BOOTHBAY REGION LAND TRUST

Boothbay Coastal Water Monitoring Program Report (v1.0)

2015-2019 data

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Executive Summary

This report summarizes the activities of the Boothbay Coastal Water Monitoring Program for the year 2019. This is the fifth year that the BRLT has been conducting this program and we are making significant contributions to the scientific community at the regional, state and national levels.

Notable Highlights include:

- Continued sampling at eleven monitoring sites in the Boothbay Region
- Offshore sampling at five sites with the Maine Coastal Observing Alliance (MCOA) in the waters from the Damariscotta River to the mouth of the Sheepscot River
- The establishment of a Science Advisory Board to aid in the technical integrity of our program
- Participation in climate change workshops with academia and state and federal agencies on ocean acidification
- Participation with the Northeast Coastal Acidification Network (NECAN) Shell Day effort on ocean acidification
- Release of five years of our data to UMaine for the National Oceanographic and Atmospheric Administration (NOAA) study on coastal acidification.
- Participation with the UMaine Darling Institute on instrument calibration.
- The continued maturation of our quality assurance processes and procedures to ensure that our data is high quality and can be made available to the research community

In the pages that follow you will read more about these highlights. You will also see numerous graphs of the 2019 data and also graphs that depict trends for the past 5 years. These trends are disturbing but consistent with the state of climate change and its effect on the Gulf of Maine coastal waters. The following is noteworthy:

- Sea surface temperature continues to increase. The effects are numerous but sea level rise is an important issue to the coastal community.
- Increases in atmospheric CO_2 are being absorbed by our oceans and leading to higher acidity (see pH graphs). This adversely affects the health of shellfish.
- The amount of dissolved oxygen (DO) in our waters is decreasing. This decrease adversely affects the health of fish. We have seen significant decreases in DO at all depths In Linekin Bay.

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 the appendix of this document.

Background

Clean water is necessary for the survival of the economically important and ecologically sensitive species in the waters of the Boothbay region and for the health of its inhabitants. A thorough understanding of the condition of the region's marine waters will allow the towns of Boothbay, Boothbay Harbor and Southport to assess with more confidence the actions required to ensure public health and economic vitality in their communities.

Over the years the waters of the greater Boothbay Region have been adversely affected by human activities[1]. As cited in the Boothbay Harbor Master Plan of 2015[2], 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.[3] Melting ice sheets will continue to be a consequence of rising ocean temperatures. Additional concerns are that rising sea temperatures will affect lobster fishing and lead to the introduction of invasive plants and animal species (e.g., green crabs). It is for reasons such as these that recommendations have been voiced to increase the volunteer monitoring programs for this region.

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.[4]

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;

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[1] http://www.gulfofmaine-census.org/about-the-gulf/human-presence/
[2] https://www1.maine.gov/dacf/municipalplanning/comp_plans/Boothbay_Harbor_2015.pdf
[3] https://www.epa.gov/ocean-acidification/understanding-science-ocean-and-coastal-acidification
[4] http://www.damariscottariver.org/wp-content/uploads/2015/11/MCOA-report-Final-small-vers.-17nov15-2.pdf

(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.

2019 Science Advisory Board

On Jan 31, 2019 the first BCWM Science Advisory Board (SAB) meeting was held in the BRLT conference room at Oak Point Farm. The SAB was established to ensure the technical integrity of the BCWM Project and that future direction is shaped consistent with the needs of the Boothbay community. The SAB included other land trusts, government, research organizations, and academia. Attending the first meeting were Angela Brewer from Maine Department of Environmental Protection, Dr. Nick Record from the Bigelow Laboratory for Ocean Sciences, Celeste Mosher from the Maine Coastal Observing Alliance, and Kathleen Thornton from the University of Maine Darling Marine Center. Also attending were Jill MacCleod from Maine Department of Marine Resources (DMR) and Ruth Indrick from the Kennebec Estuary Land Trust.

2019 Shell Day Participation

On August 22, Boothbay Region Land Trust (BRLT) took a new step in its efforts to provide sustained monitoring of coastal waters in the Boothbay region by participating in the first ever "Shell Day." Shell Day is a single-day coastal monitoring blitz organized by the Northeast Coastal Acidification Network (NECAN) and spanning shores from Long Island Sound to Down East Maine. The initiative, whose name evokes the particular threat that shellfish face from increasing ocean acidity, aims to generate a snapshot of coastal conditions along the northeast. Two BRLT Coastal Water Monitoring Program volunteers collected samples from Newagen and the Damariscotta River that were part of this multi-state sampling effort.

