A health assessment of farmed Eastern Oysters (*Crassostrea virginica)* in Quahog Bay, Maine

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ABSTRACT

Eastern Oysters (*Crassostrea virginica*) are bivalve mollusk filter feeders. Assessing oyster health is important due to their role as bioindicators and cultivation for human consumption. The objective of this study is to obtain an understanding of the health of oysters at oyster farm leases in Quahog Bay, Maine using two different condition indices. The Condition Indices were shown to rise to a peak in early July and decline again. This data can be used to assess oyster health as well as an assessment on how environmental factors such as water temperature and salinity affect the indices.

INTRODUCTION

Eastern Oysters (*Crassostrea virginica*) are bivalve mollusk filter feeders (Wheaton, 2007) endemic to the east coast of the United States. Oysters provide ecosystem services such as water filtration, creating biogenic reef habitat for fish and invertebrates, and protecting the shoreline from erosion (Pollack et al. 2011; Zimmerman et al. 1989). As filter feeders, oysters serve as reliable indicators of water quality. It is suggested that oysters could function as an indicator of contaminants in areas with human impacts, attributed to their heightened responsiveness to sediment and pollutants such as microplastics (Edge et al. 2014; Thomas et al. 2019). If a population of oysters is healthy, it likely indicates low levels of pollutants in their habitat (Lawrence & Scott 1982).

As a species that resides in shallow coastal waters, oysters are exposed to a wide range of environmental and anthropogenic stressors. The most prominent stressors are water temperature, changes in salinity (precipitation), and pollution (Lannig et al. 2006). A study performed by Lannig et al. (2006) showed oysters' ability to process water significantly decreases as water temperature increases. High precipitation leading to a decrease of salinity has been linked to disease prevalence and infection rates, reductions in oyster abundance, and the ability of oysters to filter water (Pollack et al. 2011). Similarly, when exposed to sustained low-salinity conditions, oysters show signs of extreme stress such as abnormal feeding or ceasing feeding activity altogether (Loosanoff, 1965).

Oysters are found in the wild and grown in aquaculture farms. On many aquaculture farms, oysters are bred as sterile, triploid organisms bought as seed. This extinguishes the risk of natural breeding in places where they are not native, as well as preventing genetic mixing with local oyster populations. With no energy spent on reproduction, farmed oysters can allocate their energy to feeding and substantial growth. The volume of meat within a farmed oyster is suggestive of its health; a larger meat volume indicates few environmental stressors, while a smaller meat volume indicates increased stressors (Mercado-Silva, 2005).

Assessing oyster health is important due to their role as bioindicators and cultivation for human consumption. The Condition Index (CI) is a tool used to estimate the effect of a variety of environmental factors on oyster health and meat quality (Mercado-Silva, 2009). The oyster index provides baseline information that allows farmers and scientists to understand how a particular population of oysters are responding to the environment. CI compares the dry meat weight of the animal to the interior “volume” of the shell (Mercado-Silva, 2009). A singular standardized condition index for oysters does not exist, instead, there are multiple that compare different areas of interest such as meat weight and cavity volume. CI has been used to study the effect of changing water temperature and pollution (Lannig et al. 2006) on oysters which caused decreased carbohydrate and protein production, meaning the oysters’ tissue mass was smaller than its potential (Austin et al. 1993). It has also been used to look at effects on oyster growth among oysters living in different salinity and temperature ranges (Mercado-Silva, 2009).

The objective of this study is to obtain an understanding of the health of oysters at both Snow Island Oysters farm leases using two different condition indices. I aim to determine the average health of Snow Island Oysters’ oysters over time. I also aim to compare precipitation and temperature to oyster conditions in a qualitative analysis from the ten weeks of data collection. After evaluating the current health of the mollusks, comparisons and further investigations will be made on the effects on oyster condition farmed at Dogs Head and Snow Island sites in Quahog Bay. I hypothesize that an inverse correlation will be found for condition and precipitation as well as a positive correlation with condition and temperature. The CI information gathered over the course of this study will serve as baseline data for annual CI records and quality monitoring.

METHODS

Snow Island Oysters has two farmed lease sites off the coast of Harpswell, Maine, in Cundy’s Harbor. One site is east of Snow Island and the other is just south of Dogs Head Island (see Figure 1,) and are respectively referred to as Snow Island (SI) or Dogs Head (DI).

