2019

ECOSYSTEM MONITORING REPORT

EDGARTOWN GREAT POND

GREAT POND FOUNDATION

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Ecosystem Monitoring Report - Edgartown Great Pond

Executive Summary

After decades of careful management, Edgartown Great Pond (EGP) is a restoration success story. This preservation was made possible due to partnerships between the Great Pond Foundation (GPF) and the Town of Edgartown, Martha's Vineyard Commission, Martha's Vineyard Shellfish Group, and many other individuals and organizations who have worked together to restore this natural resource. While once impaired, EGP is now one of the healthiest estuaries in the region. Much of this success lies in the collaborative management efforts that have become cornerstones of successful pond restoration. Regular and timely pond cuts are vital to control pond elevation, flush pond water with the ocean, and maintain salinity within healthy limits for species that inhabit the pond. Yearly dredging near the barrier beach from 2009-2019 increased circulation of seawater during pond cuts and enabled openings to be consistently successful. Eelgrass, an important plant species indicative of excellent water quality, has expanded in both distribution and density while oysters and other shellfish, which help filter the water and support local shellfishing, are more abundant.

In an effort to document the restoration of EGP and build a database of water quality data, GPF developed an Ecosystem Monitoring Program beginning in 2016. The monitoring program builds on recommendations from previous scientific studies of the Great Pond, namely the Massachusetts Estuary Project (MEP) report and a 1993 study by Arthur Gaines. The MEP established management targets for numerous water quality parameters based on the land use and hydrology of EGP and the ranges of these parameters commonly found in healthy ecosystems. GPF uses these targets to help evaluate the health of the Pond by collecting data at 12 stations throughout the Pond. GPF is committed to gathering as much data as possible on the condition of the Pond and using these data to inform management decisions, such as when the Pond should be opened to the ocean.

The Ecosystem Monitoring Program is also used to assess the efficacy of management activities such as dredging and breaching the barrier beach. Pond cuts are the primary management tool for EGP, and every cut is unique. Ideally, cuts should remain open long enough for the Pond to drain and become tidal. This tidal exchange with the ocean allows the Pond to fill with cooler, salty water, which species such as eelgrass need to survive. Dredging near the barrier beach is necessary to increase duration of pond openings and strengthen tidal exchange with the ocean, flushing out excess nitrogen and leading to more successful pond cuts. Continuation of regular dredging of the delta north of the barrier beach is essential to the current and future health of Edgartown Great Pond.

The Pond was cut 3 times in 2019, and each opening was considered successful based on duration and the increase in salinity seen throughout the Pond. July 2019 was unusually hot, while an algal bloom occurred in August. These factors were associated with low dissolved oxygen readings throughout the summer. Despite some concerning dissolved oxygen measurements, EGP remains one of the healthiest estuaries on Martha's Vineyard. Yet, this restoration success does not make the Pond immune to future impairment. Air and water temperatures continue to rise, placing pressure on coastal ecosystems. Hotter summer temperatures, combined with nutrient pollution, fuel algal blooms and can lead to poor water quality. It is necessary to have frequent, extensive water sampling to detect occurrences such as algal blooms or low oxygen events, which may be missed with less frequent sampling. Robust sampling regimes also help determine long-term trends. In 2020 GPF will expand the Ecosystem Monitoring Program and begin monitoring biodiversity within the Pond, while further strengthening efforts in public education of science and conservation.

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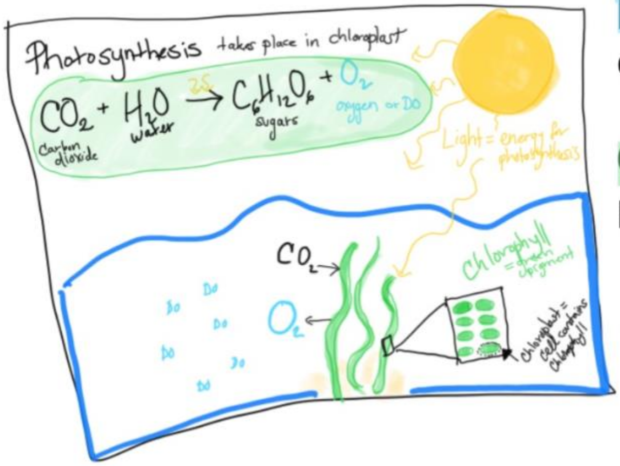
Visual Glossary: **Water Quality Parameters**

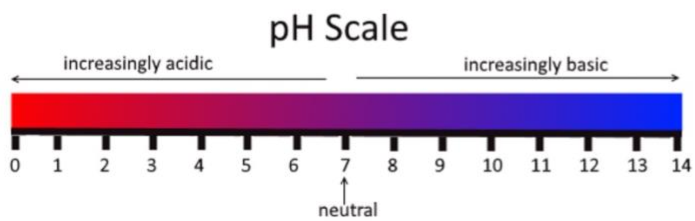


Dissolved Oxygen (DO): the amount of oxygen (O_2) dissolved in water, measured in milligrams per liter (mg/L).

Chlorophyll: Chlorophyll is a pigment plants use for photosynthesis, measured in micrograms per liter (µg/L).

Photosynthesis = the process by which green plants and algae make food (sugar) using carbon dioxide and water.

pH: a measurement of how acidic or basic a solution is. Neutral pH is 7.



Salinity: the amount of salt dissolved in water, measured in parts per thousand (ppt). Ocean salinity is 32-35 ppt, while freshwater is 0 ppt.

Turbidity: a measure how many particles are dissolved in the water, which affects water transparency. Water with high turbidity appears murky.

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, which can be harmful to the health of a body of water.

Visual Glossary: **Healthy & Impaired Ecosystems**

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.

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.

Algal Bloom: a sudden and rapid increase in growth of aquatic plants. Algal blooms can occur with microscopic phytoplankton, or larger macroalgae (AKA "seaweed").

