Boothbay Region Land Trust

"Edwin J. Green
Coastal Water Monitoring Program"

2023 Annual Report

Apr 2, 2024

2015-2023 data

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Executive Summary

This report summarizes the activities of the Boothbay Coastal Water Monitoring Program for the year 2023. This is the ninth year that the Boothbay Region Land Trust (BRLT) has conducted this program and we continue our contribution to the scientific community.

Notable Highlights include:

- Received Maine Department of Environmental Protection (DEP) approval in 2020 of our Quality Assurance Project Plan which defines our processes and procedures to ensure that our data is high quality and allows inclusion of our data in the DEP report to the U.S. Environmental Protection Agency
- Continued to provide the Maine Coastal Observing Alliance (MCOA) offshore samples from five sites of the waters from the Damariscotta River to the mouth of the Sheepscot River
- 2021 and 2022 data entered into the Maine Department of Environmental Protection (DEP) Maine Environmental and Geographic Analysis Database (EGAD)[1] for inclusion in DEP's biennial report to EPA
- 2023 data were shared with Maine DEP to assist with their Marine Vegetation Mapping Program (MVMP). Secchi depth data and water quality observations from BRLT and other organizations were used to inform water clarity at additional locations[2].

In the pages that follow you will see summary graphs that depict trends for the past 9 years. These trends are disturbing but consistent with the state of climate change and its effect on the Gulf of Maine coastal waters. The trends have been consistent each year. The following is noteworthy:

- Sea surface temperature continues to increase. The effects are numerous but the impact on the lobster industry will be significant for Maine's economy. Additionally, sea level rise due to rising temperatures is an important issue to our coastal community.
- The amount of dissolved oxygen (DO) in our waters is decreasing. This decrease, if continued, will adversely affect the health of fish.
- pH continues to decrease. Lower pH can have detrimental effects on shellfish[3].
- New for 2023 was a marked decline in salinity, likely due to the high amount of rainfall in 2023.

We want to thank the many dedicated volunteers that make this program a success. Our monitoring activity begins in May and concludes in October. It is a long season with often cold and wet days but they endure and are making the essential contribution to this important activity. A list of our volunteers is included in Appendix 1 of this document.

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[1] https://www.maine.gov/dep/maps-data/egad/index.html

[2] https://www.maine.gov/dep/water/monitoring/coastal/2023%20MVMP%20Legislative%20Report_Final.pdf

[3] https://www.seasidesustainability.org/post/what-ocean-acidification-means-for-maine

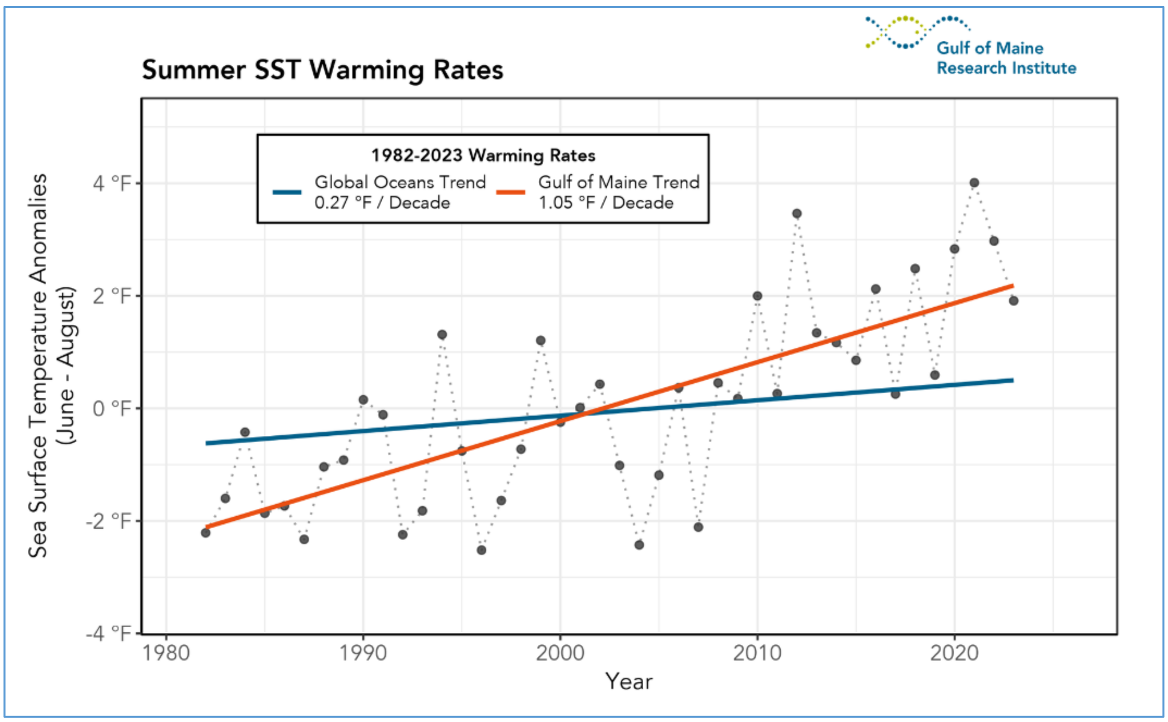
Background

The Boothbay Harbor Master Plan of 2015[4] stated that the waters of Linekin Bay have suffered a decrease in the concentrations of dissolved oxygen. Causes for this depletion may include storm water runoff, increased water temperatures, changes in circulation, and increasing concentrations of bacteria and chlorine content from overboard discharge systems. In this same report, it was recommended to increase the monitoring of these oxygen levels. Similarly, this same general area, to include the estuaries of the lower Damariscotta River, the Sheepscot River and the waters of Southport Island, have seen clam beds closed and shellfish harvesting stopped due to unsafe waters.

With the advent of the human impact on our environment, we are faced with increased levels of CO2 impacting increased acidity. As seawater becomes more acidified, carbonate is less available for animals to build shells and skeletons. Under conditions of severe acidification, shells and skeletons can dissolve.[5]

The Gulf of Maine is warming at four times the rate that global ocean summer sea surface temperatures are warming[6], faster than 99% of the world's oceans, and is beginning to lose its subarctic characteristics. Ocean warming, acidification, and sea level rise are already affecting ecosystems and coastal areas and will continue to accelerate as the climate warms[7]. Figure 1 is a Gulf of Maine Research Institute graphic which shows the warming trend of the Gulf of Maine (red line) compared to the global oceans warming trend (blue line).

Figure 1 Summer Sea Surface Temperature Warming Trends[8]



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[4] https://www1.maine.gov/dacf/municipalplanning/comp_plans/Boothbay_Harbor_2015.pdf
[5] https://www.epa.gov/ocean-acidification/understanding-science-ocean-and-coastal-acidification
[6] https://www.gmri.org/stories/gulf-of-maine-warming-update-summer-2023/
[7] https://www.nrcm.org/news/gulf-maine-warming-faster-than-99-percent-worlds-oceans/
[8] https://www.gmri.org/stories/gulf-of-maine-warming-update-summer-2023/

Melting ice sheets will continue to be a consequence of rising ocean temperatures. Additional concerns are that rising sea temperatures will affect lobster fishing[9][10] and lead to the introduction of invasive plants and animal species. It is for reasons such as these that recommendations have been voiced to increase the coastal and tributary water monitoring programs for this region. For a better understanding, readers are encouraged to read the short articles by the Northeast Coastal Acidification Network at http://necan.org/overview and http://necan.org/marine-life.

