2021

ECOSYSTEM MONITORING REPORT

CRACKATUXET POND

GREAT POND FOUNDATION

Ecosystem Monitoring Report – Crackatuxet Pond

Executive Summary

Crackatuxet Pond is a 33-acre pond located in Edgartown, Massachusetts. Historically, Crackatuxet Cove was part of Edgartown Great Pond (EGP), however this connection has become limited due to the installation of a sluiceway in the 1970's. While there is some groundwater exchange between Edgartown Great Pond and Crackatuxet, these two bodies of water have evolved as independent ecosystems since the installation of the sluiceway. Given that these two waterways are managed as separate ecosystems, Crackatuxet Cove is referred to as Crackatuxet Pond (CRX) in this report. The sluiceway is vital for water lever control in CRX and EGP and due to nutrient loading in the watershed, water should only flow from EGP to Crackatuxet (west to east) across the sluiceway.

Overall, CRX is suffering from a myriad of water quality issues, and monitoring results indicate that eutrophication is occurring. These factors ultimately decreased habitat quality, limiting biodiversity and reducing ecosystem health. The primary source of impairment in CRX is due to excess nitrogen, likely introduced via septic systems and fertilizer use on properties within the watershed.

Most notably, CRX showed signs of impairment due to low dissolved oxygen. There was a clear seasonal trend, where dissolved oxygen was reduced across all depths at all sampling stations during the summer months. Two stations, CRX1 and CRX3, experienced hypoxia at bottom depths, where dissolved oxygen dropped below 2 mg/L, which can cause harm to plants and animals. A dissolved oxygen data logger detected long periods of hypoxia and even anoxia (oxygen of 0 mg/L) at station CRX1, indicating that bottom waters were inhospitable for most organisms. Additionally, nutrient concentrations, particularly nitrogen, were elevated in CRX. Total nitrogen values were above the 0.5 mg/L management threshold for the majority of the monitoring period, reaching their highest levels in August. Similarly, chlorophyll-a was above the 10 µg/L threshold at least once at all CRX sampling stations. Moreover, all CRX sampling stations exhibited nutrient and chlorophyll concentrations above the nearest EGP station. CRX was also included in the first year of the Martha's Vineyard Cyanobacteria Monitoring Program (MV CYANO). All CRX sampling stations had at least one sample classified in the orange category, or "BLOOM WATCH" risk level, with cyanobacteria abundance peaking on August 27. CRX is at an increased risk of cyanobacteria blooms compared to EGP and other south shore ponds of Martha's Vineyard.

Crax Ecosystem Health:

- Dissolved O_2 – POOR
- pH 6.5 – 8.5. – GOOD
- Temperature – GOOD
- Transparency – POOR < than ideal
- Total nitrogen : POOR 0.6 – 1.6 mg/L
- Chlorophyll-a pigments: POOR > 9 – 90 µg/L

2021 Ecosystem Monitoring Data

Overview of Ecosystem Monitoring Program

Great Pond Foundation (GPF) began monitoring the water quality and ecosystem health of Crackatuxet Cove in November 2020, as part of a one-year monitoring plan. The sampling regime consisted of 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.

Crackatuxet Cove is a 33-acre pond located in Edgartown, Massachusetts. Historically, Crackatuxet Cove was considered part of Edgartown Great Pond (EGP). A direct connection to Katama Bay also existed, allowing water to flow between EGP, Crackatuxet Cove, and Katama Bay via the Mattakesett Herring Creek. However, these connections have been restricted by sand buildup and growth of invasive species, despite numerous attempts to restart water flow in recent history. Most recently, the 2002 Herring Creek Restoration Project returned the cement sluiceway, originally built in the 1970's, to full functionality. The reconstruction of the sluiceway allowed for control of pond height by manipulation of wooden boards, which restrict water flow between EGP and Crackatuxet Cove. This allows the water level of EGP to be controlled between openings to ensure successful pond cuts, while allowing EGP to be drained if needed due to weather events and extreme flooding. An operational sluiceway can also be used as a nutrient management tool, as water levels can be adjusted to time EGP openings to maximize nutrient level reduction, since high-nutrient pond waters are flushed away with ocean water after a successful cut (MEP, 2007). In addition to water level control in Crackatuxet and EGP and stormwater management, the sluiceway is important for maintaining salinity, and due to nutrient loading in the watershed, water should only flow from EGP to Crackatuxet (west to east) across the sluiceway, not the reverse (Gaines, 1993).

Since the 2002 sluiceway restoration, sand has shoaled around the sluiceway which restricts waterflow. Additionally, the boards of the sluiceway are usually kept in place, further blocking waterflow between the two waterways. Control of pond water levels due to placement of the boards in the sluiceway, as well as the timing and scheduling of EGP pond cuts is the responsibility of the Town of Edgartown Shellfish Department. Due to the repeated shoaling and the management of the sluiceway to restrict water flow, the two ponds have become separate ecosystems. Because of this separation, while Crackatuxet Cove is the name historically used, it will be referred to as Crackatuxet Pond (CRX) in this report.

Data collection was centered on 5 sampling stations throughout the Pond (Figure 1). These water sampling stations cover all aspects of the ecosystem: from adjacent to the barrier beach, in front of the sluiceway and Herring Creek, and the northern parts of the pond. At each station parameters such as temperature, salinity, dissolved oxygen, pH, water clarity and turbidity are measured throughout the entire water column (see Glossary in Appendix for explanations of parameters). Additionally, concentrations of nutrients such as nitrate, phosphate, and ammonium are analyzed at these stations on select sampling days. These parameters are regularly used to assess impairment and ecosystem health.

The 2021 field season began on May 20 and the last water sampling collection occurred on October 25. During this 23-week monitoring period, the Scientific Program Manager, Watershed Outreach Manager, and interns collected water samples approximately every two weeks. There were 13 sampling days across 6 months (see table, below), providing a relatively high-resolution dataset from the end of spring to the end of fall with over 1200 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, yet the cold weather also limits biological activity making regular sampling unnecessary. In addition to sampling during site visits, GPF installed dissolved oxygen, salinity, and water level sensors that continuously monitor these parameters, further enhancing GPF's ability to monitor water quality in the Pond. These sensors were located at station CRX1. These data loggers were deployed on June 8 and collected data every half hour until they were removed from the water on October 25. A water level logger was installed on June 4 and remains installed, as pond elevation is important to monitor year-round. These data can help answer questions about the health of the Pond and add to the growing water quality database in Crackatuxet Pond.

Figure 1. Map of the five Crackatuxet Pond (CRX) sampling stations. The location of the sluiceway and the Mattakesett Herring Creek is noted.

2021 Dates of Site Visits to Crackatuxet Pond					
May	**June**	**July**	**August**	**September**	**October**
5/20	6/8	7/8	8/5	9/1	10/7
	6/23	7/14	8/10	9/17	10/25
		7/21	8/27		

Pond Elevation

- *CRX is hydrologically connected to EGP via groundwater, as the water level of CRX lowered after EGP was cut to the ocean on 8/7/21, despite being physically separate.*
- *The boards to the sluiceway were unexpectedly removed around 6/22/22, allowing water from EGP to flow into the Pond for at least 2 weeks, impacting the water level of the two ponds.*
- *CRX pond elevation responded rapidly to large rain events.*

The elevation of Crackatuxet Pond was continuously monitored via a water level logger deployed in the Pond. This data logger measures pond height relative to sea level and collects data every 30 minutes (Figure 2). The water level logger was installed in the beginning of June and remains deployed continuously collecting pond elevation data. This data logger is a crucial tool in understanding how water level is impacted by rainfall and how the Pond responds to changes in the water level of EGP.

CRX is connected to EGP via the sluiceway, however this connection is intentionally closed via the placement of wooden boards inside the sluiceway to prevent CRX water from flowing into EGP. Additionally, sand has shoaled around the sluiceway in EGP, which further blocks water exchange when the elevation of EGP is low. However, CRX remains hydrologically connected to EGP, meaning water can flow underground between the two ponds. This becomes evident when EGP is cut and drains into the ocean, as CRX elevation subsequently decreases. CRX is also connected to Katama Bay via Herring Creek, although the degree of exchange is currently unmonitored.