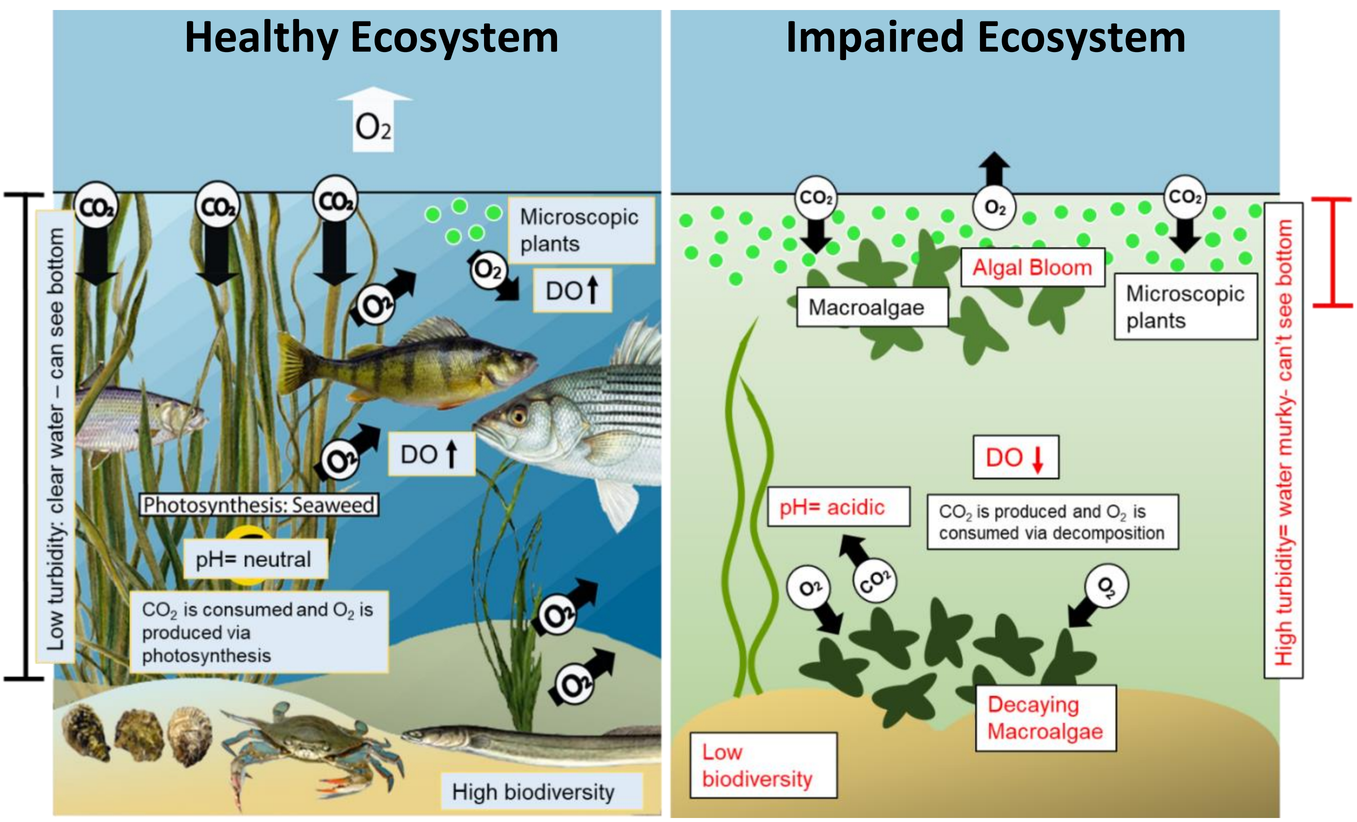


Illustration of a healthy ecosystem compared to one that is impaired. The healthy ecosystem (left) is biodiverse with excellent water quality and high levels of dissolved (DO). This is in contrast with the impaired ecosystem (right), which is experiencing an algal bloom and suffers from poor water quality and low biodiversity.

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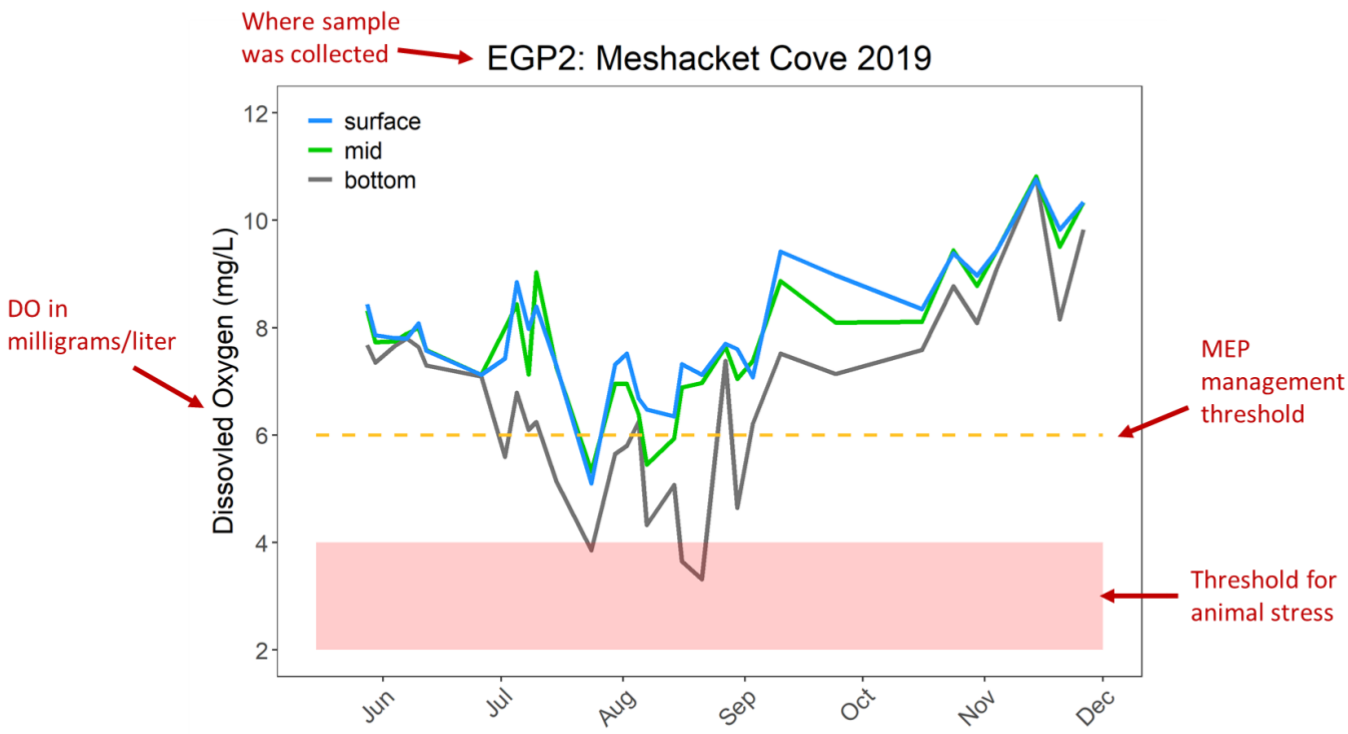
Making Sense of the Figures



Fundamental to understanding data is reading and deciphering a graph. Graphs are key tools scientists use to visualize numerous data points in one place. Without graphs, there would be thousands of data points and extracting trends from these numbers would be impossible. A good graph is self-explanatory, but it is important to understand all the components in order to fully ascertain the data.

Most graphs have two variables: the independent variable and the dependent variable. The independent variable is usually along the x-axis (horizontal) and is a parameter that does not depend on any other variable, such as date. The dependent variable is on the y-axis (vertical), usually on the left, is the parameter of interest in a plot. This variable is affected by changes in the independent variable, such as how temperature fluctuates with time. It's important to always look at the scale on the axes, because it shows the magnitude of change.