2023: Studies and Findings

The National Oceanic and Atmospheric Administration (NOAA), NASA, UK Met, and several other scientific organizations all conducted analyses that show that, globally, 2023 was even warmer than 2022, which was previously the warmest year on record[11]. Boothbay water sampling data reflects the same rising water temperature trend seen by numerous studies. This trend is expected to have negative impacts on Maine's economy[12] [13]

In addition to rapid warming, a 2023 study found that acidity is increasing in the Gulf of Maine faster than at other locations on the East Coast which could harm sea scallop populations.[14] BCWM data shows increasing acidity at our sampling sites (BCWM pH trend data, figure 11, page 20 of this report).

Coastal vegetation provides critical habitat, nursery grounds, storm surge protection, carbon sequestration, and water quality benefits to the nearshore environment, and requires routine mapping to detect changes in extent and condition. In 2023, the Maine DEP Marine Vegetation Mapping Program (MVMP) surveyed the Midcoast Region (Phippsburg to Port Clyde) through the acquisition of high-resolution, low tide, true color aerial orthoimagery followed by targeted field-validation and photointerpretation of aerial signatures[15]. In response to a Maine DEP request, BRLT provided water clarity data (Secchi disk readings) to assist with the program.

What Can Be Done?

The effect of runoff into Maine's tributaries on coastal acidification is well documented. Continued monitoring of coastal waters is vital to improve awareness and understanding of the health of Maine's coastal waters.

Individuals and towns can all take action to reduce coastal acidification by

- Reducing or eliminating fertilizers on our lawns, gardens, and farms
- Making sure your septic system is working properly
- Improving sewage treatment and reduce runoff
- Help to protect eelgrass beds and salt marshes

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[9] https://www.climate.gov/news-features/featured-images/warming-ocean-temperatures-push-lobster-populations-north

[10] https://www.mainelobsternow.com/blog/new-england-water-temperature-impact

[11] https://www.noaa.gov/news/2023-was-worlds-warmest-year-on-record-by-far

[12] https://climatecouncil.maine.gov/reports

[13] https://umaine.edu/news/blog/2016/09/21/dmc-bigelow-study-rising-ocean-temperatures-threaten-baby-lobsters/

[14] https://www.pressherald.com/2023/03/22/newly-published-study-shows-maine-scallop-industry-could-be-in-danger/

[15] https://www.maine.gov/dep/water/monitoring/coastal/2023%20MVMP%20Legislative%20Report_Final.pdf

The reader can learn more about these at http://necan.org/action.

To do its part, in 2015, under the guidance of the already established water sampling program at the Kennebec Estuary Land Trust (KELT), BRLT joined forces with the Maine Coastal Observing Alliance (MCOA) and began recording pH, temperature, dissolved oxygen, salinity, and turbidity levels of seawater. MCOA collects this data from citizen scientists throughout Maine's estuaries, from Casco Bay to Penobscot Bay. The MCOA summary report from the first year's monitoring found that the estuaries were generally healthy, in terms of nutrients and oxygen, but that low pH levels are a concern.[16]

Through the measurement, recording and dissemination of these data, the primary goals of the BCWM Program are the following:

(1) Continue a sustainable volunteer water quality-monitoring program in the Boothbay region that follows state-approved methods and procedures;

(2) Raise awareness about the region's coastal ecosystems and water quality in local communities and in statewide settings;

(3) Allow ongoing and expanded water monitoring in subsequent years that will enhance public awareness and guide water resources management by the region's towns to better sustain local fisheries, recreation, and residents' health;

(4) Provide the data we collect to appropriate state, university, and research venues to assist in the determination of the impact of water quality on the coastal environment and ecosystem.

Quality Assurance Project Plan

To ensure correctness and consistency of methodology, and to ensure uniformity with data collected by other organizations which are monitoring water quality in other estuarial waters of coastal Maine, BRLT has developed a Quality Assurance Project Plan (QAPP) and is seeking input from and, eventually, approval by the Maine Department of Environmental Protection. The QAPP, together with the Volunteer Manual, defines the training program and standard procedures for instrument calibration, sample collection and measurement of several environmental factors and of specific water quality variables including pH, salinity, dissolved oxygen, turbidity[17], and quality assurance.

Data Distribution

The BCWM program will continue the collaboration initiated in 2015 with the following: Maine Department of Environmental Protection (DEP), responsible for protecting and restoring Maine's natural resources and enforcing the state's environmental laws; the Bigelow Laboratory of Ocean Sciences, a nonprofit institution located in East Boothbay that is dedicated to research, education, and the promotion and use of knowledge related to ocean sciences; the Kennebec Estuary Land Trust (KELT), which assisted in establishing the initial BCWM water quality monitoring project in 2015, and the Maine Coast Observing Alliance (MCOA), a consortium of local citizen groups seeking to build a regional perspective of estuarine water quality. BRLT will provide the data collected to the Maine DEP for inclusion in their database and biennial report to the EPA and to MCOA so it may be aggregated with other MCOA members' data for analysis and archiving to build a long-term database.

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[16] http://www.damariscottariver.org/wp-content/uploads/2015/11/MCOA-report-Final-small-vers.-17nov15-2.pdf

[17] See the Boothbay Coastal Water Monitoring Program Quality Assurance Project Plan

Volunteer Training

The sampling methods used were selected because they are relatively easy for volunteers, affordable, and they align with methods in use by other coastal volunteer water quality monitoring programs in Maine. All program volunteers are trained in the same techniques and follow the same set of sampling procedures. Face to face training for 2024 is scheduled to take place in May 2024. For refresher training, BRLT has made a training video available at https://www.youtube.com/watch?v=JkBTcYrhuF0

Quality Assurance Process

The BCWM Program Manager or a volunteer Program Coordinator visited field sites during the collection season to ensure that data collection follows the procedures in the volunteer manual and meets the guidelines outlined in the QAPP, and to encourage a cross-flow of techniques and lessons learned.

Sampling Sites

The sampling domain for the Boothbay Region is shown in Figure 2 and is concentrated to the lower reaches of the Sheepscot and Damariscotta Rivers and the bays that connect these two estuaries. This region is marked by the Sheepscot River Estuary to the west, the Damariscotta River Estuary to the east, and the numerous islands, coves and bays that constitute the region of Sheepscot Bay, Boothbay Harbor, and Linekin Bay.