However, the hydrologic connection to EGP was not limited to groundwater in 2021. GPF observed an anomaly in water level measurements in EGP and CRX in late June which suggested that water was flowing between the two ponds through the sluiceway. A GPF site visit to the sluiceway on July 9 confirmed that boards were missing in the sluiceway. This was immediately brought to the attention of the Edgartown Shellfish Department, who reinstalled the boards on July 10. Data from the water level loggers indicate that these boards were removed on approximately June 22, resulting in at least 2 weeks of surface water exchange with EGP (red box in Figure 2). Since the elevation of EGP was high, around 2.8 feet above sea level, this resulted in EGP draining into CRX. The drainage of EGP into CRX caused EGP to lose approximately 0.75 feet of elevation, which delayed the summer opening of EGP.

Once the boards were reinstalled by the Shellfish Department, water exchange between the two ponds was cut off. This resulted in a precipitous drop in Crax water level, from approximately 2.75 feet to less than 2 feet (Figure 2). EGP is a much larger pond with a significantly larger watershed compared to CRX. Without this steady supply of water, the CRX water level dropped, likely by draining into Katama Bay via Herring Creek. However, this cannot be confirmed because water flow in Herring Creek is not monitored.

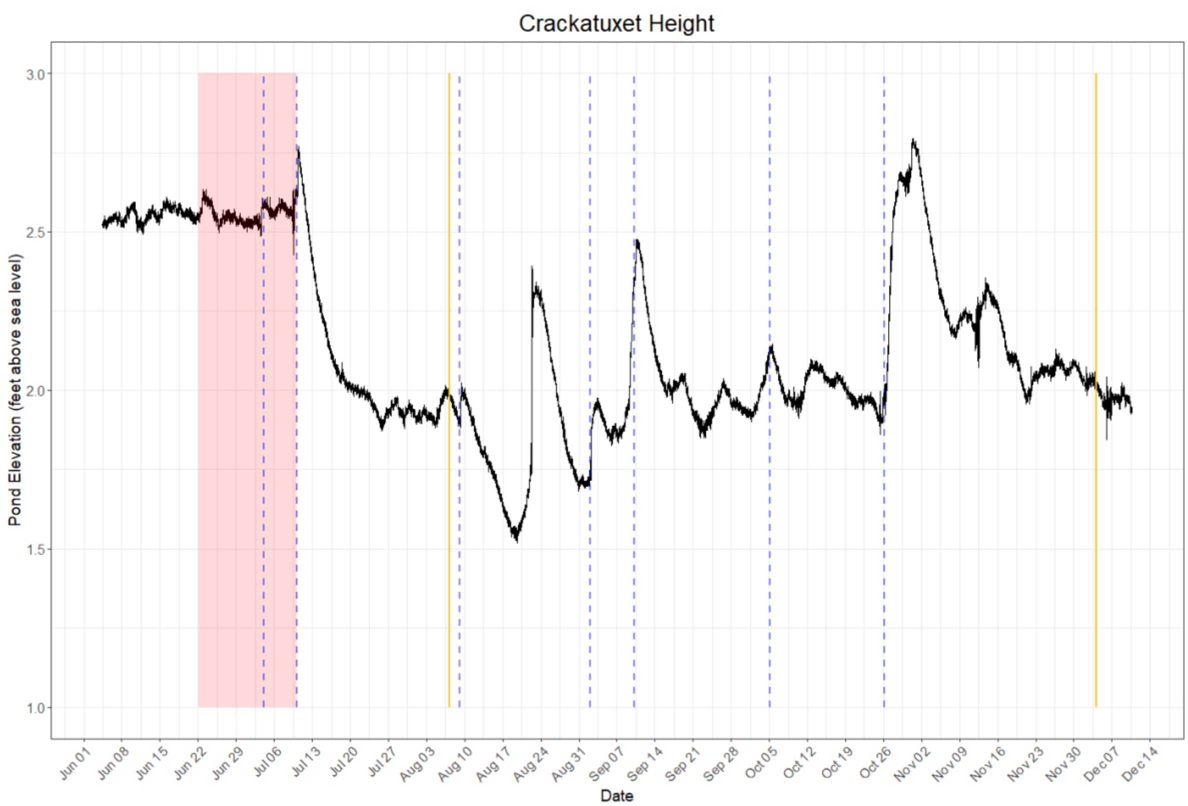

Figure 2. Pond elevation of Crackatuxet Pond in 2021. Data were generated by a water level logger on the northwest shore of the Pond. The solid yellow lines are when EGP was cut to the ocean. The dashed blue lines are when precipitation exceed 1 inch. The red box indicates when the boards to the sluiceway were removed.

Water level in CRX dropped again when EGP was opened to the ocean on August 7 (yellow line in Figure 2). This caused water elevation to drop nearly 0.5 feet over the course of two weeks. As a pond with a smaller volume of water, CRX is highly influenced by changes in water level in EGP. Additionally, rainfall events had a large impact on water elevation in CRX. Each time precipitation exceeded 1 inch (blue dashed lines in Figure 2), CRX water height subsequently increased, often significantly. Rain events totaling less than 1” in precipitation also impacted the Pond’s elevation, however these are not marked on Figure 2. Each spike in pond height is followed by a drop, suggesting the surge of water is flowing out of the pond. To further understand where this water is flowing, a detailed hydrologic study of the area is needed. 2021 was the first year that GPF monitored Crax water height, therefore comparisons to previous years cannot be made.

Salinity

- *Salinity was consistent across the 5 CRX sampling stations, with deeper stations exhibiting more vertical variation within the water column than shallow stations.*
- *Salinity ranged from 8.73-19.6 ppt throughout the sampling season. There were significant changes in salinity when EGP was cut, when the boards to the sluiceway were removed, and when large rain events occurred.*

Salinity is a measure of how much salt is dissolved in water, measured in parts per thousand (tap water = 0 parts per thousand (ppt), ocean water = 34 ppt). Salinity is important to monitor because it can be an indicator of the hydrology of Crackatuxet Pond, or how water flows in and out of the Pond both above and below ground. While the Pond is never intentionally opened to the ocean, some salt water can enter via wash-over events from the ocean, salt spray from waves, or through seepage under the dunes. Additionally, the extent of exchange with Katama Bay via the Herring Creek is unknown. Similarly, while the sluiceway blocks direct exchange with Edgartown Great Pond, it is likely that some connection occurs via groundwater.

Salinity ranged from 8.73 ppt to 19.6 ppt (Figure 3). The lowest salinity was observed in May, where surface salinity was below 10 ppt at all stations. On this sampling day, stratification of the water was particularly pronounced. Stratification, or the existence of horizontal layers in the water, occurs due to differences in density caused by differences in salinity and temperature. Saltwater is denser than freshwater, which causes it to sink below the more buoyant, fresher water. This is evident at stations CRX1- 4 on May 20.

A rapid increase in salinity occurred between May 20 and July 8. During this time, the boards to the sluiceway were unexpectedly removed and water from EGP flowed into CRX. In June the salinity of EGP was 21 ppt, high enough to alter the salinity of CRX. No cuts to EGP occurred during this time, and the connection to Katama Bay via the Herring Creek did not change, suggesting that the increase in salinity in CRX was due to influx of higher-salinity EGP water. Furthermore, once the sluiceway boards were reinstalled on July 10, salinity in CRX began to drop again. This indicates that the source of saltier water (i.e. EGP) was cut off.

A second spike in salinity occurred on Aug 27 (Figure 3). This coincided with the EGP opening to the ocean, which was on August 7. Salinity jumped from around 14 ppt on the August 5 sample collection, to upwards of 18 ppt on August 27. As the sluiceway boards were fully installed, this rise in salinity indicates that CRX and EGP are hydrologically connected and water flow occurred underground. This exchange of water underground is likely slow, as the salinity in CRX jumped 4 ppt over 20 days, whereas the salinity in nearby stations of EGP jumped 15 ppt in 6 days after the cut.

