2021

ECOSYSTEM MONITORING REPORT

Tisbury Great Pond

GREAT POND FOUNDATION
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Ecosystem Monitoring Report – Tisbury Great Pond

Executive Summary

Great Pond Foundation (GPF) began monitoring the water quality and ecosystem health of Tisbury Great Pond in May 2021, as part of a one-year monitoring plan to assess ecosystem health. The sampling methodology consisted of regular monitoring during the spring, summer and fall seasons at 9 sampling stations throughout the Pond. At each station parameters such as temperature, salinity, dissolved oxygen, pH, water clarity and turbidity were measured throughout the entire water column. Additionally, concentrations of nutrients such as nitrate, phosphate, and ammonium were analyzed at these stations on select sampling days. These parameters are commonly used indicators for impairment and ecosystem health.

Monitoring data indicate that TGP is a struggling ecosystem, despite meeting multiple management thresholds in 2021. Salinity was mostly consistent across the 9 TGP sampling stations. Town Cove stations exhibited the greatest vertical variations in salinity within the water column. Water temperature at all 9 sampling stations remained below the 85°F management target throughout the summer season, with a maximum observed water temperature of 83.12°F on 7/21/21. Visibility into the water column was typically at least 4 feet, yet rarely extended to the bottom. All stations with the exception TGP8 experienced elevated turbidity and reduced water clarity. High turbidity is generally indicative of impaired water quality. Chlorophyll-a was above the 10 µg/L management threshold at least twice at all TGP sampling stations except for TGP7. Chlorophyll-a concentrations peaked throughout the Pond during the summer months, indicating increased phytoplankton growth, which is commonly associated with reduced water clarity.

Sufficient dissolved oxygen (DO) concentrations were observed throughout the upper portions of the water column in TGP. This is in contrast to the bottom depths, where lower DO concentrations were consistently observed. Measurements recorded from a continuous DO logger deployed at station TGP4 in Town Cove regularly detected periods of hypoxia (DO < 2 mg/L), most often during nighttime hours. Large fluctuations in DO such as this are often an indicator of impairment and decreased habitat quality. Total nitrogen (TN) values in TGP were below management targets for the majority of the monitoring period, peaking in July and August at most stations. Average TN values were below the recommended limits established by the Massachusetts Estuaries Project (MEP) report. TN measurements at station TGP7 were comparably lower than at other stations. This is likely a factor of TGP7's location in the main basin of the pond, which experiences greater wind and tide-driven circulation compared to the coves.

Overall, Tisbury Pond is suffering from multiple water quality issues, including low dissolved oxygen, elevated chlorophyll, and a history of elevated nitrogen concentrations within the water column. Measurements of water clarity occasionally fell below recommended limits during the course of this monitoring program. These combined factors ultimately decrease habitat quality, limiting biodiversity and reducing overall ecosystem health. However, TGP benefited from increased circulation as a result of pond cuts. TGP was opened to the ocean 5 times in 2021, 4 of which were man-made and 1 which occurred naturally during a storm event. The pond was open to the ocean for a total of 185 days in 2021. Opening length varied from 18-48 days, with an average opening duration of 37 days.

Continued monitoring is strongly recommended to further document the impact of eutrophication on water quality. This can be accomplished via a combination of site visits with handheld sampling equipment and deployed data loggers. Additionally, continued monitoring of nutrient concentrations throughout the pond is recommended. Assessment of nutrient concentrations within the groundwater recharge area north of the pond may identify nitrogen hotspots within the watershed and help to inform future management plans.

2021 Ecosystem Monitoring Data

Overview of Ecosystem Monitoring Program

Tisbury Great Pond (TGP) is a coastal estuary approximately 740 acres in size. TGP consists of a main basin and several tributary coves (Town Cove, Pear Tree Cove, Tiah's Cove, Deep Bottom, and Thumb Cove). TGP and its watershed is located within two towns: Chilmark and West Tisbury, Massachusetts. Two tributary streams supply freshwater to TGP, the Mill Brook and Tiasquam River, which both flow into Town Cove. A barrier beach separates TGP from the Atlantic Ocean, which is intentionally breached or "cut" 3-4 times per year to drain the pond and allow it to be flushed with salty ocean water. Water from the Atlantic Ocean is also low in nutrient concentrations compared to TGP, making flushing during openings a nutrient management tool. Pond cuts are temporary, and close due to natural forces. The timing of openings is determined by the commissioners of the Riparian Owners of Tisbury Great Pond, who consider factors such as pond elevation, pond water quality, weather, and the migration patterns of important species such as river herring. After closure of the cut, TGP gradually refills due to groundwater and surface water flow, as well as precipitation onto the pond's water surface.

The Great Pond Foundation (GPF) Ecosystem Monitoring Program follows the methodology of the Massachusetts Estuaries Project (MEP) and utilizes the management standards established by the TGP MEP report (Howes et al., 2013). This report found that the main basin and tributary coves were moderately to significantly impaired due to loss of eelgrass (*Zostera marina*) coverage compared to the 1951 distribution and impairment of benthic (bottom) animal habitat. This loss of habitat resulted from summer oxygen depletions and organic enrichment due to excess nitrogen. The MEP developed threshold nitrogen levels based on modelling the water circulation within TGP and nitrogen loading from its watershed. These thresholds establish the concentration of nitrogen the system can accommodate in order to restore high habitat quality. Regular monitoring of water quality in TGP is required to determine if nitrogen levels in the pond are meeting these thresholds, and to monitor for further degradation or improvement within the ecosystem.

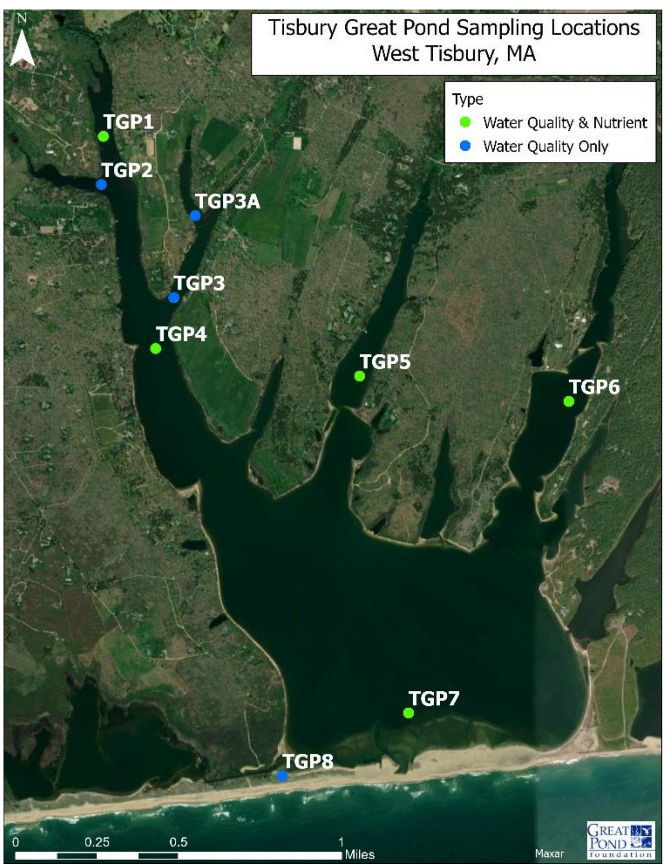

Figure 1. Map of the nine Tisbury Great Pond (TGP) sampling stations.

GPF began monitoring water quality and ecosystem health of Tisbury Great Pond in May 2021, after TGP was added to GPF's Ecosystem Monitoring Program. Sample collection methodology included regular monitoring during the spring, summer and fall seasons. Numerous sampling methods were utilized, including handheld probe measurements, lab-analyzed nutrient analyses, and continuously operated deployed data loggers.

Data collection was centered on 9 sampling stations throughout the Pond (Figure 1). These water sampling stations cover all geographic features of the TGP ecosystem: adjacent to the barrier beach, near the connecting channel to Black Point Pond, and at least one station within every cove. At each station parameters such as temperature, salinity, dissolved oxygen, pH, water clarity and turbidity were measured throughout the entire water column using a YSI ProDSS handheld water quality meter (see Glossary in Appendix for explanations of parameters). Additionally, concentrations of nutrients such as nitrate, phosphate, and ammonium were analyzed at these stations on select sampling days. Water samples were delivered to the Marine Biological Laboratory in Woods Hole for nutrient analyses. This methodology and suite of parameters are widely used standards for the determination of impairment and the assessment of ecosystem health.

GPF's 2021 field season began on May 11 and the last sample collection occurred on October 7. Water samples were collected weekly by the Scientific Program Director, Watershed Outreach Manager, and interns during the 22-week monitoring period (see Table A1 in Appendix for dates), providing a high-resolution dataset with over 73,000 unique data points. Summer is when the Pond is most biologically active, and frequent sampling allows for rapid detection of biological phenomena, such as algal blooms. Winter prohibits boat-based water sampling, however, the cold weather also limits biological activity making regular sampling unnecessary. In addition to in-situ data collection during site visits, GPF deployed dissolved oxygen and conductivity/salinity sensors which continuously monitored these parameters. Both loggers were deployed on June 16 at station TGP4 and collected measurements every half-hour (48 measurements per 24 hours) until their removal on November 4. The datasets provided by these instruments are essential to understanding temporal changes and patterns in their recorded parameters and provide greater context and comparison for the accompanying data collected during field sampling.

Pond Elevation and Pond Cuts

- *TGP was opened to the ocean 5 times in 2021, 4 of which were man-made and 1 cut occurred naturally during a storm.*
- *TGP was open to the ocean for a total of 185 days in 2021. Opening length varied from 18-48 days, with an average opening duration of 37 days.*

The barrier beach was intentionally opened to the ocean four times in 2021, with one additional opening caused by a storm on March 29 (Table 1). This natural opening occurred 5 days after the beach recovered from the first man-made cut in February 2021, which can be considered a reponing of the first cut.

Opening #	Date of Opening	Date of closure	Length of opening
1	2/10/2021	3/24/2021	42
2	3/29/2021	4/16/2021	18
3	5/8/2021	6/12/2021	35
4	9/12/2021	10/30/2021	48
5	12/29/2021	2/9/2022	42

Table 1. Dates of Tisbury Great Pond openings, when the barrier beach was breached allowing for tidal exchange with the ocean. The 3/29 opening occurred naturally during a storm (in red), while all other openings were man-made. The average length of the opening was 37 days, and TGP was open to the ocean for a total of 185 days. Opening data provided by Johnny Hoy, West Tisbury Herring Warden.

During an opening, the Pond will experience an initial drain into the Atlantic Ocean, the magnitude of which is determined by the water elevation in the Pond compared to that of the ocean prior to opening. Following this drain, the remaining fresher, nutrient-rich water from the pond will be steadily replaced by salty ocean water over the course of several tidal cycles. This exchange has the beneficial effects of reducing overall nutrient concentrations, increasing salinity, lowering temperature, and improving water circulation throughout the Pond. These conditions are of particular benefit to shellfish populations.

Following a cut, salinity is often used to measure of the extent of exchange between the Pond and the ocean and can determine the "success" of an opening. A significant increase in salinity, especially in the coves, indicates a successful flush, where salty ocean water is introduced throughout the entire Pond. However, salinity data is not always available, such as during the winter months when sample collection does not occur. The first two cuts of 2021 were made prior to the beginning of regular water sampling and no salinity data was collected. However, all man-made cuts remained open for at least 35 days, which previous data shows is more than sufficient time for successful flushing of the pond. Following both the May 8 and September 12 cut, salinity increased at all sampling stations, signaling a full exchange of water with the ocean and indicating a successful cut.

Overall, TGP was open to the ocean for a total of 185 days in 2021. Opening length varied from 18-48 days, with an average opening duration of 37 days. GPF does not have opening data from previous years, and therefore the 2021 openings cannot be easily compared to other years. However, an analysis of historical water quality data, including opening dates and duration, will be performed in a future report.