Figure 2 Site Location Map

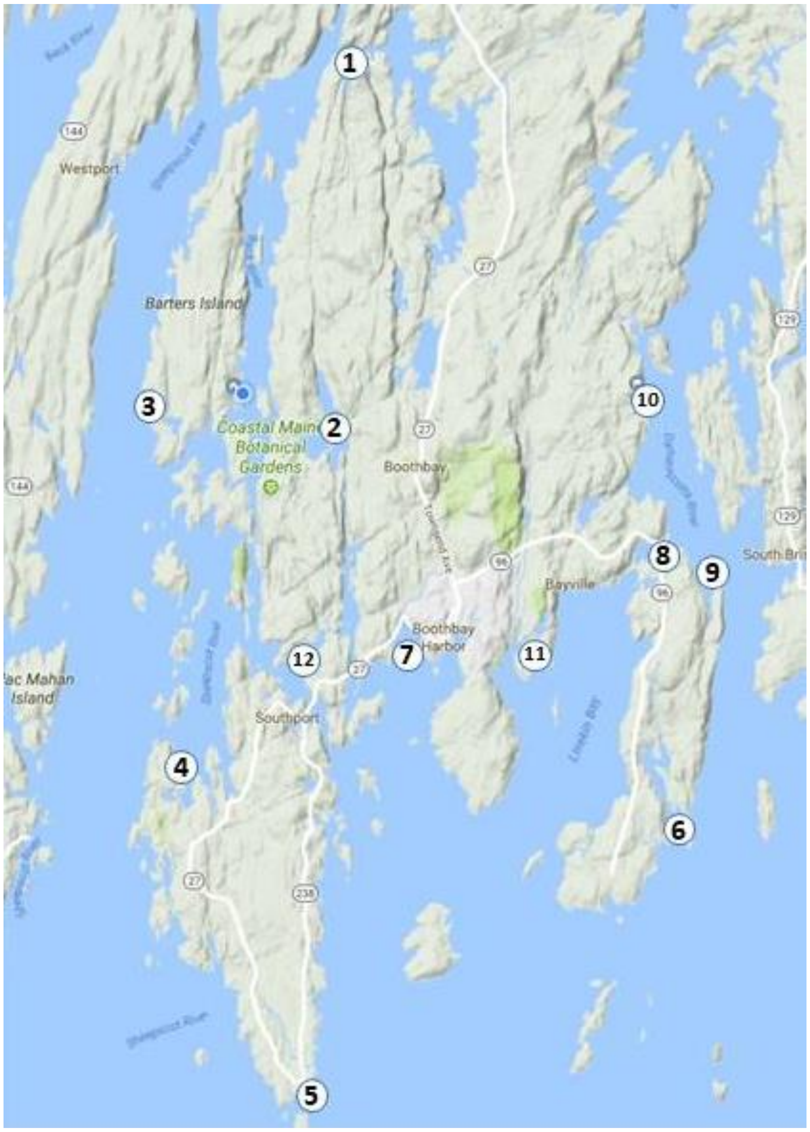


Table 1 Site Locations

Site ID	Site Description	Latitude	Longitude
B 1	Oven's Mouth	43.934520	-69.646957
B 2	Knickercane Landing	43.880323	-69.663514
B 3	Robert's Wharf	43.880068	-69.684273
B 4	Dogfish Head	43.828802	-69.679429
B 5	Newagen	43.786284	-69.655321
B 6	Little River	43.825035	-69.584009
B 7	Boothbay Harbor Footbridge	43.850950	-69.625813
B 8	Linekin Bay (Murray Hill dock)	43.861598	-69.590474
B 9	Bigelow Labs Dock	43.860503	-69.578162
B 10	Damariscotta River	43.885550	-69.588932
B11	Linekin Bay 2 (Linekin Bay Resort)	43.845661	-69.611526
B12	Oak Point Farm	43.849111	-69.656096

Sampling Schedule

Water quality monitoring is conducted from May through October to avoid times of year when low temperatures and ice are detrimental to volunteer safety. The water sampling schedule is planned so that samples are taken at high tide in the morning hours to minimize the impact of submerged plant photosynthesis on dissolved oxygen and to maximize the depth for water clarity testing. All samples are collected within a three hour window centered on high tide (+/- 1.5 hr of high tide). The schedule for 2023 is shown in Table 2:

Table 2 2023 Sampling Schedule

Date	High Tide	Sampling Range	Suggested Sampling Time
5/17	10:03 am	8:33 am-11:33 am	10:00 am
5/31	8:45 am	7:15 am-10:00 am	9:00 am
6/14	8:50 am	7:20 am-10:20 am	9:00 am
6/28	7:02 am	7:00 am-8:32 am	8:00 am
7/12	7:29 am	7:00 am-8:59 am	8:00 am
7/19	12:29 am	10:59 am-11:45 am	11:00 am
8/2	12:00 pm	10:30 am-11:45 am	11:00 am
8/16	11:58 am	10:28 am-11:45 am	11:00 am
8/30	10:52 am	9:22 am-11:45 am	11:00 am
9/13	11:00 am	9:30 am-11:45 am	11:00 am
9/27	9:39 am	8:09 am-11:09 am	10:00 am
10/11	9:44 am	8:14 am-11:14 am	10:00 am

Data Summary Caveats

The data presented in this report are a summary of the key variables collected. Many of the variables collected (% cloud cover, air temperature, etc.) are not shown in this report, but all the recorded data are kept and available for use in analysis. This report presents the data collected by BRLT volunteers—it does not reflect analysis beyond simple statistical summaries (Least Squares Regression[18]) nor does it present conclusions which are beyond the resources and responsibility of BRLT. Each blue dot in the following charts represents a data point (water temperature, pH, salinity, and dissolved oxygen) collected by a BCWM volunteer at one of our 12 sites from 2015 through 2023. Outlier data have been omitted using the 1.5*IQR method[19].

[18] The least squares line is also known as the line of best fit. The least squares line minimizes the squared distances between the line and our points. Of all the possible lines that could be drawn, the least squares line is closest to the set of data as a whole.

[19] https://sphweb.bumc.bu.edu/otlt/MPH-Modules/BS/BS704_SummarizingData/BS704_SummarizingData7.html

2023 Water Temperature Data

Figures 3 and 4 show water temperature data collected in 2023.

Figure 3 depicts the temperatures collected at each site (site numbers on the horizontal (x) axis and water temperature in °C on the vertical (y) axis).

Figure 4 depicts the temperature data from all sites vs date (date on the horizontal (x) axis and water temperature in °C on the vertical (y) axis. Figure 4 shows the rise of water temperatures from May to August then dropping temperatures from August to October as one would expect.