Overall, all 5 stations had similar salinity trends. Stations CRX4 and CRX5 had slightly lower salinity measurements, however this was minimal. Station CRX3 is located closest to the ocean, and its similarity to other stations suggests that the ocean had a minimal impact on the salinity. The proximity to EGP, which often has higher salinity than CRX, likely influences salinity more than proximity to the ocean. Salinity was also impacted by rain, which lowered the salinity after large rain events (Figure 4). The continuously operated salinity sensor detected changes caused by rainfall, where salinity decreased by as much as 3 ppt.

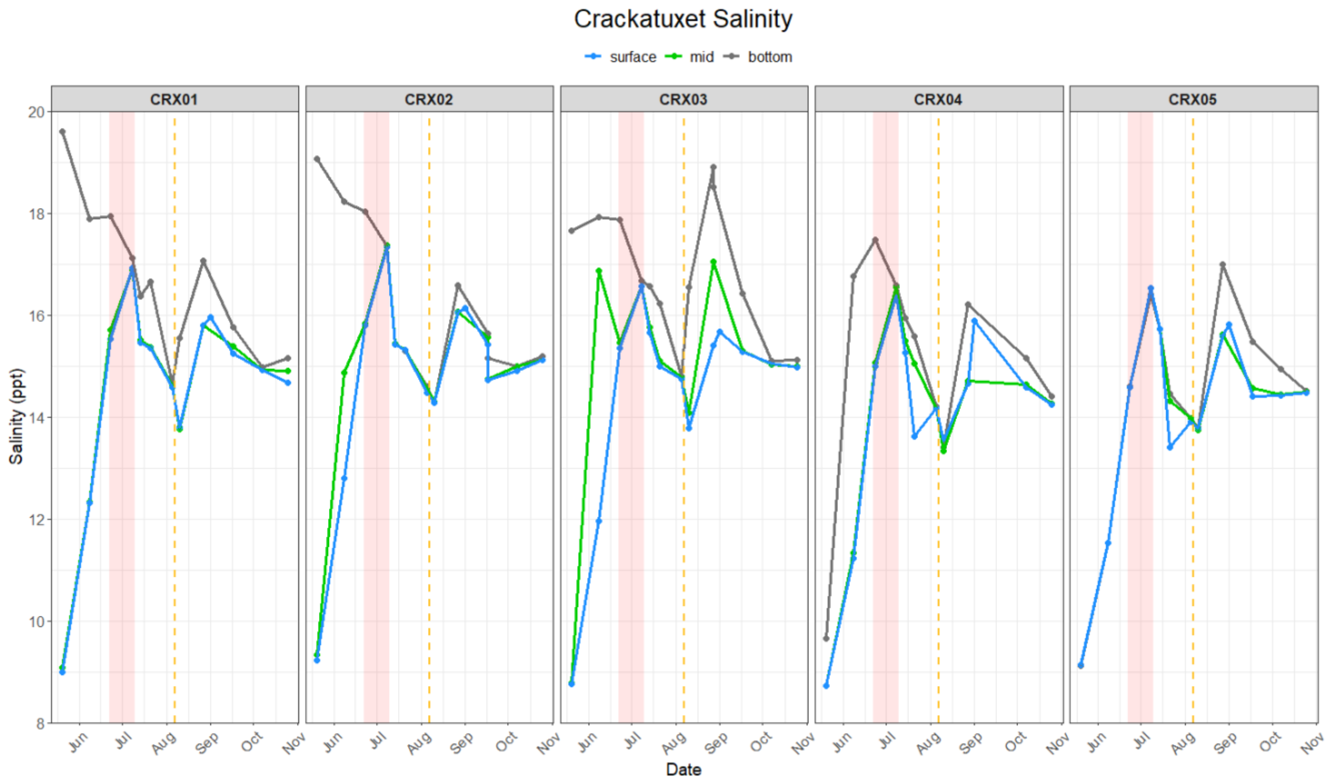

Figure 3. Salinity in parts per thousand (ppt) in Crackatuxet Pond in 2021. Data were measured with a handheld probe at the surface, mid-depth and bottom water, represented by different colors, at 5 sampling stations (different columns). The dashed yellow line is when EGP was cut to the ocean. The red box indicates when the boards of the sluiceway were removed.

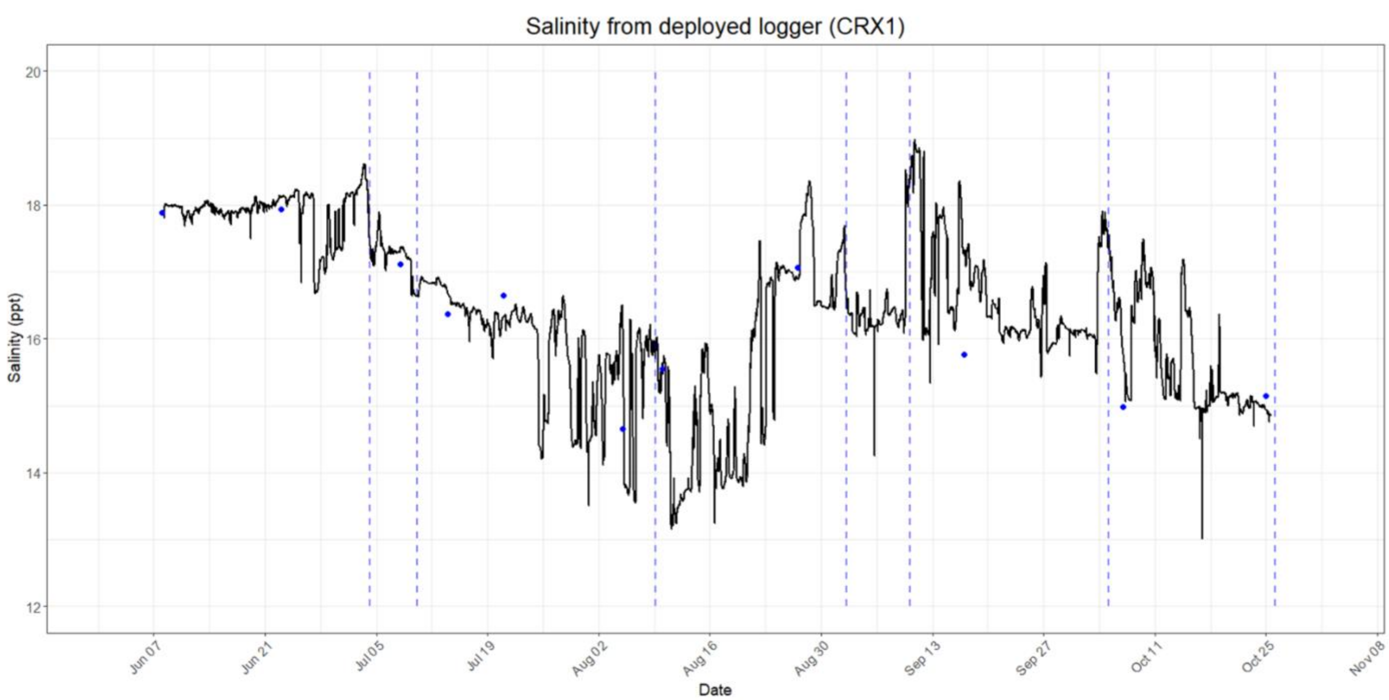

Figure 4. Salinity in parts per thousand (ppt) at station in 2021. Data were measured with a conductivity/salinity data logger deployed at station CRX1. Dashed blue lines are when precipitation exceeded 1 inch. Blue dots are salinity measured with a handheld probe during site visits.