Most of the plots in this report will have two annotations on each plot. One is a yellow dashed line that corresponds to the management thresholds for Edgartown Great Pond (EGP). The other is a box shaded red, which corresponds to when the variable in question reaches extreme values that cause concern. Occasionally, there will be multiple lines in one plot, and in that case each line is a different color corresponding to a different sampling collection, such as different depths or different years. The title on the graph (on top) will show where the data were collected, and the figure caption (adjacent to the figure) will further explain the graph or image.

Edgartown Great Pond: History of Collaboration leads to Conservation Success

- ❖ GPF and its many partners have worked to pinpoint causes of impairment in EGP and address them with collaborative solutions.
- ❖ Management solutions include annual dredging, breaching the pond to the ocean 3-4x a year, and forming a robust ecosystem monitoring program.
- ❖ Decades of work has made EGP one of the most studied estuaries in the region, and the Pond is now healthy and thriving with a diversity of life.

After decades of careful management, Edgartown Great Pond (EGP) is a restoration success story. The preservation of this cherished ecosystem was made possible due to partnerships between the Great Pond Foundation and the Town of Edgartown, Martha's Vineyard Commission, Martha's Vineyard Shellfish Group, and many other individuals and organizations who have worked together to restore this natural resource. While once impaired, EGP is now one of the healthiest estuaries in the region. Much of this success lies in the collaborative management efforts that have become cornerstones of successful pond restoration. Regular and timely pond cuts are vital to control pond elevation, flush pond water with the ocean, and maintain salinity within healthy limits for species that inhabit the pond. Yearly dredging near the barrier beach from 2009-2019 increased circulation of seawater during barrier beach breach events and enabled openings to be consistently successful. Continuation of regular dredging of the delta north of the barrier beach is essential to the current and future health of Edgartown Great Pond. Eelgrass, an important plant species indicative of excellent water quality and ecosystem stability, has expanded in both distribution and density. Oysters and other shellfish, which help filter the water, are more abundant and have recovered from a shellfish disease. The Pond is thriving and supports a wide array of plants and animals, while providing a stunning backdrop for human recreation.

Edgartown Great Pond is one of the most extensively studied coastal ponds on Martha's Vineyard. Much of the current management and monitoring efforts build on previous studies. In the 1990's scientific studies by Arthur Gaines and others outlined a decline in water quality in the Great Pond. Yet, these studies described solutions to reduce and reverse this impairment. In response, community members committed to preserving and protecting the Pond came together to form Great Pond Foundation. In 2008, the Massachusetts Estuaries Project (MEP) released a report further documenting the causes of impairment and providing detailed management guidelines and solutions. Responding to MEP recommendations, GPF purchased a dredge in 2009 and operated a winter dredging program, working with the Town of Edgartown to improve Pond flushing during Pond cuts.

A decade of dredging and informed management has brought the Pond back to health. This would not be possible without restoration and monitoring efforts from diverse stakeholders. What makes EGP unique is the combination of community leaders, nonprofits, municipalities and scientific partners working together to maintain water quality and ensure EGP is preserved. Since its inception, Great Pond Foundation (GPF) has been the anchor of this collaborative effort. GPF has been instrumental in coordinating and implementing management practices, such as purchasing a dredge and committing to high-quality scientific data collection to support continued water quality improvements. EGP is the only coastal pond on Martha's Vineyard with its own dredging program, and none have been dredged as frequently as EGP. While GPF has recently shifted toward science and education and away from maintaining and operating a dredge, regular dredging will continue in partnership with the Town of Edgartown.

The Martha's Vineyard Commission (MVC) is another important partner integral to the preservation of EGP. The MVC monitors water quality within all major estuaries on Martha's Vineyard, including EGP. Yet, the frequency with which they sample each ecosystem is limited by the large number of ponds they sample. Seeking to evaluate the effectiveness of restoration efforts, GPF increased its commitment to data collection in EGP beginning in 2016. The Foundation launched a robust year-round water sampling program with the goal of scientifically measuring and quantifying changes in water quality and comparing them to management targets. One of the critical objectives of this water sampling program was to document the seasonal variation in water quality, and to be able to track trends in the data from year to year. GPF's team sampled Edgartown Great Pond on 34 days in 2019, before and after cuts, and from the spring until early winter. This frequency and complexity of sampling enables rapid detection of potential problems, such as occurrence of algal blooms or low oxygen events and helps inform management decisions by providing a more complete picture of the health of the Pond.

Water Quality Monitoring Efforts

- ❖ The MEP report established water quality management targets for EGP, which are used to assess ecosystem health.
- ❖ Nitrogen pollution causes impairment but dredging near the barrier beach is necessary to increase duration of pond openings and strengthen tidal exchange with the ocean, flushing out excess nitrogen and leading to more successful Pond cuts.
- ❖ GPF monitors water quality parameters year-round at 12 stations throughout the Pond, with 34 separate sampling days in 2019.
- ❖ Pond elevation and salinity measurements are used to determine when a Pond cut is needed and evaluate the success of each cut.
- ❖ It is necessary to have frequent, extensive water sampling to detect occurrences such as algal blooms or low oxygen events, which may be missed with less frequent sampling. Robust sampling regimes also help determine long-term trends.

An additional MEP recommendation was development of a monitoring program to assess the efficacy of management activities such as dredging and breaching the barrier beach. GPF is committed to gathering as much data as possible on the condition of the Pond and using these data to inform management decisions. The MEP established management targets for numerous water quality parameters based on the land use and hydrology of EGP and the ranges of these parameters commonly found in healthy ecosystems (see definitions in glossaries on page 1 and in the appendix). GPF uses these targets to help evaluate the health of the Pond (Figure 1).

In addition to these parameters, GPF closely monitors salinity. Salinity is a measure of how much salt is dissolved in the water, measured in parts per thousand (tap water = 0 parts per thousand (ppt), ocean water = 34 ppt). EGP is a brackish pond, which means it is intermediate between fresh and saltwater. Salinity is important to monitor because it determines which species can live in the Pond. Usually, organisms can either live in freshwater or salty water. Since EGP is brackish and occasionally open to the ocean, the species that live in the Pond are adapted to tolerate saltwater. Yet, EGP is fed by a combination of groundwater and rainwater, both of which are freshwater. This causes salinity of Pond water to gradually fall as the Pond fills. If the water gets too fresh, plants and animals lose their ability to regulate salt in their body, which can be fatal. Eelgrass (*Zostera marina*), an important indicator species and producer of blue carbon, cannot survive in salinities less than 15 ppt. For this reason, GPF closely monitors salinity as well as pond elevation prior to Pond cuts. When Pond elevation is high and salinity is approaching this threshold for healthy eelgrass, GPF actively communicates with

MEP Management Targets for Clean Water

- **Dissolved oxygen: > 6.0 mg/L**
- **pH: 6.5 - 8.5**
- **Temperature: ≤ 85° F**
- **Turbidity/Water transparency: 0.6-3.0 meters (or to bottom of Pond)**
- **Total nitrogen: 0.5 mg N/L**
- **Chlorophyll: 3 - 10 µg/L**

Figure 1. MEP management targets of common water quality parameters for Edgartown Great Pond.

