. 2015 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

EMBAYMENT	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2014 EUTRO Index	Health Status
HUM1	51.3	74.7	62.7	0.0	50.0	47.7	Moderate
HUM3	34.8	78.3	68.2	0.0	53.3	46.9	Moderate
HUM5	36.5	73.8	91.7	0.0	35.3	47.5	Moderate
HUM7	28.1	81.0	29.3	0.0	0.0	27.7	Fair-Poor
HUM8	17.1	66.6	91.7	0.0	39.2	42.9	Moderate
LONG5	13.4	34.4	18.4	0.0	8.9	15.0	Fair-Poor
LONG6	11.8	67.6	43.7	0.0	25.7	29.7	Fair-Poor
MH1	66.1	67.6	39.4	56.9	88.8	63.7	High-Moderate
MH2	88.7	65.1	72.7	82.0	100.0	81.7	High
MH3	82.5	65.1	76.7	69.8	100.0	78.8	High
MH4	92.6	77.8	83.8	100.0	100.0	90.8	High
MP1	51.8	55.8	42.2	0.0	0.6	30.1	Moderate-Fair
MP2	70.6	70.1	58.6	0.0	52.3	50.3	Moderate
MP3	23.1	46.0	26.1	0.0	0.0	19.0	Fair-Poor
NAN1	100.0	81.3	86.9	100.0	100.0	93.7	High
NAN2	100.0	73.4	76.2	95.3	100.0	89.0	High
NAN3	100.0	77.5	83.7	80.6	96.6	87.7	High
NAN4	100.0	87.6	89.5	100.0	100.0	95.4	High
NAN5	78.8	68.0	87.6	63.3	94.0	78.4	High
NAN6	85.6	69.4	97.5	65.9	100.0	83.7	High
NAN7	67.9	74.0	79.1	100.0	100.0	84.2	High
NAN8N	77.6	75.7	91.2	100.0	100.0	88.9	High
SESA1	41.5	75.9	54.0	0.0	28.3	39.9	Moderate
SESA2	44.6	69.8	46.0	0.0	28.3	37.7	Moderate-Fair
SESA3	42.5	76.8	56.0	0.0	44.5	44.0	Moderate
SESA4	44.3	73.3	55.1	0.0	51.1	44.8	Moderate
High Quality = >69; High-Moderate = 61-69; Moderate = 39-61; Moderate-Fair = 31-39; Fair-Poor = <31							

Table 8e. 2014 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

Sta ID	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2013 EUTRO Index	Health Status
HUM-1	29.6	56.8	47.1	0.0	16.9	30.1	Fair-Poor
HUM-3	30.2	42.1	18.9	0.0	26.8	23.6	Fair-Poor
HUM-5	0.0	15.8	20.1	0.0	15.8	10.3	Fair-Poor
HUM-7	0.8	12.2	19.8	0.0	0.0	6.6	Fair-Poor
HUM-8	0.0	0.0	36.3	0.0	20.1	11.3	Fair-Poor
LONG-5	11.2	77.9	81.0	0.0	17.3	37.5	Moderate-Fair
LONG-6	9.3	25.0	74.8	0.0	1.1	22.0	Fair-Poor
MH1	64.5	52.5	33.4	22.0	71.2	48.7	Moderate
MH2	69.3	75.4	75.1	91.8	100.0	82.3	High
MH3	73.6	75.4	86.5	93.0	100.0	85.7	High
MH4	99.0	88.1	79.3	100.0	100.0	93.3	High
MP1	31.0	62.2	83.7	0.0	0.0	35.4	Moderate-Fair
MP2	41.9	30.5	44.1	0.0	0.0	23.3	Fair-Poor
MP3	27.3	56.2	0.0	0.0	0.0	16.7	Fair-Poor
NAN1	100.0	75.7	88.4	100.0	100.0	92.8	High
NAN2	97.3	68.2	75.7	82.0	83.1	81.3	High
NAN3	89.9	28.4	84.1	54.8	36.9	58.8	Moderate
NAN4	100.0	88.6	81.4	93.1	100.0	92.6	High
NAN5	70.7	42.6	91.3	64.3	48.0	63.4	High-Moderate
NAN6	76.1	20.5	72.4	61.9	44.2	55.0	Moderate
NAN7	70.0	73.8	90.9	88.6	64.4	77.5	High
NAN8	78.6	72.3	64.2	100.0	100.0	83.0	High
SES 1	78.9	83.6	40.3	0.0	62.4	53.0	Moderate
SES 2	86.4	70.2	61.6	2.8	73.5	58.9	Moderate
SES 3	88.0	77.5	52.5	0.0	80.7	59.7	Moderate
SES 4	92.1	79.3	47.9	0.0	79.9	59.8	Moderate