The Northeast region is especially vulnerable to ocean acidification, which makes this data all the more significant. At each of the participating sites, samples were collected at low, mid, and high tides. BRLT's samples were then brought to the University of Maine Darling Marine Center for analysis to determine total alkalinity (the water's ability to resist change in pH). One of the questions scientists hope to answer is whether salinity and alkalinity correlate enough to allow salinity to be used as a proxy for alkalinity. Since measuring salinity is affordable and widely available, a correlation could allow scientists to assess the vulnerability of certain coastal waters to acidification more easily. A correlation would also enable scientists to harness the growing datasets collected by citizen science programs like BRLT's, which tests for salinity, in monitoring coastal ocean acidification. No data from this program is available to BRLT as of the writing of this report.

Quality Assurance Project Plan

In order 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 and turbidity[5], and quality assurance.

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

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 and MCOA so it may be aggregated with other MCOA members' data for analysis and archiving to build a long-term database.

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. Training was conducted by BRLT in May 2019 immediately before the start of the collection season. A training video is 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 1 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 1 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	43.880053	-69.684300
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	43.861729	-69.590452
B 9	Bigelow Labs Dock	43.860532	-69.578157
B 10	Damariscotta River	43.902886	-69.580232
B11	Linekin Bay 2	43.845842	-69.611534

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). Beginning July 10, volunteers were given the time range of the three hour window except when that window went beyond 10:30 am. The schedule for 2019 is shown in Table 2:

Table 2 Sampling Schedule

Sampling Date	Sample At/Between	High Tide BBH
May 15	9:00 AM	8:40 AM
May 29	8:00 AM	7:58 AM
June 12	8:00 AM	7:21 AM
June 26	8:00 AM	6:11 AM
July 10	4:30 AM-7:30 AM	6:00 AM
July 31	9:30 AM- 10:30 AM	10:56 AM
August 14	10 AM-10:30 AM	11:23 AM
August 28	8 AM- 9 AM	9:38 AM
September 11	8:45 AM-10:30 AM	10:14 AM
September 25	6:45 AM - 9:45 AM	8:19 AM
October 9	7:30 AM- 10 AM	8:56 AM
October 23	5:30 AM-8:30 AM	6:54 AM

Data Summary Caveats

The data presented by 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 of 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[6]) nor does it present conclusions which are beyond the resources and responsibility of BRLT. In 2016, sampling did not begin until late June, which omitted the cool waters of May and early June and skewed the yearly averages. Therefore the data used for this report omits the data collected in May and early June of each year.

[6]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 of the possible lines that could be drawn, the least squares line is closest to the set of data as a whole.

2019 Water Temperature Data

Figures 2 and 3 show water temperature data collected in 2019. Figure 2 depicts the temperatures collected at each site and Figure 3 depicts the temperature data from all sites vs date. The highest temperature recorded was 24°C at site 7 on Aug 8.

