

Dissolved Oxygen in Quahog Bay, ME

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ABSTRACT

In our study of dissolved oxygen in Quahog Bay, Maine, we hoped to contribute to the data held by the Friends of Casco Bay (FOCB) by observing dissolved oxygen levels over a more extended period of time than had previously been studied. Other primary goals were to understand reasons for hypoxia and to determine seasonal patterns and ongoing trends in the dissolved oxygen variations of Quahog Bay. We collected our data at six sites in the bay on two dates, 10/04/04 and 10/25/04. All sites exhibited some degree of mixing with deeper water sites having some level of stratification as well. We found the dissolved oxygen concentrations to be affected by weather, primary productivity, and possibly decay. We discovered that dissolved oxygen varies seasonally and determined that concentrations increase as summer progresses into fall, with hypoxic conditions occurring in the summer. We would recommend further data collection to account for time and tide differences in data collection and to establish the annual cycle of dissolved oxygen in Quahog Bay.

INTRODUCTION

Our research project studied the dissolved oxygen content of Quahog Bay. Quahog Bay is a part of Casco Bay in Maine and is located at about 44 degrees north and 70 degrees west. Casco Bay experiences semi-diurnal tides. Small freshwater sources flow into the upper part of Quahog Bay. The bay gets deeper and narrower as one progresses southward towards the mouth. Centuries of human use have created chemical and biological waste that may have polluted the bay, negatively affecting water quality

(Little, 2000). Biological waste is harmful to the health of the bay because it contains organic matter. Oxygen is consumed during bacterial decay of this organic matter and can lead to anoxic conditions (Little, 2000). In addition, in recent history, Quahog Bay has experienced low levels of dissolved oxygen. This is potentially harmful to the ecosystem and therefore the economy based on lobstering and fishing.

In our research project, we compiled data to aid the Friends of Casco Bay (FOCB) in their study and monitoring of the health of Casco Bay. Friends of Casco Bay is a non-profit organization dedicated to understanding and preserving the vitality of Casco Bay. With the help of community volunteers, they collect data for different variables that affect the bay's health to aid in their research. Friends of Casco Bay served as our mentor and assisted in our development of ideas and procedures.

In our study of dissolved oxygen, we sampled the entire water column at six previously studied sites in Quahog Bay, starting at Great Island Boat Yard in the north and moving south. Our study was intended to compliment past research done by FOCB and to enhance the investigation of seasonal patterns and ongoing trends in the dissolved oxygen content of Quahog Bay. In addition to our data collected in October 2004, FOCB collected data in August and September 2003 and 2004. While we only had one data set for each date of research, FOCB collected data at both high tide and low tide on four different dates in 2003. We hypothesized that we would see a clear change in dissolved oxygen levels over the time that FOCB's data was collected. Instead, dissolved oxygen fluctuated greatly each date in 2003 with no observable overall trend.

In addition to not seeing a seasonal trend, we failed to see a consistent change in dissolved oxygen concentration between high and low tides in FOCB's data. We hoped

that adding our data to that collected by FOCB would reveal trends in dissolved oxygen concentration. Perhaps broadening the span of data would obscure some of the insignificant fluctuations and expose the significant patterns. Our analysis of these results will suggest reasons for and impacts of these patterns on the Quahog Bay ecosystem.

There are both anthropogenic and natural causes of hypoxia, defined as being less than 2.8 mg O₂/L of water (Wu, 2002). Two common causes of hypoxia are eutrophication and human pollution. A eutrophic body of water is rich in nutrients. This leads to an increase in photosynthetic activity, in turn leading to a depletion of dissolved oxygen. At first, the increase in photosynthesis produces more dissolved oxygen. However, when the photosynthesizing organisms die, the bacteria aiding in their decay use high levels of oxygen in the decay process, leading to oxygen depletion. The decaying organisms also produce higher levels of nutrients, eventually causing eutrophication. Eutrophication can result from pollution because organic pollutants contain high levels of nutrients. According to Wu (2002), the increase in nutrients in water bodies “is primarily attributable to intense farming, application of fertilizers, deforestation, and discharge of domestic wastewaters.” In addition, when water is highly stratified, lack of mixing can cause decreased concentrations of dissolved oxygen in some levels of the water column if the dissolved oxygen is not evenly mixed throughout the column. For example, if mixing only occurred in the top fifteen meters of a body of water, the lower layers would have less oxygen because of lack of contact with the atmosphere and little or no photosynthesis during mixing. These causes have been observed in Chesapeake Bay, the Gulf of Mexico, and Hakata Bay, Japan. In Chesapeake

Bay, negative changes in dissolved oxygen coincide with the application of fertilizers and human development near the Bay (Wu, 2002). As industrial buildup around the Mississippi River watershed, the main tributary of the Gulf of Mexico, has increased over time, there has been a decrease in the level of dissolved oxygen in the Gulf of Mexico. This is a result of eutrophication in the Gulf, caused by increased nutrient concentration in the river (Rabalais et al., 2001). In Hakata Bay, Japan, decreases in dissolved oxygen were observed resulting from “eutrophication, land reclamation and operation and maintenance of water resources projects” (Karim et al., 2003). The scenarios in these locations are all potentially applicable to Quahog Bay.

Hypoxia has many repercussions on an estuarine ecosystem. First, low dissolved oxygen causes a decrease in the abundance of zooplankton. For example, in concentrations of less than one mg/L, copepod mortality increases (Roman et al., 1993). This is significant to Quahog Bay and to our study because it pulls the bottom out of the food chain, negatively affecting the marine life that feeds upon it. Hypoxia also influences predator prey relationships. Depending on their physiology, either the predator or the prey is more detrimentally affected by low dissolved oxygen. For example, in Chesapeake Bay, decreased dissolved oxygen concentrations tend to affect predatory fish such as striped bass, making them less able to pursue their victim. On the other hand, hypoxia reduces the swimming speed of many larvae, making them more susceptible to predation (Breitburg et al., 1997). Thirdly, variations in the concentrations of dissolved oxygen in a stratified water body may cause vertical and horizontal migration of organisms as they seek non-hypoxic areas. The movement of fish is especially influenced by dissolved oxygen levels. In Hakata Bay, Japan, where the bottom waters are hypoxic,

fish stay near the surface and swim towards the mouth of the bay where there is more oxygen. In addition, fish often migrate towards the surface of the water where there is higher dissolved oxygen due to mixing and photosynthesis. Sheepshead minnow and sailfin molly may even surface breathe by swimming on the very top when oxygen falls below 1.5 mg/L (Wu, 2002). Finally, extreme hypoxia can result in mass deaths of marine organisms including fish and crustaceans. This can harm the land animals and birds in the ecosystem that are part of the same food web. It also has economic implications as fisheries rely on a sustainable harvest. Thus, humans can create a vicious cycle in which our own pollution harms our economy by killing the organisms on which we depend.

Understanding the nature of dissolved oxygen is essential to understanding and preserving the health of an aquatic ecosystem because all marine life depends on the presence of oxygen. All of the ecological impacts of low dissolved oxygen discussed above are significant in Quahog Bay. Friends of Casco Bay's mission is to monitor and understand the factors that harm the water quality of the Bay. We hoped that by observing changes in dissolved oxygen over a longer period of time, looking for trends and patterns in the dissolved oxygen levels, and investigating possible causes of hypoxia in the bay, we could help Friends of Casco Bay to develop an aggressive conservation plan for restoring Quahog Bay to a healthy state.