Table 8f. 2013 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

Station ID	Year	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	EUTRO Index	Health Status
HUM-1	2012	30.8	84.2	45.0	0.0	12.0	34.4	Moderate-Fair
HUM-3	2012	41.0	83.4	52.8	0.0	16.0	38.6	Moderate-Fair
HUM-5	2012	17.5	89.3	47.3	0.0	0.0	30.8	Fair-Poor
HUM-7	2012	11.3	69.5	7.9	0.0	0.0	17.7	Fair-Poor
HUM-8	2012	1.0	87.1	38.0	0.0	0.0	25.2	Fair-Poor
LONG-5	2012	0.0	70.9	30.4	0.0	0.0	20.3	Fair-Poor
LONG-6	2012	0.0	64.1	39.3	0.0	21.9	25.1	Fair-Poor
MH1	2012	65.3	100.0	3.0	17.6	3.1	37.8	Moderate-Fair
MH2	2012	83.2	100.0	20.1	68.4	100.0	74.3	High
MH3	2012	84.8	100.0	27.7	99.0	100.0	82.3	High
MH4	2012	100.0	100.0	53.8	100.0	100.0	90.8	High
MP1	2012	55.3	84.6	36.2	0.0	0.0	35.2	Moderate-Fair
MP2	2012	55.4	85.3	23.2	0.0	0.0	32.8	Moderate-Fair
MP3	2012	31.0	100.0	6.7	0.0	0.0	27.5	Fair-Poor
NAN1	2012	100.0	76.4	40.2	100.0	79.4	79.2	High
NAN2	2012	98.9	92.6	32.5	89.4	83.0	79.3	High
NAN3	2012	85.2	96.0	50.7	63.0	76.7	74.3	High
NAN4	2012	98.5	99.8	57.2	88.3	84.0	85.5	High
NAN5	2012	65.1	90.5	42.3	64.9	0.0	52.6	Moderate
NAN6	2012	79.2	80.8	46.5	41.9	38.5	57.4	Moderate
NAN7	2012	75.0	95.0	39.4	81.3	72.6	72.7	High-Moderate
NAN8	2012	71.4	76.1	39.3	84.7	85.1	71.3	High
SES 1	2012	84.2	80.4	43.6	0.0	45.4	50.7	Moderate
SES 2	2012	88.9	80.4	14.1	17.4	55.7	51.3	Moderate
SES 3	2012	95.4	80.4	36.7	17.8	71.3	60.3	Moderate
SES 4	2012	93.6	80.4	30.2	0.3	66.2	54.2	Moderate
High Quality = >69; High/Moderate = 61-69; Moderate = 39-61; Moderate/Fair = 31-39; Fair/Poor = <31								

Table 8g. 2012 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

ID	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	EUTRO Index	Health Status
HUM1	54.0	41.6	100.0	4.3	2.4	40.4	Moderate
HUM3	48.5	49.6	75.2	8.2	0.0	36.3	Moderate-Fair
HUM5	25.9	41.7	77.7	0.0	0.0	29.0	Fair-Poor
HUM7	22.4	14.5	0.4	0.0	0.0	7.4	Fair-Poor
HUM8	12.2	42.6	55.2	0.0	0.0	22.0	Fair-Poor
LONG5	0.6	55.8	100.0	0.0	0.0	31.3	Moderate-Fair
LONG6	4.6	55.8	73.9	0.0	0.0	26.8	Fair-Poor
MH1	59.0	0.3	44.5	5.4	0.0	21.8	Fair-Poor
MH2	72.8	22.3	70.7	50.3	5.4	44.3	Moderate
MH3	83.3	40.5	72.7	92.1	40.5	65.8	High-Moderate
MH4	100.0	40.5	72.4	100.0	71.8	77.0	High
MP1	54.8	37.1	63.7	0.0	0.0	31.1	Moderate-Fair
MP2	70.3	55.6	47.9	0.0	0.0	34.8	Moderate-Fair
MP3	47.1	42.8	12.9	0.0	0.0	20.6	Fair-Poor
NAN1	100.0	23.0	66.7	90.1	76.1	71.2	High
NAN2	100.0	20.9	87.2	100.0	51.8	72.0	High
NAN3	95.5	33.4	66.4	66.3	23.0	56.9	Moderate
NAN4	100.0	32.8	68.0	100.0	73.0	74.8	High
NAN5	74.8	12.5	62.1	54.1	0.0	40.7	Moderate
NAN6	81.7	16.6	69.8	49.9	0.0	43.6	Moderate
NAN7	78.1	27.1	72.3	70.4	25.6	54.7	Moderate
NAN8	86.7	27.5	62.3	100.0	77.6	70.8	High
SESA1	62.1	42.3	82.2	0.0	18.5	41.0	Moderate
SESA2	54.3	42.3	71.4	0.0	27.4	39.1	Moderate
SESA3	55.9	42.0	70.2	0.0	22.7	38.2	Moderate-Fair
SESA4	54.8	42.5	71.3	0.0	32.9	40.3	Moderate
High Quality = >69; High/Moderate = 61-69; Moderate = 39-61; Moderate/Fair = 31-39; Fair/Poor = <31							

Table 8h. 2010 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *with* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

2018 EMBAYMENT	Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2018 EUTRO Index	Health Status
HUM1	28.6	64.1	100.0	0.0	0.0	**32.1**	**Moderate-Fair**
HUM3	27.7	88.5	67.0	0.0	0.0	**23.7**	**Fair-Poor**
HUM5	10.3	100.0	75.7	0.0	0.0	**21.5**	**Fair-Poor**
HUM7	49.6	2.7	0.0	0.0	0.0	**12.4**	**Fair-Poor**
HUM8	0.0	53.4	19.1	0.0	0.0	**4.8**	**Fair-Poor**
LONG5	31.7	83.4	100.0	0.0	0.0	**32.9**	**Moderage-Fair**
LONG6	25.2	7.1	100.0	11.7	0.9	**34.4**	**Moderate-Fair**
MH1	56.7	64.9	89.5	54.5	0.0	**50.2**	**Moderate**
MH2	68.7	74.5	100.0	99.6	39.6	**77.0**	**High**
MH3	80.4	79.0	100.0	100.0	87.6	**92.0**	**High**
MH4	100.0	89.4	100.0	100.0	90.3	**97.6**	**High**
MP1	34.8	83.9	49.3	0.0	0.0	**21.0**	**Fair-Poor**
MP2	58.7	45.3	44.3	0.0	0.0	**25.8**	**Fair-Poor**
MP3	38.4	29.3	40.5	22.1	0.0	**25.2**	**Fair-Poor**
NAN1	100.0	78.3	100.0	100.0	93.3	**98.3**	**High**
NAN2	90.8	85.3	100.0	100.0	56.0	**86.7**	**High**
NAN2A	78.2	81.0	99.1	81.3	13.3	**68.0**	**High-Moderate**
NAN3	74.8	80.4	100.0	85.0	0.0	**64.9**	**High-Moderate**
NAN4	95.2	94.5	100.0	100.0	91.6	**96.7**	**High**
NAN5	65.2	84.4	100.0	78.4	27.7	**67.8**	**High-Moderate**
NAN6	82.1	83.2	100.0	83.2	12.4	**69.4**	**High**
NAN7	63.8	86.8	89.0	100.0	58.9	**77.9**	**High**
NAN8N	44.3	79.0	100.0	100.0	80.7	**81.3**	**High**
SESA1	17.4	86.9	84.9	0.0	0.0	**25.6**	**Fair-Poor**
SESA2	13.9	89.3	93.3	0.0	0.0	**26.8**	**Fair-Poor**
SESA3	14.9	84.4	97.1	0.0	0.0	**28.0**	**Fair-Poor**
SESA4	15.9	91.8	100.0	0.0	0.0	**29.0**	**Fair-Poor**