Figure 3 Water Temperatures collected by site; 2023 data

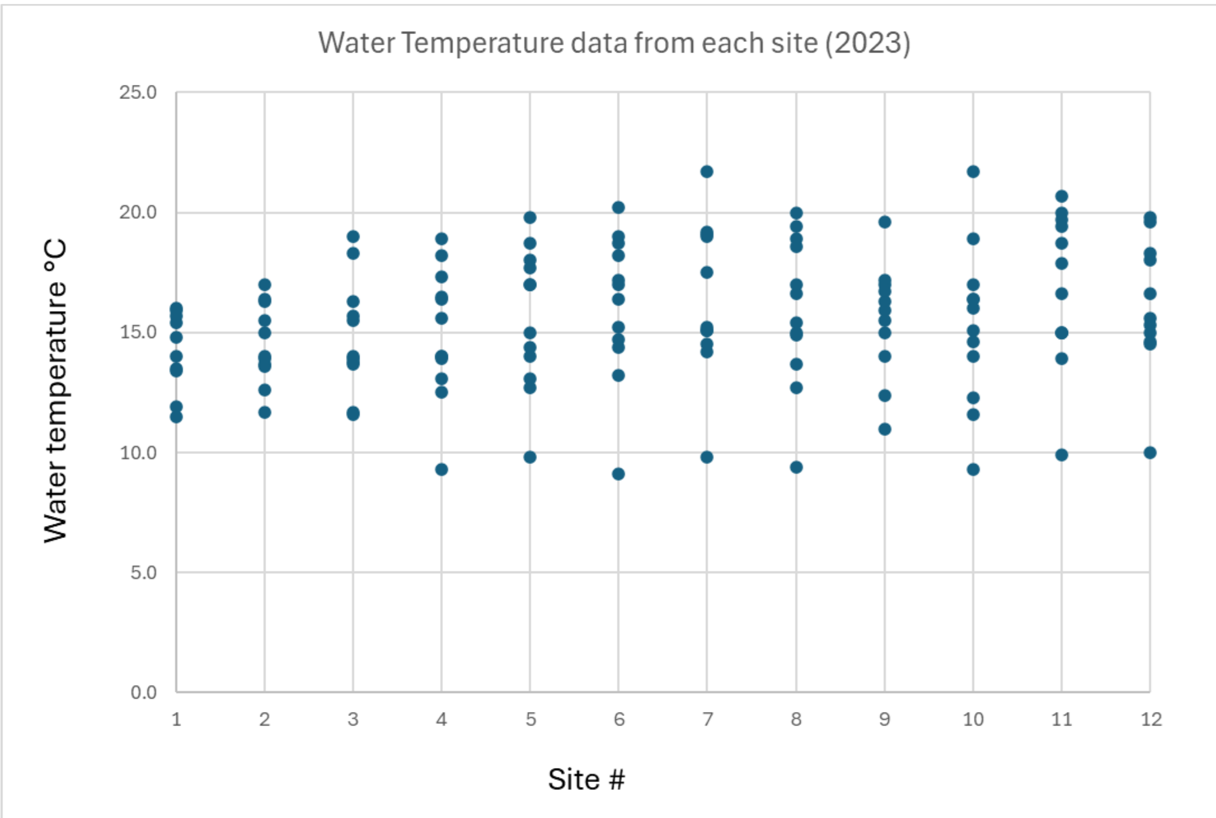
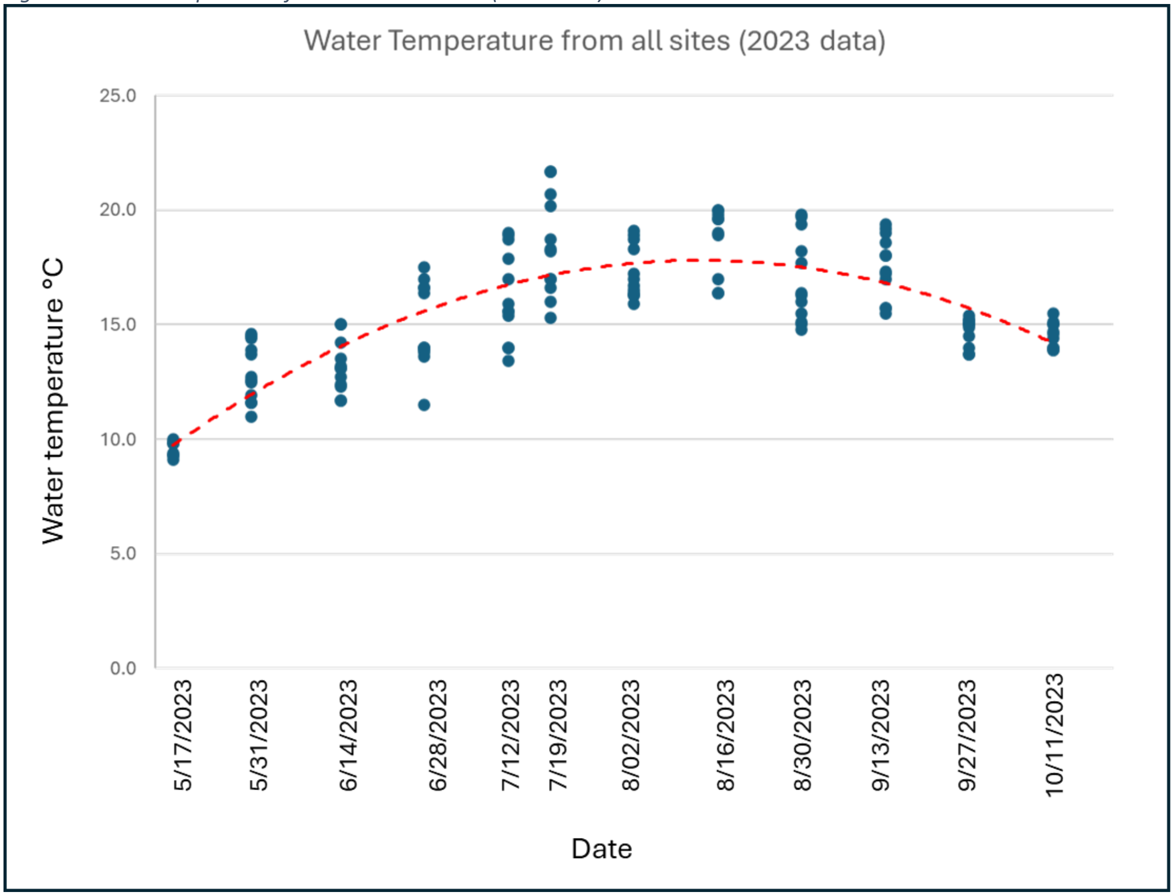


Figure 4 Water Temperature from all sites vs date (2023 data)



2023 pH Data

Figure 5 depicts the pH data collected from all sites in 2023. Site numbers are on the horizontal (x) axis and pH values are on the vertical (y) axis. Of note are the higher pH values of site 7 (Boothbay Harbor footbridge), site 8 (Murray Hill boat dock) and site 11 (Linekin Bay Resort boat dock).

Figure 5 pH data from each site (2023 data)