METHODS

DESCRIPTION OF STUDY LOCATIONS

We collected dissolved oxygen data from six different sites in Quahog Bay, Maine (Figure 1). Data were collected at sites QB6, QB5, QB4A, QB4B, QB3, and QB2 (Table 1). Site QB6 is the closest site to the Great Island Boat Yard at the tip of the bay. The water at this site is shallowest, 9.5 feet at ebbing tide on 10/25/04. The bay becomes deeper as it opens. In comparison with QB6, site QB5 is located in much more open water. QB4B is a site that we created ourselves in line with the other five sites, in order to test more accurately because there is a large gap between QB4A and QB3. There was also a site, along the same latitude, QB4, that we did not test, so we created QB4B as its counterpart along the same line as the rest of the sites. QB4B is located off the southwest end of Center Island. Our final testing site, QB2 is located between Pole Island and Card Cove. It is important to note that the bay becomes deeper as it becomes less enclosed. QB2 is 50.5 feet deep at ebbing tide, 41 feet deeper than the northernmost site.

Table 1. Latitude and Longitude of Testing Sites

Site	QB6	QB5	QB4A	QB4B	QB3	QB2
Latitude (°)	43.83099	43.82342	43.81478	43.81131	43.80526	43.79393
Longitude(°)	69.91481	69.91548	69.91803	69.91887	69.92212	69.92726

DATES CONDUCTED

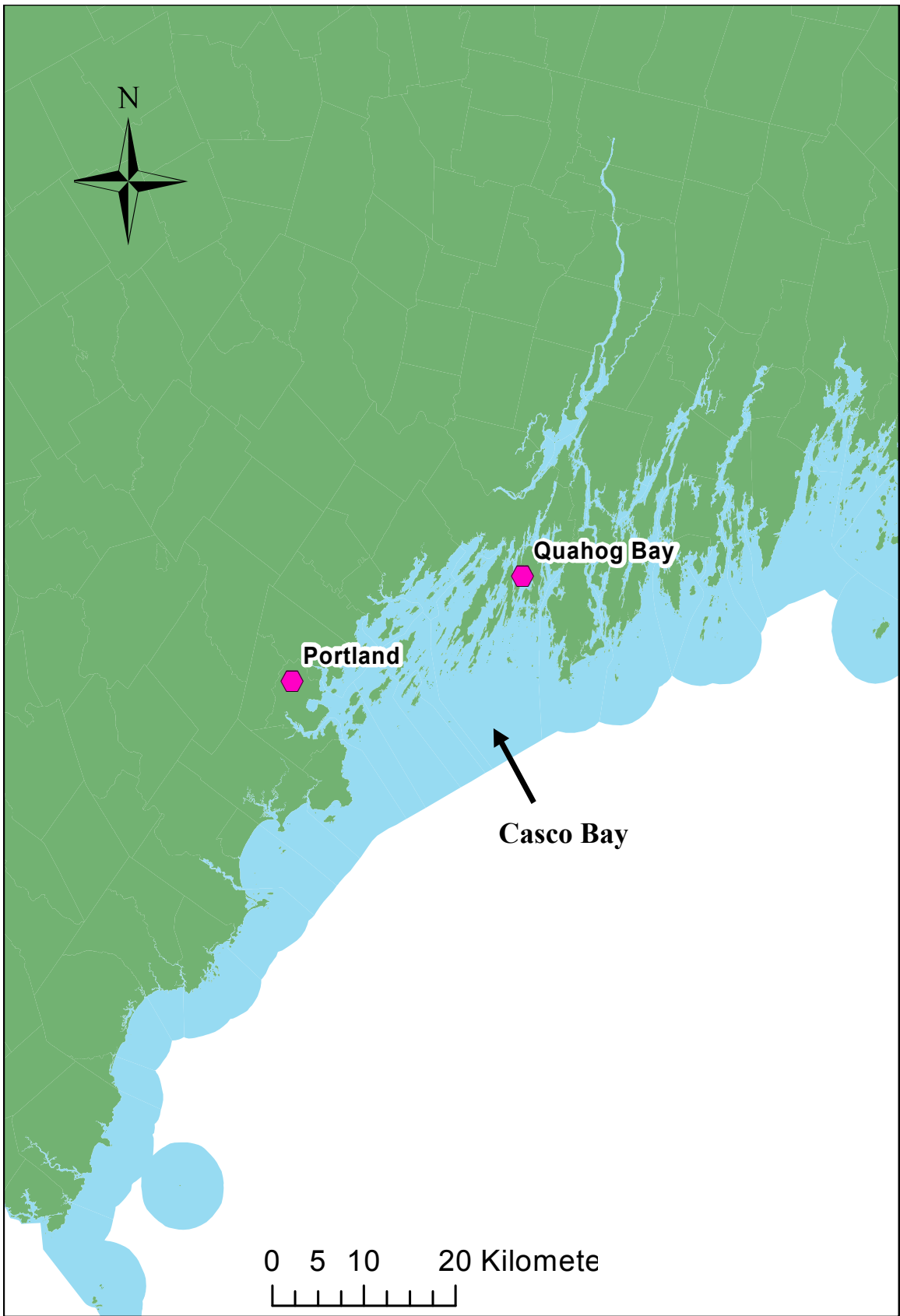
We were in the field on 10/04/04 and 10/25/04. On the first date, we left the dock at 2 o'clock in the afternoon. The tide was coming in, and reached high tide at 3:48pm.

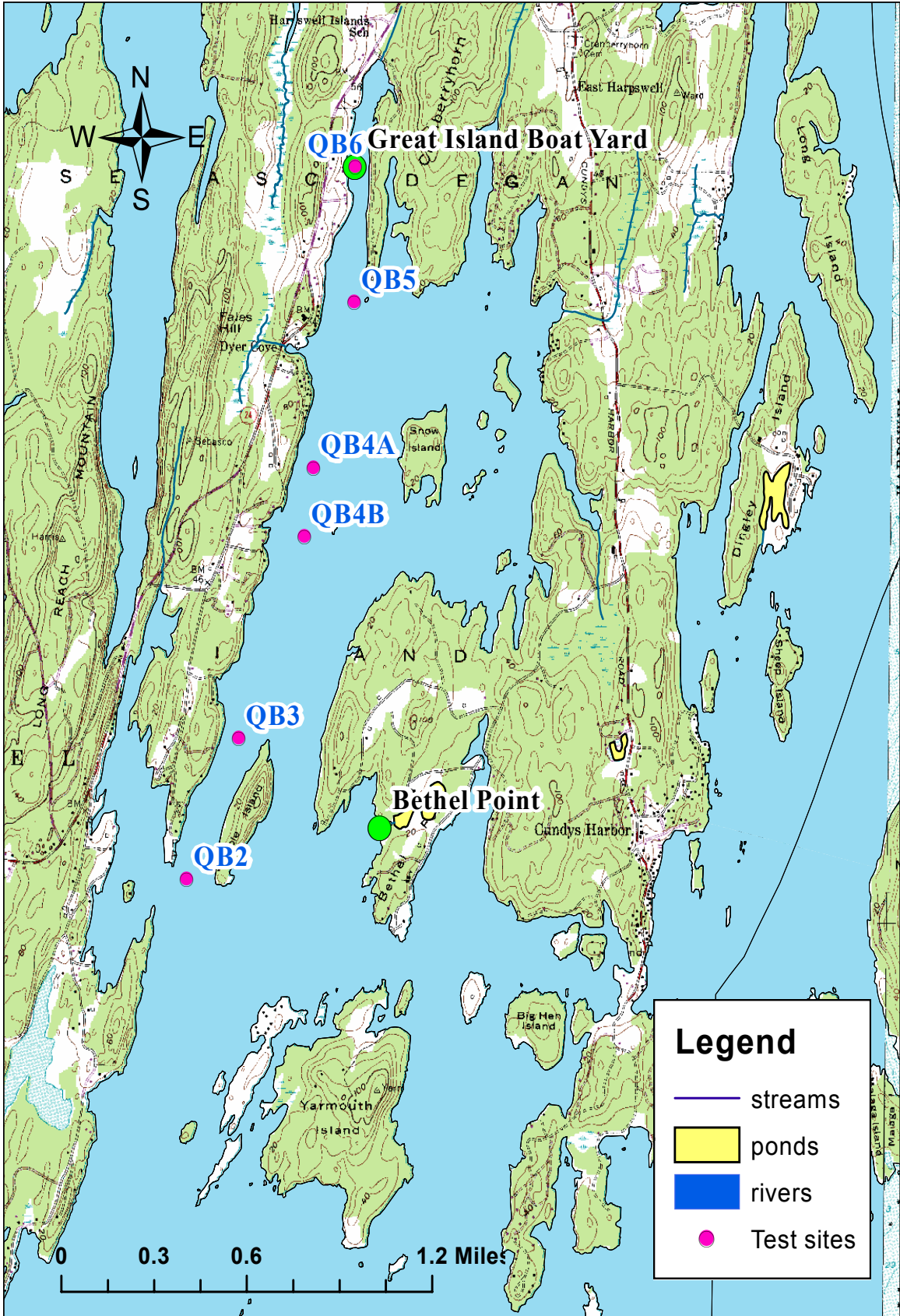
The sky was clear and there was a slight breeze. The temperature was a mild 20.85 degrees Celsius. We were in the field for approximately two hours.