Edgartown officials to advocate for an immediate Pond opening. GPF has deployed a water level sensor that continuously records pond elevation, which helps inform when cuts are needed.

When the Pond is cut, a drop in elevation occurs as the Pond drains, followed by tidal exchange with the ocean (Figure 2). A substantial drop in Pond height (> 2 feet) is the first phase of the cut, which can be detected with the pond elevation sensor. Ideally, the opening will remain long enough for the Pond to become tidal, joining the ocean tides. When this occurs colder, well-oxygenated, salty water is flushed into the Pond. The influx of

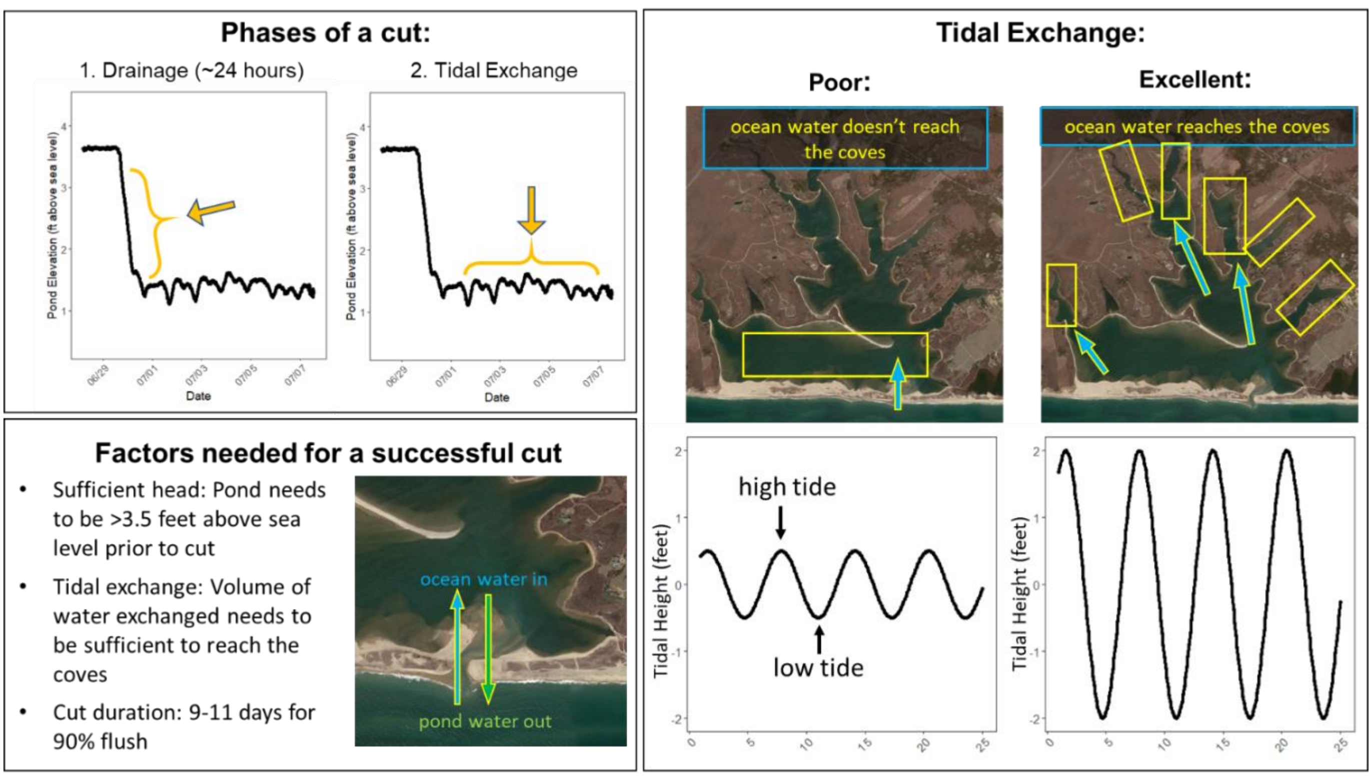


Figure 2. Phases of a cut and the factors that make cuts successful. Successful openings of the Pond occur when large volumes of Pond water are drained and exchanged with seawater, which is detected by increases in salinity. The volume of water exchanged depends on cut duration and the strength of the tides during the cut.

ocean water causes the salinity in the Pond to rise rapidly. Following a cut, salinity is used to measure the extent of exchange between the Pond and the ocean. If salty ocean water reaches up into the coves of EGP, detected by increases in salinity, the whole Pond has successfully drained and exchanged water with the ocean. Longer cut duration leads to more tidal exchange, and a stronger flush. Dredging the sand that accumulates inside the barrier beach is essential in maximizing cut duration and tidal exchange.

Pond cuts and the subsequent flushing that occurs are needed to periodically drain the Pond of excessive nutrients it has accumulated. The root cause of reduced water quality in EGP, and all other estuaries in the region, is elevated nutrient concentrations. Nutrients such as nitrate, ammonium, and phosphate are needed to sustain life. However, when their concentrations are in excess, a cascade of problems occur. Similar to a garden, when fertilizer is applied growth flourishes. When extra nutrients are introduced to a coastal waterbody, aquatic plants proliferate. A sudden and rapid increase in aquatic plant growth is called an algal bloom, and it occurs in both microscopic plankton and larger macroalgae (Figure 3). Blooms occur after an influx of nutrients, such as nitrate and phosphate. Influxes of nutrients are more likely to occur in summer months. Algal blooms can also be triggered by increases in temperature. Higher water temperatures are associated with faster growth rates for many species. While it may be beneficial for an oyster or a fish to grow quickly, it is problematic when aquatic plant species grow too fast. The combination of increased temperatures and elevated nutrients make the Pond especially vulnerable to algal blooms during the summer.