Table 9a. 2018 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org)

EMBAYMENT	2017 Secchi SCORE	Low20% Oxsat SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	2017 EUTRO Index	Health Status
HUM1	27.7	83.1	16.3	0.0	0.0	**11.0**	**Fair-Poor**
HUM3	19.8	100.0	89.1	0.0	0.0	**27.2**	**Fair-Poor**
HUM5	5.6	80.3	50.3	0.0	0.0	**14.0**	**Fair-Poor**
HUM7	68.7	30.3	15.4	0.0	0.0	**21.0**	**Fair-Poor**
HUM8	0.0	78.1	65.5	0.0	0.0	**16.4**	**Fair-Poor**
LONG5	10.7	81.9	100.0	0.0	0.0	**27.7**	**Fair-Poor**
LONG6	21.6	83.9	26.8	0.0	0.0	**12.1**	**Fair-Poor**
MH1	55.5	57.9	67.6	17.1	0.0	**35.1**	**Moderate-Fair**
MH2	63.8	89.5	88.2	67.5	31.1	**62.7**	**High-Moderate**
MH3	80.7	81.0	79.5	89.1	100.0	**87.3**	**High**
MH4	96.4	85.1	79.4	100.0	75.5	**87.8**	**High**
MP1	61.9	0.0	100.0	0.0	0.0	**40.5**	**Moderate**
MP2	81.4	0.0	100.0	5.2	6.2	**48.2**	**Moderate**
MP3	50.4	48.4	29.6	0.0	0.0	**20.0**	**Fair-Poor**
NAN1	100.0	80.6	100.0	90.6	100.0	**97.7**	**High**
NAN2	100.0	80.6	92.0	99.8	96.0	**96.9**	**High**
NAN2A	87.2	81.4	62.3	76.5	50.1	**69.0**	**High**
NAN3	83.6	87.0	70.7	77.6	32.0	**66.0**	**High-Moderate**
NAN4	90.2	87.8	100.0	100.0	68.8	**89.8**	**High**
NAN5	76.9	76.3	75.6	54.9	60.6	**67.0**	**High-Moderate**
NAN6	80.1	80.3	80.3	61.5	35.6	**64.4**	**High-Moderate**
NAN7	67.7	81.7	86.0	87.9	73.3	**78.7**	**High**
NAN8N	57.7	66.3	100.0	100.0	100.0	**89.4**	**High**
SESA1	32.9	51.7	100.0	0.0	0.0	**33.2**	**Moderate-Fair**
SESA2	26.9	33.3	100.0	0.0	0.0	**31.7**	**Moderate-Fair**
SESA3	18.4	94.0	100.0	0.0	2.9	**30.3**	**Moderate-Fair**
SESA4	27.0	100.0	100.0	0.0	6.5	**33.4**	**Moderate**

Table 9b. 2017 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

EMBAYMENT	Secchi SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	No DO EUTRO Index	Health Status
HUM1	37.7	100.0	15.7	0.0	38.3	Moderate
HUM3	37.2	100.0	0.0	5.1	35.6	Moderate-Fair
HUM5	34.3	100.0	11.3	12.8	39.6	Moderate
HUM7	62.7	7.1	23.3	28.7	30.4	Moderate-Fair
HUM8	35.7	94.8	8.9	0.0	34.9	Moderate-Fair
LONG5	22.0	93.1	0.0	9.2	31.1	Moderate-Fair
LONG6	16.7	100.0	0.0	0.0	29.2	Fair-Poor
MH1	63.3	74.5	24.2	60.6	55.6	Moderate
MH2	81.4	52.4	61.2	98.1	73.3	High
MH3	80.0	100.0	83.3	99.9	90.8	High
MH4	99.0	100.0	82.2	100.0	95.3	High
MP1	19.0	56.6	0.0	0.0	18.9	Fair-Poor
MP2	17.9	42.1	0.0	0.0	15.0	Fair-Poor
MP3	24.5	25.8	0.0	0.0	12.6	Fair-Poor
NAN1	97.1	100.0	83.5	79.5	90.0	High
NAN2	92.0	86.6	68.7	69.6	79.2	High
NAN3	60.1	77.1	49.3	14.7	50.3	Moderate
NAN4	100.0	100.0	97.4	85.2	95.6	High
NAN5	67.6	85.7	52.2	79.2	71.2	High
NAN6	74.8	97.5	56.9	68.4	74.4	High
NAN7	68.7	96.4	61.7	83.1	77.5	High
NAN8N	79.7	100.0	89.3	97.8	91.7	High
ORS1	100.0	91.5	22.6	6.3	55.1	Moderate
ORS2	48.0	85.2	83.1	86.2	75.6	High
ORS3	0.0	34.6	40.4	91.0	41.5	Moderate
ORS4	0.0	57.4	60.6	83.8	50.4	Moderate
ORS5	21.6	99.9	35.8	100.0	64.3	High-Moderate
ORS6	0.0	64.6	19.0	72.5	39.0	Moderate
SESA1	25.5	100.0	0.0	0.0	31.4	Moderate-Fair
SESA2	9.6	100.0	0.0	0.0	27.4	Fair-Poor
SESA3	9.6	100.0	0.0	0.0	27.4	Fair-Poor
SESA4	7.8	100.0	0.0	0.0	26.9	Fair-Poor
High Quality = >69; High-Moderate = 61-69; Moderate = 39-61; Moderate-Fair = 31-39; Fair-Poor = <31						