On October 25th, we departed from the marina at 2:15pm. The tide was going out, and reached low tide at 4:00pm. The day was overcast with little wind, and it began to rain lightly at about 2:45pm. The temperature was approximately 8.8 degrees Celsius. We completed our data collection at 3:30pm.

DESCRIPTION OF FIELD AND LAB METHODS

Our group had both field and lab components in our study of dissolved oxygen in Quahog Bay. In the field, we went out on the boat to each of our six different testing sites and took a depth integrated sample of dissolved oxygen at each site. To do this we used an YSI 6600 which we lowered down to the bottom of the bay while collecting data on a handheld data collector. We lowered the YSI at each site one or two times, and used the cast with the most points for our data. We did this on two different days. Once we had our data on the YSI, it was put into an Excel spreadsheet, from which we could make graphs in Ocean Data View. We used these graphs to draw conclusions about dissolved oxygen levels in the bay. In addition to taking surface to bottom dissolved oxygen profiles, we took water samples at three sites, QB5, QB2, and QB4A on 10/25/04, to use for Winkler titrations. Using the FOCB method for Winkler titrations, we checked the dissolved oxygen values given by the YSI. For each site, we took three samples and did Winkler titrations on two of them, assuming that the titrations were within 0.3 mg/L of each other. However, for each site, the first two samples that we tested were within 0.3 mg/L of each other.





Testing Sites in Quahog Bay

RESULTS

8/20/04

On 8/20/04, the data were collected near dawn at low tide. The dissolved oxygen concentration ranged from 6.5 mg/L to 8.5 mg/L (Figure 1). The dissolved oxygen reached no saturation higher than 105%, with the lowest saturation being 70% (Figure 2). The temperature profile was very well mixed at QB6 and QB4A, but at QB2 it was well stratified. Temperatures ranged from 12°-19.5°C (Figure 3). The dissolved oxygen concentration and percent saturation profiles were also well mixed at QB6 and QB4A, and well-stratified at QB2.

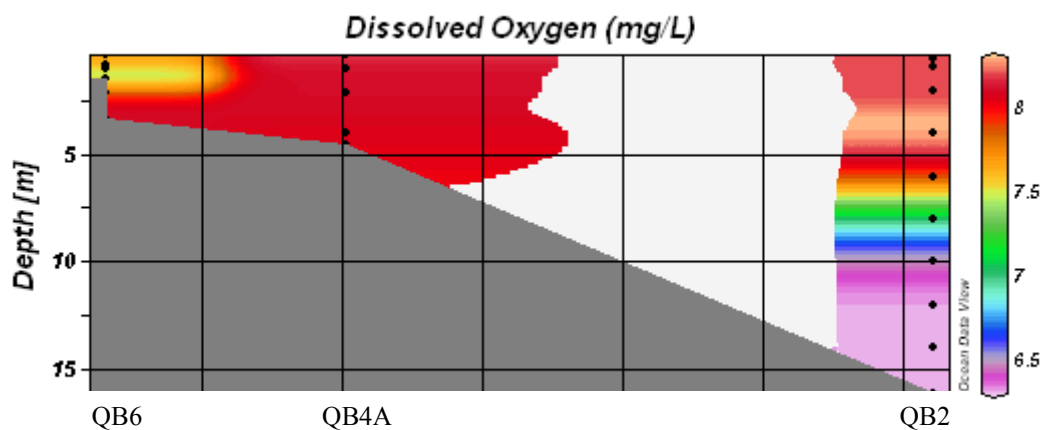


Figure 1. Dissolved Oxygen concentration. Quahog Bay, Maine.
8/20/04.

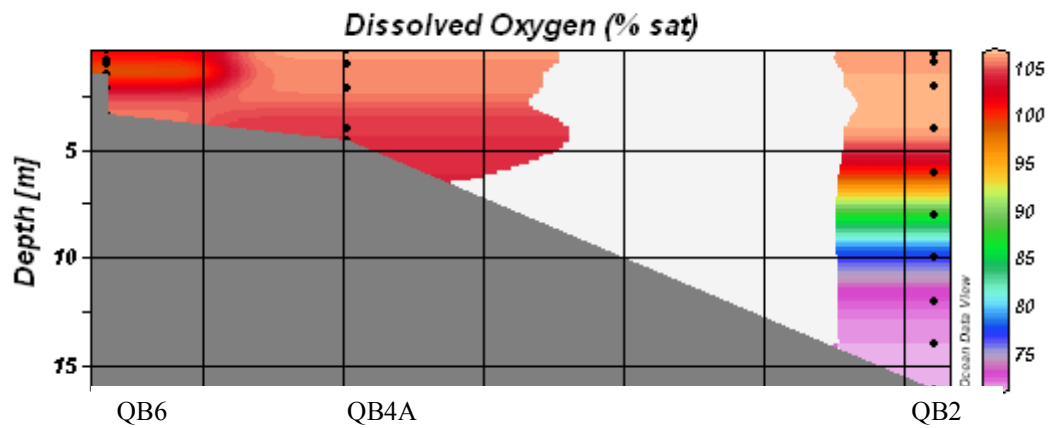


Figure 2. Dissolved Oxygen percent saturation. Quahog Bay, Maine. 8/20/04.