Figure 2 Water Temperatures collected by site; 2019

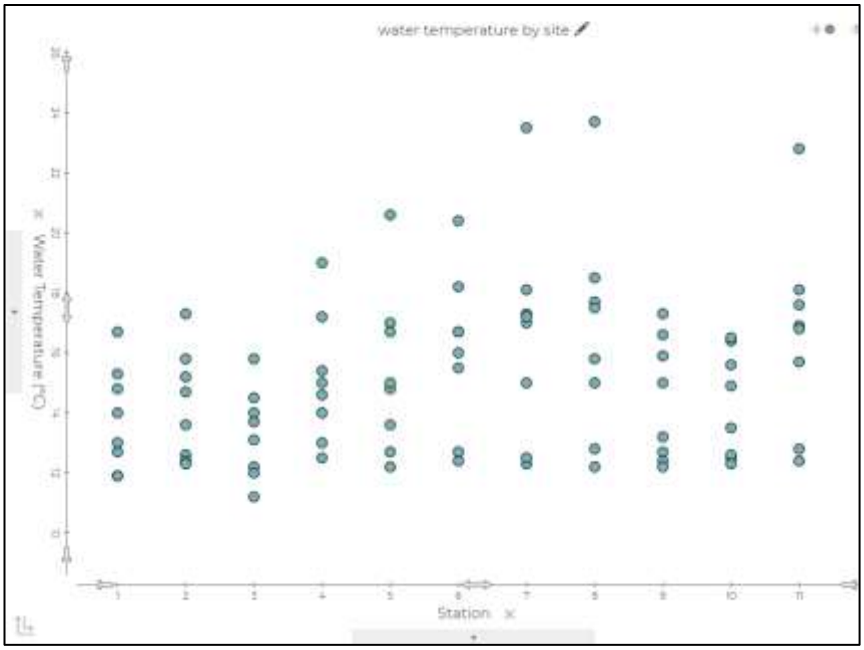
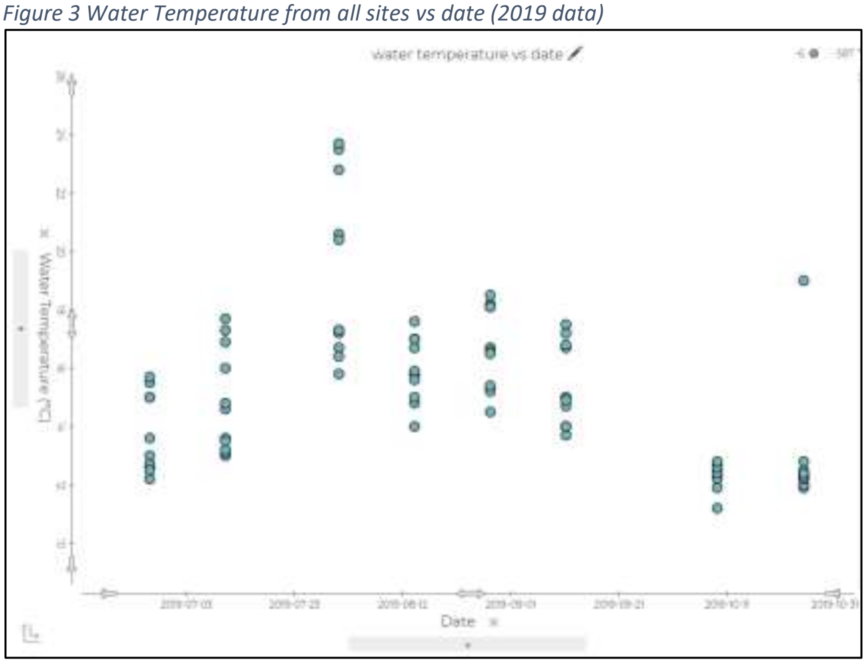


Figure 3 Water Temperature from all sites vs date (2019 data)



2019 pH Data

Figure 4 depicts the pH data collected from all sites, while Figure 5 aggregates the pH data from all sites for each collection date in 2019.

Figure 4 pH data from each site (2019 data)

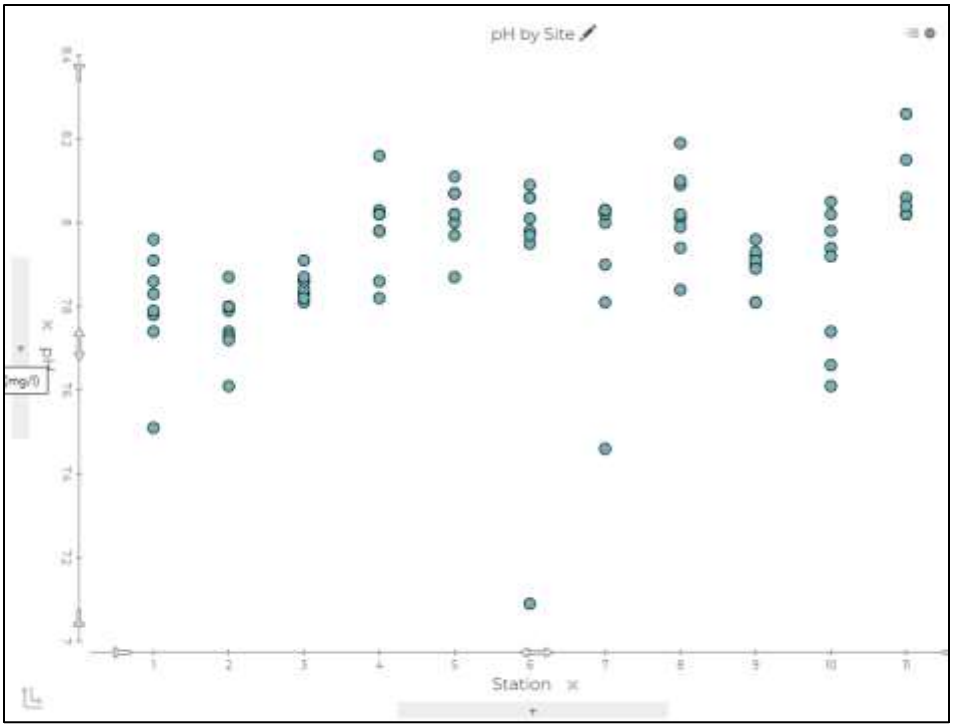
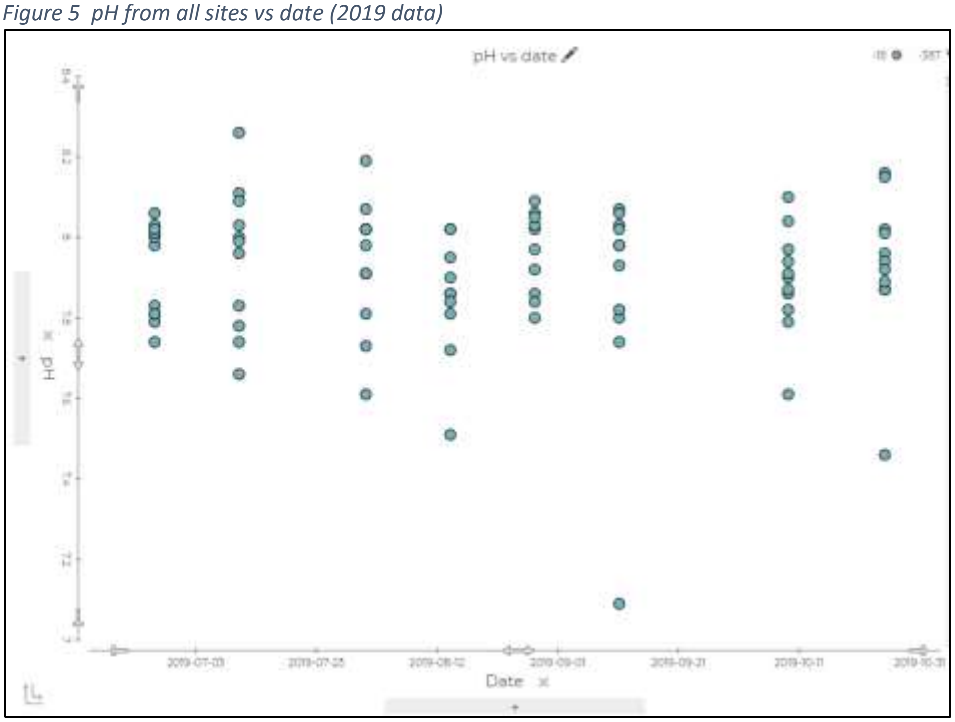