Temperature

- *Water temperature at all 5 sampling stations remained below the 85°F threshold for ecosystem health throughout the summer season.*
- *Maximum water temperature was 82.6°F on 8/12/21.*

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 CRX management goal is to maintain water temperatures of 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.

Temperature was measured throughout the water column at all stations across the Pond during site visits. Additionally, bottom water temperature was continuously monitored with a temperature sensor attached to the dissolved oxygen data logger. Maximum water temperature occurred on August 12, where temperatures reached 82.6°F (Figure 5). The site visits on August 27 and July 21 were also noteworthy, with temperatures for both days reaching 80°F. All the stations were very similar in temperature and exhibited the same seasonal trend (Figure 5A).

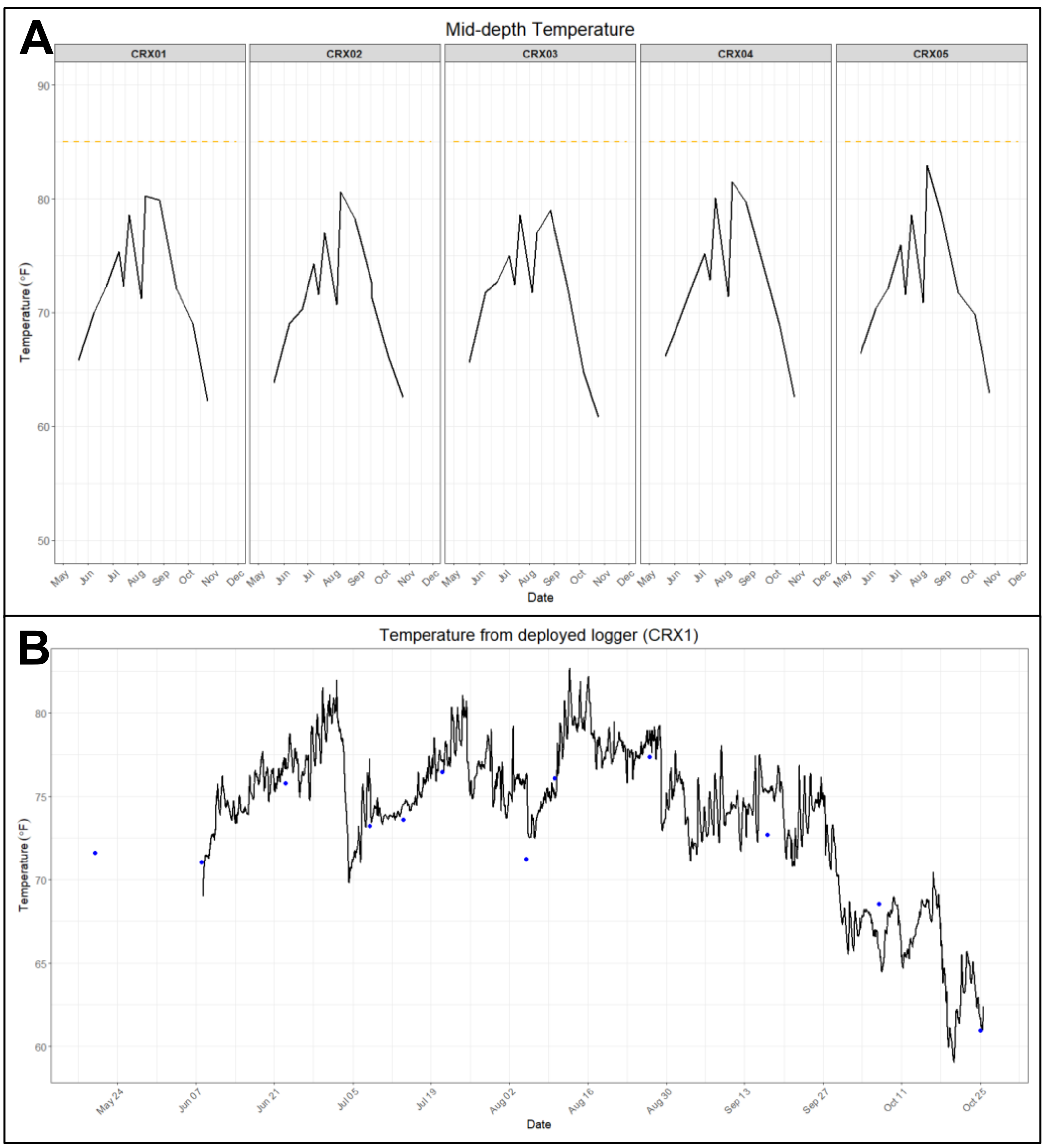

Figure 5. Water temperature in Crackatuxet Pond in 2021. (A) Temperature measured by a handheld probe at mid-depth at all stations. The dashed yellow line is the 85°F management threshold. (B) Temperature measured via a data logger deployed on the bottom at station CRX1. Blue dots are temperature measured by a handheld probe during site visits.

It is noteworthy that water temperature never exceeded the 85°F threshold. Even in the dataset from the deployed data logger, the maximum temperature was 82.6°F (Figure 5B). Small, shallow ponds such as Crackatuxet Pond often suffer from elevated temperatures in the summer. The health of CRX likely benefited from water temperatures that remained below 85°F.

Dissolved Oxygen

- *There was a clear seasonal trend, where dissolved oxygen at all depths was reduced during the hot summer months at all sampling stations.*
- *Stations CRX1 & CRX3 experienced hypoxic conditions at bottom depths, where dissolved oxygen dropped below 2 mg/L, potentially causing harm to plants and animals.*
- *The dissolved oxygen data logger detected long periods of hypoxia and even anoxia at station CRX1, indicating the bottom waters were inhospitable for most organisms.*

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 CRX1, which continuously logged the amount of oxygen in the water in 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 because most organisms require oxygen as part of their metabolism.

The Massachusetts Estuaries Project (MEP) management target for heathy ponds is 6 mg/L. 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 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 CRX2 & CRX5 sites (Figure 6). This gradient was more severe during the summer season, as the pond experienced the hottest temperatures of the year.

There was a clear seasonal trend, where DO at all depths was reduced during the hot summer months. Between July and September, all stations experienced DO concentrations which dropped below the 6 mg/L threshold at least once (Figure 6). Most often this was limited to measurements taken at the bottom 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 stations CRX1, CRX3, and CRX4 at least twice during the summer. At CRX1 and CRX3, bottom water occasionally became hypoxic, where DO dropped below 2 mg/L. These oxygen depletions are indicators of impairment and suggest this is an environment inhospitable to most aquatic life.

The DO data logger was deployed at station CRX1 on June 8 and collected measurements every half hour until October 25. 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 in order to better describe the severity of oxygen depletion. Data from this logger indicate that there were large daily fluctuations in DO during the spring and fall, and long periods of near total oxygen depletion during the summer (Figure 7). During these low oxygen events, the data logger was reading DO close to 0 mg/L. The handheld probe often had DO measurements that were higher than the logger, however this was likely due to differences in measurement depth and the difficulties of precisely collecting data from a kayak. For most of the site visits, the DO measurements from the handheld probe and the data logger were similar.