Table 9c. 2015 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

EMBAYMENT	Secchi SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	No DO EUTRO Index	Health Status
HUM1	51.3	62.7	0.0	50.0	41.0	Moderate
HUM3	34.8	68.2	0.0	53.3	39.1	Moderate
HUM5	36.5	91.7	0.0	35.3	40.9	Moderate
HUM7	28.1	29.3	0.0	0.0	14.3	Fair-Poor
HUM8	17.1	91.7	0.0	39.2	37.0	Moderate-Fair
LONG5	13.4	18.4	0.0	8.9	10.2	Fair-Poor
LONG6	11.8	43.7	0.0	25.7	20.3	Fair-Poor
MH1	66.1	39.4	56.9	88.8	62.8	High-Moderate
MH2	88.7	72.7	82.0	100.0	85.8	High
MH3	82.5	76.7	69.8	100.0	82.2	High
MH4	92.6	83.8	100.0	100.0	94.1	High
MP1	51.8	42.2	0.0	0.6	23.6	Fair-Poor
MP2	70.6	58.6	0.0	52.3	45.4	Moderate
MP3	23.1	26.1	0.0	0.0	12.3	Fair-Poor
NAN1	100.0	86.9	100.0	100.0	96.7	High
NAN2	100.0	76.2	95.3	100.0	92.9	High
NAN3	100.0	83.7	80.6	96.6	90.2	High
NAN4	100.0	89.5	100.0	100.0	97.4	High
NAN5	78.8	87.6	63.3	94.0	80.9	High
NAN6	85.6	97.5	65.9	100.0	87.3	High
NAN7	67.9	79.1	100.0	100.0	86.8	High
NAN8N	77.6	91.2	100.0	100.0	92.2	High
SESA1	41.5	54.0	0.0	28.3	30.9	Moderate-Fair
SESA2	44.6	46.0	0.0	28.3	29.7	Fair-Poor
SESA3	42.5	56.0	0.0	44.5	35.8	Moderate-Fair
SESA4	44.3	55.1	0.0	51.1	37.6	Moderate-Fair
High Quality = >69; High-Moderate = 61-69; Moderate = 39-61; Moderate-Fair = 31-39; Fair-Poor = <31						

Table 9d. 2014 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

Sta ID	Secchi SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	No DO EUTRO Index	Health Status
HUM-1	29.6	47.1	0.0	16.9	23.4	Fair-Poor
HUM-3	30.2	18.9	0.0	26.8	19.0	Fair-Poor
HUM-5	0.0	20.1	0.0	15.8	9.0	Fair-Poor
HUM-7	0.8	19.8	0.0	0.0	5.2	Fair-Poor
HUM-8	0.0	36.3	0.0	20.1	14.1	Fair-Poor
LONG-5	11.2	81.0	0.0	17.3	27.4	Fair-Poor
LONG-6	9.3	74.8	0.0	1.1	21.3	Fair-Poor
MH1	64.5	33.4	22.0	71.2	47.8	Moderate
MH2	69.3	75.1	91.8	100.0	84.0	High
MH3	73.6	86.5	93.0	100.0	88.3	High
MH4	99.0	79.3	100.0	100.0	94.6	High
MP1	31.0	83.7	0.0	0.0	28.7	Fair-Poor
MP2	41.9	44.1	0.0	0.0	21.5	Fair-Poor
MP3	27.3	0.0	0.0	0.0	6.8	Fair-Poor
NAN1	100.0	88.4	100.0	100.0	97.1	High
NAN2	97.3	75.7	82.0	83.1	84.5	High
NAN3	89.9	84.1	54.8	36.9	66.4	High-Moderate
NAN4	100.0	81.4	93.1	100.0	93.6	High
NAN5	70.7	91.3	64.3	48.0	68.6	High-Moderate
NAN6	76.1	72.4	61.9	44.2	63.6	High-Moderate
NAN7	70.0	90.9	88.6	64.4	78.4	High
NAN8	78.6	64.2	100.0	100.0	85.7	High
SES 1	78.9	40.3	0.0	62.4	45.4	Moderate
SES 2	86.4	61.6	2.8	73.5	56.1	Moderate
SES 3	88.0	52.5	0.0	80.7	55.3	Moderate
SES 4	92.1	47.9	0.0	79.9	55.0	Moderate

Table 9e. 2013 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

Station ID	Year	Secchi SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	EUTRO Index	Health Status
HUM-1	2012	30.8	45.0	0.0	12.0	22.0	Fair-Poor
HUM-3	2012	41.0	52.8	0.0	16.0	27.4	Fair-Poor
HUM-5	2012	17.5	47.3	0.0	0.0	16.2	Fair-Poor
HUM-7	2012	11.3	7.9	0.0	0.0	4.8	Fair-Poor
HUM-8	2012	1.0	38.0	0.0	0.0	9.7	Fair-Poor
LONG-5	2012	0.0	30.4	0.0	0.0	7.6	Fair-Poor
LONG-6	2012	0.0	39.3	0.0	21.9	15.3	Fair-Poor
MH1	2012	65.3	3.0	17.6	3.1	22.3	Fair-Poor
MH2	2012	83.2	20.1	68.4	100.0	67.9	High-Moderate
MH3	2012	84.8	27.7	99.0	100.0	77.9	High
MH4	2012	100.0	53.8	100.0	100.0	88.4	High
MP1	2012	55.3	36.2	0.0	0.0	22.9	Fair-Poor
MP2	2012	55.4	23.2	0.0	0.0	19.7	Fair-Poor
MP3	2012	31.0	6.7	0.0	0.0	9.4	Fair-Poor
NAN1	2012	100.0	40.2	100.0	79.4	79.9	High
NAN2	2012	98.9	32.5	89.4	83.0	76.0	High
NAN3	2012	85.2	50.7	63.0	76.7	68.9	High-Moderate
NAN4	2012	98.5	57.2	88.3	84.0	82.0	High
NAN5	2012	65.1	42.3	64.9	0.0	43.1	Moderate
NAN6	2012	79.2	46.5	41.9	38.5	51.5	Moderate
NAN7	2012	75.0	39.4	81.3	72.6	67.1	High-Moderate
NAN8	2012	71.4	39.3	84.7	85.1	70.1	High
SES 1	2012	84.2	43.6	0.0	45.4	43.3	Moderate
SES 2	2012	88.9	14.1	17.4	55.7	44.1	Moderate
SES 3	2012	95.4	36.7	17.8	71.3	55.3	Moderate
SES 4	2012	93.6	30.2	0.3	66.2	47.6	Moderate
High Quality = >69; High/Moderate = 61-69; Moderate = 39-61; Moderate/Fair = 31-39; Fair/Poor = <31							