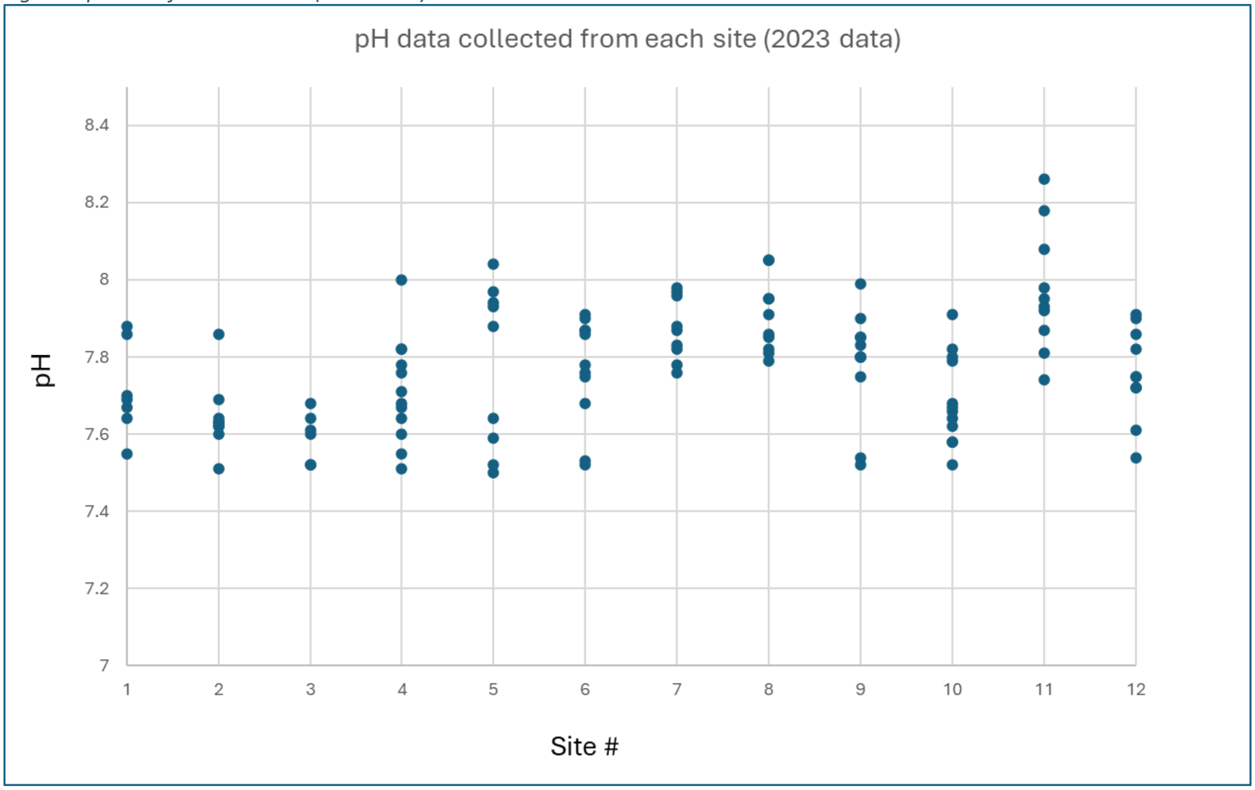
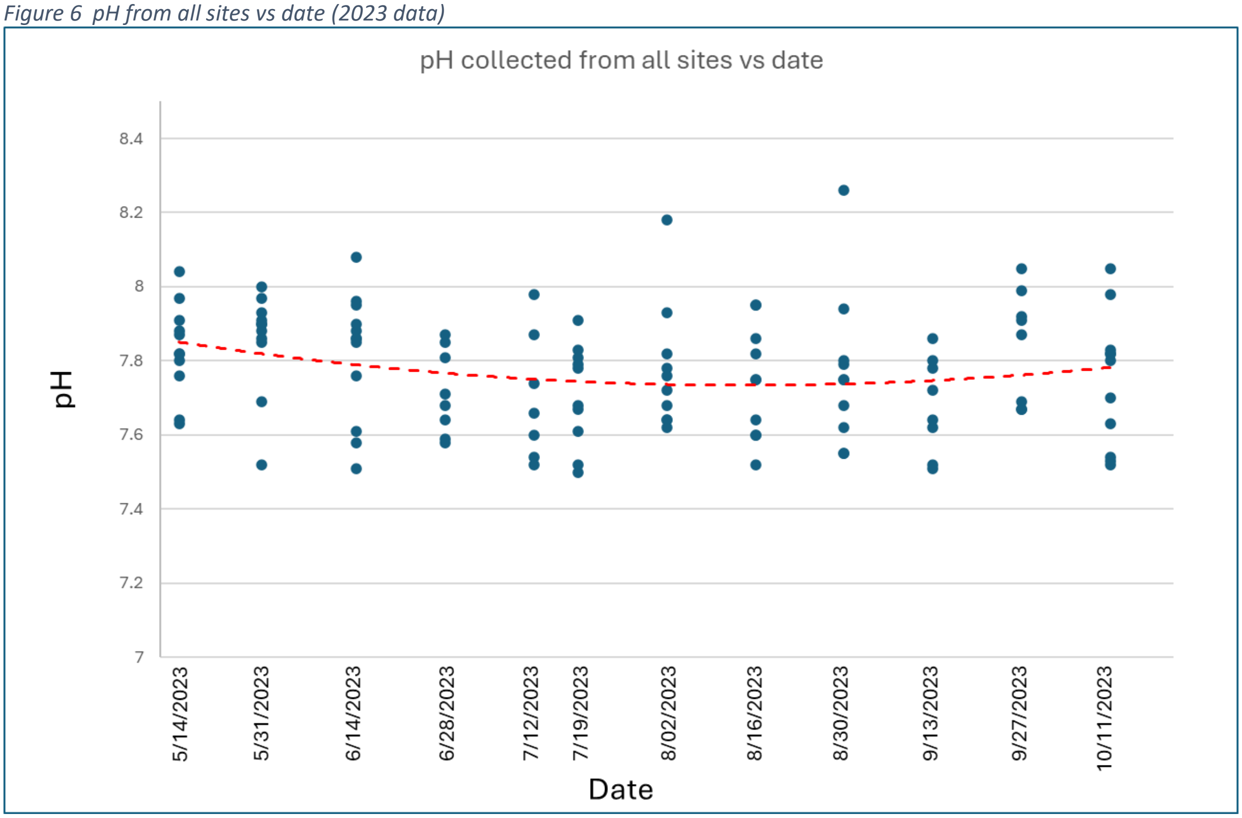


Figure 6 aggregates the pH data from all sites for each collection date in 2023. Date is along the horizontal (x) axis and pH on the vertical (y) axis. A polynomial trend line has been added which reflects a decreasing average pH from May to August. In addition to the role increasing atmospheric CO2 has on the pH of the oceans, increasing seawater temperature plays a role as well. As the temperature of seawater rises, molecular vibrations increase which results in the ability of water to ionize and form more hydrogen ions. As a result, the pH will drop.[20]

Figure 6 pH from all sites vs date (2023 data)