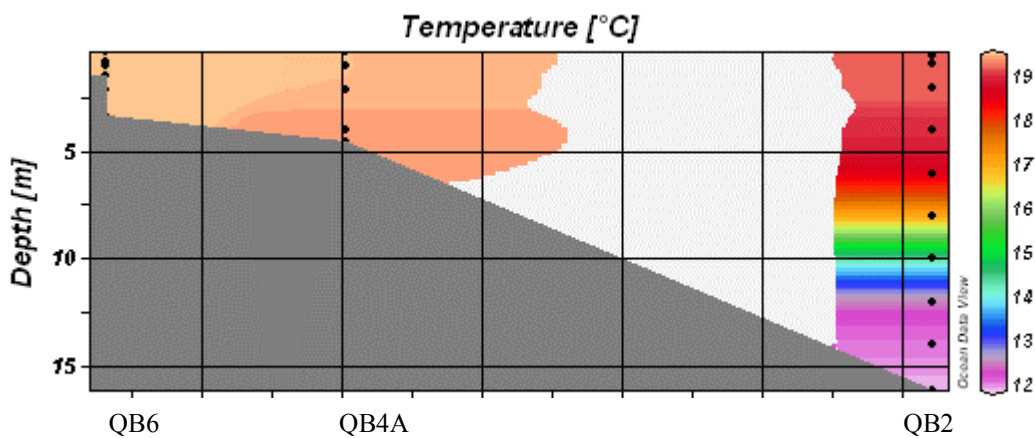


Figure 3. Temperature. Quahog Bay, Maine. 8/20/04.

9/03/04

On 9/03/04, data were also collected near dawn at low tide. The dissolved oxygen concentration values were between 5 mg/L and 9 mg/L (Figure 4). The percent saturation ranged from 60% to 113% (Figure 5). Sites QB6, QB5, and QB4A were very well stratified, but in comparison to 8/20/04, the water at site QB2 was less stratified. The dissolved oxygen concentration was lowest at QB5 on the bottom, at 5 mg/L. At QB6, the

entire water column was hypoxic with percent saturation below 85%, at QB5 hypoxia occurred below 4 meters, at QB4A hypoxia occurred below 5 meters, and at QB2, it occurred below 10 meters (Figure 5). The temperature profile was less well mixed than 8/20/04, with values ranging from 13°-18°C (Figure 6).

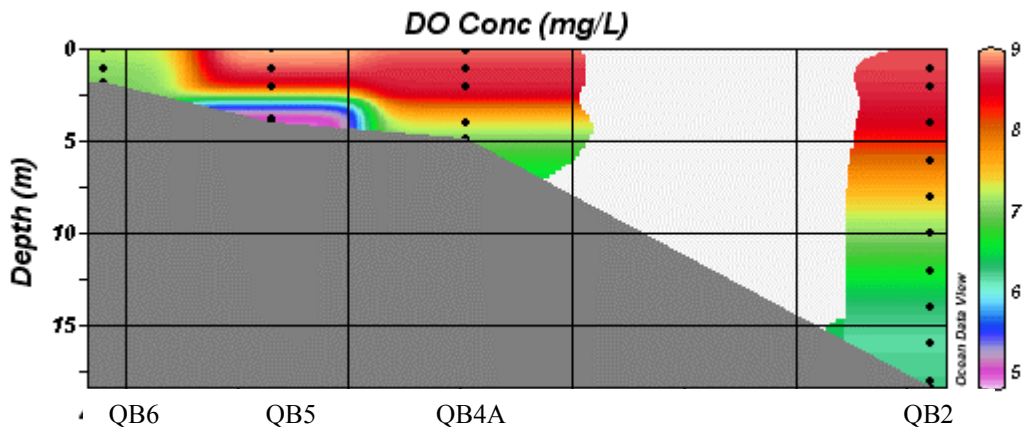


Figure 4. Dissolved Oxygen concentration. Quahog Bay, Maine. 9/03/04.

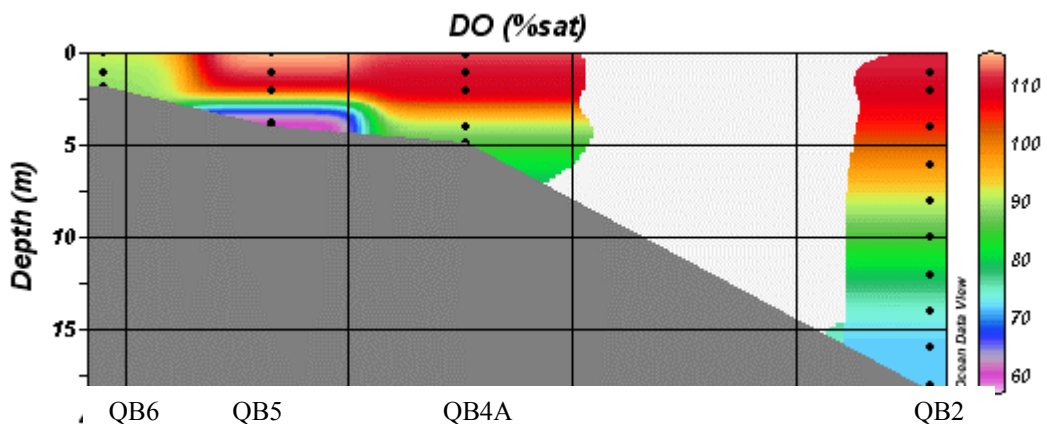


Figure 5. Dissolved Oxygen percent saturation. Quahog Bay, Maine. 9/03/04.

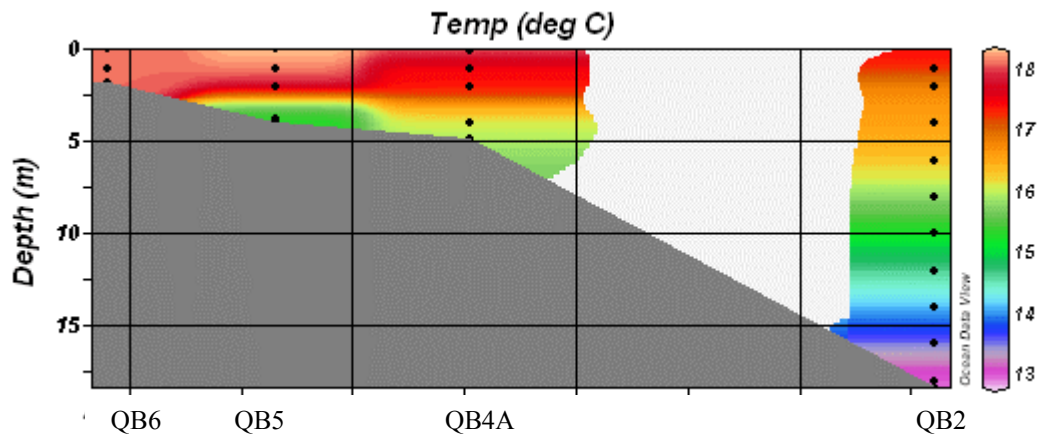


Figure 6. Temperature. Quahog Bay, Maine. 9/03/04.

9/19/04

On 9/19/04, data were again collected near dawn near low tide. The dissolved oxygen concentration ranged from 6 mg/L to 8 mg/L (Figure 7). The percent saturation ranged from 70% to 95% (Figure 8). All sites, QB6, QB5, QB4A, and QB2, were well stratified. On this date, QB6 had the lowest dissolved oxygen concentration, 6 mg/L (Figure 7). At sites QB5, QB4A, and QB2, the entire water column below five meters was hypoxic, with dissolved oxygen saturation less than 85%. At QB6, the whole water column was hypoxic (Figure 8). Temperatures ranged between 12.5° and 14.5°C, and the profile was less stratified than on 9/03/03.