Table 9f. 2012 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

ID	Secchi SCORE	DIN SCORE	TON SCORE	T-Pig SCORE	EUTRO Index	Health Status
HUM1	54.0	100.0	4.3	2.4	40.1	Moderate
HUM3	48.5	75.2	8.2	0.0	33.0	Moderate-Fair
HUM5	25.9	77.7	0.0	0.0	25.9	Fair-Poor
HUM7	22.4	0.4	0.0	0.0	5.7	Fair-Poor
HUM8	12.2	55.2	0.0	0.0	16.9	Fair-Poor
LONG5	0.6	100.0	0.0	0.0	25.2	Fair-Poor
LONG6	4.6	73.9	0.0	0.0	19.6	Fair-Poor
MH1	59.0	44.5	5.4	0.0	27.2	Fair-Poor
MH2	72.8	70.7	50.3	5.4	49.8	Moderate
MH3	83.3	72.7	92.1	40.5	72.1	High
MH4	100.0	72.4	100.0	71.8	86.1	High
MP1	54.8	63.7	0.0	0.0	29.6	Fair-Poor
MP2	70.3	47.9	0.0	0.0	29.6	Fair-Poor
MP3	47.1	12.9	0.0	0.0	15.0	Fair-Poor
NAN1	100.0	66.7	90.1	76.1	83.3	High
NAN2	100.0	87.2	100.0	51.8	84.7	High
NAN3	95.5	66.4	66.3	23.0	62.8	High-Moderate
NAN4	100.0	68.0	100.0	73.0	85.3	High
NAN5	74.8	62.1	54.1	0.0	47.8	Moderate
NAN6	81.7	69.8	49.9	0.0	50.4	Moderate
NAN7	78.1	72.3	70.4	25.6	61.6	High-Moderate
NAN8	86.7	62.3	100.0	77.6	81.7	High
SESA1	62.1	82.2	0.0	18.5	40.7	Moderate
SESA2	54.3	71.4	0.0	27.4	38.3	Moderate-Fair
SESA3	55.9	70.2	0.0	22.7	37.2	Moderate-Fair
SESA4	54.8	71.3	0.0	32.9	39.8	Moderate
High Quality = >69; High/Moderate = 61-69; Moderate = 39-61; Moderate/Fair = 31-39; Fair/Poor = <31						

Table 9g. 2010 Trophic Health Index Scores and status for water quality monitoring stations in Nantucket estuaries based upon open water embayment (not salt marsh) habitat quality scales. Index calculated *without* Dissolved Oxygen data (described in Howes et. al., 1999 at www.savebuzzardsbay.org).