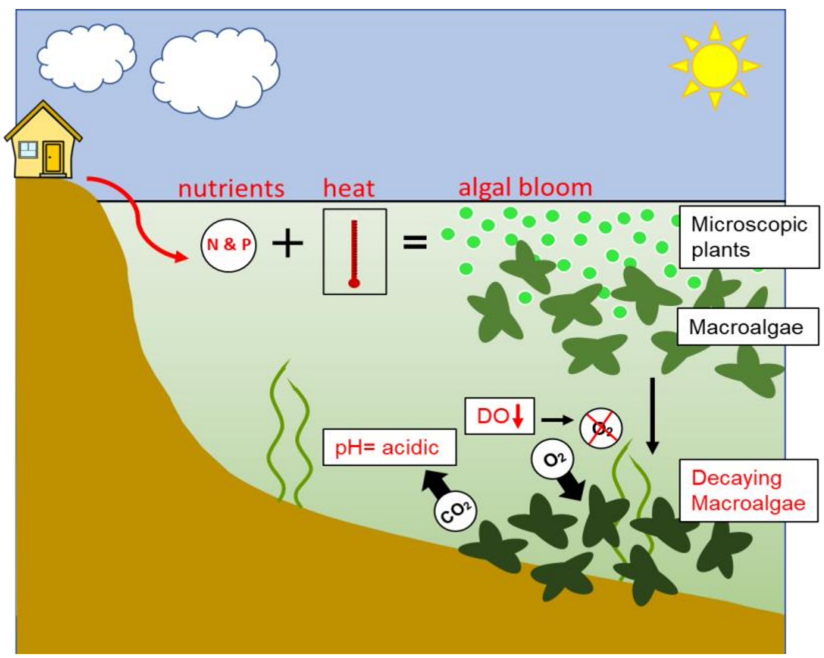


Figure 3. Causes and consequences of an algal bloom. Elevated nutrients and increases in temperature are major drivers of blooms. Blooms of both microscopic plants and macroalgae can occur, which cause problems such as low dissolved oxygen (DO) when the plants decay. The conditions created by decomposition of algal blooms can be deadly to both plants and animals.

Plants are important components of the ecosystem, as they form the base of the food web and produce oxygen via photosynthesis. Yet, excessive plant growth causes many problems when algae die. As algae decays, bacteria that break down the organic matter consume oxygen. This reduces the amount of oxygen available for animals that need it to breathe and can be fatal if dissolved oxygen reaches critically low levels. Additionally, algal blooms cause water turbidity to increase, and the murky water reduces how far light can reach into the water column. This is problematic for plants like eelgrass that are rooted into the bottom of the Pond and require light for photosynthesis. Moreover, decaying macroalgae can sink and cover eelgrass beds, completely blanketing the plants and further restricting their ability to capture sunlight.

In August of 2018, a widespread bloom of green filamentous algae occurred (Figure 4). A similar but less extensive macroalgal bloom occurred again in 2019. Algal blooms such as these demonstrate the importance of regularly monitoring the health of the Pond. Detecting ephemeral events such as algal blooms and low oxygen incidents is only possible with frequent water sampling. In 2019, the GPF field team had 34 sampling days and collected more than 8,000 discrete data points. With high resolution data such as this, GPF can detect trends that would be missed with more limited sampling effort.

Figure 4. Aerial photo of macroalgal bloom in 2018, and the macroalgae when removed from water.

Since 2016, Great Pond Foundation has maintained a robust, year-round water quality monitoring program. Edgartown Great Pond is a dynamic system that experiences many fluctuations, whether they are rapid changes that occur with every cut and or slow shifts that occur as the seasons change. In order to fully understand these dynamics and successfully manage the ecosystem, a record of water quality data is needed. Building on studies by Arthur Gaines and the recommendations in the Massachusetts Estuaries Project (MEP) Report, GPF now has 4 years of data to ascertain changes in Pond condition over time, and to observe the status of the Pond in real-time. Each year the amount of data collected has increased, as the Foundation increasingly supports science and data-informed management practices. Beginning with this report, GPF will publish an annual Water Quality Report outlining the findings from the summer field season and explaining the trends in the data.

GPF and the field team sample at 12 stations throughout the Pond (Figure 5). These water sampling stations cover all aspects of the EGP ecosystem: from the basin adjacent to the barrier beach, to the deepest parts in the center of the Pond, to the coves in the north. At each station parameters such as temperature, salinity, dissolved oxygen, pH, water clarity and turbidity are measured throughout the entire water column (see Glossary for explanations of parameters). Additionally, concentrations of nutrients such as nitrate, phosphate, and ammonium are analyzed at a select number of stations on each sampling day. In the summer months, the Scientific Program Manager and the interns collect water samples twice weekly. Summer is when the Pond is most biologically active, and sampling with high frequency allows for rapid detection of changes or observation of biological phenomena, such as algal blooms. In cooler weather, sampling is performed either weekly or biweekly, depending on weather conditions. Winter prohibits boat-based water sampling, yet the cold weather also limits biological activity making regular sampling unwarranted. In the winter, deployed sensors are the main source of data, such as the water level logger that measures Pond elevation. A goal for the future is to purchase more remotely operated sensors to enhance GPF's ability to monitor water quality during the winter.

2019 Ecosystem Monitoring Data

- The Pond was cut 3 times in 2019, and each opening was considered successful based on duration and the increase in salinity seen throughout the Pond.
- July 2019 was unusually hot, while an algal bloom occurred in August. These factors were associated with low dissolved oxygen readings throughout the summer.
- Despite some concerning dissolved oxygen measurements, EGP remains one of the healthiest estuaries on Martha's Vineyard. An indicator of improving ecosystem health is the expansion of eelgrass meadows that has been documented recently.
- In 2020 GPF will expand the Ecosystem Monitoring Program and begin monitoring biodiversity within the Pond, while efforts in public education of science and conservation will increase.

The 2019 field season began on May 28th and the last water sampling collection occurred on November 26th. This provided 6 months of high-resolution data, from the end of spring to the beginning of winter. These data can answer many questions about the health of the Pond and add to the growing database of water quality data in EGP.

Figure 5. Water sampling stations in Edgartown Great Pond.

The barrier beach was breached to the ocean three times in 2019: March 24, June 29, and November 16. Following a cut, salinity is used to measure of the extent of exchange between the Pond and the ocean. The salinity prior to the summer cut was between 18.16 and 19.14 ppt, but after the cut salinity rose to 26.26 - 30.91 ppt (Figure 6). This increase of >10 ppt, especially the rise in salinity in the coves, indicates a successful flush. For both the summer and fall cuts in 2019, salinity indicated a good flush and thus a successful cut, with cool, salty water reaching up into the coves. The spring cut occurred prior to the start of the field season, yet data from the pond elevation logger and anecdotal evidence indicate that the cut was open approximately 50 days.

The coves of the Pond are influenced by groundwater discharge, which introduces freshwater to the Pond. For this reason, the coves, especially Wintucket and Jane's Cove, have lower salinity than the rest of the Pond. Rainwater is another major source of freshwater, which combined with groundwater, causes the Pond to fill after it is cut. Eelgrass is heathiest when salinity is >15 ppt, and GPF uses this as a management threshold to preserve the eelgrass ecosystems within the Pond. In 2019, salinity was below the 15 ppt threshold three times, all of which occurred in areas with groundwater discharge. Additionally, these low salinity measurements occurred either just before or immediately after the Pond was cut. When Pond elevation is low following a cut, groundwater discharge temporarily increases due to the low water level in the Pond. The lowest salinity occurred on July 5th and was 14.04 ppt in Wintucket Cove. While below the management goal, this is not worrisome because it occurred 5 days after the summer cut and was at a station influenced by groundwater. Each time the Pond was cut in 2019, salinity increased to near ocean levels within 10 days (Figure 6). These data indicate that the Pond remained in a healthy salinity range for the entire year.

