Can Oyster Aquaculture Provide High Quality Habitat in the Chesapeake Bay?

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Abstract

Eastern oysters, *Crassostrea virginica*, are an important food source that provides ecosystem services to the Chesapeake Bay by improving water quality and by providing a diverse habitat. Oyster aquaculture in floating cages throughout the Chesapeake Bay can replicate much of the same ecological processes as wild oysters in reefs. For example, the oysters will continue to live, grow, spawn, filter the water, contribute to the larval pool, and provide beneficial habitats. Oyster aquaculture cages provide a hard surface for many fouling organisms, which allows for more productive habitat and a higher species diversity. This study analyzes a local oyster aquaculture system to determine if it is providing habitat for other organisms in the Chesapeake Bay. This study seeks to determine the effect of oyster aquaculture as habitat in the Chesapeake Bay by observing the animals associated with floating oyster cages. Observations were made at two sites in the lower Chesapeake Bay estuary: Anderson's Neck Oyster Company in Morris Bay near the York River, and the lower Mattaponi River. Organisms were counted and recorded to analyze the abundance and the taxonomic diversity at the two sites. The evidence from the results demonstrate that oyster aquaculture provides ecosystem services in the Chesapeake Bay by providing organisms a favorable habitat. It is evident that oyster aquaculture provides an adequate habitat due to the concluding p-values not being significant. If more oyster aquaculture businesses were placed in the Chesapeake Bay, the ecosystem could become restored along with creating a diverse and high-quality habitat for the neighboring organisms.

Introduction

Eastern oysters, *Crassostrea virginica*, are an important food source that provide ecosystem services to the Chesapeake Bay by improving water quality and by providing a diverse habitat. Since the mid-19th century, habitat destruction has affected oyster reefs due to over-harvesting. The historical loss of live oysters and their reefs corresponds to an ongoing quantitative habitat loss for the oysters and the surrounding environment (Ozbay et al., 2014). With the decline of oyster reefs in the Chesapeake Bay, comes the related decrease in critical three-dimensional, complex habitat.

Oyster restoration has been an ongoing concern in the Chesapeake Bay due to the immense decline of the species and the habitat lost. Oyster restoration construction costs are found to range widely, from a low of $3,826 per hectare to a high of $2,180,361 per hectare, with an average cost of $299,999 per hectare (Hernandez et al., 2018). This research shows that millions of dollars have been invested in oyster reef restoration in the Chesapeake Bay to help restore the struggling species, however, there has been limited success.

The filtration of the Chesapeake Bay's water by its oyster population is critical for keeping excess nutrients, sediments, and other harmful contaminants in check. Oysters can filter about 50 gallons of water and food particles a day through their gills and also dispose of sediments, chemical contaminants as pseudofeces, that assists in keeping the water clean (Chesapeake Bay Program, 2015). As the oysters continue to grow, subsequent layers of younger oysters form, creating abundant spaces for other organisms to inhabit. These complex estuarine reefs provide homes for hundreds of species in the Chesapeake Bay, such as Polychaeta worms, other mollusks, and many crab species including Blue crabs, cnidarians like sea anemones, juvenile and adult fish, and other filter feeders like barnacles (Marshall et al., 2019).

Bivalve aquaculture has become one of the most important seafood industries in the Chesapeake Bay. Oysters are one of the major species that contributes 33% to global production (Wijsman et al., 2019). Research has shown that oyster aquaculture does not provide the exact ecosystem services as natural functioning reefs, but can help provide some of the same benefits without the input of significant taxpayer funds (Kellogg et al., 2018). Although, there have been very few studies conducted in the Chesapeake Bay that detail the benefits and the impacts of commercial aquaculture operations. There is the potential to restored habitat diversity in the Chesapeake Bay ecosystem as a positive side effect of the growing oyster aquaculture industry.

Oysters that are grown in floating structures called Taylor floats throughout the Chesapeake Bay replicate much of the same ecological processes as if they were wild oysters in reefs. For example, the oysters continue to live, grow, spawn, filter the water, contribute to the larval pool, and provide beneficial habitats (Marenghi and Ozbay, 2010). The cages also help provide habitat space and refuge for surrounding organisms within the ecosystem. The oyster cages provide a hard surface for many fouling organisms, which allows for more productive habitat and a higher species diversity. Many reef obligate organisms, such as blue crabs (*Callinectes sapidus*) and grass shrimps (*Palaemonetes pugio)*, need a functioning oyster reef ecosystem to survive (NOAA, 2019), however, there are also many visitors that come to the reef such as rockfish (*Morone saxatillis)* and catfish (*Ictalurus furcatus)*. In one study, the diversity of the ecosystem around oyster cages was observed and compared to eelgrass beds (*Zostera marina*) and non-vegetated bottoms (Ozbay et al., 2014). There is growing evidence that oyster aquaculture could be beneficial to the Chesapeake Bay environment by providing similar ecosystem services and a diverse habitat for many surrounding organisms. This study seeks to determine the effect of oyster aquaculture as habitat in the Chesapeake Bay by observing the animals associated with oyster aquaculture.

Hypotheses

H_o: Organisms commonly found in association with natural oyster reefs will not be found in similar abundance in aquaculture oyster systems.

H_a: Organisms commonly found in association with natural oyster reefs will be found in similar abundance in aquaculture oyster systems.

H_o: Chesapeake Bay oyster reef taxa will not colonize oyster aquaculture systems.

H_b: Chesapeake Bay oyster reef taxa will colonize oyster aquaculture systems.