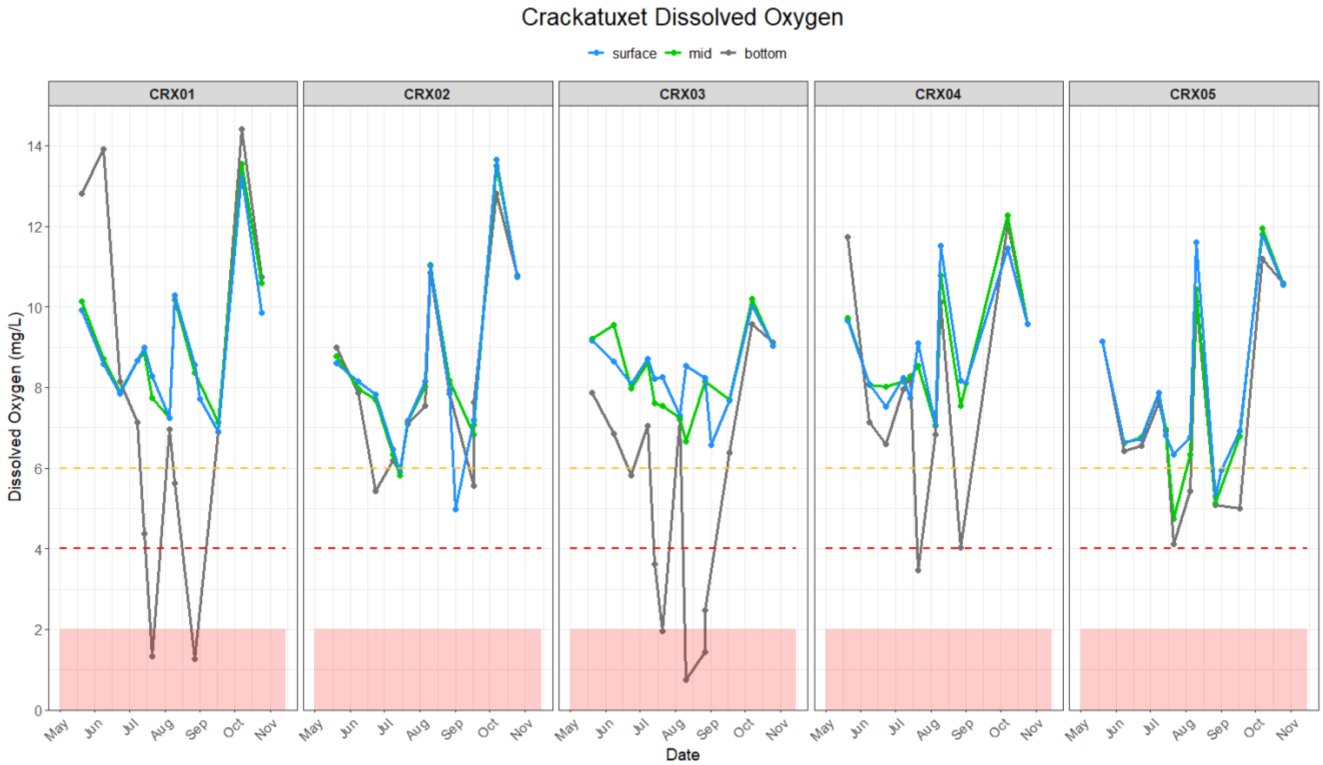

Figure 6. Dissolved oxygen (DO) measured in milligrams per liter (mg/L) in Crackatuxet Pond in 2021. Data were measured with a handheld probe at the surface, mid-depth and bottom water at 5 sampling stations. The dashed yellow line is the 6 mg/L management target, and the red dashed line represents when DO was critically low, below 4 mg/L. The red box indicates when hypoxia was occurring, with DO < 2 mg/L.

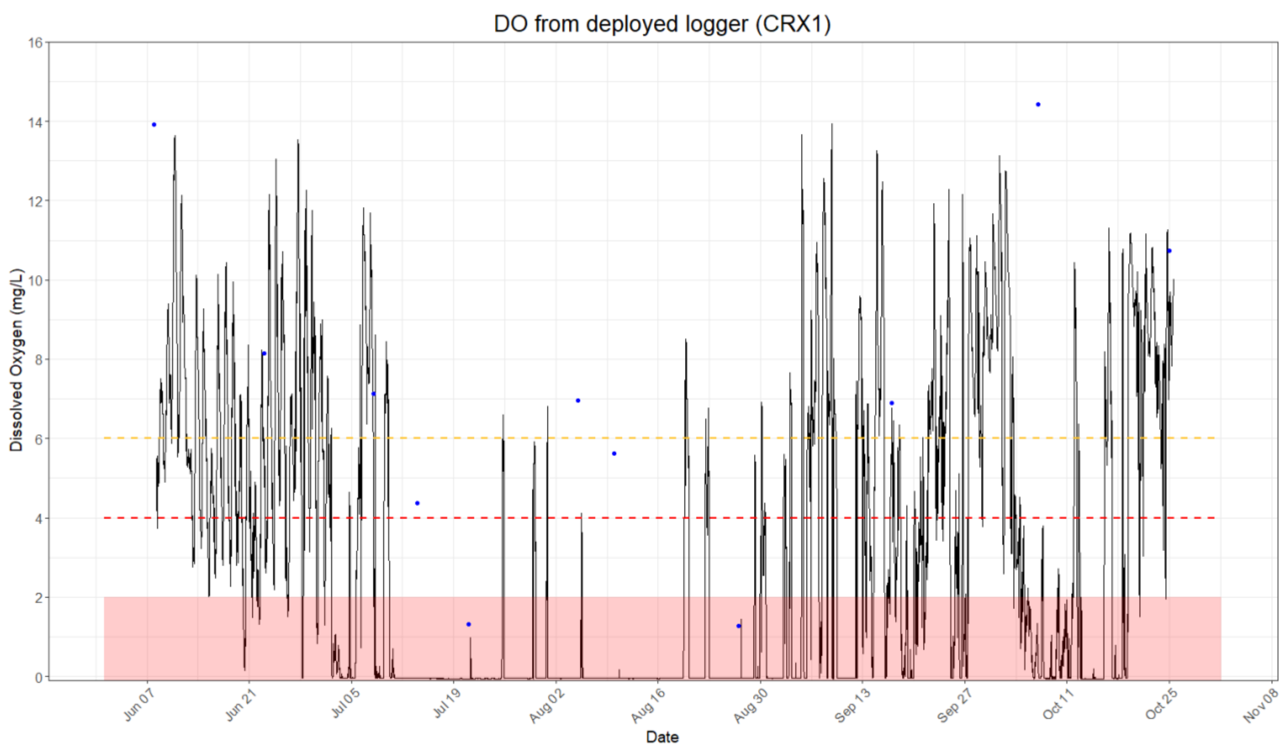

Figure 7. Dissolved oxygen (DO) at station CRX1 in 2021. Data were measured with a data logger deployed approximately 3 inches from the pond bottom. The dashed yellow line is the 6 mg/L management target, and the red dashed line represents when DO was critically low, below 4 mg/L. The red box indicates when hypoxia was occurring, with DO < 2 mg/L. Blue dots are DO measured by a handheld probe during site visits.

These results indicate that while the majority of the water column retained sufficient oxygen concentrations, the near-bottom portions were consistently depleted. The low DO readings from the data logger are especially concerning, as this suggests that the bottom of the pond suffers from long 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 mount and housing are designed to prevent the device from sinking into the sediment. Therefore, these low DO readings are representative of the near-bottom portion of the water column and indicate the presence of an unusually large anoxic zone above the sediment layer. This is further corroborated by the observed absence of attached fouling organisms, such as barnacles and tunicates, on the data logger housings during routine maintenance. In other ponds, these housings were typically covered with these fouling organisms. These animals require oxygen and likely could not survive in the oxygen-depleted bottom waters of Crackatuxet Pond.

The duration of hypoxic conditions in the bottom water was surprising, given the density of aquatic vegetation in CRX. GPF did not actively identify these plants, however passive observation suggests they are likely a combination of widgeon grass (*Ruppia maritima*) and possibly milfoil (*Myriophyllum* sp). These plants thrive in freshwater and brackish marine habitats and are known to expand rapidly and aggressively under favorable conditions. It is possible that the high density of these aquatic plants hinder or prevent the movement and mixing of bottom waters with oxygen-rich surface water. Oxygen is produced at the surface, but wind-mixing and diffusion may have been blocked by the thick canopy of the aquatic plants. Similar phenomena have been observed in other ponds (Unmuth et al., 2000).