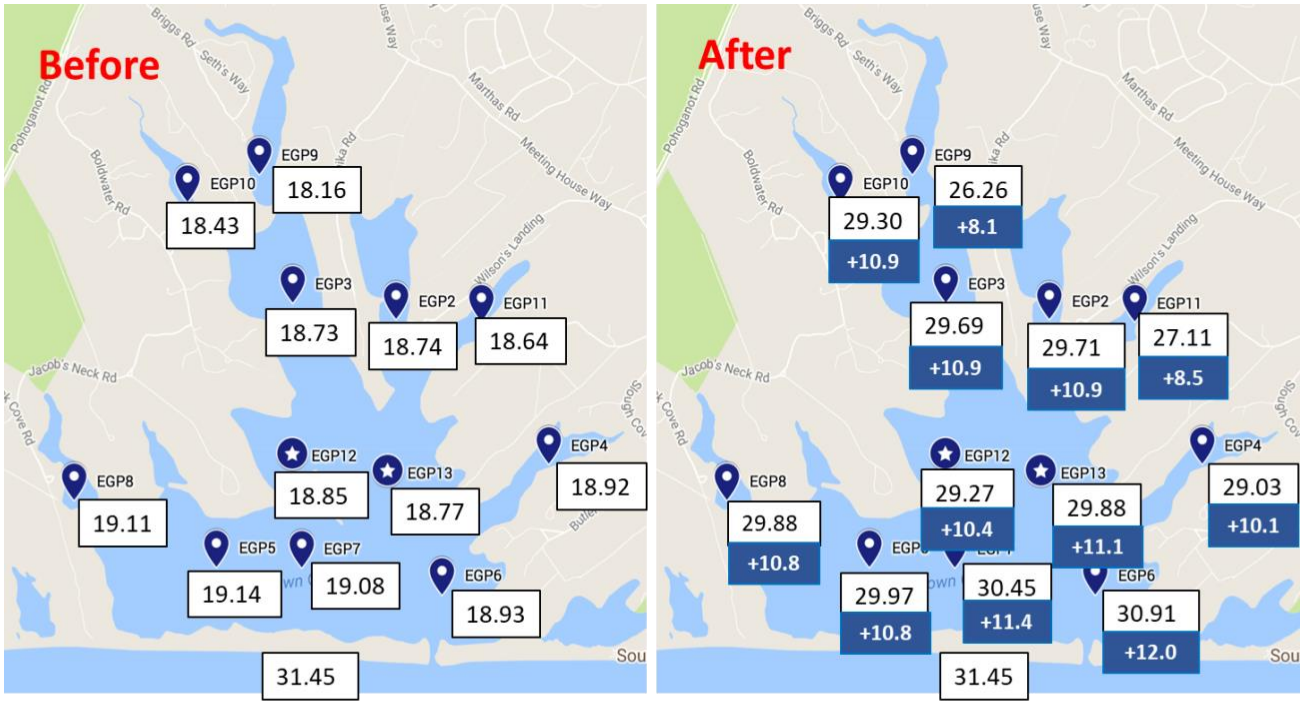


Figure 6. Change in salinity 3 days before and 9 days after summer cut.

Another important parameter to monitor is temperature. Much like the temperature of our own bodies, elevated water temperature is often associated with problems affecting ecosystem health. The EGP management goal is to maintain water temperatures less than 85° F during the summer. However, unlike other parameters that can be influenced by management decisions, there is no way to control temperature.

Usually, peak summer heat occurs in mid to late August. However, in 2019 there was a heat wave in July which caused water temperatures to reach their maximum earlier than in previous years (Figure 7A). Temperatures peaked twice, once in mid-July and again at the end July and into August. Additionally, hot temperatures in July were exacerbated due to how shallow the Pond was after the cut. The Pond was cut on June 29th and remained open for around 16 days, causing the Pond elevation to drop 3.5 feet. When the Pond is shallow, water temperature can change more quickly compared to when Pond elevation is high and there is a larger volume of water. This, combined with the heat wave in July, resulted in unusually high temperatures throughout the entire water column. The top 5 hottest days in 2019 all occurred on or before August 4th. On July 22nd, average daily water temperature was 84.95° F, as measured from a deployed thermometer on the water level logger. The maximum daily temperature occurred on August 1st, which was 85.36° F. This exceeded the management threshold of 85° F.

In Meshacket Cove, temperature collected from GPF sampling trips never exceeded the 85°F threshold in 2019 (Figure 7B). Throughout the summer, all sampling stations remained below this temperature threshold, except for EGP4 (Slough Cove) and EGP9 (Jane's Cove), both of which occurred just once on August 2nd, when the water was 86° F. EGP4 and EGP9 are both shallow stations, which are more susceptible to changes in air temperature than deep stations. Additionally, these data were collected during sampling trips, which occur early in the morning. Water sampling just after sunrise is standard water quality sampling protocol, as it maximizes the chances of detecting low DO. However, by sampling early in the day temperatures are cooler, and higher temperatures that occur in the afternoon are not captured. Based on data from the deployed temperature sensor that continuously records temperature, it is likely that water temperature exceeded 85° F at more stations and more