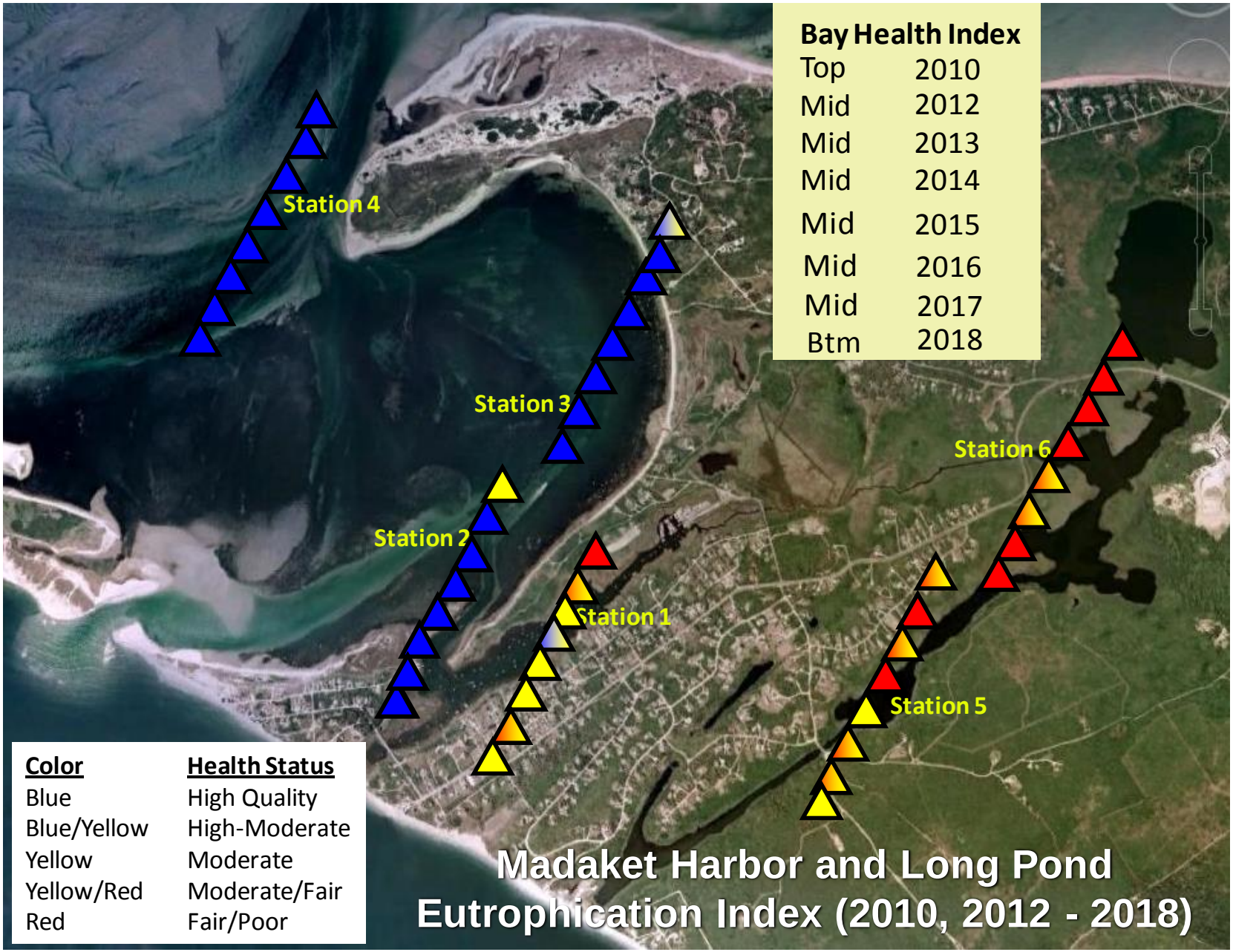

Figure 20. Madaket Harbor Eutrophication Index 2010 (top triangle) and 2018 (bottom triangle). Index was calculated with dissolved oxygen. Colors indicate High (Blue), Moderate (Yellow), Fair/Poor (Red) nutrient related water quality.

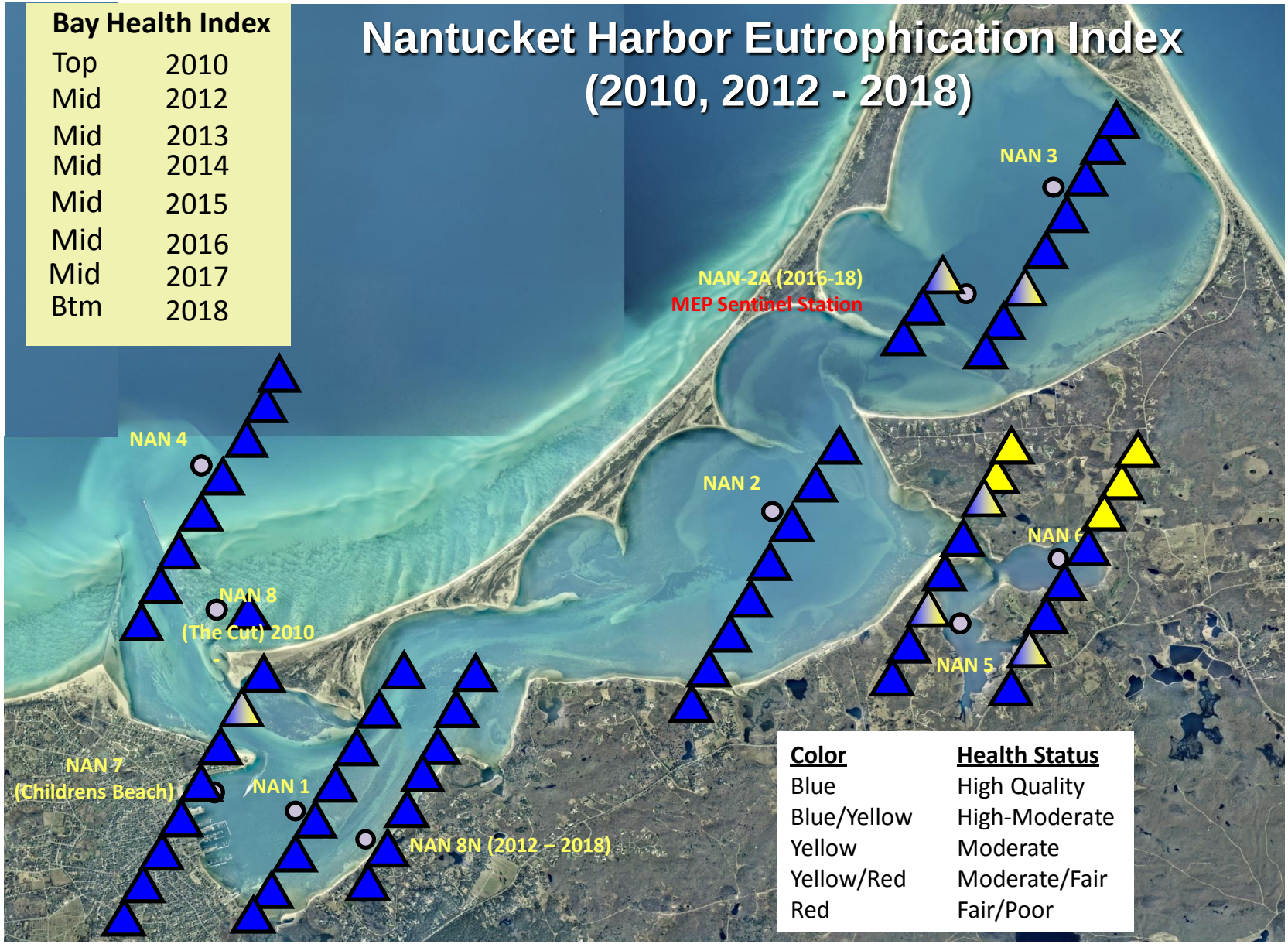

Figure 21. Nantucket Harbor Eutrophication Index 2010 (top triangle) and 2018 (bottom triangle). Index was calculated with dissolved oxygen. Colors indicate High (Blue), Moderate (Yellow), Fair/Poor (Red) nutrient related water quality. Station Nan-2A MEP Sentinel Station.