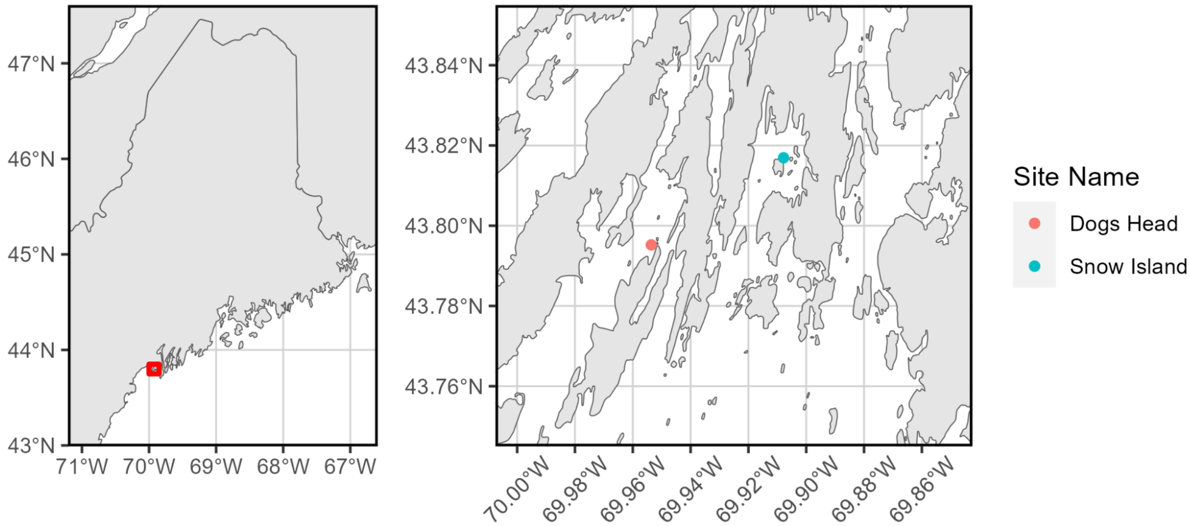

Figure 1: Snow Island Oyster's aquaculture lease sites in Harpswell, ME.

Field Protocol:

Each week, one oyster bag from each site was chosen at random and five oysters were blindly pulled from the bag. The oysters were kept cold and were processed within the day at the Quahog Bay Conservancy lab. Using a YSI Multiparameter Digital Water Quality Meter (YSI ProDss), environmental data such as water temperature, salinity and pH were recorded at the time of oyster collection. Turbidity was collected using a Secchi Disk and percent cloud cover.

Lab Protocol:

Using a sponge and cold water, each oyster was cleaned of epibionts such as limpets and barnacles, as well as mud or any other fouling on the shell. Each clean oyster was placed in a tin tray, labeled with a unique ID. The Oyster IDs are: collection site initials, week of collection, and a letter (A-E) for each of the five oysters. For example: SI 1A, for Snow Island, week one, oyster A or (⅕). Each whole oyster was measured with calipers for length and width measurements (mm, nearest hundredth). The oysters were then weighed (g, nearest thousandth). The oysters were shucked and the meat, along with all of the wet contents of the oyster, were placed into a separate tin from the shell, making sure to scrape any remaining tissue from the shell. Next, the mass of the shell and the meat tins were measured independently. Then each of the tins were placed in a drying oven set to 70°C for at least 24 hours. After 24 hours, the oyster's meat is dried completely. The new masses of the dry samples were recorded.

Statistical Methods:

The indices used in this study were indices one and three outlined by Mercado-Silva (2009). Index one: *(Dry tissue weight (g) / shell cavity volume) x 10.* In this index, shell cavity volume is a mass measurement. "Volume" in this context is defined as the weight of the whole wet oyster subtracted by the weight of the wet shell in order to determine the contents capacity of the oyster. Index three: *(Dry tissue weight (g) x 100) / dry shell weight.* Water temperature and precipitation data was analyzed to determine environmental factors associated with fluctuation in CI. Water temperature data was collected by the NOAA tide gauge in Portland Harbor. Precipitation data for Harpswell Neck was obtained from the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS, 2023). Quantitative analysis was used to compare this data to the CI findings. All data was analyzed using R studio.