Salinity

- *Salinity was relatively consistent across the 9 TGP sampling stations. Stations within Town Cove had the largest range and exhibited more vertical variation within the water column.*
- *Salinity ranged from 0.18 – 30.72 ppt throughout the sampling season. There were significant changes in salinity when TGP was cut, which rapidly increased salinity pond-wide.*

Salinity is a measure of how much salt is dissolved in water, measured in parts per thousand (ppt) (tap water = 0 parts per thousand, ocean water = 34 ppt). Salinity can be an indicator of the local hydrology within TGP, or of how water enters, circulates, and exits the pond. Additionally, salinity can be used to assess the success of pond cuts. During a successful opening, the whole pond is flushed with ocean water, which causes the salinity to increase throughout the main basin and into the coves. Most fresh water enters TGP along these coves via groundwater and tributary streams, making them typically less saline than the basin.

All 9 stations exhibited similar salinity trends. Overall, salinity ranged from 0.18 ppt to 30.72 ppt (Figure 2). The lowest measured salinity was observed in early June, where salinity was below 5 ppt at stations TGP1 and TGP2. These two sampling stations often exhibited the lowest salinity in the pond due to their proximity to the Mill Brook and Tiasquam River tributaries. These two sources of freshwater cause the water column within Town Cove to become stratified. Stratification, or the existence of horizontal layers in the water, occurs due to differences in density caused by variations in salinity and temperature. Saltwater is denser than freshwater, which causes it to sink below the more buoyant, fresher water. Stratification was observed at stations TGP1- 4 throughout GPF's monitoring period.

Salinity rapidly increased following pond cuts. While GPF was not monitoring TGP prior to the May 8 cut, salinity at a majority of monitoring stations was typically above 20 ppt at the start of the monitoring period (Figure 2). Salinity gradually decreased throughout the summer to an average of 9.48 ppt on 9/8, 4 days before the September 12 cut. During the period immediately following a cut, fresh groundwater flow into the Pond from the surrounding water table will temporarily increase due to a hydrostatic pressure gradient caused by the rapid draining of the pond. After this initial drop following the September 12 cut, salinity levels jumped to a pond-wide average of 23.5 ppt on 9/21, 9 days after the cut. These trends were also captured by the continuous conductivity logger deployed at station TGP4 (Figure 3).

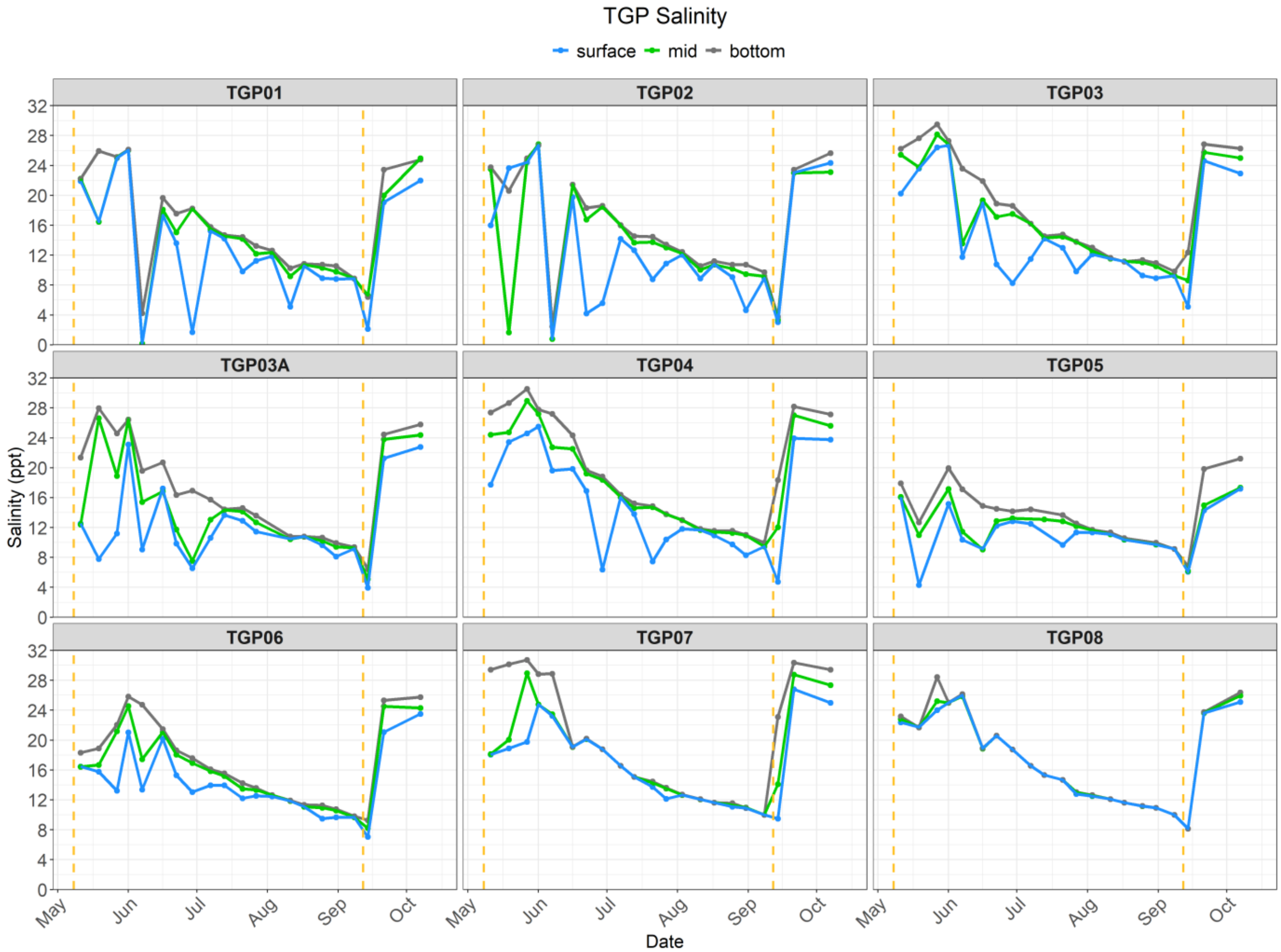

Figure 2. Salinity in parts per thousand (ppt) in Tisbury Great Pond in 2021. Data were measured with a handheld probe at the surface, mid-depth and bottom water, represented by different colors, at 9 sampling stations (different panels). The dashed yellow line is when TGP was cut to the ocean.

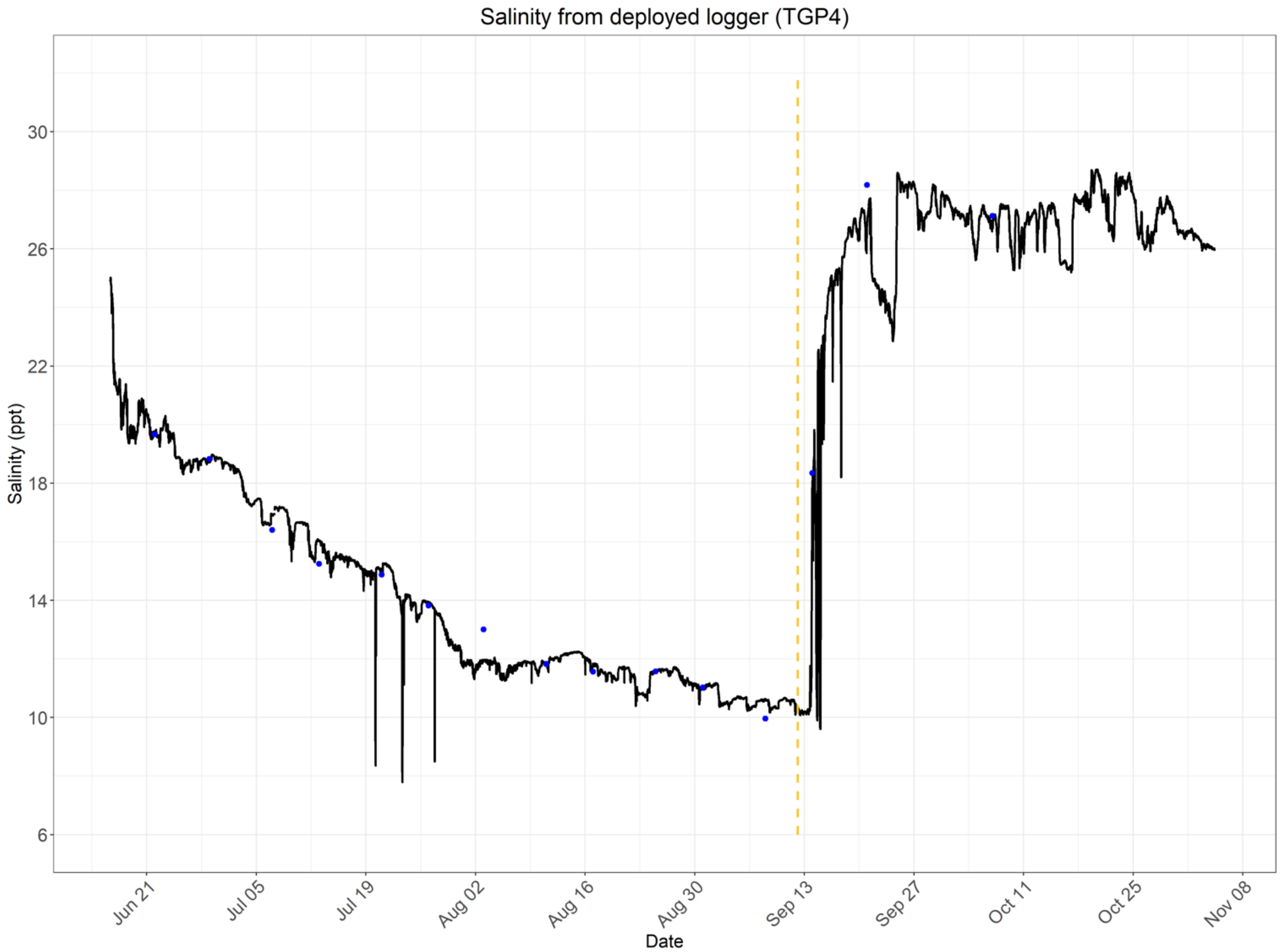

Figure 3. Salinity in parts per thousand (ppt) in 2021. Data were measured with a conductivity/salinity data logger deployed at station TGP4. Blue dots are salinity measured with a handheld probe during site visits. The dashed yellow line is when TGP was cut to the ocean on 9/12/21.

Temperature

- *Water temperature at all 9 sampling stations remained below the 85°F threshold for ecosystem health throughout the summer season.*
- *Maximum water temperature was 83.12°F on 7/21/21.*

Temperature is an important factor within aquatic ecosystems, as it drives biological growth rates and chemical reaction speeds. Much like the temperature of our own bodies, elevated water temperature is often associated with problems affecting ecosystem health. The TGP management goal from the MEP report is to maintain water temperatures of less than 85° F during the summer (Howes et al., 2013). However, unlike other parameters that can be influenced by direct management decisions, there is no way to control temperature. Water temperature typically decreases after the pond has been cut, as ocean water is often cooler than pond water during the summer. However, water temperature in the Pond is primarily driven by ambient air temperature.

Water temperature was measured throughout the water column at all stations across the Pond during each site visit. Additionally, bottom water temperature was continuously monitored with a temperature sensor attached to the conductivity/salinity data logger at station TGP4. Maximum water temperature occurred on July 21, where temperatures reached 83.1°F at station TGP3A (Figure 4), while average mid-depth temperature for the entire pond was 80.96 °F on the same day. Other notably higher temperatures were observed on June 29, August 17, and August 25, with average measurements reaching 80˚F on these dates. All stations were fairly similar in temperature relative to each other and exhibited the same seasonal trend (Figure 4). Stations TGP7 and TGP8 were consistently cooler throughout the sampling period, likely due to their location within the main basin and their proximity to the ocean.