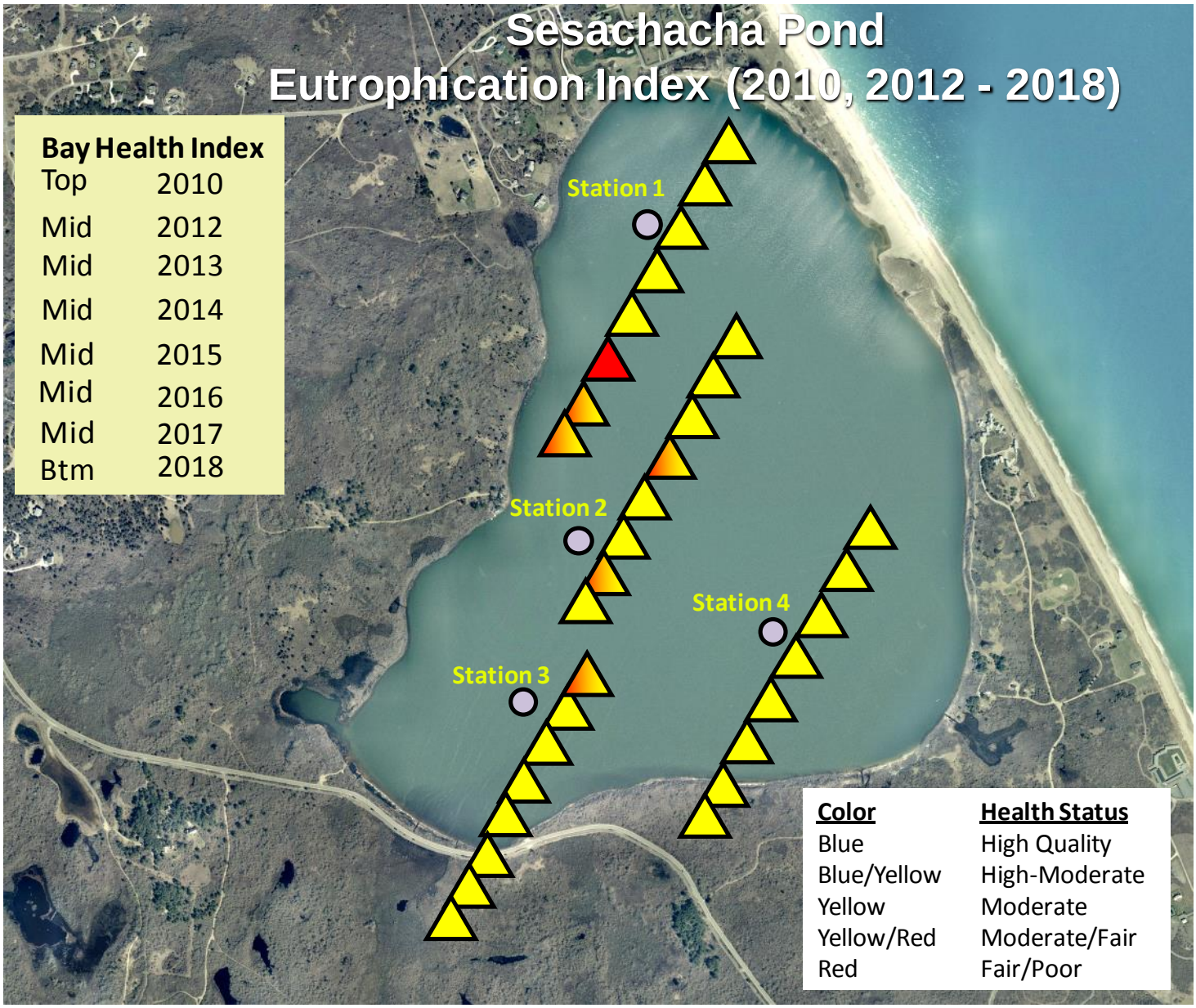

Figure 22. Sesachacha Pond Eutrophication Index 2010 (top triangle) and 2018 (bottom triangle). Index was calculated with dissolved oxygen. Colors indicate High (Blue), Moderate (Yellow), Fair/Poor (Red) nutrient related water quality.