The extent of hypoxic conditions throughout the bottom waters of the pond are unknown due to the limited number of deployed, continuous DO sensors available for this study. Hypoxia was also observed at CRX3, the deepest station, but probe data from other stations did not detect DO below 2 mg/L at any other station. Additionally, the DO logger shows there were large daily fluctuations in DO in the beginning and end of the summer. It is normal for DO within a pond to fluctuate daily, as oxygen is only produced by plants during the day, causing a decline in DO at night. However, a healthy ecosystem will maintain adequate levels of oxygen in the water throughout the night and will be able to balance out any extreme variations. The large fluctuations that occurred are an indicator of impairment.

Overall, these data indicate that CRX is a struggling ecosystem, such that habitat quality is severely impacted, especially on the bottom of the pond. Organisms that cannot move to areas of higher oxygen, such as shellfish, are not likely to survive.

Water Clarity

- *Visibility was usually at least 2.5 feet, however the water was frequently too murky to see the pond bottom.*
- *Station CRX3 was the deepest station and often 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 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. Vegetation requires sunlight to photosynthesize, which 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 and other microscopic organisms that often reproduce quickly and make 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 land 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 into the water. The depth at which it disappears from view corresponds to the depth at which the water turbidity is too high for light to reach plants and animals. A typical management goal for Secchi depth is 3 meters (9.8 feet), or the bottom of the body of water. Crackatuxet Pond is less than 3 meters deep, so adequate Secchi depth would be the bottom of the pond, or total depth at the sampling site.

Water clarity in CRX varied depending on the location within the pond. Visibility was usually at least 2.5 feet, as measured by a Secchi disk (Figure 8). However, measuring water clarity was complicated due to the vegetation in the pond. Stations CRX1, CRX4, and CRX5 were particularly thick with vegetation. The presence of aquatic plants restricted visibility through the water column, as the canopy blocked sight of the bottom and anything beneath the plants. Station CRX2 was exceptionally shallow and the bottom of the pond was consistently visible. Station CRX3 had the greatest depth and often experienced elevated turbidity and reduced water clarity. Stations CRX1 and CRX4 were also repeatedly too murky too see the bottom. Most of these high turbidity days occurred in late-spring and late-summer, which can likely be attributed to hotter temperatures and increased nutrient inputs from surrounding properties via surface water runoff.

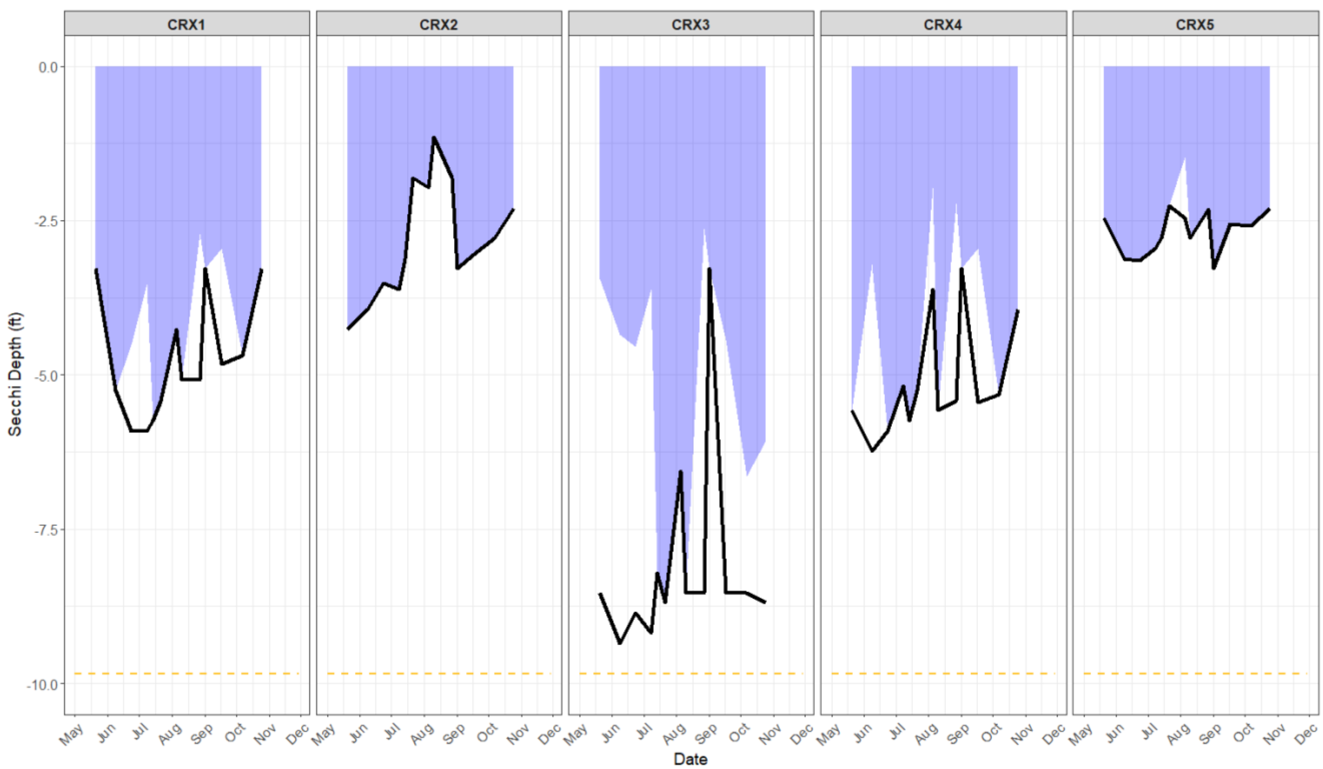

Figure 8. Secchi depth and total depth in feet at each sampling station in Crackatuxet Pond in 2021. Secchi depth is the depth at which a standardized disk disappears from sight, which often corresponds to total depth. Total depth in the figure is the thick black line, and Secchi depth is the blue shaded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

Nutrient Concentrations

- *Nutrient concentrations, particularly nitrogen concentrations, were elevated in CRX. Excess nutrients cause eutrophication, which reduces water quality and ecosystem health.*
- *Total nitrogen values in CRX were above the 0.5 mg/L management target for the majority of the monitoring period, peaking in August.*
- *All CRX stations exhibited the same trends with no single station notably higher in nutrient concentrations. However, all had nutrient levels above the nearest EGP station.*
- *Chlorophyll-a was above the 10 µg/L threshold at least once at all CRX sampling stations, peaking during the summer months.*

GPF collected samples to measure the concentrations of phosphate, nitrate, ammonium, as well as chlorophyll pigments in Crackatuxet 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 and human development. Measuring the concentration of nutrients in the water can indicate if eutrophication is occurring. Brackish coastal ecosystems often exhibit an excess 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.

Overall, nutrient concentrations in CRX were elevated, particularly 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 Massachusetts Estuaries Project study on EGP used this threshold, where values under 0.5 mg/L are needed to avoid impairment. In absence of a threshold specific to CRX, the EGP TN target of 0.5 mg/L was used. TN values in CRX were above the 0.5 mg/L threshold for the majority of the monitoring period (Figure 9). The lowest TN recorded was 0.47 mg/L, which occurred on 7/14/2021 at stations CRX3 and CRX4, while the highest TN value was 1.7 mg/L at station CRX5 on 10/7/2021. However, this measurement is unexpectedly high and could potentially be the result of an anomaly in the sampling procedure. Outside of this outlier, the highest TN concentration occurred on 8/10/21 at CRX3, of 0.93 mg/L.

Excluding the outlier at CRX5 on October 7, all Crackatuxet stations followed the same trend and no single station exhibited notably higher nutrient pollution. TN measurements at all stations peaked on August 10, with lower TN values earlier in the summer and in the fall. Regardless of the time of year, all CRX stations had elevated nitrogen levels. With the exception of two measurements of 0.47 mg/L, all other measurements were above the 0.5 mg/L threshold. This indicates that eutrophication is occurring and that the ecosystem is impaired.