It is noteworthy that observed water temperatures never exceeded the 85°F threshold. This trend was also observed by the continuous data logger deployed at TGP4, which recorded a maximum temperature of 83.3˚F (Figure 5). Coastal ponds such as Tisbury Great Pond often suffer from elevated temperatures in the summer. GPF's active monitoring timeframe falls between 6-11AM and does not include regular afternoon sampling. It is possible that temperatures may have exceeded the threshold at shallower locations, such as the heads of the coves, during the hotter times of day. Additional continuous logger(s) in shallower areas of the pond could help to clarify this possibility. Regardless, the health of TGP likely benefited from fairly consistent water temperatures that remained below 85°F.

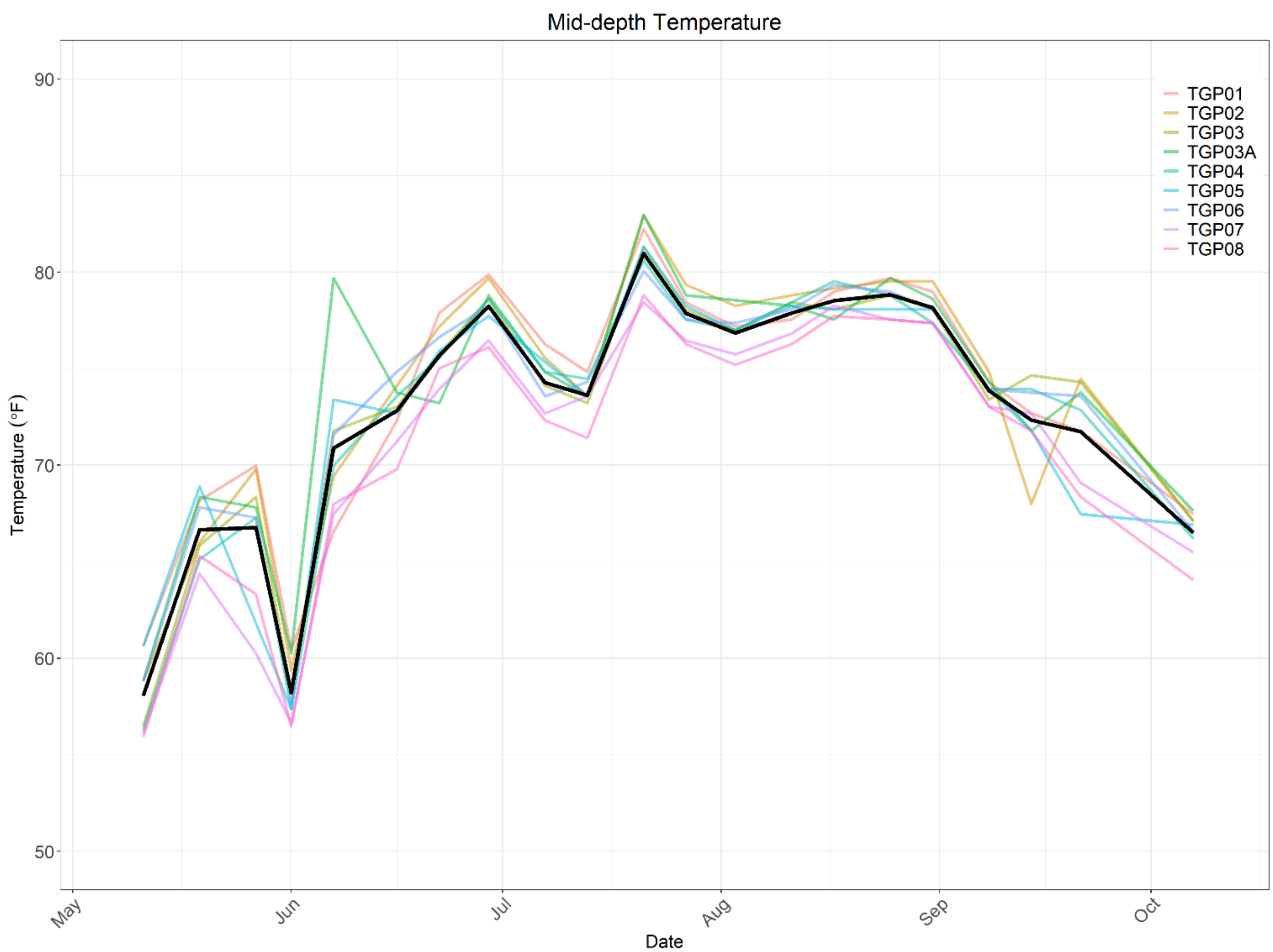

Figure 4. Temperature in Tisbury Great Pond in 2021. Colored lines represent data from the different sampling stations, and the black line is the pond-wide average temperature for each site visit.

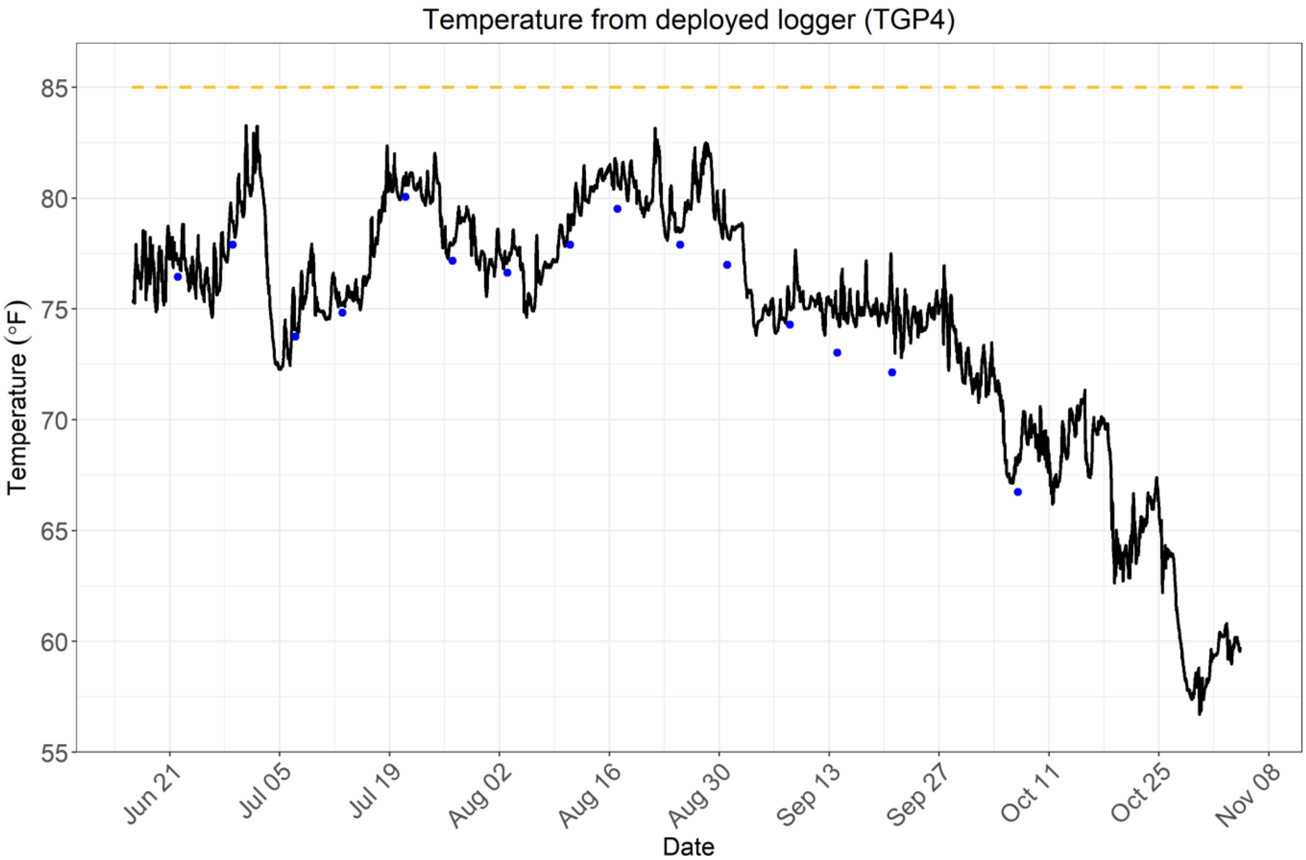

Figure 5. Temperature measured with a continuous data logger deployed at station TGP4. Blue dots are temperature measured with a handheld probe during site visits. The dashed yellow line is the 85°F management threshold.

Dissolved Oxygen

- *Results indicate that the majority of the water column had sufficient oxygen concentrations, however, near-bottom portions consistently exhibited lower dissolved oxygen levels.*
- *The dissolved oxygen data logger detected periods of hypoxia at station TGP4, most often at night, indicating decreased habitat quality in the bottom waters of Town Cove. The large fluctuations in DO that occurred in this area are an indicator of impairment.*

Dissolved oxygen (DO) is the amount of oxygen dissolved in the water, measured in milligrams per liter (mg/L). A battery-operated DO sensor was deployed at station TGP4, which continuously logged the amount of oxygen in the water at 30-minute intervals. Oxygen enters the water through diffusion from the air but is primarily produced by aquatic plants via photosynthesis. Adequate oxygen levels are important as most organisms require oxygen as part of their metabolism.

The MEP DO management target for heathy ponds is 6 mg/L (Howes et al., 2013). When concentrations drop below 4 mg/L, aquatic life begins struggling to breathe. Critically low levels of oxygen (<2 mg/L) are considered hypoxic and can be deadly to most organisms. Normally, the bottom of the water column has lower DO compared to surface waters. This is because oxygen moves from the air into the water at the surface, and most plants, which produce oxygen, are found at or near the surface where there is direct sunlight. Additionally, oxygen is consumed via decomposition of organic matter, which primarily occurs on the bottom and within the sediment. Due to these processes, deeper water often has lower DO concentrations than at the surface. This can be clearly seen when DO from surface, mid-depth, and bottom waters are plotted together on the same graph. A gradient of decreasing oxygen concentration with increasing depth was observed at most monitoring stations, with the exception of the shallower TGP8 site (Figure 6). This gradient was more severe during the summer season, while the pond experienced the hottest temperatures of the year.

There was a slight seasonal trend, where DO was reduced during the hot summer months. Between July and September, all stations experienced DO concentrations below the 6 mg/L threshold (Figure 6). Most often this was limited to measurements taken at bottom depths and only occasionally did mid-depth or surface DO measurements drop below the 6 mg/L threshold. DO fell below the 4 mg/L threshold into the zone of concern, where oxygen deprivation begins to occur, at all stations except TGP7 and TGP8 at least twice throughout the summer. While this indicates that bottom water was low in dissolved oxygen, it is typical for coastal estuaries, especially ecosystems with a history of impairment, to experience periodic oxygen depletion. For most stations, the data suggest the water column had adequate oxygen to support aquatic life.

However, the data generated by the deployed DO logger indicate that Town Cove experienced periods of hypoxia at its bottom depths (Figure 7). Hypoxia is when DO drops below 2 mg/L, potentially causing harm to plants and animals. The DO data logger was deployed at station TGP4 on June 16 and collected measurements every half hour until November 4. This logger was at a fixed depth, approximately 3 inches above the pond sediment. This deployment configuration is designed to capture DO concentrations at their minimum to better describe the

Figure 6. Dissolved oxygen (DO) measured in milligrams per liter (mg/L) in Tisbury Great Pond in 2021. Data were measured with a handheld probe at the surface, mid-depth and bottom water (represented by different colors) at 9 sampling stations. The dashed yellow line is the 6 mg/L management target, and the red dashed line represents when DO was critically low, below 4 mg/L. The red box indicates when hypoxia was occurring (DO < 2 mg/L).

severity of oxygen depletion, if any. Data from this logger indicate that there were large daily fluctuations in DO, especially during the late summer (Figure 7). Additionally, DO regularly fell below 2 mg/L to near anoxic conditions, which occur when there is no oxygen present. During these low oxygen events, the data logger recorded DO measurements close to 0 mg/L. These periods of hypoxia most often occurred at night when plants are not photosynthesizing and producing oxygen.