RESULTS

Over the course of the summer, CI values created a curve that rose and fell. The mean CI values rose until a peak and then steadily declined again to similar conditions as the beginning of the study (see Figures 2 & 3). Oyster conditions using index one peaked in the first week of July. During the peak, the mean CI one for Dogs Head Island was 12.5 and Snow was 11.7 (see Figure 2). This peak in early July is matched in index three, with peak values reaching 6.1 at Dogs Head and 5.8 at Snow Island (see Figure 3). There is a slightly bigger gap between Snow Island and Dogs Head data in CI three. The indices at both sites start off similarly and progressively spread further apart. Dogs Head CI three does not decline to the extent that Snow does.

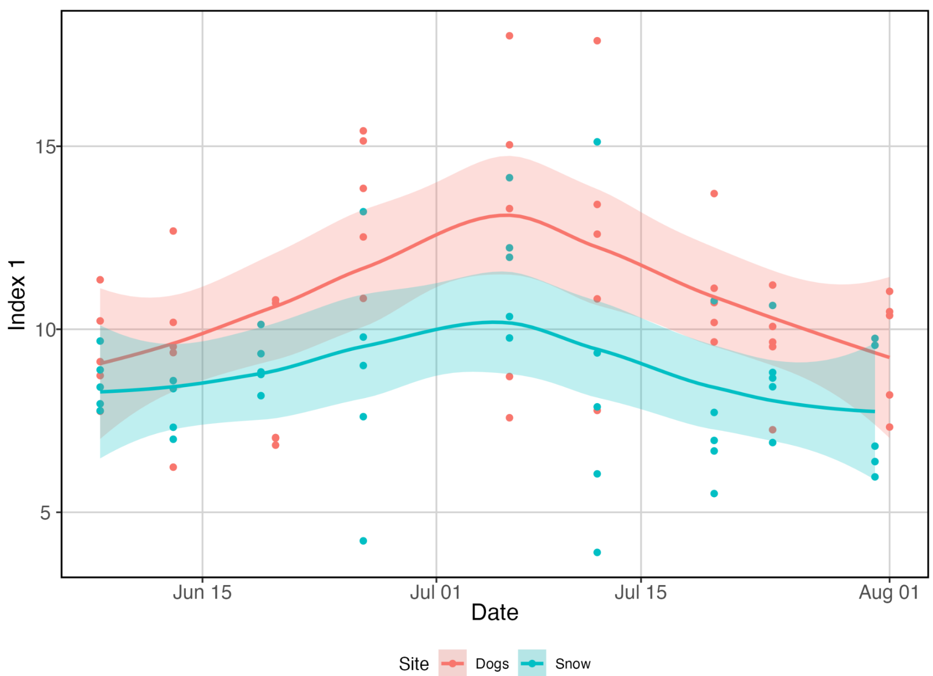

Figure 2: Condition Index one from Dogs Head and Snow islands.