Figure 5 pH from all sites vs date (2019 data)



2019 Dissolved Oxygen Data

Figure 6 shows the dissolved oxygen (DO) readings from all sites in 2019. Figure 7 shows aggregates the DO data from all sites vs date.

Figure 6 Dissolved Oxygen from each site (2019 data)

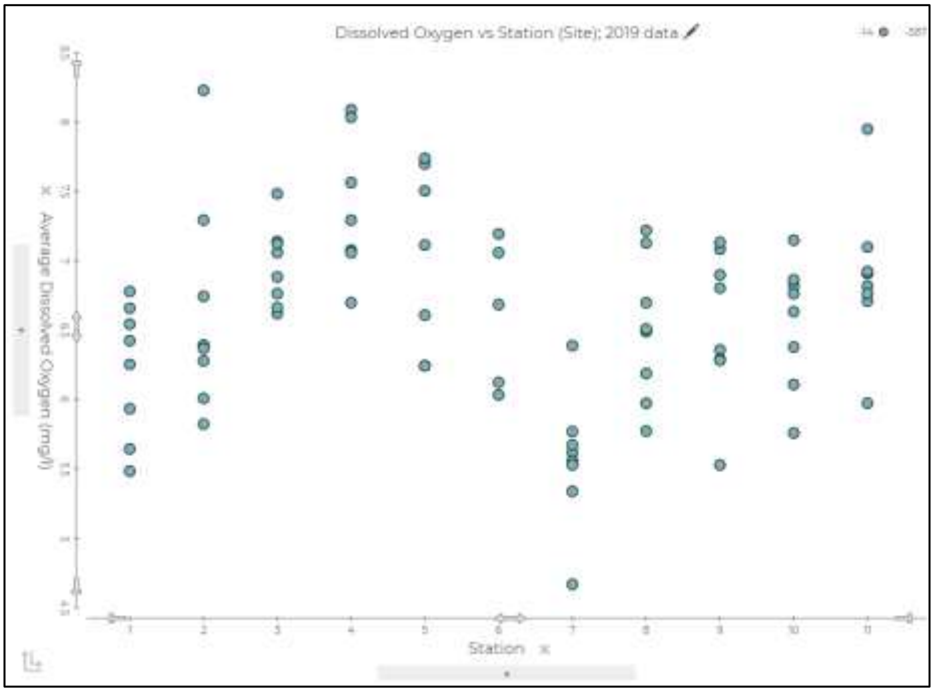
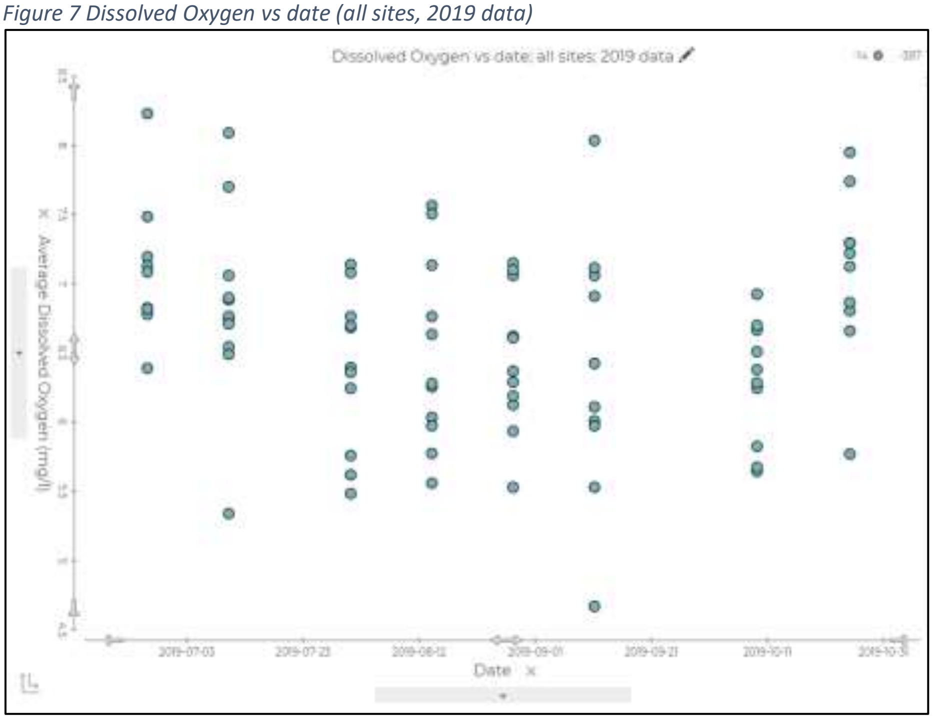