Data recorded using the handheld water quality meter did not capture the same severity of the oxygen depletion that occurred in Town Cove. DO naturally undergoes daily fluctuations, as the processes of respiration and decomposition consume oxygen, while aquatic plants produce oxygen only during the day. Typically, the lowest DO measurements occur just before sunrise. The GPF Water Quality Monitoring Program was designed to capture this DO minimum by beginning field sampling days just after sunrise. Yet, even with strict protocols, the GPF sampling team often arrived on station after DO levels began to rise. As such, the data from the handheld sensors did not capture the true DO minimum. This inconsistency illustrates why deployed sensors are useful as a supplement to boat-based sampling efforts. Only one DO logger was deployed in TGP throughout the 2021 monitoring period, and therefore, comparative measurements from other locations within the pond are unavailable. It is reasonable to assume that other tributary coves in TGP experienced low DO concentrations at night, but this hypothesis cannot be confirmed without the deployment of additional sensors.

These results indicate that the majority of the water column retained sufficient oxygen concentrations, while the near-bottom portions were consistently depleted at night. Low DO readings from the continuous data logger are concerning, as this suggests that the bottom of Town Cove suffers from short periods of hypoxia (DO < 2 mg/L). It is common for eutrophic ponds to have anoxic sediment, meaning there is no oxygen present. This is due to large amounts of organic matter decomposing on the bottom of the pond, a process which consumes oxygen. The logger mounts and housing are designed to prevent the instrument from sinking into this sediment layer. Therefore, these low DO readings are representative of the near-bottom portion of the water column and indicate the presence of a hypoxic zone above the sediment layer. Regular oxygen depletions are indicators of impairment and suggest that this is an environment inhospitable to most aquatic life.

Additionally, the continuous DO logger recorded large daily fluctuations in DO at the beginning and end of the summer (Figure 7). DO concentrations within a healthy ecosystem fluctuate on a daily basis, yet still retain adequate levels to buffer against extreme variations which may occur during nighttime hours. The large fluctuations that occurred at TGP4 are an indicator of impairment. Overall, these data indicate that TGP, and especially Town Cove, is a struggling ecosystem. Habitat quality was negatively impacted by oxygen depletions, especially on the bottom of the pond. Organisms that cannot move to areas of higher oxygen, such as shellfish, may have struggled to survive. However, hypoxia was temporary at TGP4, and handheld probe data indicated that oxygen levels recovered to levels which can support aquatic life during the day.

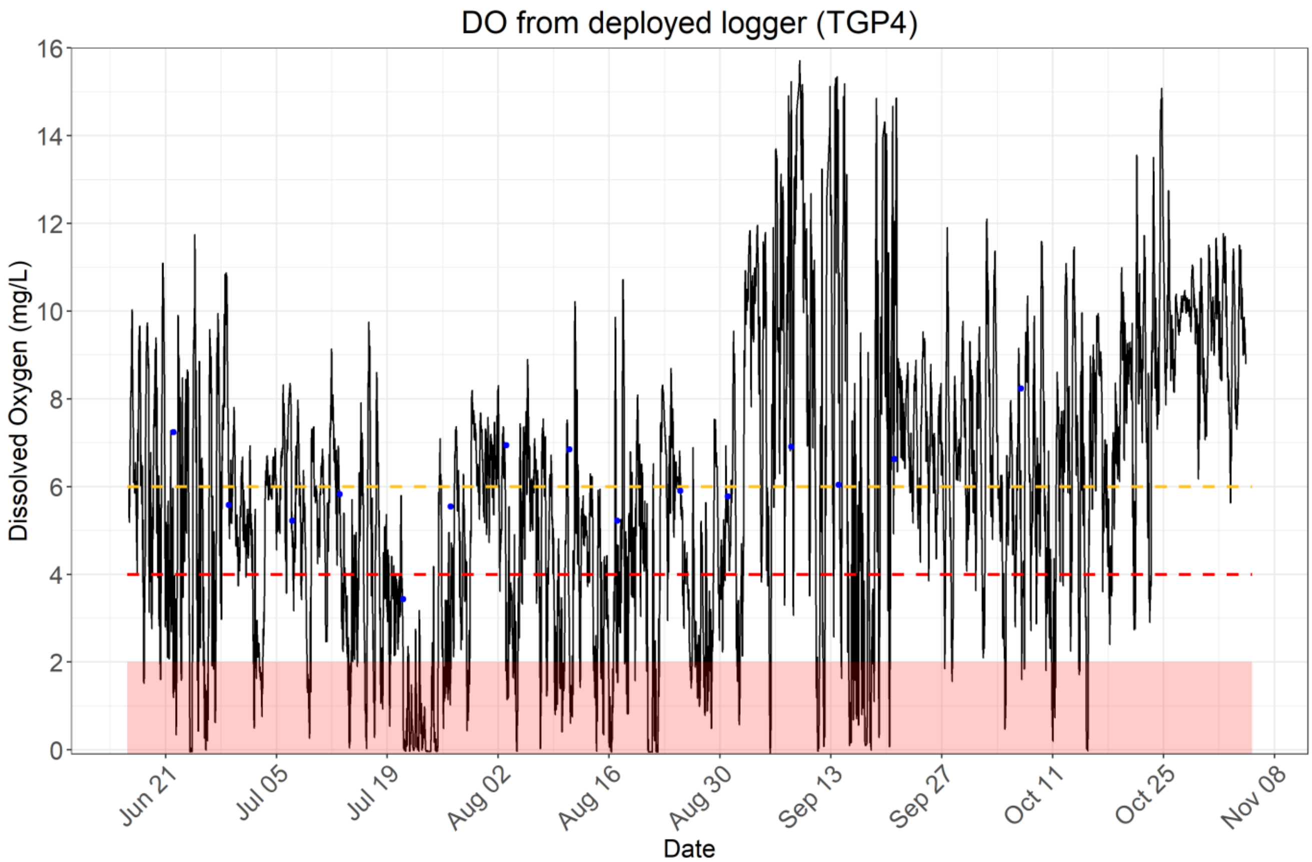

Figure 7. Dissolved oxygen (DO) at station TGP4 in 2021. Data were measured with a data logger deployed approximately 3 inches from the pond bottom. The dashed yellow line is the 6 mg/L management target, and the red dashed line represents when DO was critically low, below 4 mg/L. The red box indicates when hypoxia was occurring (DO < 2 mg/L). Blue dots are DO measured by a handheld probe during site visits. The black line represents a 2-hour moving average of the DO measurements, which were logged every 30 minutes.

Water Clarity

- *Typical visibility was at least 4 feet; however, the water was frequently too murky to see the pond bottom.*
- *All stations except TGP8 experienced elevated turbidity and reduced water clarity. Murky, high turbidity water is generally indicative of impaired water quality.*

Turbidity is a measure of how many particles are dissolved in the water, which affects how much light is transmitted through the water column. Water with low turbidity is clear, with visibility often extending to the bottom, while water with high turbidity appears murky. High turbidity is detrimental to submerged aquatic vegetation, as less sunlight can penetrate the water. Vegetation requires sunlight to photosynthesize, which in turn, provides oxygen to other organisms living in the water. The particles that cause high turbidity can be either living or nonliving. Living particles include microscopic plants called phytoplankton, along with other microscopic organisms which have the ability to reproduce quickly, making the water appear green or brown in color. Elevated concentrations of nutrients and increased temperatures can stimulate growth of these microscopic species. Nonliving particles are usually comprised of sediment that was either resuspended from the bottom of the pond or entered the water from adjacent lands via runoff. Because of this, murky or turbid water is common after rain events.

Turbidity is often used as a benchmark for water quality analyses as it is simple to measure and interpret. Murky water is generally indicative of impaired water quality. One method of measuring turbidity is with a Secchi disk. A Secchi disk is a standardized black and white disk attached to a measuring tape that is lowered through the water column. The depth at which it disappears from view corresponds to the depth at which turbidity is too high for light to penetrate to deeper depths. Thus, light cannot easily reach benthic plants and animals when turbidity is elevated. The MEP management goal for Secchi depth is 3 meters (9.8 feet) or the bottom of the body of water (Howes et al., 2013). Most of TGP is approximately 3 meters deep or less, making adequate Secchi depth the bottom of the pond, or "total depth", at the sampling site.

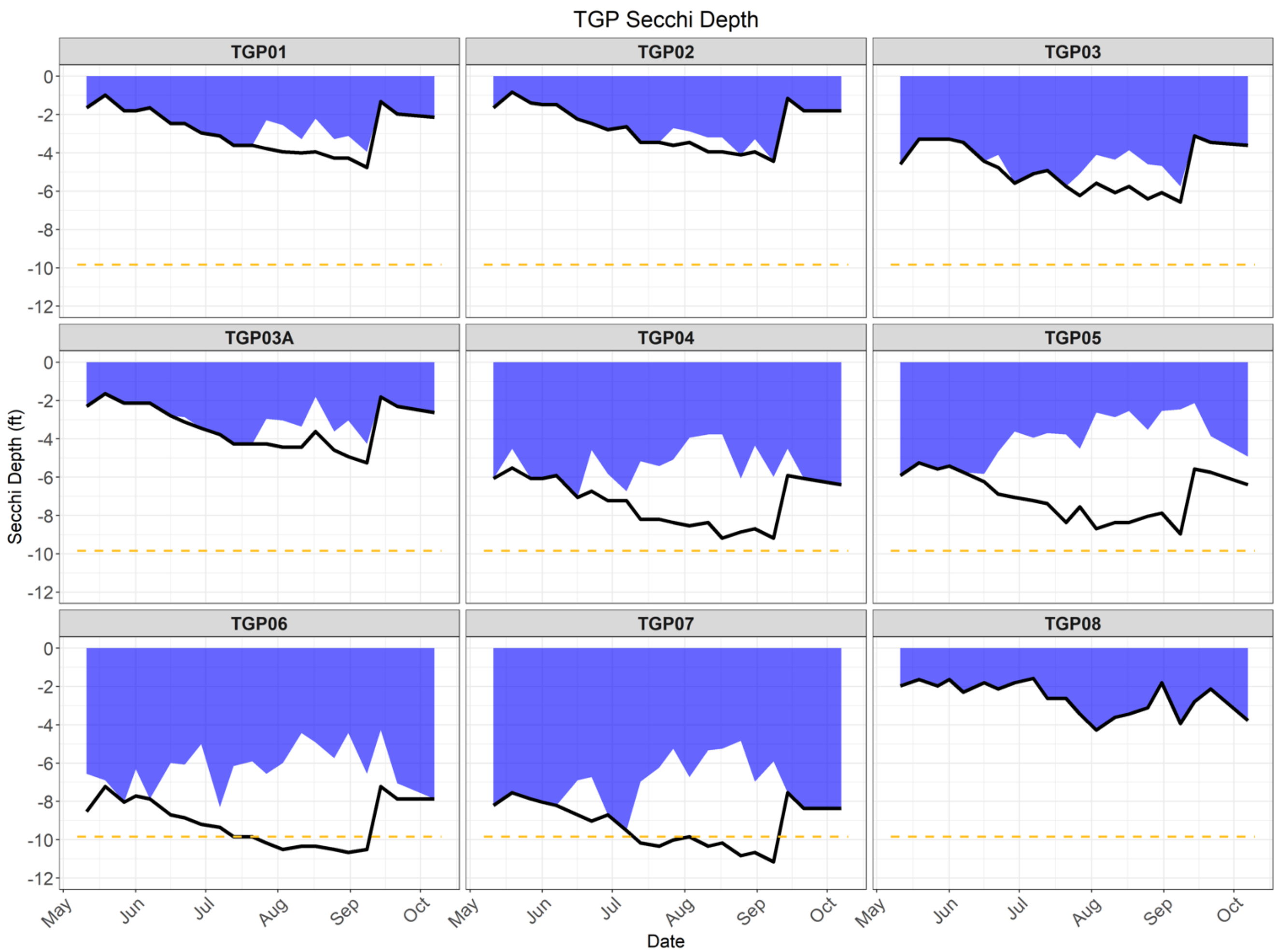

Figure 8. Secchi depth and total depth in feet at each sampling station in Tisbury Great Pond in 2021. Secchi depth is the depth at which a standardized disk disappears, which often corresponds to total depth. Total depth in the figure is the thick black line, and Secchi depth is the blue shaded area above the black line. The management target for Secchi depth to equal total depth, or be at least 9.8 feet, shown by the yellow dashed line.