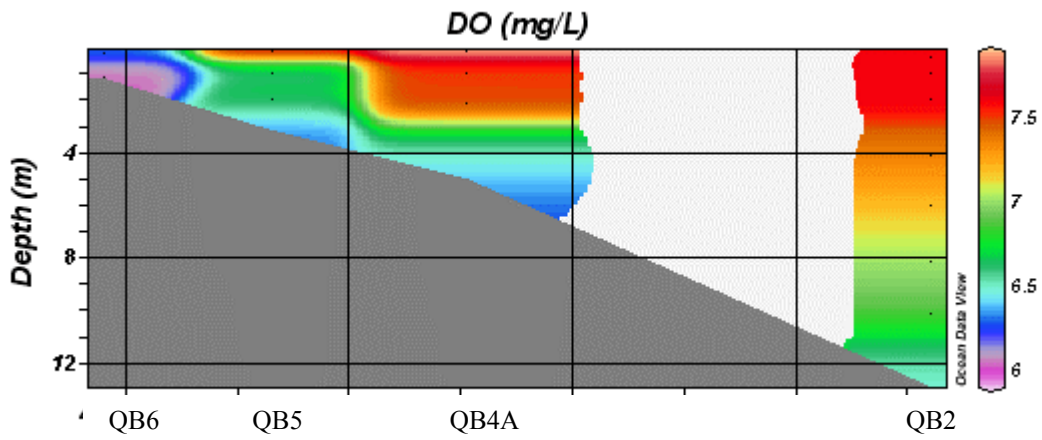


Figure 7. Dissolved Oxygen concentration. Quahog Bay, Maine. 9/19/04.

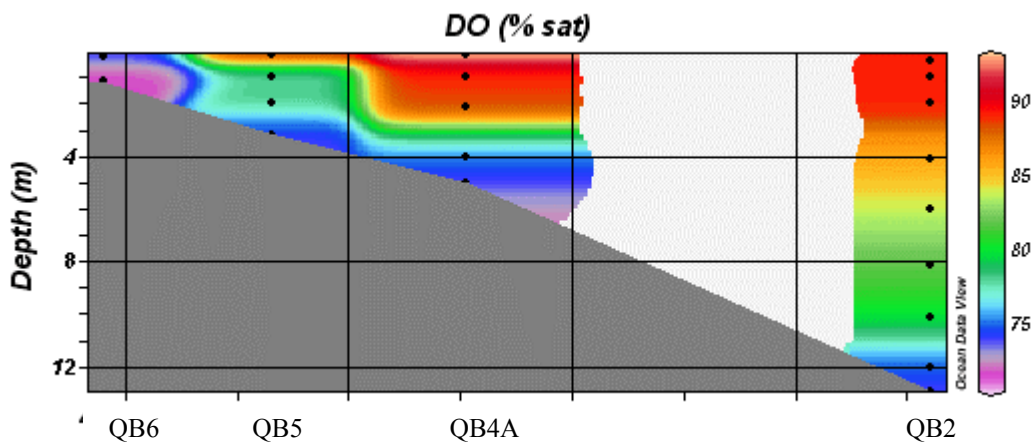


Figure 8. Dissolved Oxygen percent saturation. Quahog Bay, Maine. 9/19/04.

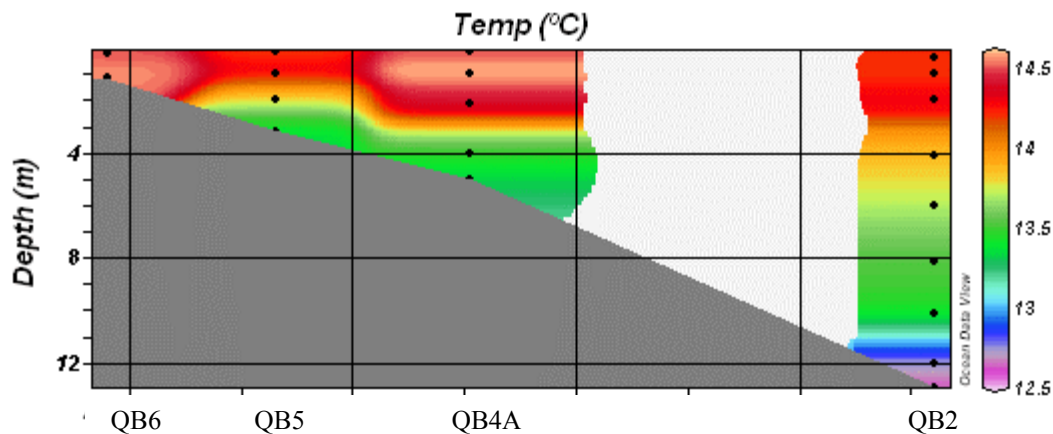


Figure 9. Temperature. Quahog Bay, Maine. 9/19/04.

OVERALL CHARACTERISTICS OF FOCB DATA

The data collected by FOCB shows overall lower dissolved oxygen concentrations and saturations than the data we collected on 10/04/04 and 10/25/04. It also shows that as late summer progresses into early fall, the water column at sites QB6, QB5, and QB4A became more stratified, while the water column at QB2 became less stratified. In addition, the water got colder as the seasons changed.

10/04/04

On 10/04/04 the values for dissolved oxygen concentration were mostly between 9 mg/L and 9.7 mg/L (Figure 10). In deeper water, especially at QB2, the water was very well stratified with respect to both dissolved oxygen concentration and percent saturation. The highest dissolved oxygen levels were at the surface, and concentration and percent saturation decreased with depth (Figures 10 and 11). In addition, the dissolved oxygen saturation was above 100% at all sites, except QB2 below 18 meters (Figure 11). The temperature profile for 10/04/04 showed a well mixed water column in the shallower water, with most surface temperatures between 14°C and 15°C (Figure 12). Notably, on

10/04/04, the temperature profile at QB2 was stratified as well, with higher temperatures at the surface (Figure 12).

On 10/04/04 there were anomalies in both concentration and percent saturation in comparison to the dissolved oxygen profile of the rest of the bay. At QB6 and QB5, there was a relatively large pocket of higher dissolved oxygen water, about 9.7 mg/L, just below the surface (Figure 13). It extended from a depth of about 4 meters to the bottom of the bay. Temperature in this area was about 14.7-15.2°C (Figure 12).

Another irregularity occurred near QB3 (Figure 13). From the surface to a depth of about 2.5 meters, the dissolved oxygen concentration was lower (8.5 mg/L) than the 6 meters below it. After the first 2.5 meters, the dissolved oxygen concentration increased quickly, from 8.5 mg/L to 9.3 mg/L in less than a meter, then decreased normally with depth. Temperature in this region was about 14.8°C (Figure 12).

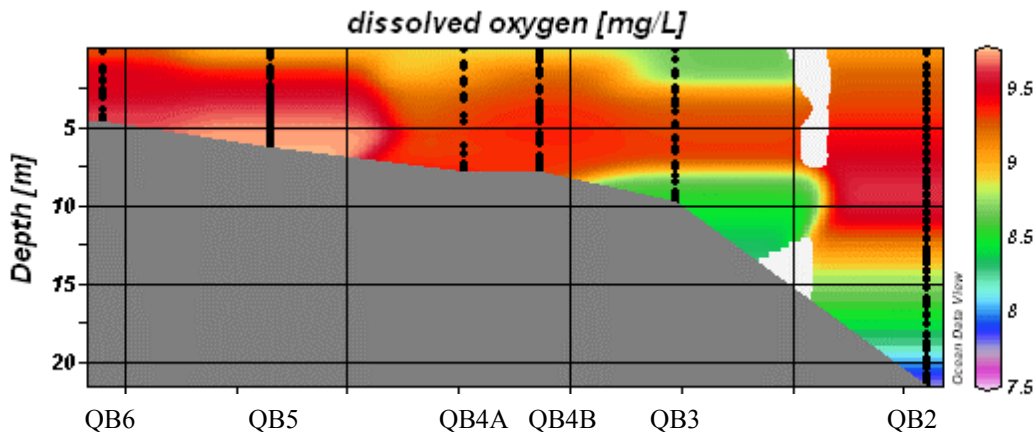


Figure 10. Dissolved Oxygen concentration. Quahog Bay, Maine. 10/4/04.