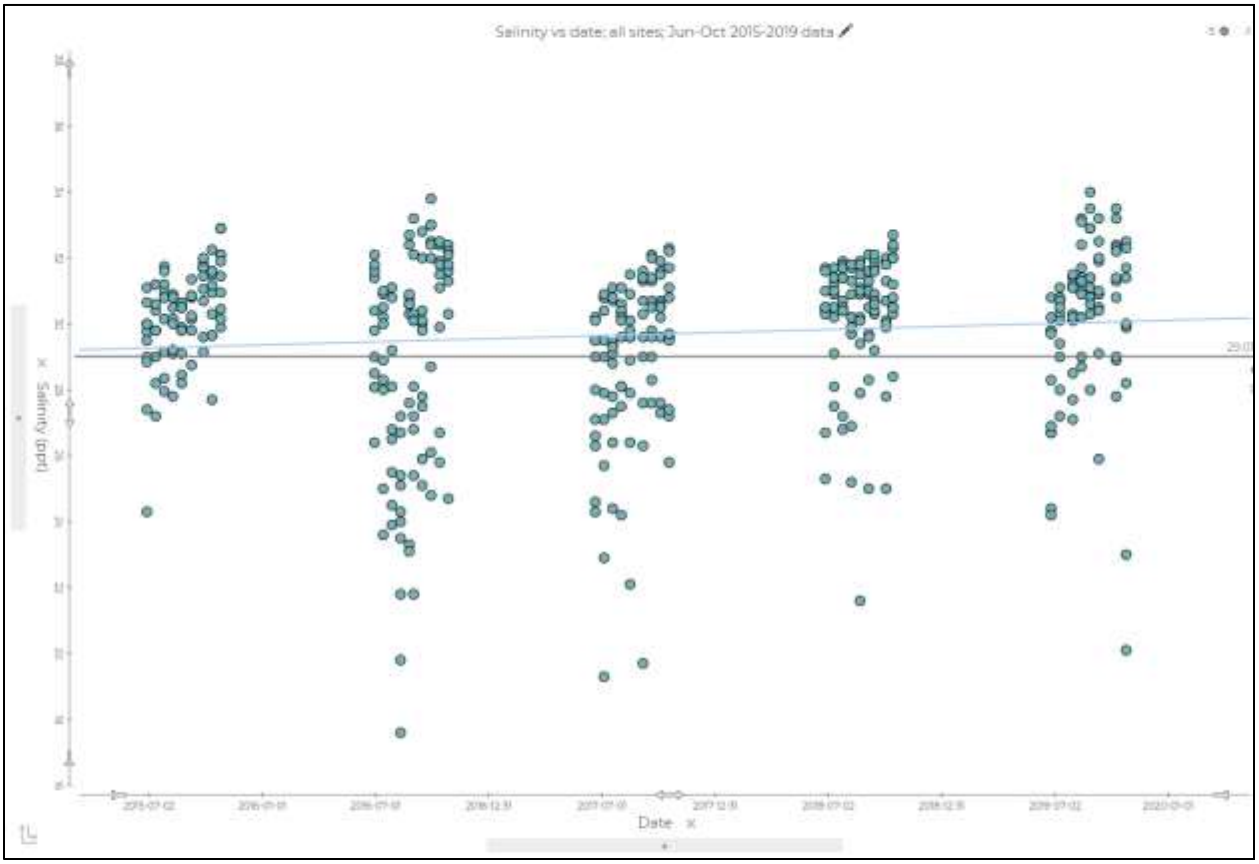
Figure 7 Dissolved Oxygen vs date (all sites, 2019 data)