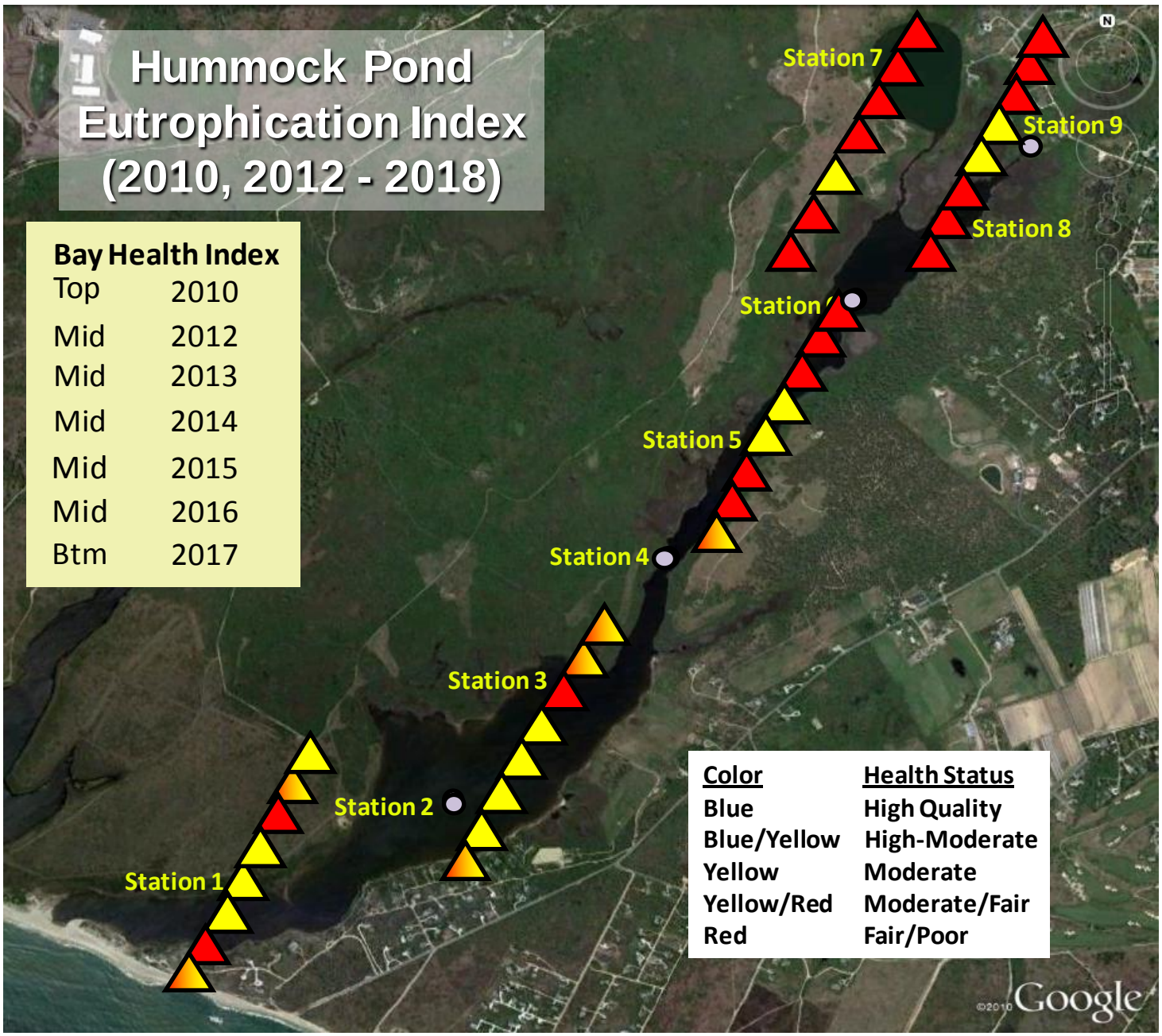

Figure 23. Hummock Pond Eutrophication Index 2010 (top triangle) and 2018 (bottom triangle). Index was calculated with dissolved oxygen. Colors indicate High (Blue), Moderate (Yellow), Fair/Poor (Red) nutrient related water quality.

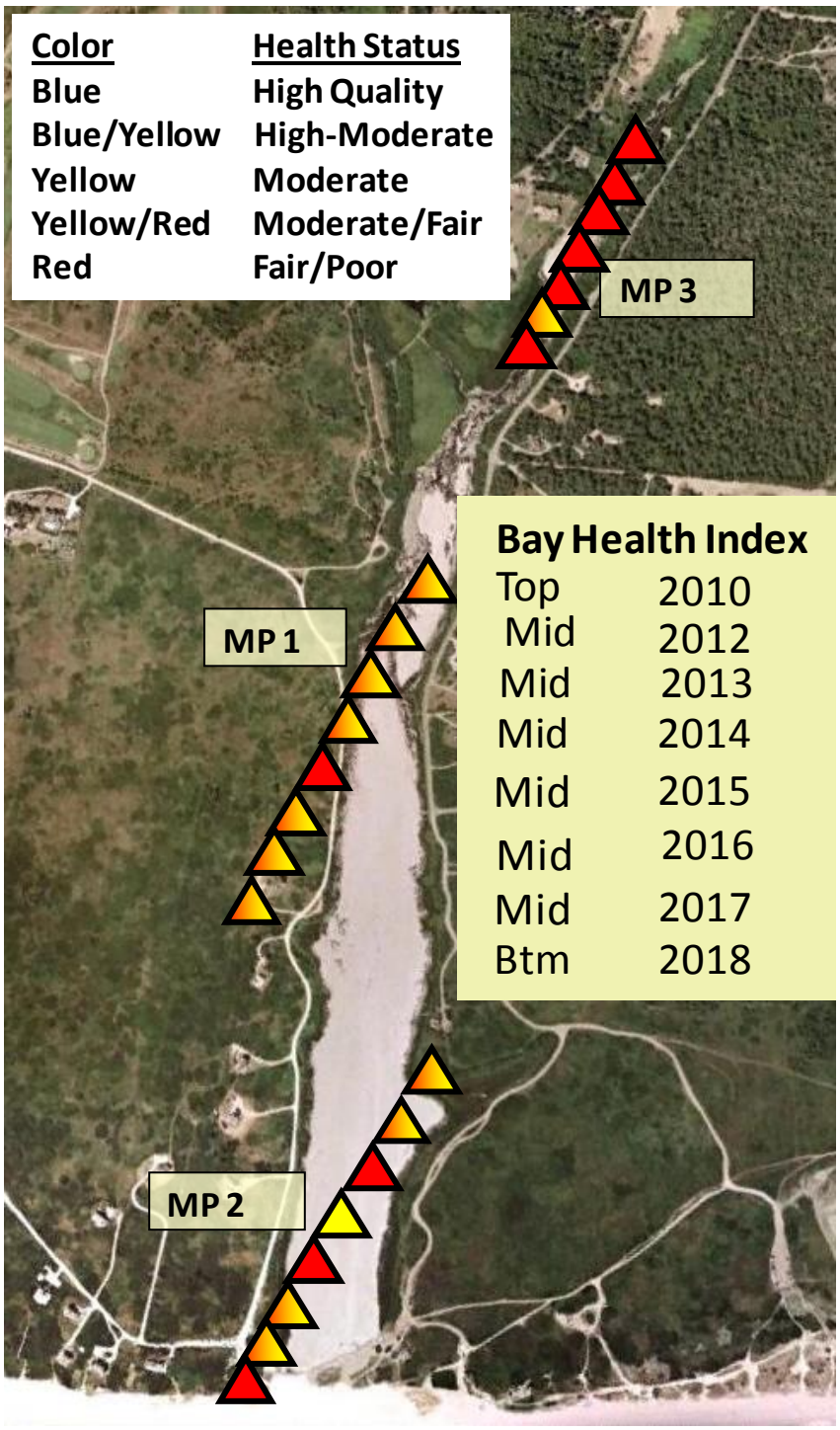

Figure 24. Miacomet Pond Eutrophication Index 2010 (top triangle) and 2018 (bottom triangle). Index was calculated with dissolved oxygen. Colors indicate High (Blue), Moderate (Yellow), Fair/Poor (Red) nutrient related water quality.