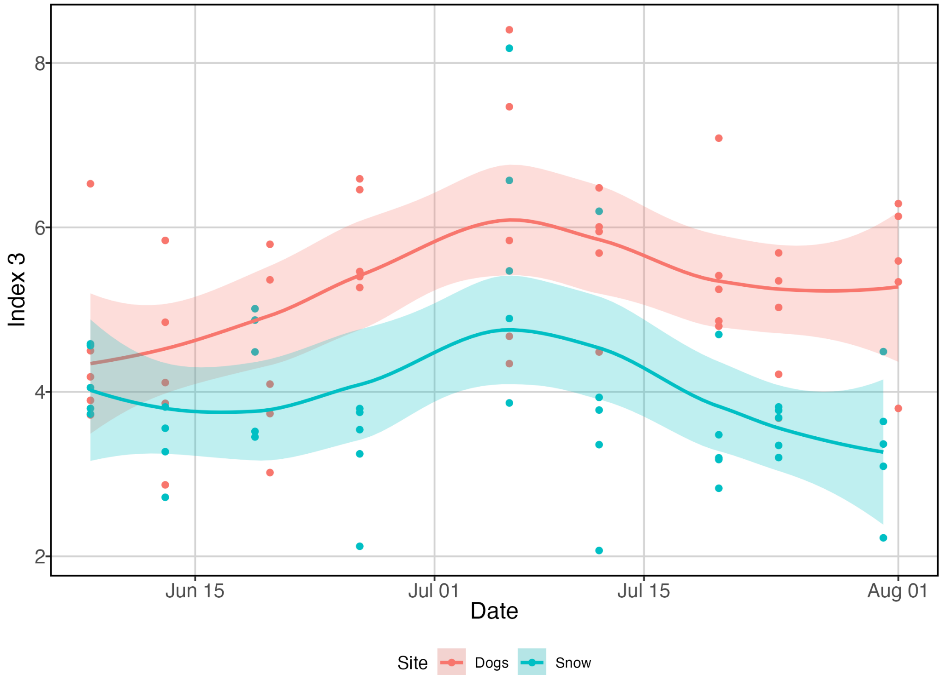

Figure 3: Condition Index three from Dogs Head and Snow islands.

Our findings showed that the condition indices at each site are significantly different from each other. A t-test was used to compare the sites. Oysters at Dogs Head have consistently higher health indices than those grown near Snow Island. This holds true for both index one ($t = -5.2081$, $df = 86.993$, p-value = 1.264e-06, see Figure 4A) and index 3 ($t = -3.6249$, $df = 84.546$, p-value = 0.0004929, see Figure 4B).

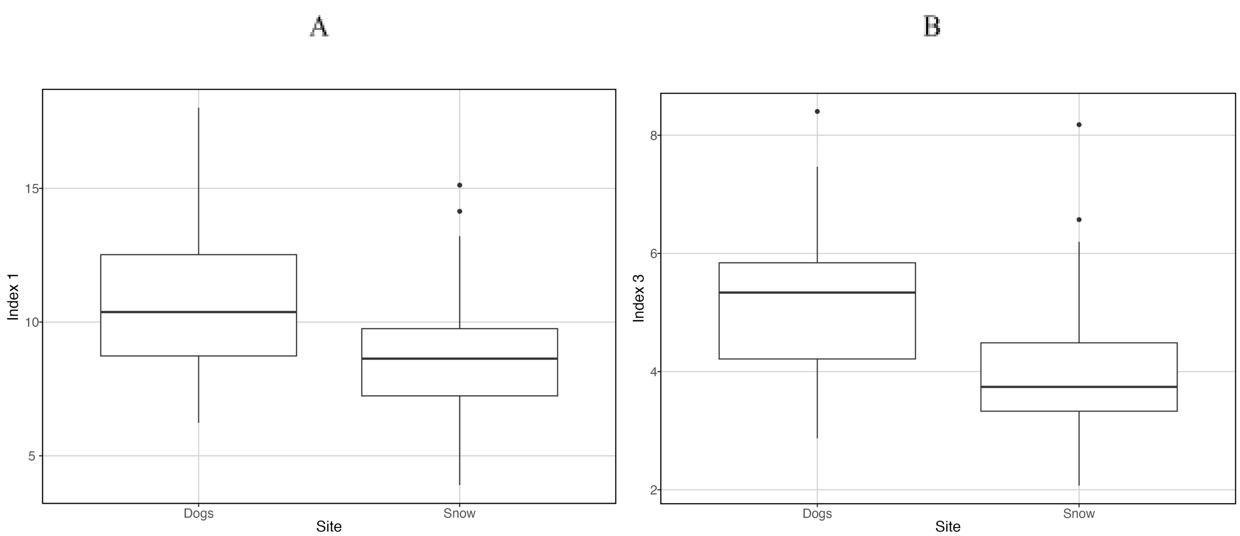

Figure 4: Box and whisker plot comparing Snow Island and Dogs Head Condition Indices.

Precipitation data was plotted using a seven-day rolling average from a rain gauge on Harpswell Neck, Maine. There is a cyclical pattern of rainfall that repeats every two weeks over the course of the summer. There is a spike of heavy rainfall and a rapid decline of precipitation, until another spike. The peak precipitation occurred the last days of June and leading into July.