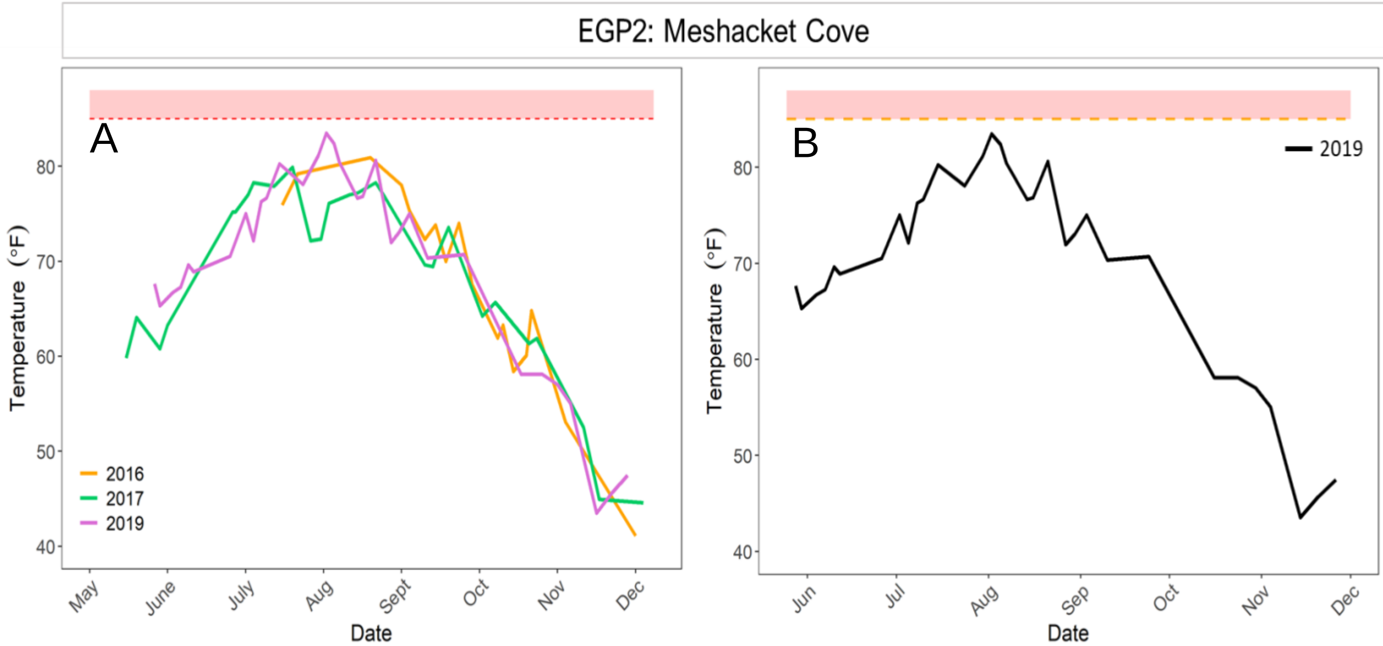


Figure 7. Mid-depth water temperature in Meshacket Cove. The left panel shows multiple years of data (shown in different colors), with 2019 being the warmest year. The right panel is showing data for 2019 only.

frequently than on August 2nd. Having additional in situ sensors would provide enhanced insights into the temperature dynamics within the Pond.

These higher temperatures not only fueled algal growth, but also had a negative effect on the dissolved oxygen (DO) in the Pond. DO refers to the amount of oxygen available for consumption by marine species and is essential to the metabolism of plants and animals in an estuarine ecosystem (Figure 8). The management threshold for DO is 6 mg/L. Low levels of DO can inhibit the growth of plants and animals and can even cause mortality in cases of prolonged or severe oxygen depletion. However, the amount of oxygen that can physically dissolve in water is negatively related to both temperature and salinity. Colder, fresher water can hold more oxygen molecules than warmer, saltier water (Figure 8). This has major implications for EGP, since both temperature and salinity can change rapidly after the Pond is cut.

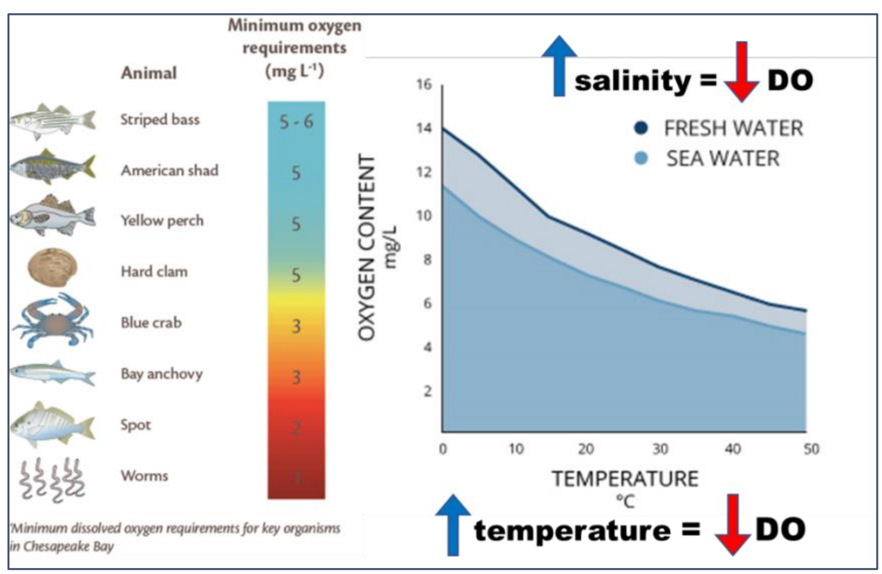


Figure 8. A. Minimum dissolved oxygen (DO) requirements for common estuarine species. B. The relationship between DO, temperature and salinity. Warm saltwater water holds less oxygen than cold freshwater.

The combined effects of temperature and salinity on dissolved oxygen contributed to low DO measurements in July after the summer cut. The Pond was shallower, which exacerbated the effects of a heat wave and led to maximum temperatures. Additionally, an algal bloom occurred in August that affected most of the Pond. The decay of the algal bloom, as well as the negative effects of temperature and salinity on DO, led to widespread low DO readings.

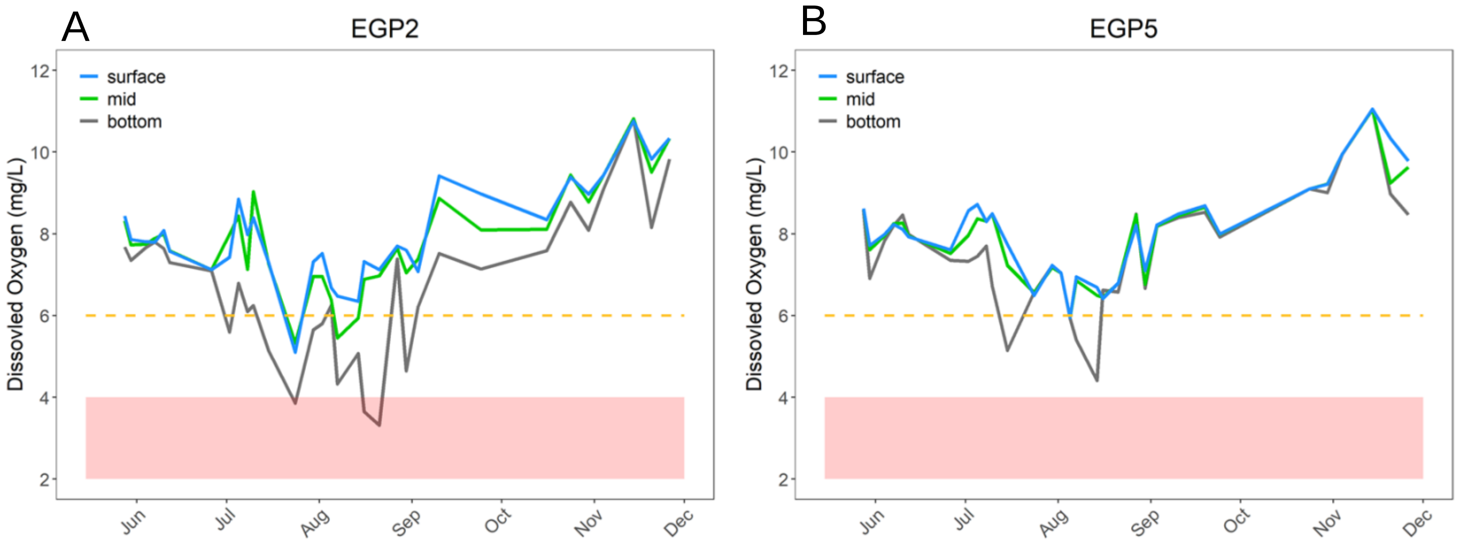


Figure 9. Dissolved oxygen (DO) levels taken at the bottom, mid-depth, and surface at EGP2 (Meshacket Cove) in A and from EGP5 (SW of Pond by the barrier beach) in B. The yellow dashed line depicts the management threshold of 6 mg/L, and the area shaded in red depicts when oxygen levels are low enough to cause stress to organisms. Both stations had healthy DO levels the majority of the summer, however bottom DO at EGP2 dropped into the zone of concern (red box) 3 times.