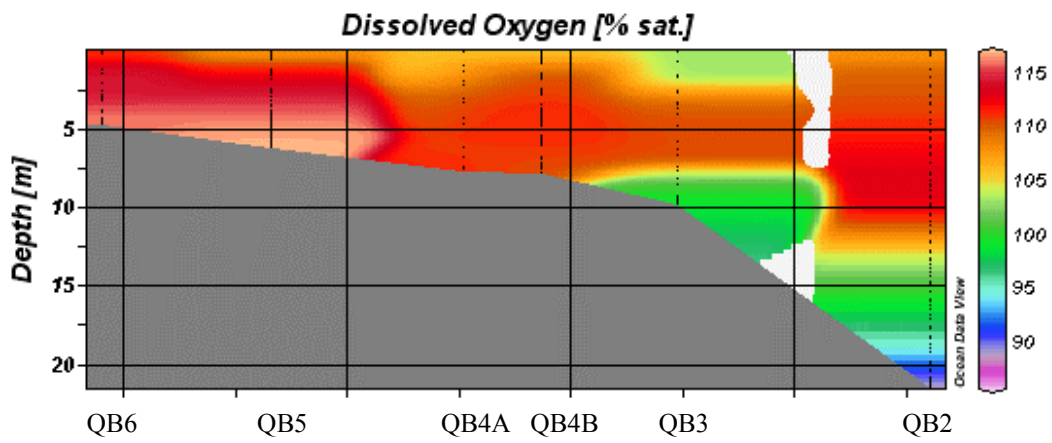


Figure 11. Dissolved Oxygen percent saturation. Quahog Bay, Maine. 10/04/04.

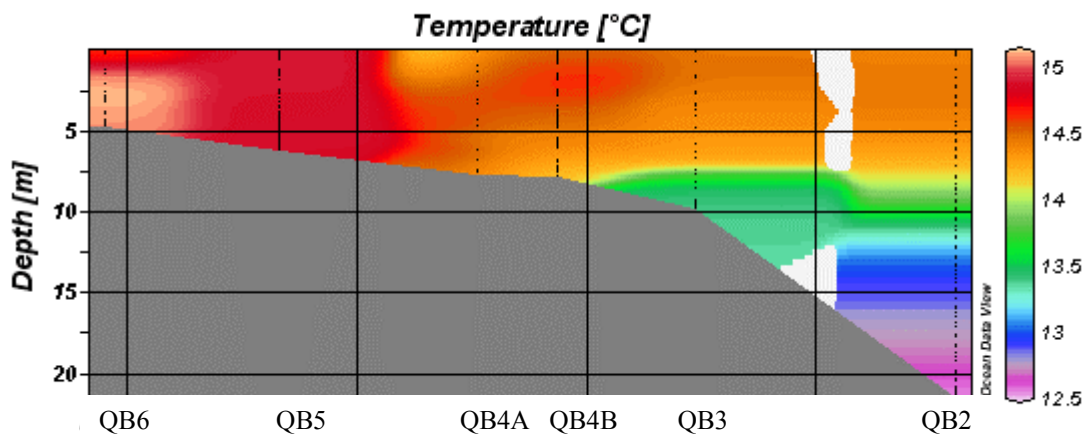


Figure 12. Temperature. Quahog Bay, Maine. 10/04/04.

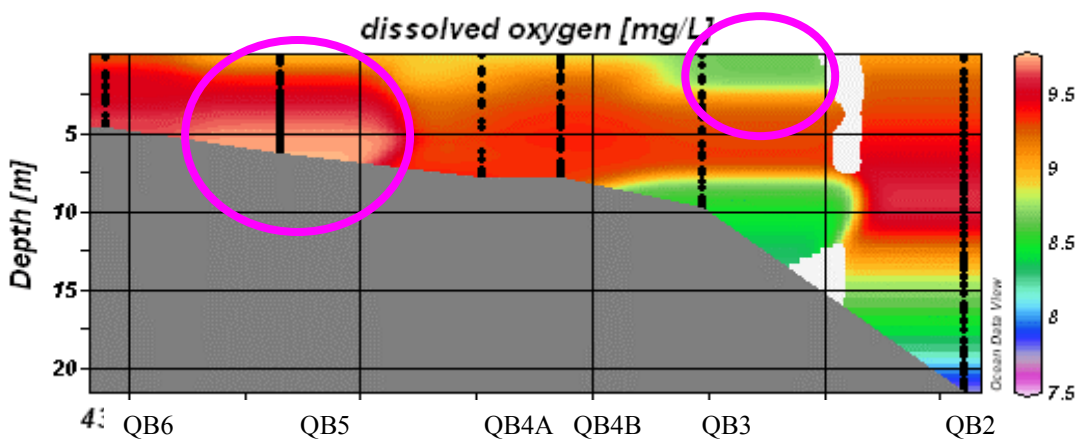


Figure 13. Dissolved Oxygen concentration. Quahog Bay, Maine. Anomaly on 10/04/04.

10/25/04

On 10/25/04, the dissolved oxygen concentration ranged between 8.8 mg/L and 9.6 mg/L (Figure 14). The dissolved oxygen saturation was above 100%, except at QB2 below 5 meters (Figures 15). There appeared to be a clinal variation at a depth of approximately 2.5 meters at site QB3 (Figure 15). This corresponded to a sharp change in percent saturation of dissolved oxygen below which the water was well-mixed. The temperature profile was slightly more stratified than 10/04/04 (Figure 16). The correspondence between temperature and dissolved oxygen concentration that occurred on 10/04/04 did not occur on 10/25/04.

The anomaly at QB5 and QB6 still existed, though it was closer to the surface and smaller than on 10/04/04 (Figure 17). It extended from the surface down to about 2 meters, and the temperature in this region was about 8.9°C (Figure 16).

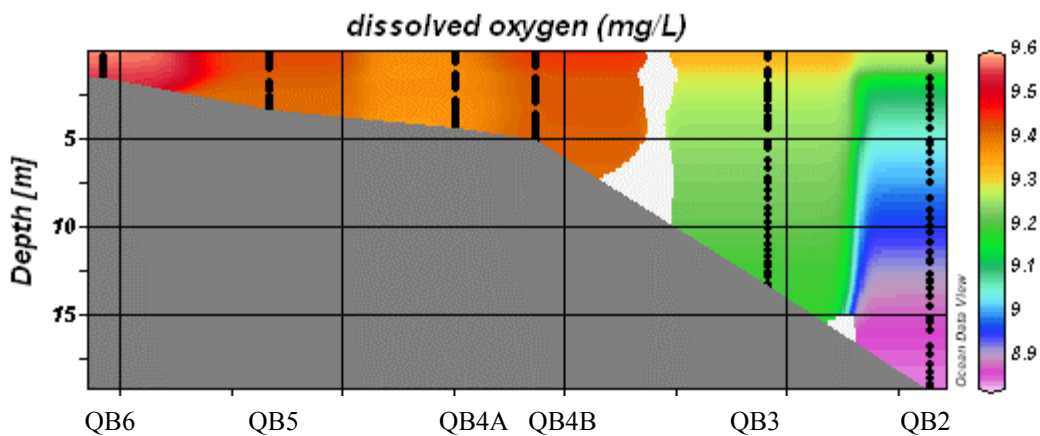


Figure 14. Dissolved Oxygen concentration. Quahog Bay, Maine. 10/25/04.