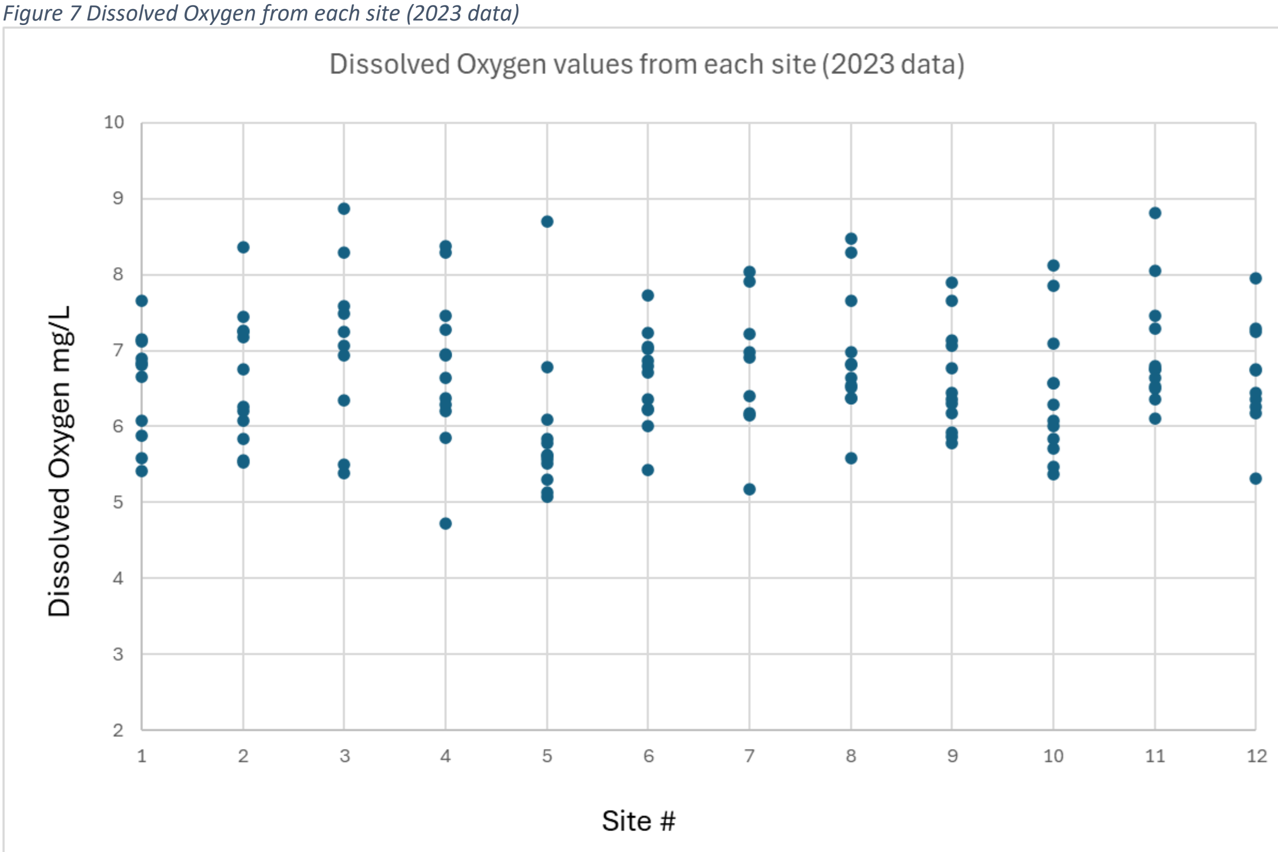
[20] https://www.westlab.com/blog/how-does-temperature-affect-ph

2023 Dissolved Oxygen Data

High temperatures reduce the solubility of oxygen in water (i.e., warm water holds less DO than cold water)[21]. This means that rising seawater temperatures can cause a decrease in dissolved oxygen levels.

Figure 7 shows the dissolved oxygen (DO) readings collected at each site in 2023. Site numbers are on the horizontal (x) axis and DO values are on the vertical (y) axis. Of note is the lower DO at the Newagen town dock (site 5).

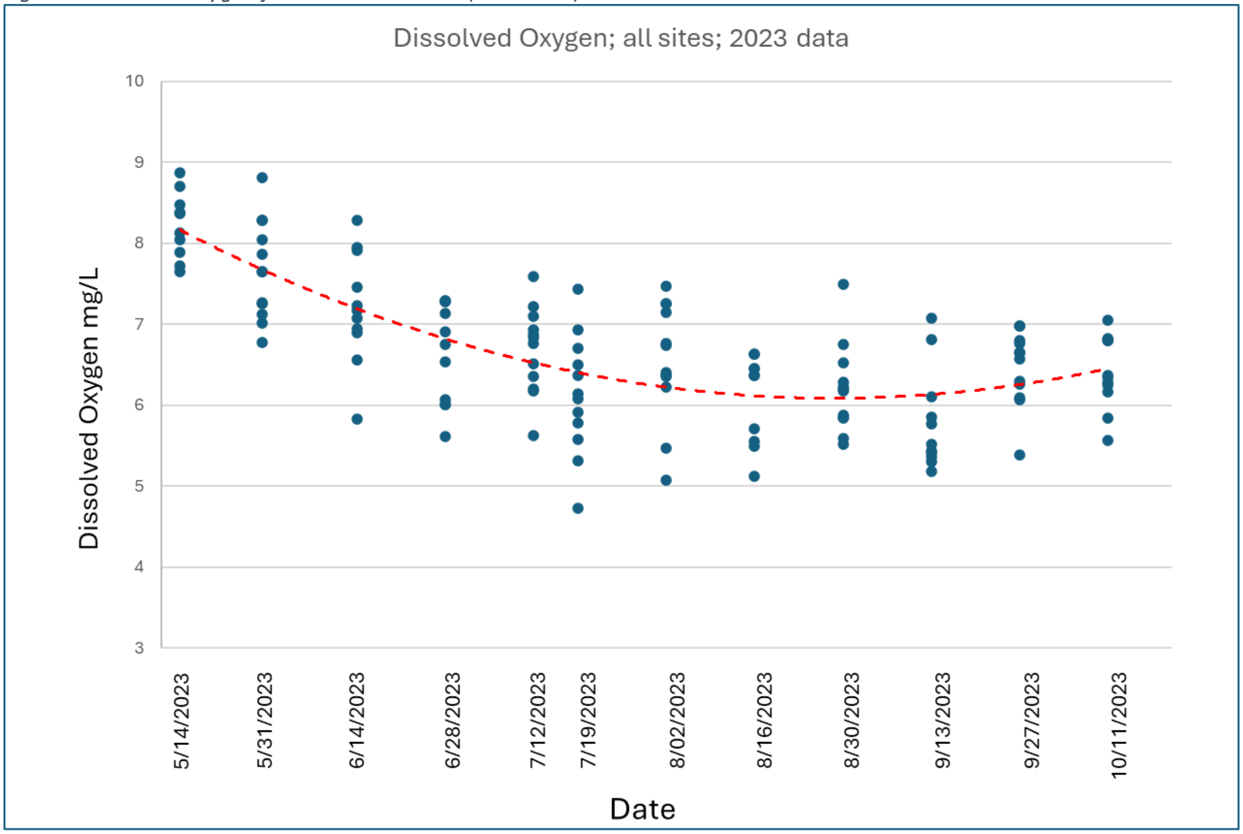
Figure 7 Dissolved Oxygen from each site (2023 data)



[21] https://www.epa.gov/caddis-vol2/dissolved-oxygen

Figure 8 shows the DO data from all sites vs date. The red dashed trendline reflects lower dissolved oxygen during the warmer summer months as expected[22]. Dissolved Oxygen is on the vertical (y) axis and is in milligrams per liter (mg/L).

Figure 8 Dissolved Oxygen from all sites vs date (2023 data)



[22] https://www.usgs.gov/special-topic/water-science-school/science/dissolved-oxygen-and-water?qt-science_center_objects=0#qt-science_center_objects

Trend data; salinity (all sites, 2015-2023)

Figure 9 plots salinity data collected from all sites from 2015 through 2023. Salinity in parts per thousand is plotted along the vertical (y) axis and date along the horizontal (x) axis. The dashed red line depicts a Least Squares Regression and shows that the average salinity of the waters around the Boothbay region has increased over the last 9 years, although the 2023 values are markedly lower than previous years. A possible explanation is the higher rainfall Maine experienced in 2023 compared to previous years (see NOAA graphic in Figure 10).