Salinity Data (all sites, Jun-Oct 2015-2019)

Figure 8 presents salinity readings collected from all sites from 2015 through 2019. The blue line depicts a Least Squares Regression and shows that, on average, salinity in the waters of the Boothbay region is increasing. The gray line is for reference at 29 parts per thousand (ppt).

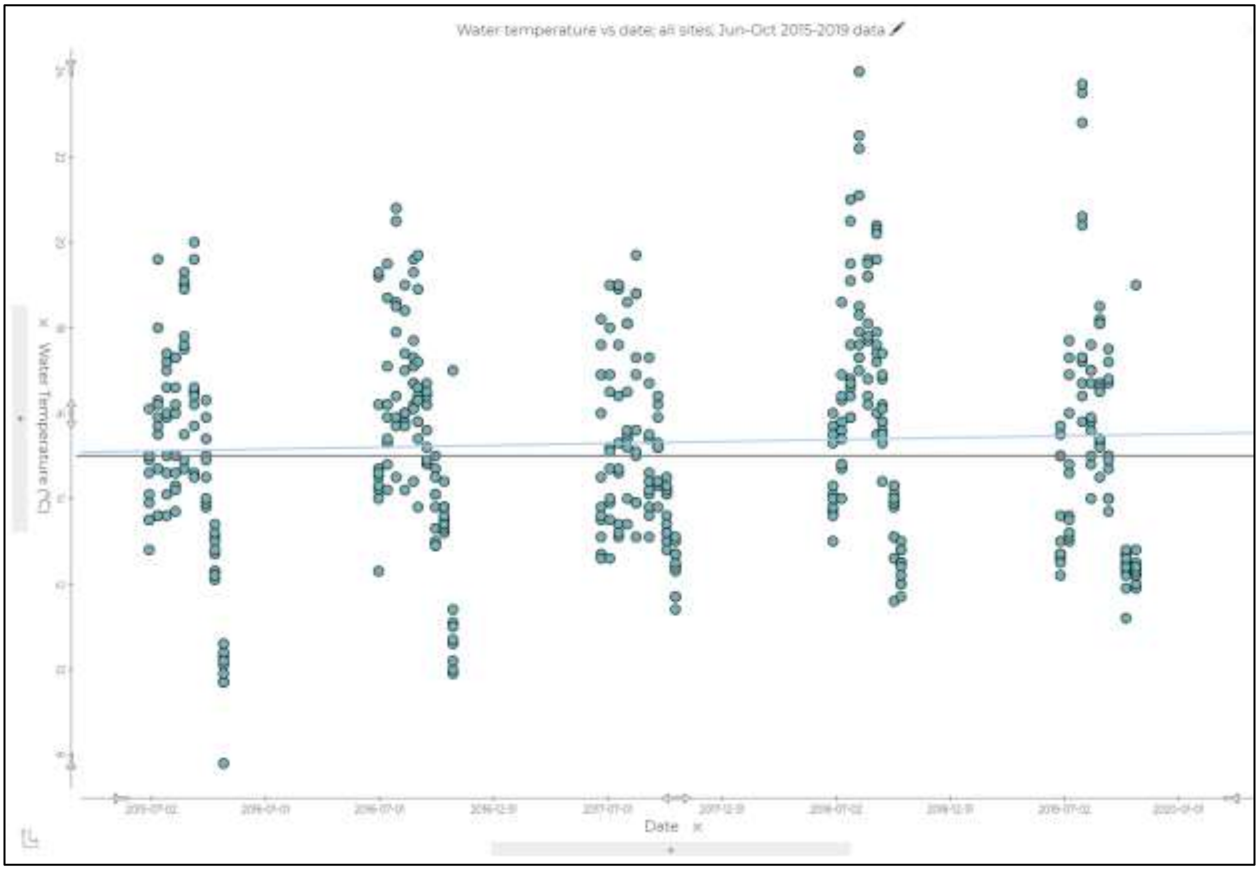
Figure 8 Salinity vs date (all sites, 2015-2019)



Water Temperature Data (all sites, Jun-Oct 2015-2019)

Figure 9 presents water temperature along the y axis in degrees Celsius and date along the x axis. The blue line is a statistical Least Squares Regression line. A gray horizontal line is superimposed on the chart at 15°C for visual reference. The Least Squares Regression line demonstrates an increase in average water temperature.