Each sampling station experienced DO levels below the 6 mg/L threshold at least twice during the summer of 2019. On August 14th, all 12 stations were below 6 mg/L. Additionally, there were two times (8/14 and 8/21) when 11 out of 12 stations were below this management threshold. GPF has never observed such widespread low DO, which is indicative of the ecosystem struggling to deal with imbalances caused by an algal bloom.

Furthermore, some stations dropped below the 4 mg/L threshold, below which organisms start to become oxygen deprived. Normally, the bottom of the water column has lower DO than 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 the surface where there is direct sunlight. Additionally, decomposition of organic matter occurs on the bottom and in the sediments, which consumes oxygen. Due to these processes, deeper water often has lower dissolved oxygen than the surface.

In Meshacket Cove (EGP2), bottom dissolved oxygen fell below the 6 mg/L management goal multiple times throughout the summer (Figure 9A). Once in July (7/24) and twice in August (8/16 and 8/21), bottom DO dropped below the 4 mg/L threshold, into the range that causes stress to plants and animals (shaded in red in Figure 9). Twice, surface and mid-depth readings were below 6 mg/L, which indicates oxygen depletion extended beyond the bottom depths. These low DO events occurred due to increased temperatures in July and an extensive algal bloom in August. Meshacket Cove is one of the more impaired locations within EGP, as it is affected by effluent from the Edgartown wastewater treatment plant. Additionally, it is a deeper cove with no eelgrass beds.

This is in contrast to a station such as EGP5, which is located in the main basin in the southwest corner of the Pond. Bottom DO at EGP5 dipped below 6 mg/L 4 times, once on July 15th and 3 times in August, associated with the heat wave and the August algal bloom (Figure 9B). DO never dropped into the zone of concern below 4 mg/L, and surface and mid-depth readings were always at or above 6 mg/L. EGP5 is closer to the cut, and thus gets thoroughly flushed when the Pond is opened. Additionally, there are vast eelgrass meadows in this region of the Pond, which control the amount of carbon dioxide in the water and regulate pH. Eelgrass also provides habitat for many other species, increasing the biodiversity at this station, another sign of excellent ecosystem health. Except for 4 DO measurements below 6 mg/L, all parameters were within management limits throughout the entire summer at EGP5 in 2019.

EGP has been monitored continuously for several years, and despite some concerning measurements of dissolved oxygen and temperature in 2019, the pond health continues on a positive trajectory. Every ecosystem endures seasonal fluctuations and is occasionally stressed when these fluctuations are extreme. Peak summer temperatures will always lead to a reduction in DO based on physics alone, and there is no pond management strategy to control temperature. High temperatures, low DO, and algal blooms are problems all coastal ecosystems in the region faced in 2019, and these threats will likely continue due to climate change. Overall, the Pond remains one of the healthiest estuaries on Martha's Vineyard, largely due to the efforts of the GPF.

One sign of health is the continued expansion of eelgrass beds in EGP. In 2007 when the MEP conducted their surveys, no eelgrass was present due to habitat impairment. Management strategies, which include the purchase and operation of GPF's dredge Nessie, have improved this habitat and allowed eelgrass to become reestablished. In 2019, GPF hosted scientists from the EPA who conducted SCUBA surveys of eelgrass at 3 stations in the Pond. They confirmed eelgrass has indeed expanded in both distribution and density. These scientists will return in 2020 to further document the expansion of this keystone species. Additionally, GPF and the MVC were awarded a grant from the Edey Foundation to conduct aerial surveys of eelgrass meadows. A drone with GPS technology will take photographs and produce maps of eelgrass distribution, focused in Slough Cove. These maps, combined with the underwater surveys by the EPA, will provide valuable data on the habitat restoration that has occurred since the MEP collected data in 2007. Additionally, these maps can be used to document future expansions of eelgrass meadows.

In addition to science and pond management, GPF is committed to educating the public on the importance of estuarine ecosystems and the species that reside in them. Much of these efforts will focus on blue carbon, which is the carbon that is sequestered by salt marshes and eelgrass meadows. This carbon is removed from the atmosphere and is stored in bottom sediments, often for centuries or more. Since carbon dioxide is a major driver of global climate change, it is imperative that these blue carbon ecosystems are preserved. Supporting water quality monitoring and working to improve Pond health is thus an important, yet often overlooked, tool to combat climate change.

Outside of water quality monitoring, 2019 ended on a high note for GPF as it was announced to be the recipient of an Impact Grant from the Permanent Endowment for Martha's Vineyard. This grant will create a Biodiversity Monitoring Program, which expands upon the existing Ecological Monitoring Program. Clean, healthy waters support many species, such as eelgrass, plankton, shellfish, and finfish. With this grant, GPF will purchase equipment such as a beach seine net, plankton nets, a microscope, and identification guides, as well as support an invertebrate survey with a scientist from Woods Hole Oceanographic Institution. Observing biodiversity within the Pond will elucidate links in the food chain, providing important data on the food sources of fish and shellfish. Additionally, monitoring the seasonal changes in plankton and fish species composition, abundance, and distribution will further enhance GPF's internship and outreach programs, providing valuable skills to young scientists and local students. With the ability to collect data on biodiversity, GPF can now assess long-term estuary health. By investigating biodiversity and water quality simultaneously, GPF will have a more thorough understanding of how variations in physical properties of the water influence the community of living organisms.

Appendix

Glossary of Water Quality Parameters

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.

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. The GPF management threshold is **15 ppt**, which is the lowest salinity in which eelgrass can survive.

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.

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.

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**.

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 EGP, nitrate and ammonium have been elevated in the past and are monitored closely, with a management goal of keeping total nitrogen (TN) to **0.5 mg/L** of nitrogen or less.

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 EGP and set the management goal of **0.5 mg/L TN**.

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.

Ammonium (NH_4^+): Ammonium is a nutrient that 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.

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.

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.

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