Figure 9 Salinity vs date; all sites (2015-2023)

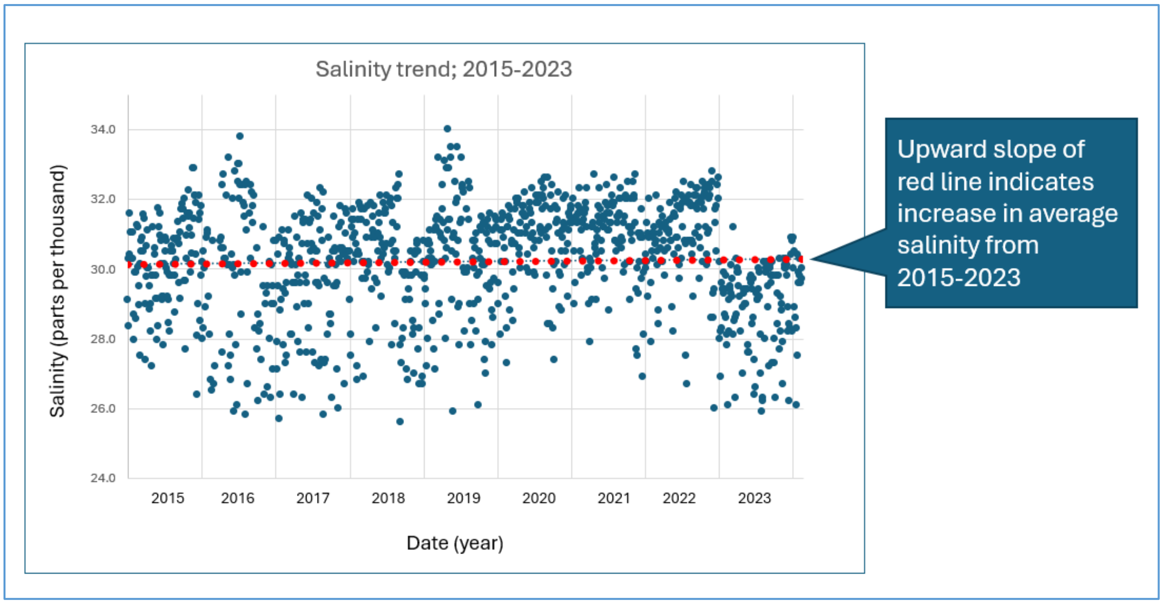
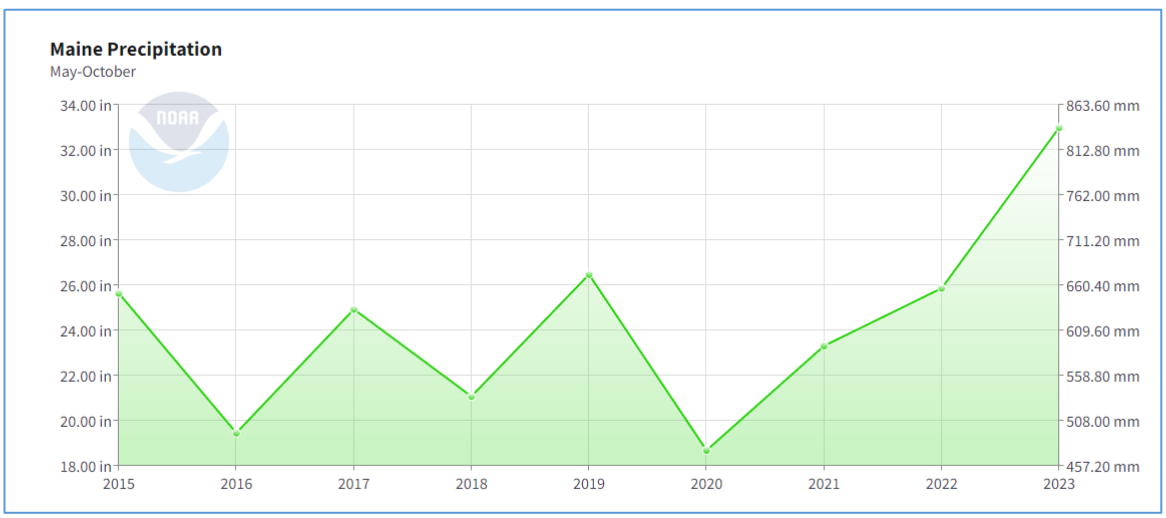


Figure 10 2023 experienced the highest rainfall since BRLT program began in 2015[23]

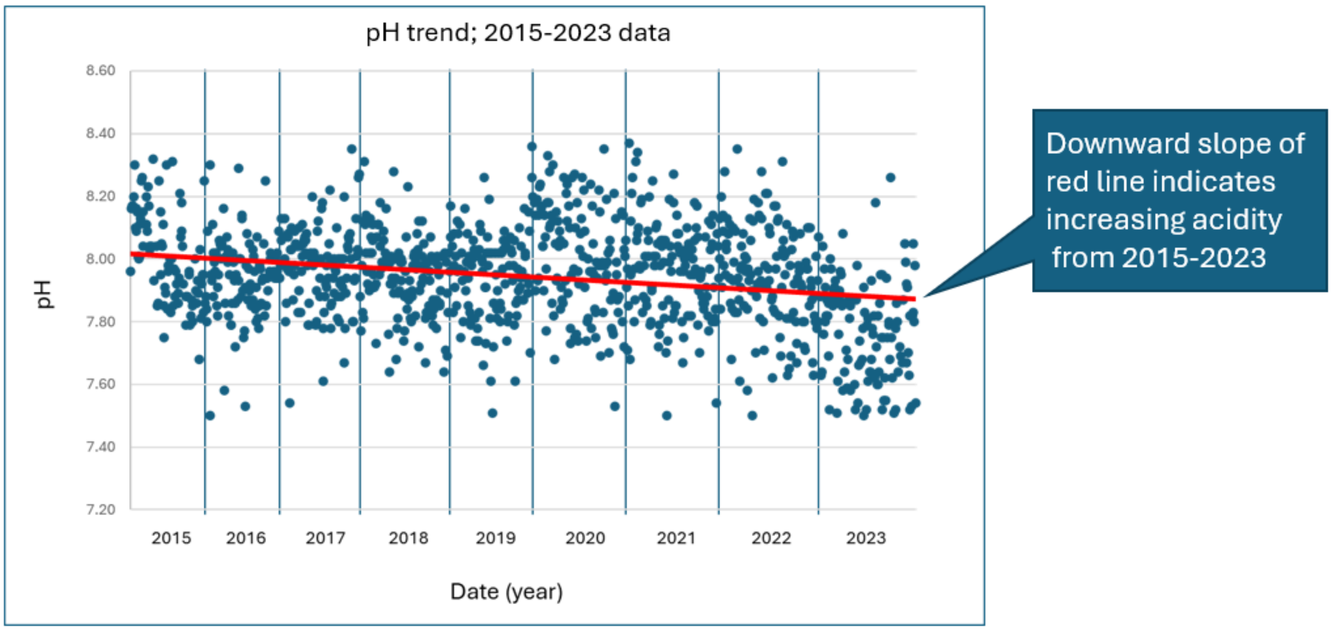


[23] https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series/17/pcp/6/10/2015-2023

Trend data; pH (all sites, 2015-2023)

Figure 11 plots pH data collected from all sites from 2015 through 2023. pH is plotted along the vertical (y) axis and date along the horizontal (x) axis. The dashed red line depicts a Least Squares (linear) Regression and shows that the average pH of the water around the Boothbay region is slowly decreasing over time. Of note are the dramatically lower pH values in the 2023 data.