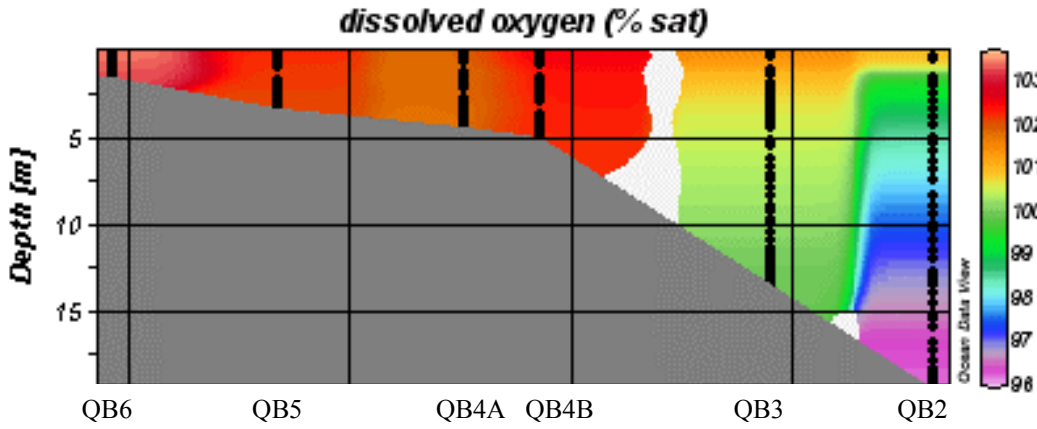


Figure 15. Dissolved Oxygen percent saturation. Quahog Bay, Maine.

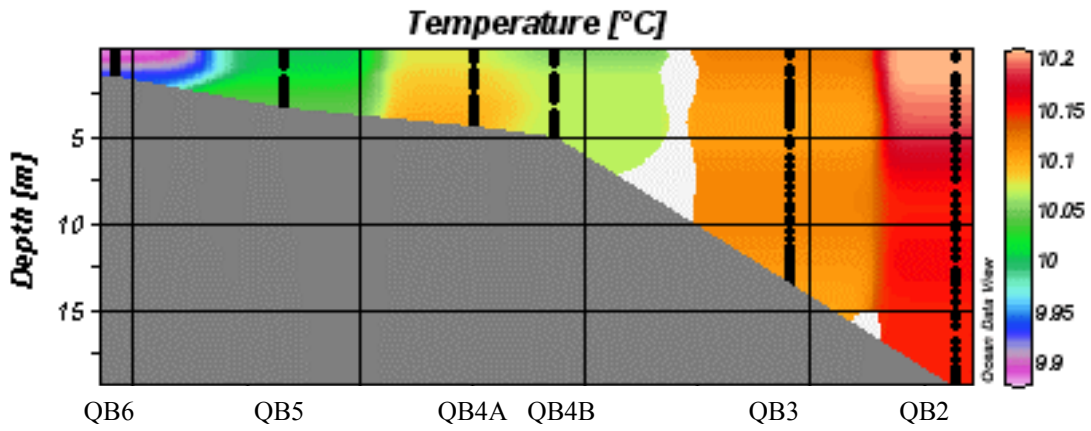


Figure 16. Temperature °C. Quahog Bay, Maine. 10/25/04.

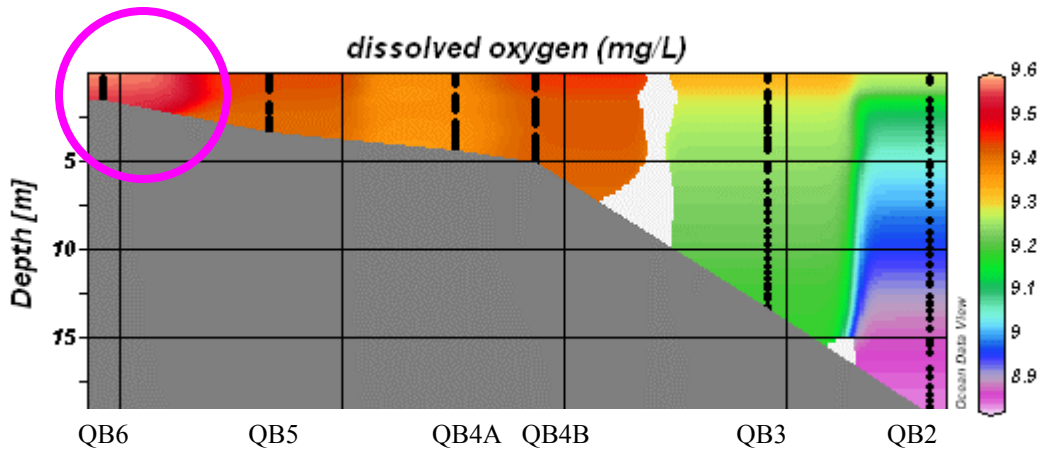


Figure 17. Dissolved Oxygen concentration. Quahog Bay, Maine. Anomaly on 10/25/04.

OVERALL CHARACTERISTICS

The overall dissolved oxygen concentration and saturation of 10/04/04 were higher than those of 10/25/04. The highest dissolved oxygen saturation of 10/04/04 was about 115%, whereas the highest dissolved oxygen saturation of 10/25/04 was 103% (figures 12 and 15). This difference corresponds with a lower average temperature on 10/25/04, a high of 10.2°C compared to 15°C on 10/04/04 (figures 16 and 12). While the highest value of dissolved oxygen concentration was the same on both days, a larger area of the bay had a dissolved oxygen concentration of 9 mg/L or greater on 10/25/04.

DISCUSSION

One of our main goals was to contribute to the data set already collected by Friends of Casco Bay (FOCB) in order to discover patterns and trends of dissolved oxygen levels over a longer period of time and through the season. After looking at FOCB's data from 8/20/04, 9/03/04 and 9/19/04, we determined that the dissolved oxygen levels varied from season to season. Despite this, we were unable to determine exactly how much they varied seasonally because FOCB collected their data near dawn, when dissolved oxygen is usually at its lowest, and during low tide. Dissolved oxygen is lowest near dawn because it has been dark all night and no photosynthesis has occurred, only respiration. We collected our data in the middle of the afternoon and near high tide, when photosynthesis was at or near its peak for the day. While these differences in collection times account for some of the variance in dissolved oxygen, the range is too great to be caused only by these factors. Therefore, we know that the lower dissolved oxygen in the summer is a seasonal trend, and that the dissolved oxygen levels continue

to increase as the fall progresses. However, to confirm this, data should be collected over a longer period at the same time and tide each date. With these data, one could tell whether the anomalies discussed below are a constant occurrence in the bay or are a result of abnormal weather conditions or decay, as well as become more aware of potential hypoxic conditions in the bay.