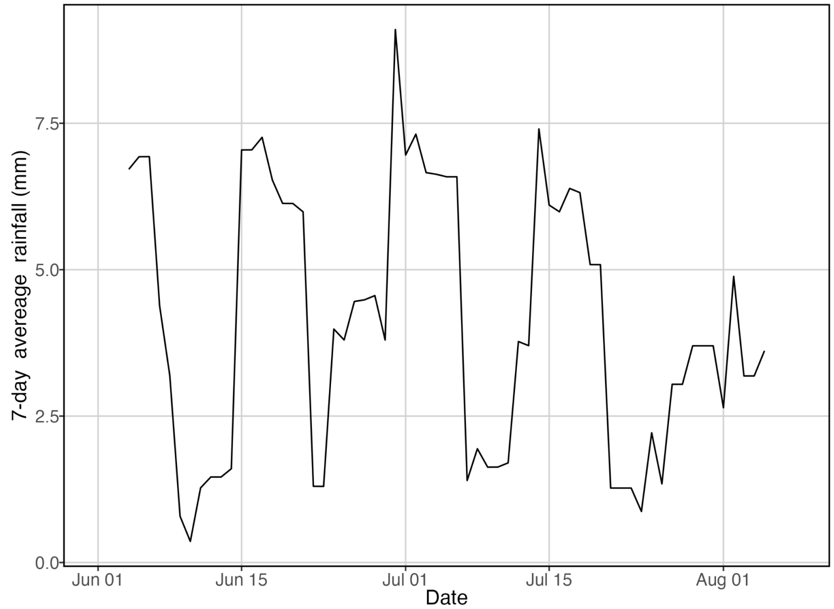

Figure 5: weekly average precipitation, June-August, 2023.

The water temperature data is a seven-day rolling average from Portland's tide gauge. Water temperature increased over the course of the summer (see Figure 6). The shape of the graph is not linear, instead it shows a rapid increase through June, a slight dip in early July, hit its peak in late July around 18º C and started a rapid decline into early August.

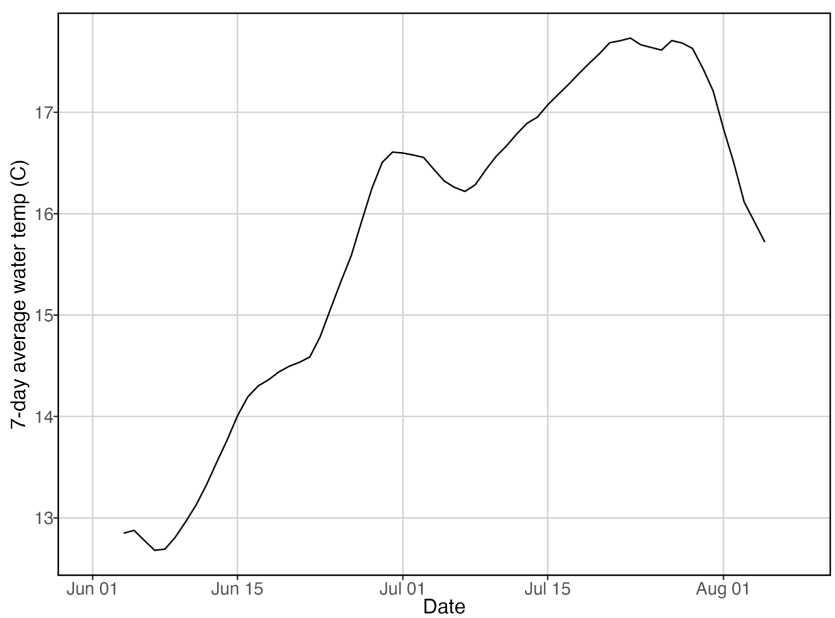

Figure 6: weekly average water temperature in Portland, ME, June-August, 2023.

DISCUSSION

Both indices show a matching temporal trend that rose until a peak in early July, followed by a decline. This trend is matched by both sites while Dogs Head oysters are consistently significantly “healthier” than Snow Island’s. The variation observed between the site’s mean weekly CIs can likely be attributed to their spatial separation. Because of oysters’ sensitivity to environmental factors such as water temperature and rainfall, the nonlinear relationship is likely due to the fluctuating environment. The Snow Island site is in more shallow water that can tend to be warmer than the deeper water near Dogs Head. Snow island is also in a more protected area of the bay that does not have as much access to the open ocean. This could mean the oysters near Snow Island are exposed to different nutrients and different stressors than those at Dogs Head.