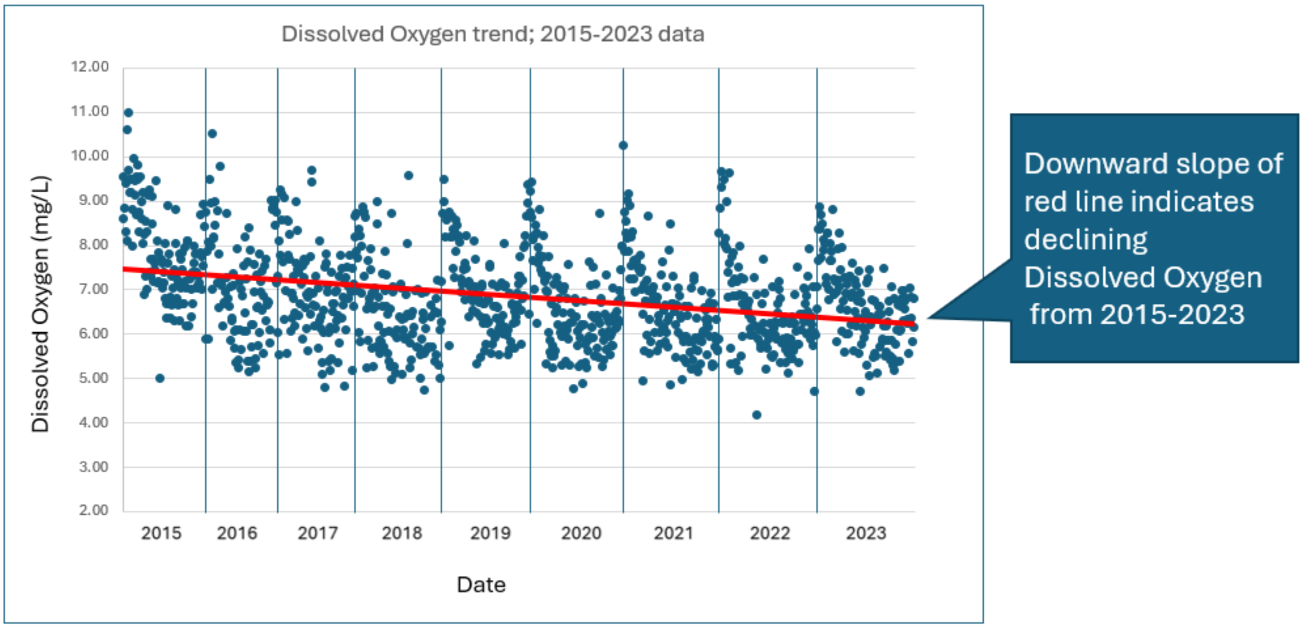
Figure 11 Trend data; pH vs date (all sites, 2015-2023)



Trend data; Dissolved Oxygen (DO) (all sites, 2015-2023)

Figure 12 plots DO data collected from all sites from 2015 through 2023. DO is plotted along the vertical (y) axis and date along the horizontal (x) axis. The dashed red line depicts a Least Squares (linear) Regression and shows that the average DO of the waters around the Boothbay region is decreasing over time.

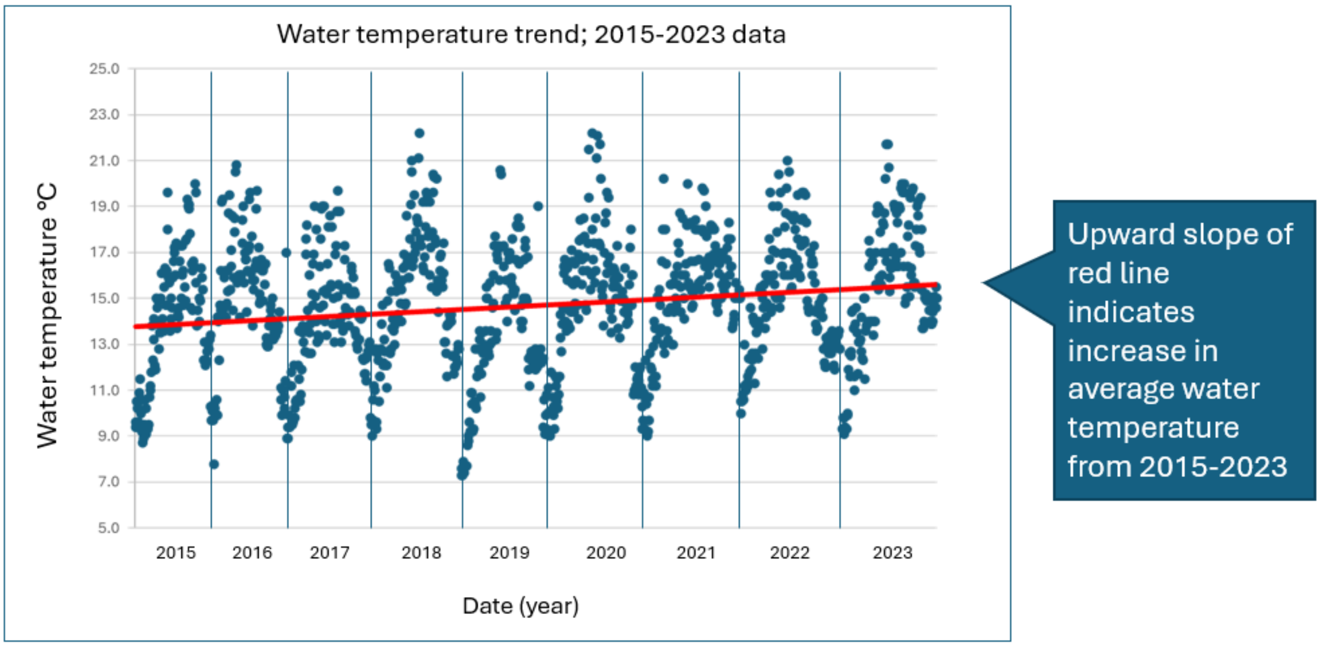
Figure 12 Trend data; DO vs date (all sites, 2015-2023)



Trend data; Water temperature (all sites, 2015-2023)

Figure 13 plots water temperature data collected from all sites from 2015 through 2023. Water temperature is plotted along the vertical (y) axis and date along the horizontal (x) axis. The dashed red line depicts a Least Squares Regression and shows that the average water temperature of the waters around the Boothbay region is increasing over time.

Figure 13 Trend data; water temperature vs date (all sites, 2015-2023)



Appendix 1: Boothbay Coastal Water Monitoring Volunteers (2023)

Deborah Berrill
Michael Berrill
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Lee Corbin
Jim Darrow
Chris Devitt
Marcia Donald
Karen Grindall
Bill Hammond
Nancy Harriman
Robert Jordan
Christine Kipp
Fred Kraeuter
Doug Mackay
Alyssa Mitchell
Roberta Roberts
Ron Ross
John Schindler
Jane Wissman
Will McPhee