We also hoped to better understand the causes of hypoxia in the bay, which we found to be potentially seasonal. Hypoxia could also be dependent on “water column depth, local wind conditions, and proximity to fresh water inflows . . .” (Breitburg et al., 1997). FOCB defined hypoxic conditions as less than 85% saturation of dissolved oxygen. Our data do not indicate hypoxia by this definition in the bay on our testing dates (10/04/04 and 10/25/04). Although there are many causes for hypoxia, such as pollution and eutrophication, both due to “excessive anthropogenic input of nutrients and organic matters into water bodies,” (Wu, 2002) it is possible that these only manifest themselves seriously in Quahog Bay during the summer, as is shown by FOCB’s 2004 data. In the summer, storms are much less fierce, and though there is more primary productivity from increased sunlight, there is also more decay. Also, the water is warmer due to warmer air temperatures and less disruption from storms. Warmer water usually holds less dissolved oxygen than cold water. In addition, ice in the winter prevents sunlight and exchange of oxygen with the atmosphere from adding dissolved oxygen into the bay. Therefore, fall is one of the seasons during which Quahog Bay is expected to have high dissolved oxygen content. Since our data did not show signs of hypoxic conditions in Quahog Bay, we were unable to determine through our analysis possible causes of low dissolved oxygen that may occur during other seasons.

Factors affecting dissolved oxygen levels include temperature, atmospheric conditions, and nutrient/primary productivity levels. With FOCB's data and our data, we were able to analyze certain patterns and correlations within the testing period. There were many differences between our two test dates, but there were similarities as well. We were able to analyze our data in terms of mixing and stratification of the bay, in addition to making several conjectures about the causes of various anomalies in the dissolved oxygen profile.

Our first day of data collection, 10/04/04, was a windy (the average wind speed was 7.6 mph) day and sunny, with relatively warm air temperature (28.83°) despite the wind chill. The strong wind probably caused the shallow (0-8 m deep) water near QB6, QB5, QB4A and QB4B to be well-mixed because it was churned up by the high wind. The dissolved oxygen was highest in this region because of increased atmospheric contact due to mixing, as well as the fact that all or almost the entire water column at these sites is within the photic zone. However, at all of our test sites, and especially at the shallower sites, percent saturation was almost always well over 100%. Because the water is comparatively shallow throughout Quahog Bay (the deepest is about 21 meters), atmospheric conditions have a great effect on the amount of dissolved oxygen in the water. “. . . The enhanced gas transfer rates found at high wind speeds . . . and the injection of air bubbles to depths of several meters . . .” (Lazarevich et al., 2004) churn up the water, thus forcing more dissolved oxygen into the water and increasing saturation. Therefore, these heightened values of dissolved oxygen saturation are not abnormal as can be seen in the case of the Gulf of Aqaba, where over 100% saturation occurs year-round due to oxygenation from winter mixing and oxygen production from

photosynthesis (Badran, 2001). At greater depths, such as near site QB2, the water is much more stratified because wind and storms cannot churn it up (i.e. below ~12 meters). Overall, the dissolved oxygen saturation levels were higher on 10/04/04, which was probably due in large part to sunlight and to the wind mixing up the water, and not a result of temperature. Water temperature on this date was warmer than on 10/25/04, so the water should not have held as much oxygen. Increased oxygen levels could have occurred, however, if windy and turbulent conditions forced more oxygen to be dissolved in the water. These higher levels could also be due to the fact that 10/04/04 was a much sunnier day than 10/25/04, so more photosynthesis would occur.

The second day of testing, 10/25/04, was cloudy, rainy, cold (8.8°) and less windy (5.6 mph) than 10/04/04. The data from this day also show a mostly well mixed dissolved oxygen profile extending from QB6 to QB3. This is similar to 10/04/04, with the exception of QB3. Unlike on 10/04/04, there is some stratification at this site, showing a well-mixed water column. Even though the water is colder and should hold more oxygen, overall dissolved oxygen saturation is lower than on 10/04/04. This could be a result of less wind forcing oxygen into the water, or it could be a result of cloudy and rainy conditions impeding photosynthesis. While saturation is lower overall, in most locations it is still over 100%, for the same reasons as discussed above. The wind was less strong, but the turbulence that it caused in the water still may have resulted in over-saturation of the bay.

Within the mixed or stratified profiles of the testing sites, we noticed several anomalies that did not seem to fit the rest of the profile. On 10/04/04, there was a pocket of increased dissolved oxygen near the bottom in the area of sites QB6 and QB5 that

could be the result of a variety of factors. The temperature in the area of this pocket was higher than that of the rest of the bay (~15° C). In conjunction with the fact that colder water holds more dissolved oxygen, this pocket theoretically should not exist. However, if this was a region of primary productivity and an algal bloom was occurring, the photosynthesizing organisms would produce increased levels of dissolved oxygen. This is supported by the fact that in nutrient and chlorophyll data collected on 10/04/04, chlorophyll levels are highest in the middle and bottom of the water column (8.8 and 7.7 µg/L respectively) and lowest at the top of the water column (0.3 µg/L). The highest chlorophyll level overall at QB6 was in the middle of the water column (Monday Lab, Nutrient and Chlorophyll group). This corresponds with what our data shows. An algal bloom could have occurred in the area of QB5 and QB6 as a result of the sunlight on 10/04/04. The increased temperature and light would have increased phytoplankton production which would have released oxygen into the water (D'Autilia et al., 2004). Another possible cause of this region of increased dissolved oxygen is that the incoming tide carried colder, oxygen-rich water into Quahog Bay from Casco Bay that would not have been affected by primary productivity or mixing. Supporting the idea that the bay's dissolved oxygen characteristics could result from outside of the bay, data from Gray's Harbor in Washington "confirms the assumption that the abnormal dissolved oxygen concentrations of the incoming water were a characteristic of the oceanic environment rather than a result of man's activities or water discharge." (Holt et al., 1960) The mass of cold water could have traveled in along the bottom of the bay, thus resulting in a pocket of cold, oxygen rich water at the top of Quahog Bay near high tide.

This pocket of high dissolved oxygen is also present on 10/25/04, but it only occurs near QB6 and it is on the surface of the bay. Increased primary productivity and photosynthesis are also possible causes on this date, but there is another, perhaps more realistic manmade cause. On this date, we collected data at QB6 last instead of first, and our boat approached it at a higher speed than normal. When our boat turned around quickly to collect data at this site, the propeller created turbulence in the water, and thus probably increased the dissolved oxygen by forcing more air bubbles into the water. Not only did the propeller create turbulence directly around it, but it created a wake. This wake could have brought much more dissolved oxygen into the region with air bubbles, thus causing the pocket of high dissolved oxygen we observed.

In addition to the anomalies at QB5 and QB6, there was an irregularity near QB3 on 10/04/04. The surface waters had lower dissolved oxygen content than the water below. The profile at QB3 shows an area of low dissolved oxygen, followed by an area of higher dissolved oxygen that gradually decreased with depth. A possible cause for this region on the surface could be a decaying organism floating just under the surface. This could be the remains of an algal bloom that died, or perhaps even a dead fish. The bacteria that aid in the decay process of organisms consume oxygen, thus using and decreasing the dissolved oxygen levels in a particular area, as may have been the case near QB3 on 10/04/04. Also, it is possible that a school of fish was swimming in the area during our cast. Fish need oxygen to breathe and would have used much of the dissolved oxygen in the water. All of these processes require the use of dissolved oxygen and so could have depleted the levels at QB3.

Through analysis of our data and FOCB's data, we discovered that the bay is not necessarily hypoxic year-round. Our data showed no signs of hypoxic conditions, and in fact most of the water in the bay was over-saturated with dissolved oxygen at the time of our data collection. We were also able to add valuable data to FOCB's research and gain more insight into the causes of dissolved oxygen variation in Quahog Bay. We found that dissolved oxygen is greatly affected by weather, primary productivity, and possibly even decay. We believe that a more extensive set of data is necessary to fully understand dissolved oxygen in Quahog Bay. Given more time, a full profile of the changes in concentrations and reasons for these changes could be formed.

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