Water clarity in TGP varied depending on the location within the pond. Visibility was typically at least 4 feet, as measured by a Secchi disk (Figure 8). However, the water was frequently too murky for the Secchi disk to be seen on the pond bottom at most stations. Moreover, all stations except TGP8 had Secchi depths less than the management goal of 9.8 feet. Station TGP8 was exceptionally shallow, and the bottom of the pond was consistently visible. Stations TGP4, TGP5, TGP6 and TGP7 were most reduced in water clarity, with Secchi depths occasionally measuring half of the total depth. These stations had the greatest depth profiles and experienced elevated turbidity and reduced water clarity throughout the entire summer, while other stations exhibited reduced water clarity mostly during August. This can likely be attributed to higher average temperatures during the summer that fuel algal growth coupled with increased nutrient inputs from surrounding properties via surface water runoff (e.g. from fertilizer application).

Nutrient Concentrations

- *Total nitrogen values in TGP were below the management targets for the majority of the monitoring period, peaking in July and August for most stations. Mean TN values were below the recommended limits established by the MEP report.*
- *TN measurements at station TGP7 were consistently lower than at other stations, as TGP7 is located in the main basin of the pond which has improved circulation compared to the coves.*
- *Chlorophyll-a was above the 10 µg/L threshold at least twice at all TGP sampling stations except TGP7. Chlorophyll-a peaked during the summer months.*

GPF collected samples to measure the concentrations of phosphate, nitrate, ammonium, as well as chlorophyll pigments in Tisbury Great Pond. Abundant concentrations of nutrients in coastal waters can lead to eutrophic conditions and an overall deterioration in water quality. Nutrient pollution in marine and brackish ecosystems is often the result of excessive nutrient loading from adjacent land areas, which stems from human development. Measuring the concentration of nutrients in the water can indicate if eutrophication is occurring. Brackish coastal ecosystems often exhibit an excess of inorganic nitrogen, such as nitrate and ammonium, as well as excess organic nitrogen. Nutrient analyses were performed at the Marine Biological Laboratory in Woods Hole. Nutrient sample collection was limited to once per month due to the high cost of analysis and labor involved. Further, nutrient samples were limited to stations TGP1, TGP4, TGP5, TGP6 and TGP7.

Overall, nutrient concentrations in TGP were only slightly elevated, particularly with regards to nitrogen concentrations. Total nitrogen (TN) measures both inorganic and organic forms of nitrogen and is the metric typically used to assess whether eutrophication is occurring in coastal ecosystems. In saltwater estuaries, the management target for TN is commonly 0.5 milligrams per liter (mg/L) or lower. The 2013 MEP study for TGP determined two separate thresholds for habitat impairment, one for the main basin of the pond (TGP7) and one for the tributary coves (TGP4, TGP5, TGP6). Stations TGP4, TGP5 and TGP6 represent the "sentinel station" for TGP. The MEP report states that the average TN concentration should remain below 0.48 mg/L at the sentinel station (average of stations TGP4, TGP5, and TGP6), and below 0.46 mg/L at station TGP7, across a 100-day period from the end of May to mid-September (Howes et al., 2013). According to the MEP report, TGP7 retains a different threshold due to evidence that the main basin of TGP can support eelgrass (*Zostera marina*) habitat, which is more sensitive to nitrogen inputs.

TN values in TGP varied throughout the monitoring period but were mostly below the threshold values. Each station within the coves exhibited one measurement above the 0.48 mg/L TN threshold (Figure 9). TN values at TGP7 were below the 0.46 mg/L threshold for all samples collected. For all stations except TGP1, TN values peaked in July and August. The maximum TN concentration recorded was 0.65 mg/L at TGP1 on October 7. This measurement was an anomaly, as all other stations experienced a decrease in TN levels during the October sample collection. This elevated reading is likely a result of a removal operation of an aquatic invasive species along the banks just north of station TGP1 on October 6, one day prior to the sampling date. To adequately remove the deeply rooted vegetation, specialized equipment was needed to dig into the sediment. This removal process re-suspended sediment particles in the vicinity, increasing turbidity for several days. This is confirmed from the October 7 nutrient analyses, which measured higher particulate nitrogen than previous sample dates at TGP1 (Figure A1 in Appendix). Furthermore, unassociated supplementary TN samples gathered on October 6 from the Mill Brook, approximately 0.5 miles north of station TGP1, as part of a Town monitoring project (Mill Brook

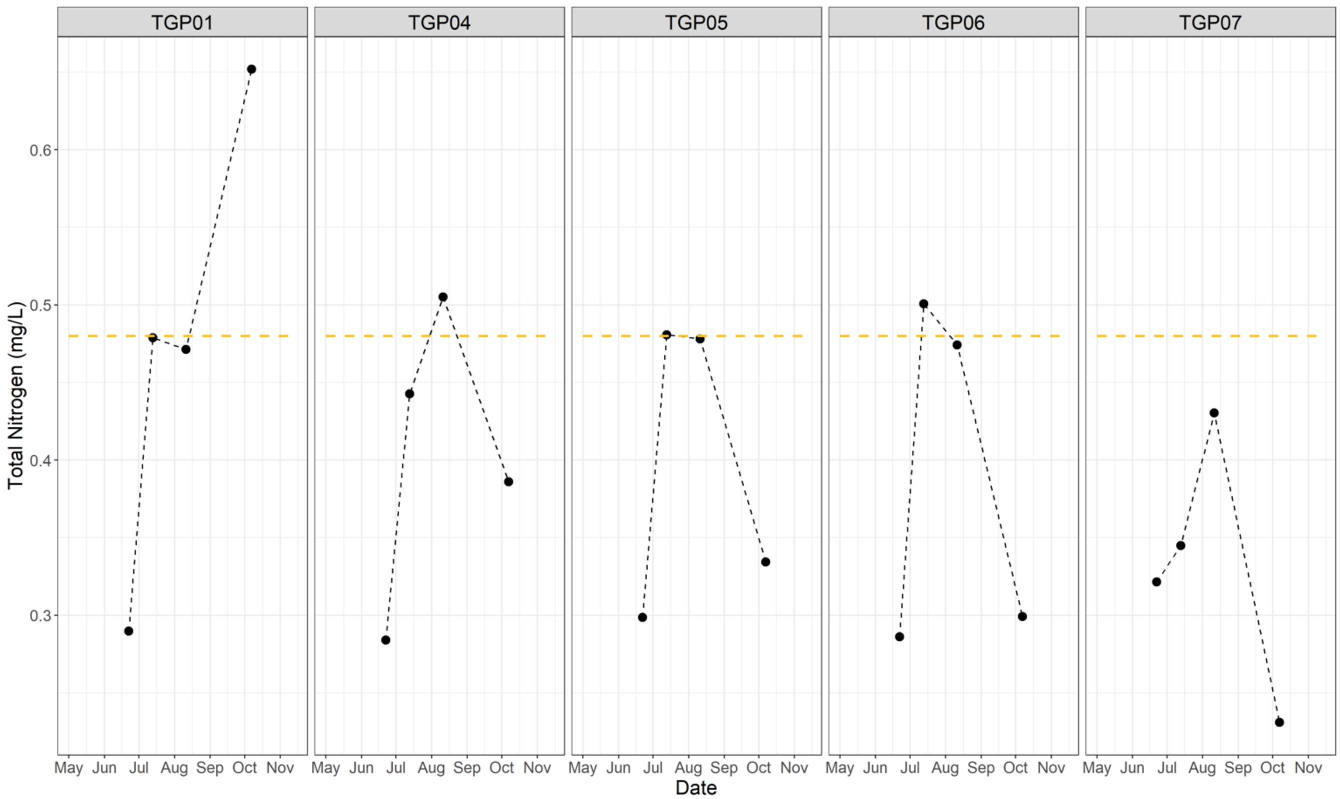

Figure 9. Total nitrogen in milligrams per liter (mg/L) in 2021. Data are from 5 TGP sampling stations (different panels). The dashed yellow line represents the 0.48 mg/L TN management target for the sentinel station (mean of TGP4, TGP5, & TGP6) established by the MEP report. The TGP7 management threshold (TN=0.46) is not shown in the figure, but measurements were below this limit for the duration of the monitoring period.

Watershed Management Committee), had a TN concentration of 0.28 mg/L. This suggests that water flow exiting the mouth of the Mill Brook was not responsible for this elevated TN measurement at TGP1.

Outside of TGP1, maximum TN measurements were 0.5 mg/L at TGP4 and TGP6. TN measurements at station TGP7 were consistently lower compared to other stations. This is likely due to the location of TGP7 within the main basin of the pond, which experiences improved water circulation. Additionally, the main basin of the pond is more thoroughly flushed during pond cuts compared to the coves. Furthermore, ocean water likely percolates through the sand along the barrier beach to the immediate south, even when the pond is closed.

At stations within Town Cove and Tiah's Cove, particulate nitrogen and dissolved nitrogen each contributed roughly the same amount to TN concentrations, whereas dissolved nitrogen was the primary nitrogen source at TGP6 (Deep Bottom Cove) and TGP7 (main basin) (Figure A1 in Appendix). At all stations, organic nitrogen was higher than inorganic nitrogen (Figure A2 in Appendix). Organic nitrogen is nitrogen that is already incorporated into the living tissues of plants and animals, whereas inorganic nitrogen is the form that is available to plants and animals for consumption as part of their metabolism. Inorganic nitrogen is comprised of nitrate, nitrite, and ammonium, which can be measured as dissolved or particulate inorganic nitrogen. Other inorganic nutrients include phosphate and silicate. Excess inorganic nutrients can fuel plant growth and lead to eutrophication. Increased growth caused by elevated inorganic nutrients can lead to high organic nitrogen as the nutrients are utilized by plants and animals.

Phosphate measurements exhibited a different trend than TN. Phosphate measurements at all stations were mostly lower in the summer and sharply increased during the October sample collection (Figure 10). This is likely because TGP is an ecosystem driven by nitrogen, which fuels plant and algal growth. This growth also requires phosphate, which is consumed during the summer when growth rates are highest. In the fall, plant growth subsides and the demand for phosphate declines, leading to more dissolved phosphate in the water. Most coastal estuaries are impacted by elevated nitrogen concentrations rather than phosphorus, and the 2013 MEP report did not include a management target for phosphate concentrations. The US Environmental Protection Agency (EPA) has published ambient water quality criteria recommendations to avoid eutrophication in freshwater ponds. The criteria for Massachusetts indicate that total phosphorus should remain below 0.02 mg/L. This is an imperfect comparison, since TGP is a brackish coastal pond, and phosphate concentrations were measured instead of total phosphorus. Regardless, phosphate measurements often exceeded this freshwater total phosphorus limit, especially from the October samples (Figure 10).