Changes in factors such as temperature and salinity would not affect the condition index immediately. Instead, results would occur days to weeks after. This is because changes to an oyster’s condition index reflect the cumulative negative or positive environmental factors affecting its ability to feed and grow over a longer time period. Oysters are potential bio indicators of their surrounding environment. They are strongly affected by things such as water temperature and precipitation leading to changes in the ocean’s salinity. To see if I could attribute the fluctuations in the oysters’ conditions throughout the summer, both rainfall data from Harpswell Neck and water temperature from Portland were plotted. Harpswell neck and Portland were the closest collection sites with consistent and accurate data collection for the information of interest. Precipitation shows a cyclical pattern of rainfall this summer. This does not directly connect to the condition index beside the heavy rainfall in the last week of June and first week of July. This potentially helped spark the decline of oyster condition the following week. The Water temperature increased over the course of the summer. There is a rapid increase through June, a slight dip in early July, and a rapid decline in late July and early August. To connect this to the CI, the oysters likely appreciated the warming waters to a point, and then towards mid July, the water got too warm for their optimal health. If the oyster index was continued and temperature dependent, the indices may increase again in response to the early August dip in temperature (Figure 6).

There is a lack of site-specific water temperature and precipitation data that could provide insights as to why oysters at the Snow Island site consistently have a lower CI. Water temperature was collected by the NOAA tide gauge in Portland Harbor. Precipitation data for Harpswell Neck was obtained from the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS, 2023). These are the closest places to collect necessary data, and are useful in qualitative general analysis, but more specific data is needed for further investigation.

There are some specific implications that may be affecting Snow Island Oysters’ CI. Currently both lease sites have tested positive for SSO (*Haplosporidium costale*). SSO or seaside organism disease, is a pathogen outlined by Andrews et al. (1962). This season, Snow Island has experienced particularly high rates of mortality. A comparison of indices at both farm sites may provide insight into some of the potential effects of SSO on overall oyster health. There is limited information on what environmental factors contribute to SSO, however it is usually observed in high salinity water (above 25 ppt) although occasional cases are found at lower salinities (20 to 23 ppt) (Andrews et al. 1962).

Overall, the condition indices mirror each other. CI one holds more specific information than CI three. CI three compares dry meat to dry shells, which is helpful in understanding how much of the mass of an oyster is meat. However, it does not account for shell capacity. Some oysters grow narrower or have shallow cups that do not leave room for bigger tissue mass. CI one attempts to compare the actual meat contents of the oyster to its potential capacity.

There are several improvements that can be made to this study. One improvement includes reduction of shucking error. For example reducing water escape that should be directed into the oysters' tissue baking tin. As well as making sure there are not small pieces of shell in the tissue tin, or small bits of meat stuck to the shell. The lab could also find a way, using water displacement or otherwise to determine shell capacity as a volume measurement. To improve this study, Quahog Bay Conservancy could collect its own site specific precipitation and water temperature data to create more accurate conclusions about the variation observed between the two site's mean weekly CIs. The relationships between CI and environmental factors could not be quantified because we didn't have data from close to our sites. Instead, we could only make qualitative observations based on water temperature and precipitation data taken within 15 miles of our study location. It would be good to sample oysters for a few weeks before water temperatures consistently hit 10º C (minimum threshold of optimum temperature range) so we can watch CI increase as feeding frequency and efficiency increase. The study could be repeated next year to get more data and to get an idea of inter-annual variation.

This study showed how oyster index fluctuated at both of Snow Island Oysters farming lease sites using two Oyster Condition Indices. Both indices showed a curve of steady increase until July and then a steady decrease. This study helps us understand when the oysters were at their optimum health this summer. Next steps in this research include continuation and expansion of the study. To create a long-term time series analysis of the CI. It would be interesting to be able to compare Snow Island Oysters indices to other farms in the area. QBC can start collecting their own continuous environmental data to better inform factors contributing to fluctuations in CI.

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