Total nitrogen values can be compared to values in EGP, specifically at station EGP6, which is adjacent to the CRX sluiceway (see map in Appendix). All TN measurements for EGP6 were below the 0.5 mg/L threshold (Figure 9). Nutrient concentrations in EGP are reduced after the pond is opened to the ocean, and the August cut likely influenced TN levels at EGP6. Regardless, these nutrient data indicate that Crackatuxet Pond experiences a higher nitrogen load than the adjacent region of EGP.

Additionally, chlorophyll pigments were elevated in Crackatuxet in 2021 (Figure 10). 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. 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 only the results from the Woods Hole laboratory are included in this report.

The Massachusetts Estuary Report (MEP) determined that the management target for EGP was 10 µg/L of chlorophyll-a. This threshold is commonly used for coastal ponds, as chlorophyll-a can be an indicator for nutrient pollution. Chlorophyll-a was above this 10 µg/L threshold at least once at all CRX sampling stations (Figure 10). Chlorophyll-a concentrations were highest during July and August. This was expected due to hotter temperatures and increased nutrient inputs from surrounding properties. The maximum observed chlorophyll-a concentration was 62.15 µg/L at station CRX5. This measurement is uncharacteristically high compared to other stations that day, suggesting an anomaly in the sampling procedure. Outside of this outlier, the highest chlorophyll-a concentration was 33.6 µg/L on July 14 at CRX3. Early summer and fall chlorophyll-a measurements were below the 10 µg/L target at all stations. While CRX stations were occasionally below this target, comparison to the closest EGP station shows that Crackatuxet experiences more phytoplankton blooms and thus higher chlorophyll levels than the adjacent region of EGP.

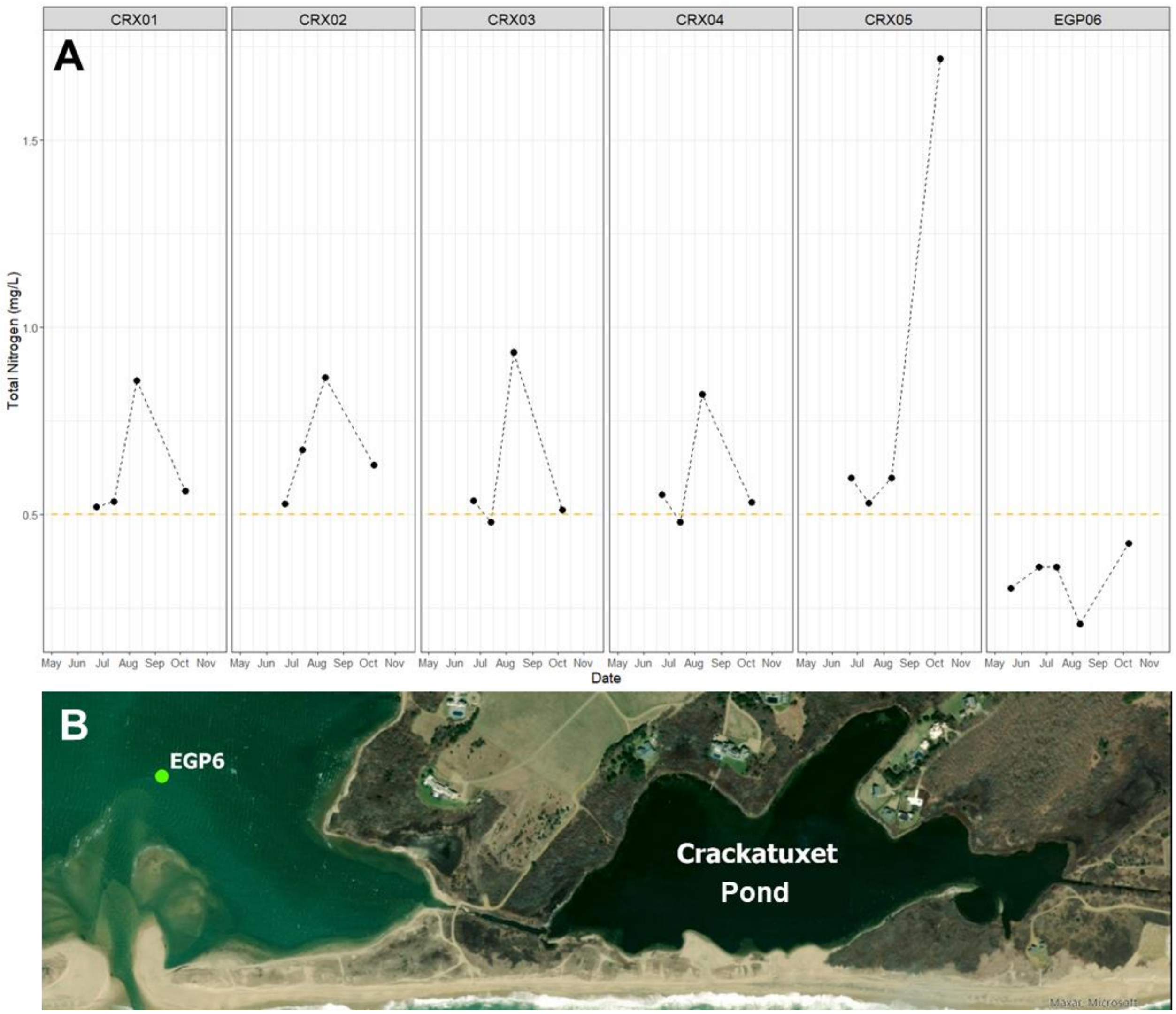

Figure 9. Total nitrogen in milligrams per liter (mg/L) in 2021. Data are from all 5 CRX sampling stations and station EGP6 for comparison (map in panel B). The dashed yellow line represents the 0.5 mg/L management target for healthy coastal ponds.