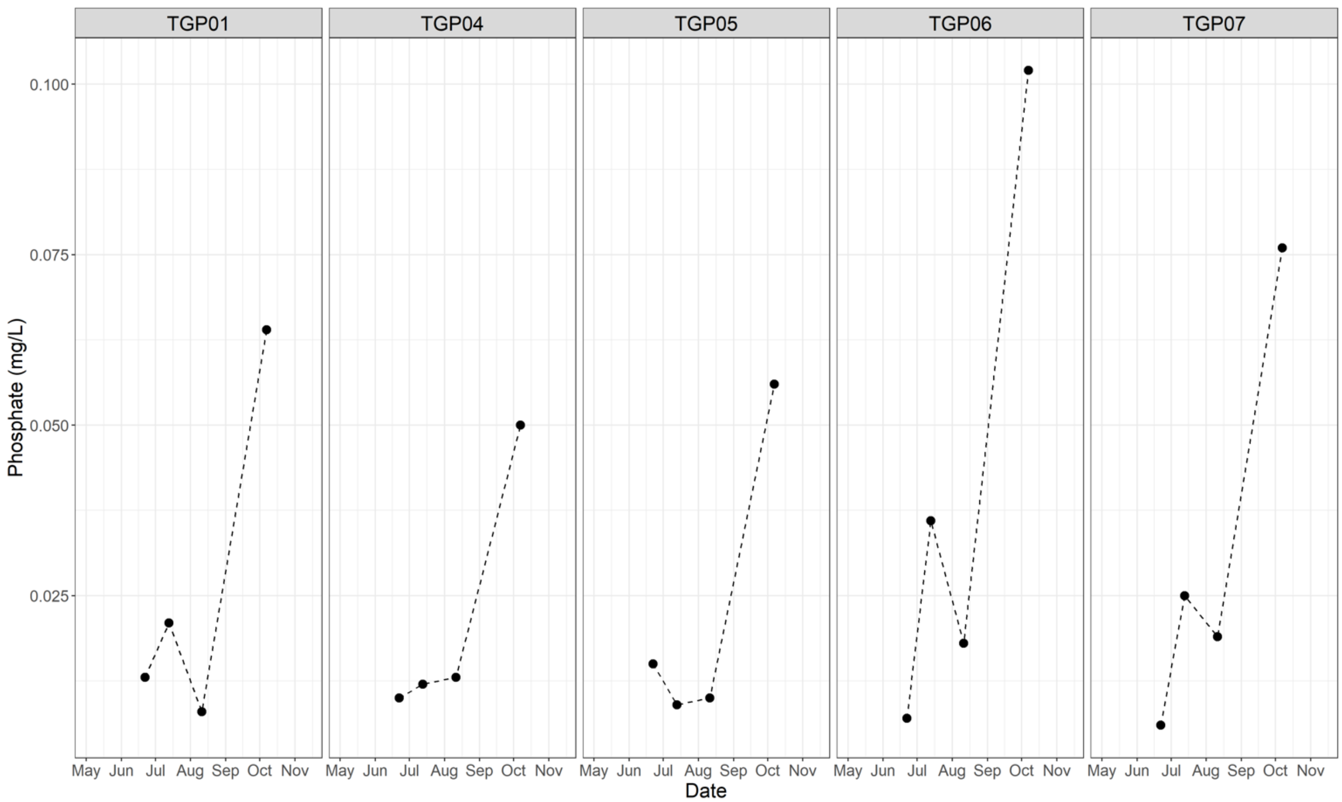

Figure 10. Phosphate concentrations in milligrams per liter (mg/L) in Tisbury Great Pond in 2021. Data are from 5 TGP sampling stations (different panels).

Overall, average nitrogen values in TGP were below threshold values for habitat impairment. While each station other than TGP7 had one measurement that exceeded the TN management target, the 2013 MEP report indicates that the mean concentration across the summer months (May-September) should be used. Mean TN across June-August sample dates at the sentinel station (TGP4, TGP5, TGP6) was 0.417 mg/L, while mean TN of all sample dates (including October) was 0.397 mg/L (Table 2). This is below the 0.48 mg/L TN limit. Further, the summer mean TN at TGP7 was 0.366 mg/L, below the 0.46 limit. Nutrient samples were also collected at TGP1, which is not included in the MEP sentinel station, but was included to help gauge nutrient inputs from the Mill Brook. Mean TN of all stations in 2021 was 0.399 mg/L. While TN values were below the threshold values, other water quality parameters indicate the pond was impaired. TGP was open to the ocean for 185 days in 2021, which may have reduced the concentration of nutrients in the water.

2021 was the first year that TGP was included in the GPF Ecosystem Monitoring Program, so comparisons to previous years cannot be made. However, the Martha's Vineyard Commission (MVC) has been collecting water quality data on TGP for decades. An analysis of these long-term data will be performed in a supplementary report, the results of which will be made available upon completion. The 2020 State of the Pond report from the MVC indicates that despite some variability, average TN values in the past 4 years have regularly been higher than the 0.48 TN limit. The nutrient sample analysis methodologies for GPF and MVC are very similar, and the data produced are comparable. At the time of publication of this report, MVC data from 2021 were not yet publicly available.

Date	Mean TN of sentinel station (limit=0.48) (mg/L)	TN of TGP7 (limit=0.46) (mg/L)	Mean TN of all stations (mg/L)
6/22/2021	0.290	0.322	0.296
7/13/2021	0.475	0.345	0.450
8/11/2021	0.486	0.430	0.472
10/7/2021	0.340	0.231	0.380
Summer mean	**0.417**	**0.366**	**0.406**
2021 mean	**0.397**	**0.332**	**0.399**

Table 2. Mean Total Nitrogen (TN) values from Tisbury Great Pond in 2021. Mean values were calculated for the sentinel station (TGP4, TGP5, & TGP6), only station TGP7, and all stations at which nutrient data were collected (includes TGP1). The MEP report determined different threshold TN values for the sentinel station (limit=0.48 mg/L) and for TGP7 (limit=0.46 mg/L).

In addition to nutrient levels, the amount of chlorophyll pigment in the water is an indicator of water quality. Chlorophyll is a pigment used by plants during photosynthesis. Measuring the amount of chlorophyll in the water, specifically the pigment chlorophyll-a, provides an estimate of microscopic plant abundance in the water. Microscopic aquatic plants, called phytoplankton, require nutrients to grow. High levels of chlorophyll can indicate that nutrients such as nitrate and phosphate are in excess and readily available for primary production. Elevated concentrations of nutrients can spur rapid phytoplankton growth, called a phytoplankton bloom. Chlorophyll pigments were measured in two ways: laboratory analysis at the Marine Biological Laboratory in Woods Hole and via fluorometry at the GPF lab. While both are accurate, for simplicity this report focuses on the results from the Woods Hole laboratory. Another plant pigment called phaeophytin was also measured, which is produced as chlorophyll degrades at the end of a phytoplankton bloom. Measurements of total pigment, the sum of phaeophytin and chlorophyll-a, are available from GPF upon request.

For most TGP sampling stations, chlorophyll was elevated during the summer (Figure 11). The MEP uses a management target of 10 micrograms per liter (µg/L) of chlorophyll-a for coastal ponds, and measurements in excess of 10 µg/L are an indicator of impairment (Howes et al., 2013). Chlorophyll-a was above this 10 µg/L threshold at least twice at all TGP stations except TGP7 (Figure 11). Chlorophyll-a concentrations were lowest in June and October and peaked during July and August. This was expected due to hotter temperatures in the summer and increased nutrient inputs from surrounding properties. The maximum observed chlorophyll-a concentration was 25.71 µg/L at station TGP1 on August 11. Stations TGP6 and TGP7 experienced a smaller summer peak in chlorophyll-a measurements, while TGP6 consistently had the lowest chlorophyll measurements and was below the 10 µg/L threshold for all sampling dates (Figure 11). While other TGP stations were occasionally below this target, the peak in the summer indicates that TGP experienced widespread phytoplankton blooms, especially in Town Cove and Tiah's Cove. The lower measurements from Deep Bottom Cove (TGP6) do not preclude the occurrence of a phytoplankton bloom in 2021, as one may have occurred between sample collections. Samples for fluorometric chlorophyll analyses were taken more frequently and at all 9 sampling stations. These measurements were consistently above the 10 µg/L chlorophyll threshold during the summer months for all stations except TGP8.

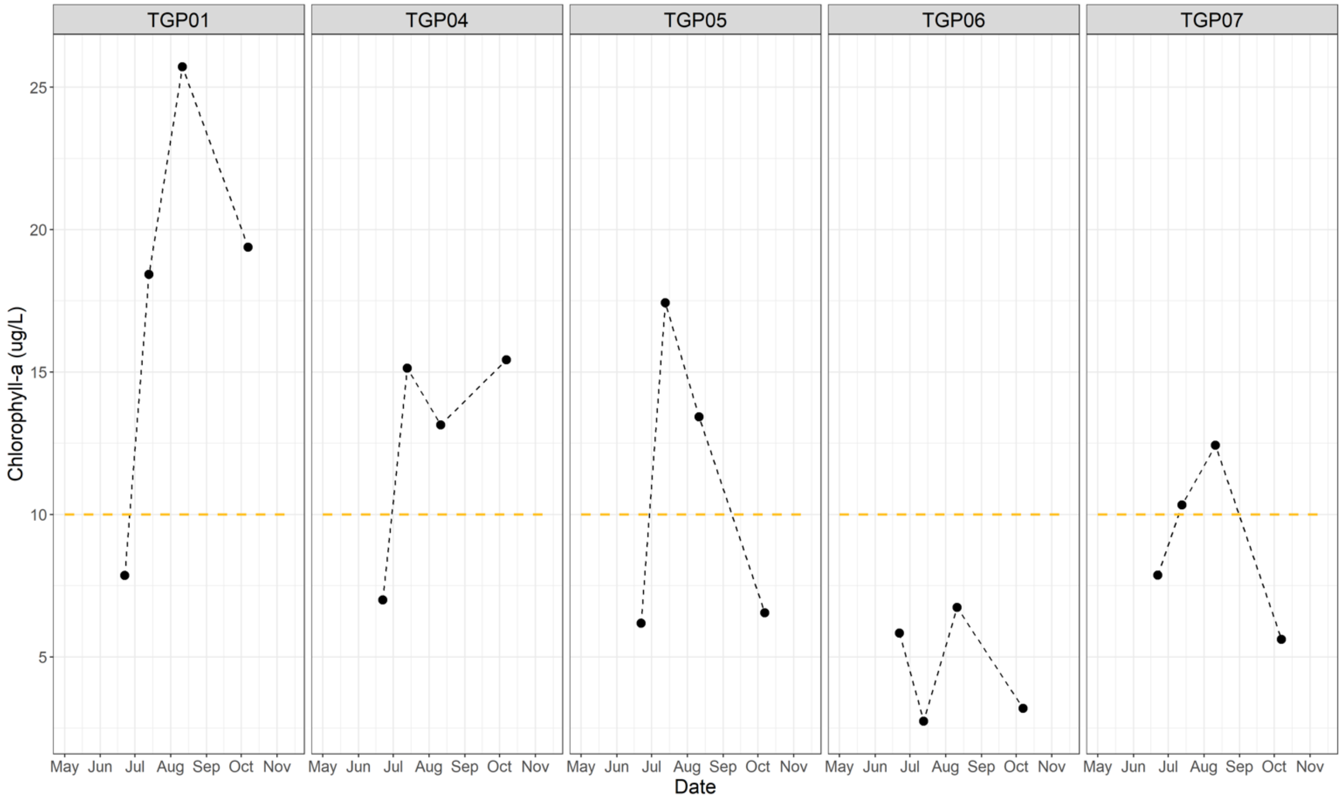

Figure 11. Chlorophyll-a pigments in micrograms per liter (µg/L) in 2021. Data are from 5 TGP sampling stations. The dashed yellow line represents the 10 µg/L management target for healthy coastal ponds.