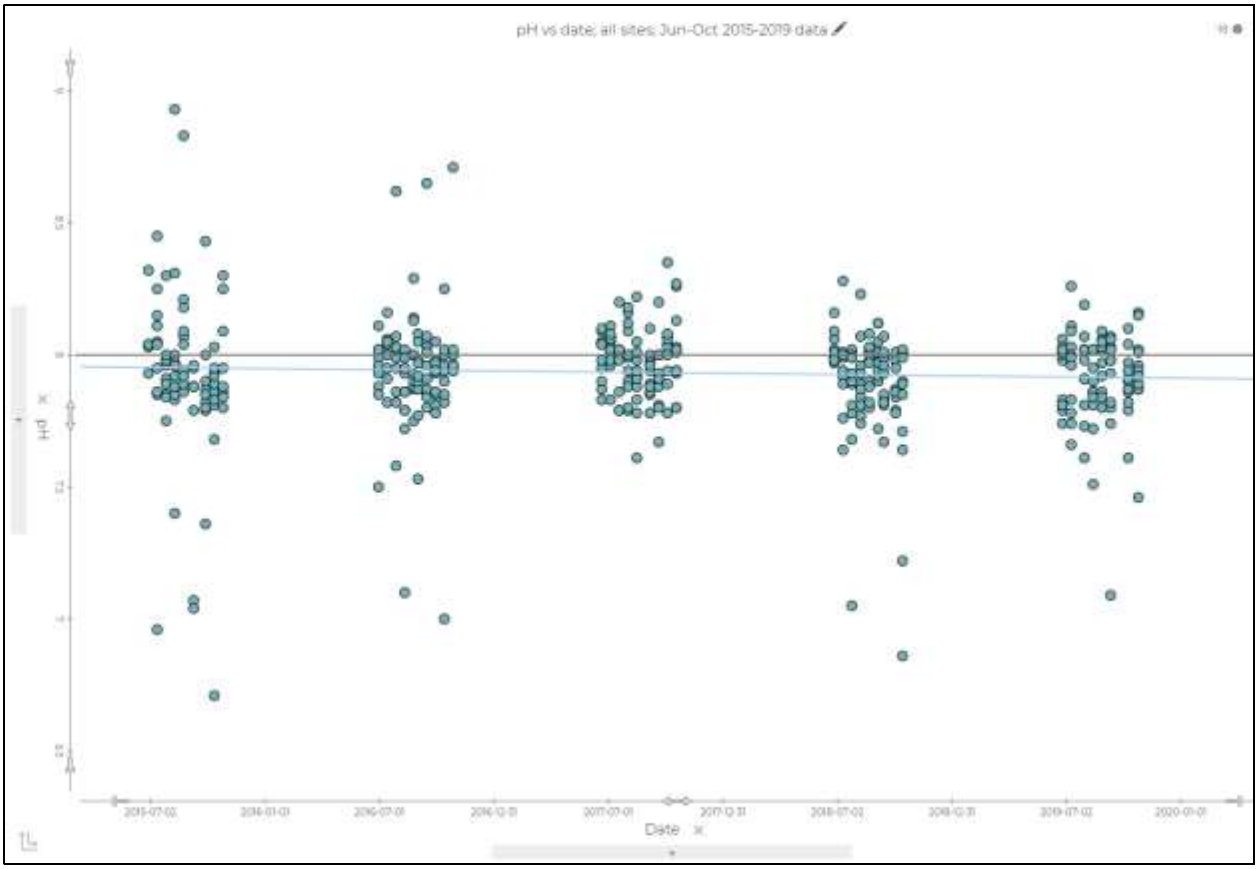
Figure 9 Water Temperature vs date (all sites, 2015-2019 data)



pH Data (all sites, Jun-Oct 2015-2019)

Figure 10 shows all pH data collected from June to October, 2015-2019. The blue line is a statistical Least Squares Regression line. The gray line is a horizontal line at pH 8.0 which was added as a visual reference. It illustrates the negative slope of the trend line showing decreasing pH (increasing acidity) from 2015 to the present.