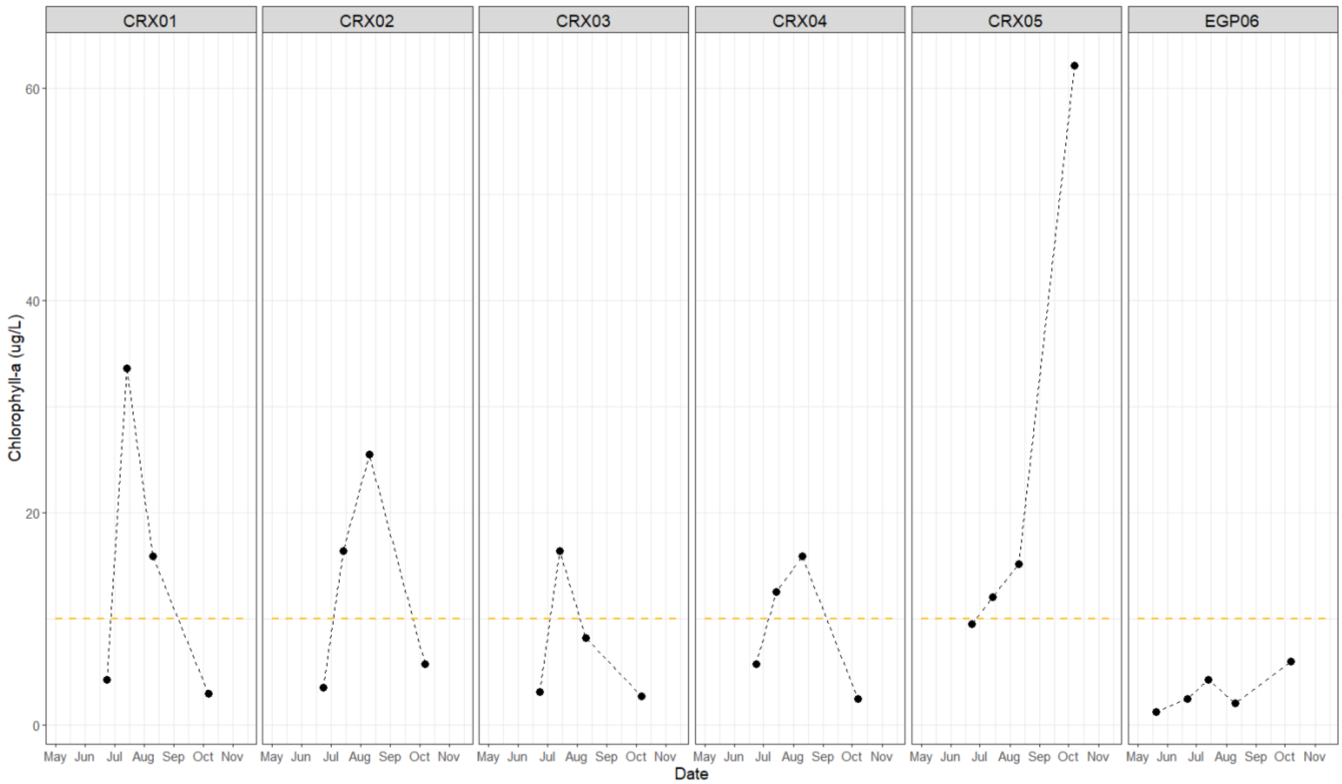

Figure 10. Chlorophyll-a pigments in micrograms per liter (µg/L) in 2021. Data are from all 5 CRX sampling stations and station EGP6 for comparison (see Appendix for map). The dashed yellow line represents the 10 µg/L management target for healthy coastal ponds.

MV CYANO

- *All CRX sampling stations had at least one sample classified in the orange category, or "BLOOM WATCH" risk level.*
- *CRX is at an increased risk of cyanobacteria blooms compared to EGP and other nearby ponds.*

Crackatuxet 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, can 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 (see 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 identify 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 the majority of the monitoring period, CRX water samples were in the yellow category, corresponding to the "ALERT" risk level (Figure 11). This classification indicates that environmental conditions could support rapid growth of cyanobacteria and that a bloom is possible but not present. All CRX sampling stations had at least one sample 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. Samples in the orange category may be sent to an external laboratory for toxin analysis and quantification. Cyanobacteria abundance in CRX samples was highest on August 27, peaking at nearly 35 µg/L at station CRX3. These samples would have qualified for toxin analysis, however logistical issues prevented further analysis in this instance. For comparison, most EGP sampling stations were in the green MV CYANO category for the duration of the field season, indicating that no cyanobacteria were present. Further, cyanobacteria concentrations in CRX were routinely higher than any other pond in the MV CYANO monitoring program, outside of bloom conditions.

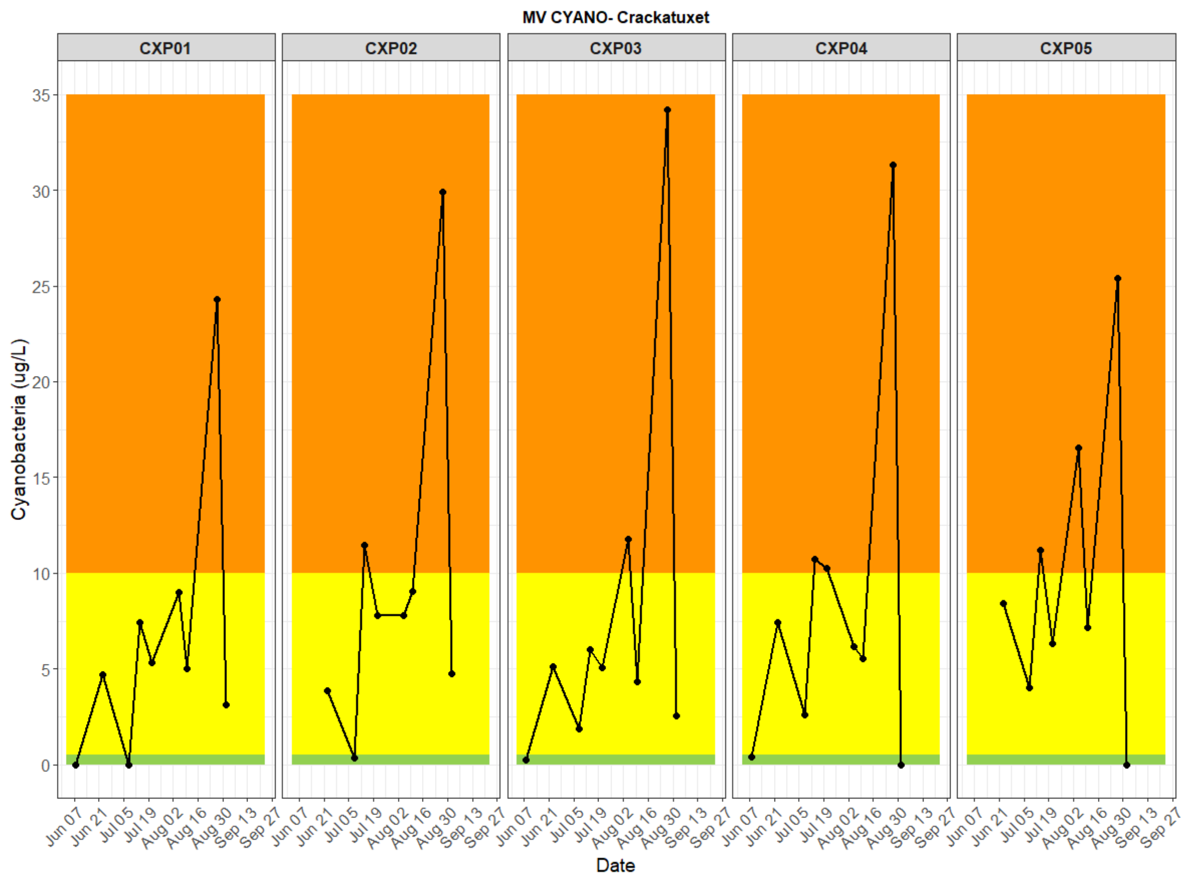

Figure 11. Cyanobacteria concentrations in micrograms per liter (µg/L) at all CRX stations in 2021. Samples were taken from surface waters and measurements were obtained via a fluorometer. Background colors correspond to the color-coded risk matrix used by the MV CYNAO monitoring program (see Appendix).

Conclusions

Overall, Crackatuxet Pond is suffering from a myriad of water quality issues, including low dissolved oxygen and elevated chlorophyll and nitrogen concentrations within the water column. Cyanobacteria, a potentially harmful variety of bacteria, were found at levels higher than other nearby ponds, although no cyanobacteria blooms were observed. Additionally, water clarity occasionally fell below recommended limits during monitoring. These factors ultimately decreased habitat quality, limiting biodiversity and reducing ecosystem health.

Monitoring results indicate that eutrophication, or excess nutrient concentrations, is occurring. The primary source of impairment in CRX is due to nitrogen loading. 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 CRX was particularly threatening, as critically low levels of oxygen were detected in bottom water. A reduction in the inputs of nitrogen would help reduce these impairments. These nutrients mostly enter the pond via surface water and groundwater, where they initially are introduced to the environment from septic systems and fertilizers. Additionally, an increase in circulation and flushing may alleviate these problems. However, introducing high-nutrient waters into either Edgartown Great Pond or Katama Bay may have negative impacts on the water quality of those ecosystems. Previous studies have recommended that water flow from EGP into CRX and drain into Katama Bay based on higher nutrient concentrations in CRX and Herring Creek (Gaines, 1993). Results from GPF's monitoring indicate nutrient concentrations remain a concern in CRX, and thus drainage of CRX into EGP should be avoided.

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 may identify nitrogen hotspots within the watershed.

Regardless of the water quality within Crackatuxet Pond, it remains an ecosystem admired for its recreational and aesthetic value. Additionally, the habitat is used by a diversity of birds and coastal river otters. If nitrogen pollution is not addressed, water and habitat quality will likely further degrade. Crackatuxet Pond is a beloved ecosystem with a rich history and further deterioration of the pond should be avoided.

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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 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.

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

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

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.

Map of Crackatuxet Pond and nearby Edgartown Great Pond Sampling stations

MV CYANO color-coded matrix

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.