MV CYANO

- *All TGP sampling stations were in the "green" risk category for the majority of the monitoring season, indicating very few to no cyanobacteria were detected.*
- *TGP was at a decreased risk of cyanobacteria blooms compared to other ponds monitored by MV CYANO in 2021.*

Tisbury Great Pond was included in the first year of the Martha's Vineyard Cyanobacteria Monitoring Program (MV CYANO). MV CYANO is a partnership between GPF and the Boards of Health of Chilmark, West Tisbury, and Edgartown. Cyanobacteria, a.k.a. blue-green algae, are a group of microorganisms naturally occurring in all Vineyard waters. When cyanobacteria grow rapidly or bloom, they can produce cyanotoxins, which when concentrated may cause adverse health effects in humans, pets, or livestock who wade in or ingest blooming waters. This pilot program successfully developed a workflow for regular sample collection, analysis, and subsequent presentation of spatial and numeric data to the Boards of Health to aid in their decision-making process regarding postings and closures. This workflow included a color-coded matrix, where different data-driven risk thresholds were represented by associated colors and categories, each with a corresponding sign to be posted at pond access points (Figure A3 in Appendix).

This program utilizes a sensor called a fluorometer to detect and quantify the abundance of cyanobacteria in water samples. While the species of cyanobacteria cannot be identified without a microscope, samples analyzed with a fluorometer can estimate the concentration of cyanobacteria in an ecosystem, which is needed to detect when a bloom occurs. Each color in the MV CYANO color-coded matrix corresponds to different concentrations of cyanobacteria and therefore represent increasing likelihood of bloom occurrence.

For a majority of the monitoring period, TGP water samples were in the "green" category, corresponding to a low level of risk (Figure 12). Some stations were designated into the "yellow", or "ALERT" risk level at least once, most notably at TGP5 (Tiah's Cove). This classification indicates that environmental conditions could support rapid growth of cyanobacteria and that a bloom is possible but not present. No samples exceeded the yellow category. Even the stations in Town Cove, which have lower salinities which favor cyanobacteria growth, remained in the green, low risk category for a majority of the monitoring period. Cyanobacteria abundance in TGP samples was highest on August 31, peaking at 5.08 µg/L at station TGP5. For comparison, nearby Chilmark Pond had a maximum cyanobacteria concentration of 11.0 µg/L, which was classified in the orange category, or "BLOOM WATCH" risk level. Samples in the orange category have slightly elevated cyanobacteria levels and the likelihood of a bloom is increased. TGP samples consistently measured among the lowest cyanobacteria biomass amongst the ecosystems monitored for MV CYANO, suggesting that the overall risk for a cyanobacteria bloom in 2021 in the pond was low.

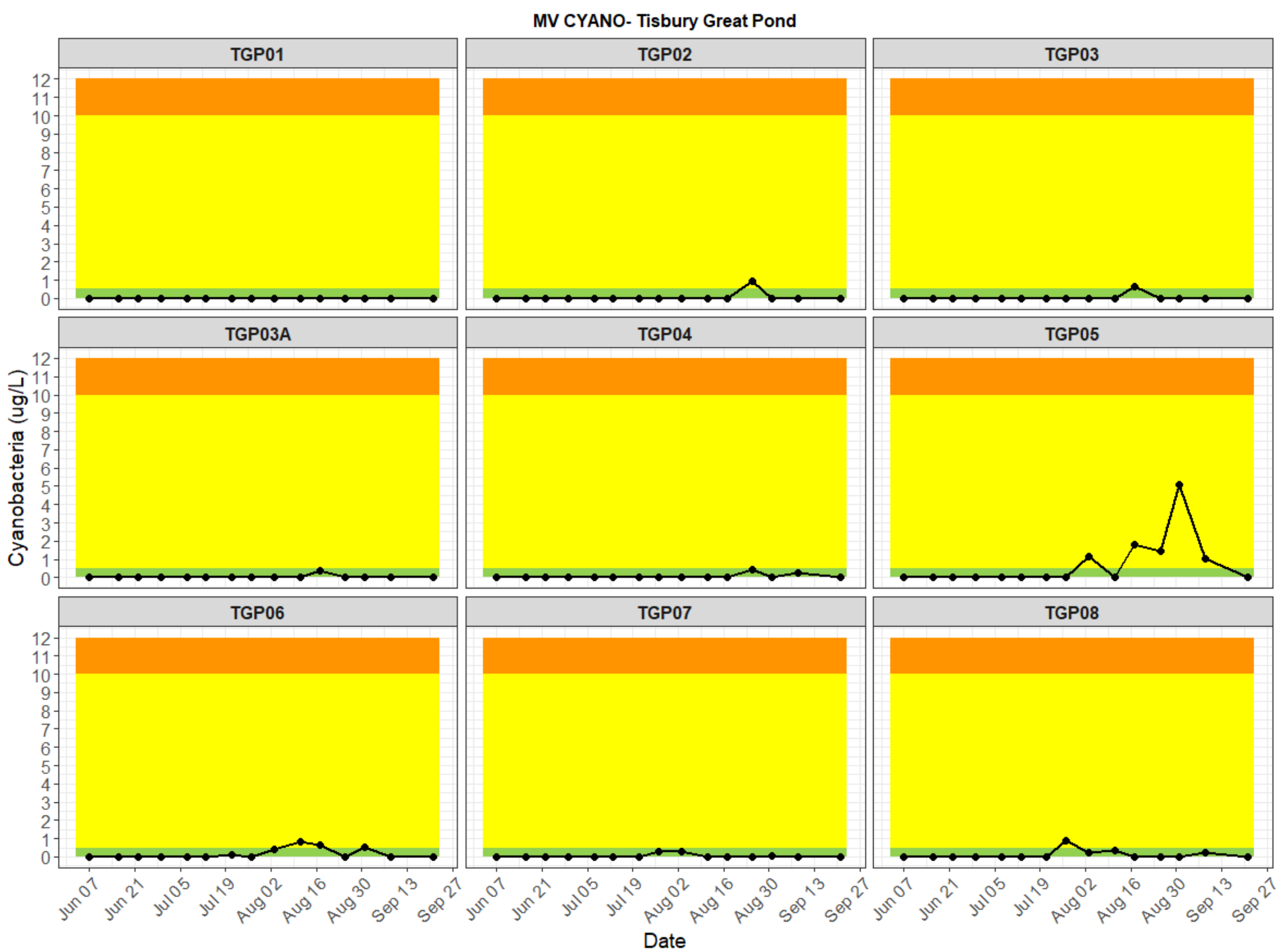

Figure 12. Cyanobacteria concentrations in micrograms per liter (µg/L) at all TGP stations in 2021. Samples were taken from surface waters and measurements were obtained via a fluorometer. Background colors correspond to the color-coded risk matrix used by the MV CYNAO monitoring program (see Figure A3 in Appendix).

Conclusions

Overall, Tisbury Great Pond is suffering from multiple water quality issues, including low dissolved oxygen and elevated chlorophyll within the water column. Measurements of water clarity occasionally fell below recommended limits during the course of this monitoring program. These combined factors ultimately decrease habitat quality, limiting biodiversity and reducing overall ecosystem health.

Previous studies by the MVC and the Massachusetts Estuaries Project have found that eutrophication, or excess nutrient concentrations, is occurring in TGP. The primary source of impairment in TGP is due to nitrogen loading from wastewater and agriculture. While nutrient concentrations from the GPF Ecosystem Monitoring Program were not above threshold nitrogen limits, other water quality indicators such as dissolved oxygen, chlorophyll, and turbidity all suggest water quality in TGP was impaired in 2021. Excess nitrogen fueled microscopic and macroscopic plant growth, leading to elevated chlorophyll concentrations. As these plants died and decayed, dissolved oxygen was reduced. Dissolved oxygen in TGP was particularly concerning, as critically low levels of oxygen were detected in the bottom waters of Town Cove. A reduction in local nitrogen inputs would help reduce these impairments. These excess nutrients are primarily introduced to the environment as a result of human development, such as septic systems, fertilizers, and agriculture, and enter the pond via surface water runoff and groundwater.

Continued monitoring is recommended to further document the impact of eutrophication on water quality. This can be accomplished via a combination of site visits with handheld sampling equipment and deployed data loggers. Additionally, continued monitoring of nutrient concentrations throughout the pond is recommended. Assessment of nutrient concentrations within the groundwater north of the pond will help to identify nitrogen hotspots within the watershed. Comparative analysis of data from ongoing, complementary studies in the Mill Brook and Tiasquam River tributary stream systems by the Town of West Tisbury will help to elucidate their downstream impacts on TGP water quality. TGP has been the subject of numerous studies in the past, and there are many possibilities for future research on this ecosystem such as analysis of the recharge rate and water budget, investigations into the biodiversity and community structure of the phytoplankton community, and long-term trend analysis using historical data.

Regardless of the water quality challenges that exist within TGP, it remains a priceless ecosystem admired not only for its important ecological functions, but also for its many recreational and aesthetic qualities. The TGP habitat is used by a multitude of bird, shellfish, and finfish species, as well as populations of native fauna such as coastal river otters. If nitrogen pollution is not eventually addressed, water and habitat quality will likely continue to degrade, and further deterioration of the pond should be avoided. Additionally, taking steps to address water quality will help protect the pond and its surrounding habitats and human communities from the threats posed by climate change. The pond is a beloved ecosystem with deep-rooted ties to the history and character of the surrounding community. Many of the solutions to these issues already exist, and the Pond continues to benefit from a dedicated and engaged community of stakeholders.

Acknowledgments

The Ecosystem Monitoring Program on Tisbury Great Pond and the release of this report would not be possible without the support of many people who kindly offered their assistance and expertise. The majority of the field data were collected by David Bouck, GPF Watershed Outreach Manager, who also contributed greatly by providing valuable feedback on an earlier draft of this report. David and Lynn Bouck generously provided a boat for use on TGP and performed the necessary maintenance, with engine repairs done by Marty Harris. Boats were also borrowed from Chris McIsaac and Ollie Becker. Interns Maggie Sandusky, Kendall Rudolph, and Becca Eyrick were vital members of the field team. Johnny Hoy, West Tisbury Herring Warden, provided data on 2021 TGP opening and closure dates. The Great Pond Foundation expresses gratitude to everyone who contributed.

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https://www.mass.gov/doc/tisbury-great-pondblack-point-pond-system-dennis-ma-2013/download

Appendix

Glossary of Water Quality Parameters

Ammonium (NH_4^+): Ammonium is a nutrient plants need to survive, however it is also a waste product from animal metabolism. Ammonium is converted to ammonia (NH_3), which in high concentrations acts as a toxin.

Biodiversity: the variety of life found in a particular place. An ecosystem with a large diversity of species is more resilient than one with fewer species.

Chlorophyll: Chlorophyll is a pigment plants use for photosynthesis, measured in micrograms per liter (µg/L). Monitoring chlorophyll concentrations can tell you if excessive plant growth is occurring, such as an algal bloom. The management goal for chlorophyll is **3-10 µg/L**.

Dissolved Oxygen (DO): the amount of oxygen dissolved in the water, measured in milligrams per liter (mg/L). Organisms require adequate oxygen concentrations for their metabolism and will become stressed if DO becomes depleted. The management goal for a healthy pond is **6 mg/L**. DO levels below 4 mg/L are when organisms begin to suffer from lack of oxygen, and when DO drops below 2 mg/L the water becomes hypoxic, where oxygen deficiencies can be fatal. The amount of oxygen that can physically dissolve in water is dependent on temperature, salinity and pressure.

Ecosystem: A community of living organisms and their connection to the nonliving physical and chemical components of their habitat. Species are often connected via food webs and depend on factors such as weather and the water cycle, all of which are components of an ecosystem.

Eutrophication: When nutrients such as nitrogen or phosphorus are in excess in an ecosystem, which causes many downstream problems such as algal blooms and low levels of dissolved oxygen. Eutrophication is often caused by nutrient pollution from human sources such as wastewater, farming waste, and fertilizer runoff.

Nitrate (NO_3): The most common form of inorganic nitrogen in coastal waters. Nitrate is naturally occurring, but excess nitrate comes from sources such as septic systems, wastewater treatment plants, runoff from livestock in farms, and runoff from fertilizer in both agriculture and household landscaping.