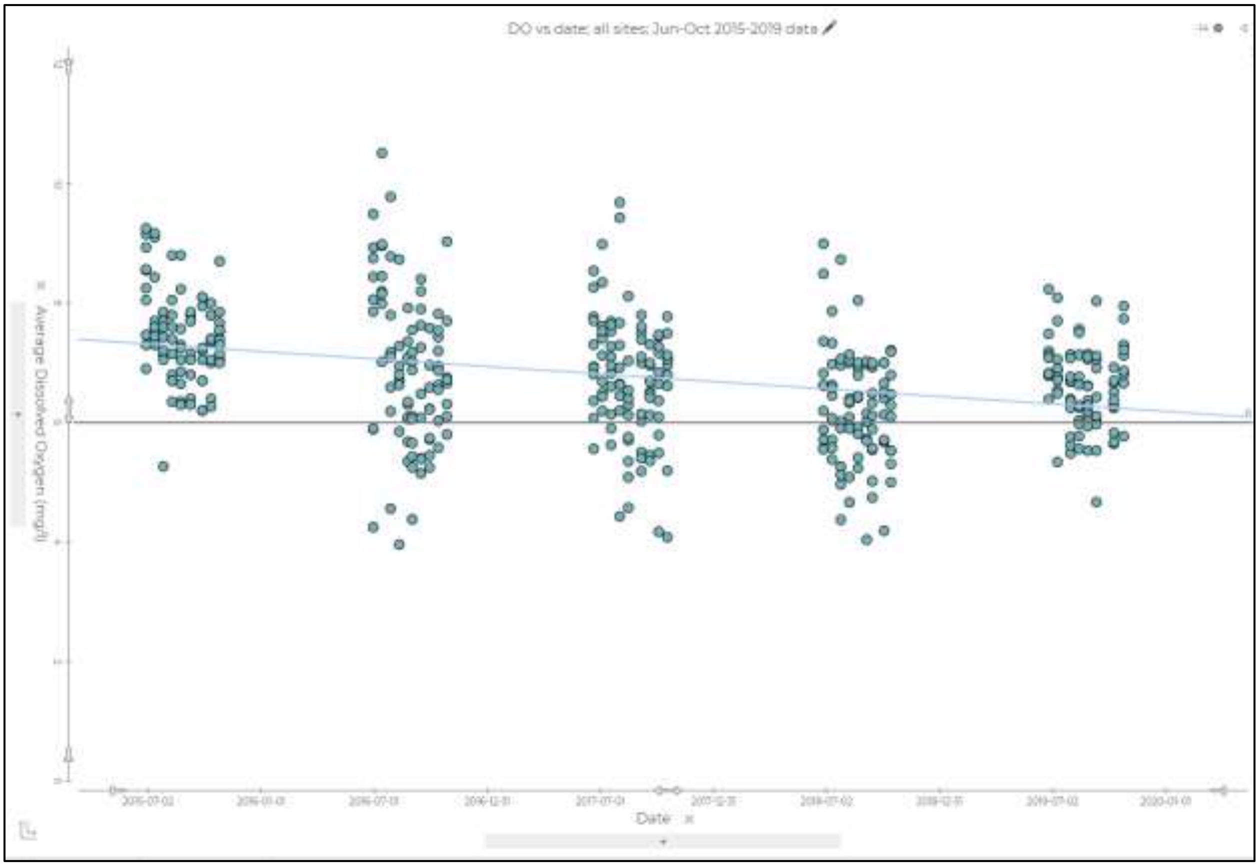
Figure 10 pH vs date (all sites, 2015-2019)



Dissolved Oxygen (DO) Data (all sites, 2015-2019)

Figure 11 shows all DO data collected from June to October, 2015-2019. The blue line is a statistical Least Squares Regression line. The gray line is a horizontal line at 6.0 mg/L which was added as a visual reference. It illustrates the negative slope of the trend line showing decreasing DO from 2015 to the present. One data point of 11.75 mg/L recorded on 7-27-2015 was removed from the chart since it is so far from all other values that it appears to be erroneous.

Figure 11 Dissolved Oxygen vs date (all sites, Jun-Oct 2015-1019 data)



Appendix: Boothbay Coastal Water Monitoring Volunteers (2019)

Deborah Berrill

Michael Berrill

John Brennan

Jim Darrow

Marcia Donald

Barbara Fowler

Ed Green

Tracey Hall

Robert Jordan

Christine Kipp

Fred Kraeuter

Cyrus Lauriat

Doug MacKay

Ron Ross

John Schindler

Christine Selman

Nick Ullo

Jane Wissman