Nutrient Concentrations: Dissolved concentrations of nitrate, phosphate, silica, and ammonium, measured in milligram/liter (mg/L). Living organisms need these nutrients to survive, however they are often elevated in coastal waters. Elevated nutrient levels usually come from fertilizer and septic systems, and lead to excessive plant growth and deteriorated water quality, a process called eutrophication. In TGP, nitrate and ammonium have been elevated in the past and are monitored closely, with a management goal of keeping total nitrogen (TN) to **0.48 mg/L** of nitrogen or less.

pH: a measurement of how acidic or basic a solution is. Neutral pH is 7. pH of coastal waters often range from **6.5-8.5**, which is the management goal. pH will often become acidic if there is excessive decaying organic matter in the water or sediment.

Phosphate (PO_4): Phosphate is a form of inorganic phosphorus. PO_4 is more important in freshwater ecosystems, where it often causes eutrophication. The biggest source of PO_4 is from detergents in our dishwashing and laundry soaps.

Salinity: the amount of salts dissolved in the water, measured in parts per thousand (ppt). Ocean water has a salinity of 32-35 ppt, while freshwater is 0 ppt. Most organisms are adapted to live in either freshwater or saltwater and cannot tolerate both.

Silicate (SiO_2): Silicate is an inorganic form of silica. It comes from the weathering of rocks, as rain and sun erode the molecules that form rocks. Silicate is a requirement for certain types of phytoplankton, or microscopic plants, that need it to form shells. Shells in crustaceans and shellfish are mostly made of carbonate (CO_3^{2-}), an inorganic form on carbon.

Total Nitrogen (TN): The amount of inorganic and organic nitrogen in the water and the sum of all the different forms of nitrogen. The MEP found that nitrogen was driving impairment in TGP and set the management goal of **0.48 mg/L TN** at stations TGP4, TGP5 and TGP6. There is a second nitrogen limit of **0.46 mg/L** for TPG7.

Turbidity: a measure how many particles are dissolved in the water, which affects how much light is transmitted through the water column. Water with low turbidity is clear and you can often see the bottom, while water with high turbidity appears murky. High turbidity is detrimental to submerged aquatic vegetation, as less sunlight can penetrate the water. The management goal is to have sufficient water clarity to see **3 m** down, or to the bottom of the Pond.

Watershed: A land area that channels rainfall and snowmelt to creeks, streams, and rivers, and eventually to outflow points such as reservoirs, bays, and the ocean.

Table A1.

2021 Dates of Site Visits to Tisbury Great Pond					
May	**June**	**July**	**August**	**September**	**October**
5/11	6/1	7/7	8/3	9/8	10/7
5/19	6/7	7/13	8/11	9/14	
5/27	6/16	7/21	8/17	9/21	
	6/22	7/27	8/25		
	6/29		8/31		

Figure A1

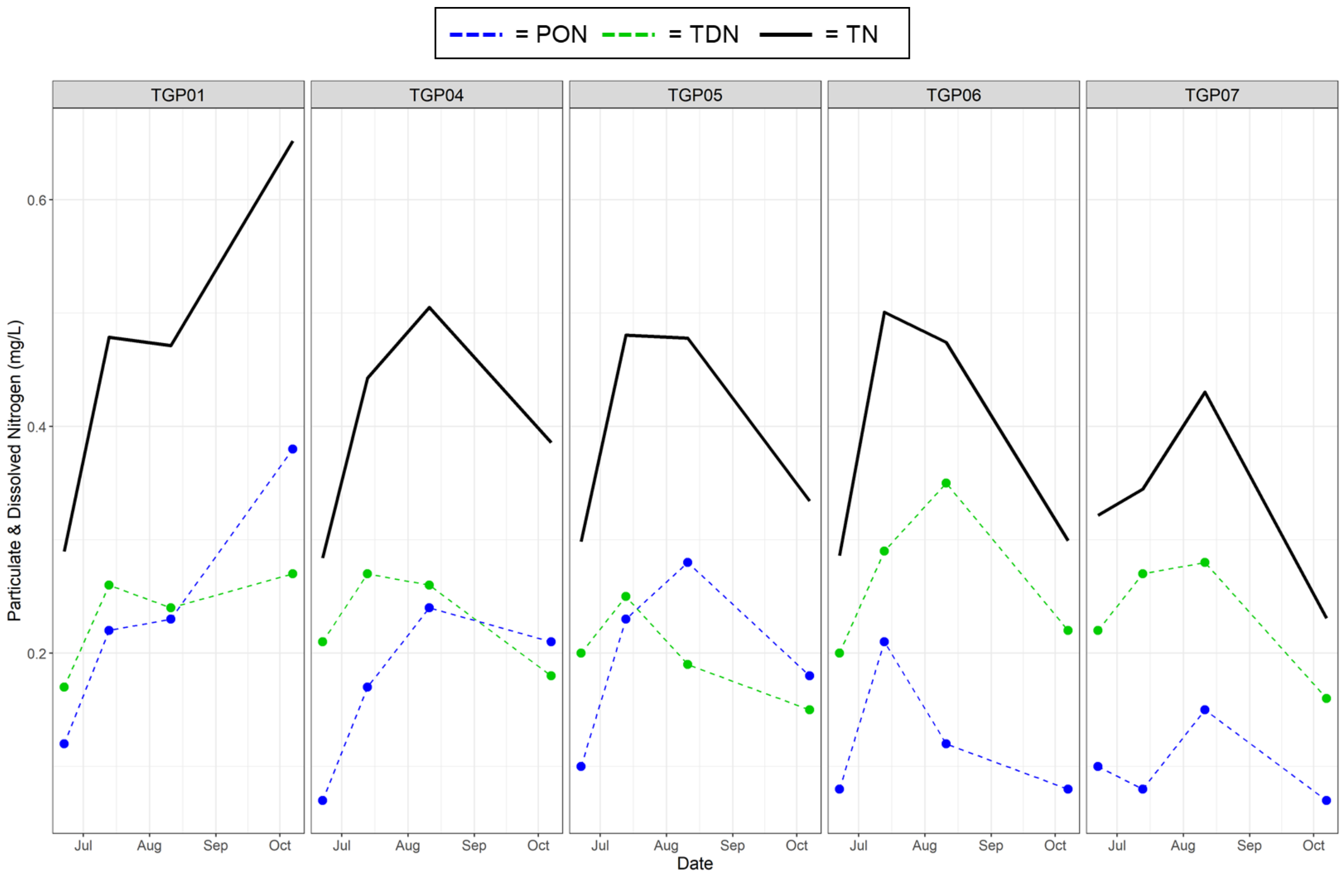

Figure A1. Particulate and dissolved nitrogen sources from 5 stations in Tisbury Great Pond in 2021. Data are in milligrams per liter (mg/L). The blue line is particulate organic nitrogen (PON), the green line is total dissolved nitrogen (TDN) and the black like is total nitrogen (TN). TN is comprised of both PON and TDN.

Figure A2

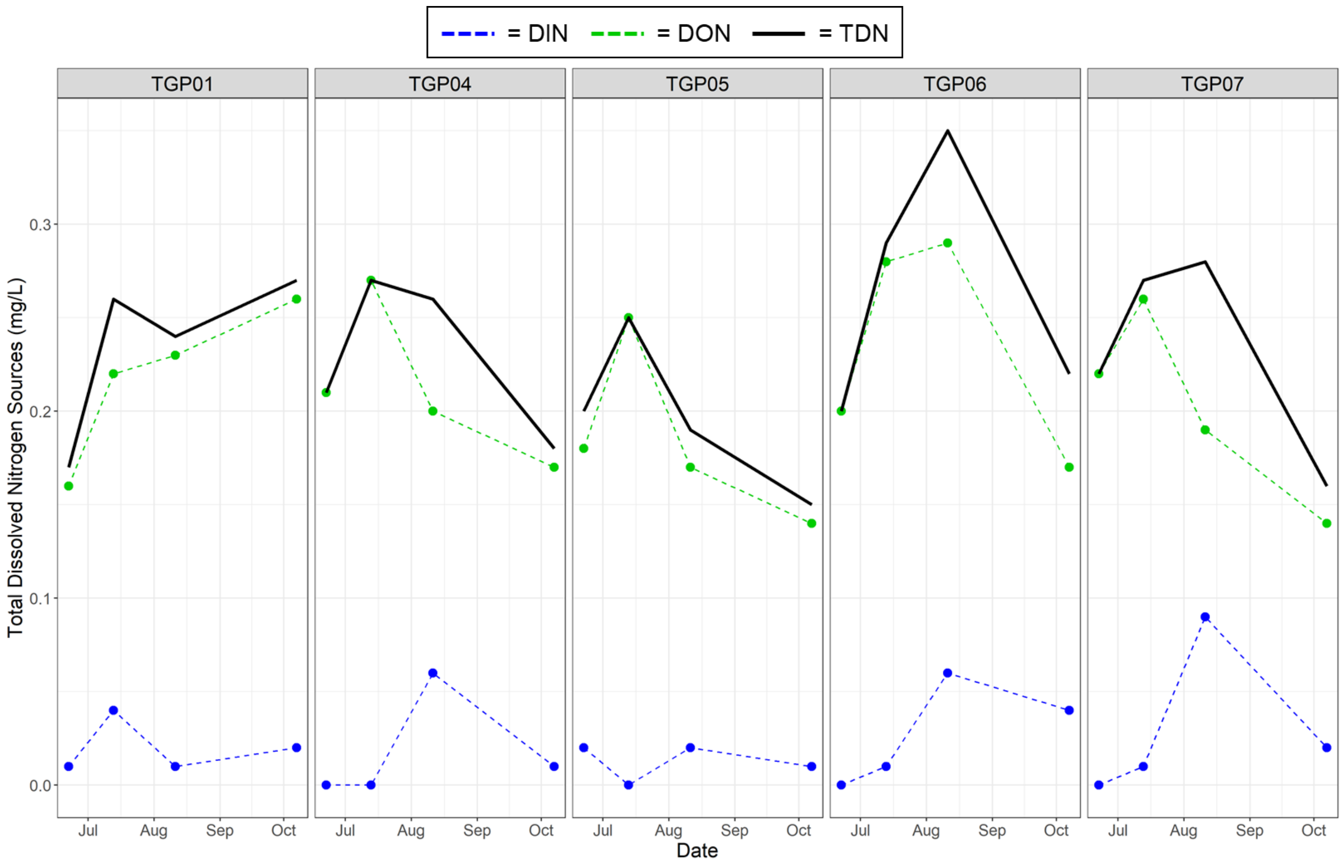

Figure A2. Total dissolved nitrogen sources from 5 stations in Tisbury Great Pond in 2021. Data are in milligrams per liter (mg/L). The blue line is dissolved inorganic nitrogen (DIN), the green line is dissolved organic nitrogen (DON) and the black like is total dissolved nitrogen (TDN). TDN, along with total particulate nitrogen, make up total nitrogen (TN).

Figure A3

GREEN		**BLOOM NOT PRESENT** Conditions are not favorable for a Cyanobacterial Bloom. **OK:** Swimming, boating, paddling, wading, fishing, and consuming shellfish, crabs, of finfish. No known cynaobateria risks to humans, pets, and livestock.
YELLOW		**CYANOBACTERIA ALERT** It is the season where Cyanobacterial Blooms are possible. **OK:** Swimming, boating, paddling, wading, fishing, and consuming shellfish, crabs, of finfish. **USE CAUTION:** risk to humans/pets/ livestock when ingesting water.
ORANGE		**CYANOBACTERIA BLOOM WATCH** **OK**: Boating. **USE CAUTION:** risk for swimming, paddling, and wading, fishing. **ADVISE AGAINST:** humans/pets/livestock ingestion of water, comsuming shellfish, crabs, or finfinsh.
RED		**CYANOBACTERIA BLOOM ADVISORY** There is an active Cyanobacteria bloom, cyanotoxins may be present. **OK**: Boating. **ADVISE AGAINST**: pets/livestock/human ingestion of water, fishing, comsuming shellfish or finfinsh, swimming, paddling, and wading.

Figure A3. The MV CYANO color-coded matrix.