The presence of *Crassostrea virginica* oysters at the two different testing sites will be the independent variable of the study. The dependent variable will be the biodiversity and abundance of associated organisms found at each site. Constants include: the species of oysters (*Crassostrea virginica*) the number of oysters in each treatment, the type of aquaculture cages used, the water quality, and the general environmental conditions of both sites.

Materials and Methods

Observations were made at two sites in the lower Chesapeake Bay estuary. The first site is Anderson's Neck Oyster Company in Morris Bay near the York River, and the second site is in the lower Mattaponi River. Researchers wore gloves and proper clothing to ensure physical safety during the sampling. At both testing sites, two bags of oysters approximately 5 liters each, were removed from the oyster cages, then the oyster bags were placed in a bucket in order to separate the oysters from the neighboring organisms. The organisms found in the bags were counted and recorded. The oysters were then cleaned and measured to obtain shell height measurements in centimeters of 15 randomly selected oysters from each bag. The oysters were then placed into two new clean bags and placed back into the oyster cages. Finally, using a fishing pole, eel pot, and crab pot, organisms inhabiting the area around the aquaculture were sampled to observe the surrounding diversity.

Figure 1. The established testing site of about 4 years is located in Morris Bay, VA. The new testing site of about 4 months is located in Mattaponi, VA.

Observations were made every two weeks for a 5-month period from June through October of 2019. Water quality testing was completed during each trial to look at the water quality differences between the two locations. Water quality was tested by using a pH test, nitrate test, nitrite test, and ammonia test. The temperature of the water was measured with a thermometer, and salinity of the water was recorded with a refractometer. The taxonomy of organisms from both areas was analyzed to see if there were statistical differences between the organisms that were found at each site. The taxonomy was determined by counting each individual species recorded from each of the six days from both the Mattaponi River and the Morris Bay. The Shannon Index was used to determine the richness and the evenness of the communities at both sites. A Shannon Index calculator (Young, 2020) was used to determine the values of each site by using the total taxa of the given day, the type of species, the total amount of each species, and the latitude and longitude of the area. The values from the Shannon Index were used to calculate a total mean and standard deviation for each site.

Results

Throughout the study, the water quality parameters of ammonias, nitrates, and nitrites remained relatively constant at both sites (Appendix A: Table 1). The salinity levels ranged

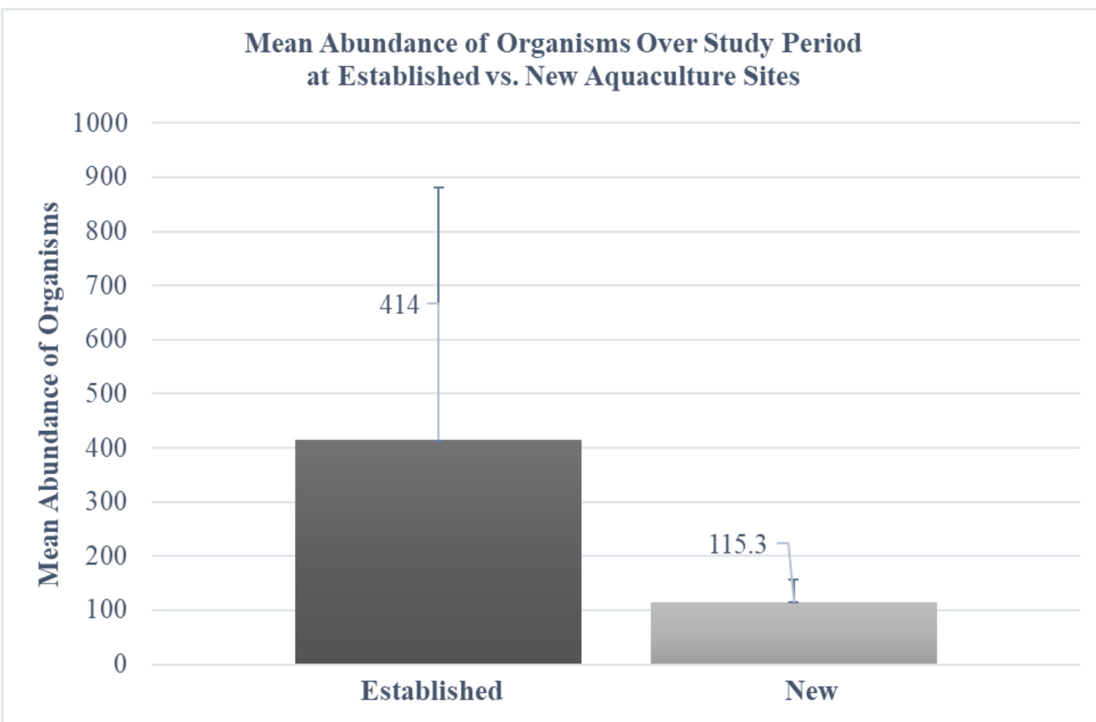

Figure 2. The mean abundance of organisms recorded from the established site and the new site varied threefold. In the established site, there was a mean of 414 organisms found each day over the study period. In the new site, a mean of 115.3 was observed.

between 10ppt and 17ppt at the established site in Morris Bay, whereas the salinity levels ranged from 5ppt to 20ppt at the new site in the Mattaponi River. The recorded temperatures consistently dropped as the seasons changed over the 5-month period from June to October (Appendix A: Table 1). The pH levels at the established site ranged from 7.1 to 7.8, and in the new site the pH levels ranged from 7.4 to 8.2 (Appendix A: Table 1).

The number of organisms found at the established site varied throughout the summer months and as the beginning of September approached. At the new site, the oysters began growing in the beginning of September and the diversity was recorded until the end of October (Appendix C: Table 3). A 2-tailed T-test was used to determine the numerical differences between the organisms at both testing sites concluding in t-test $p = 0.216$.

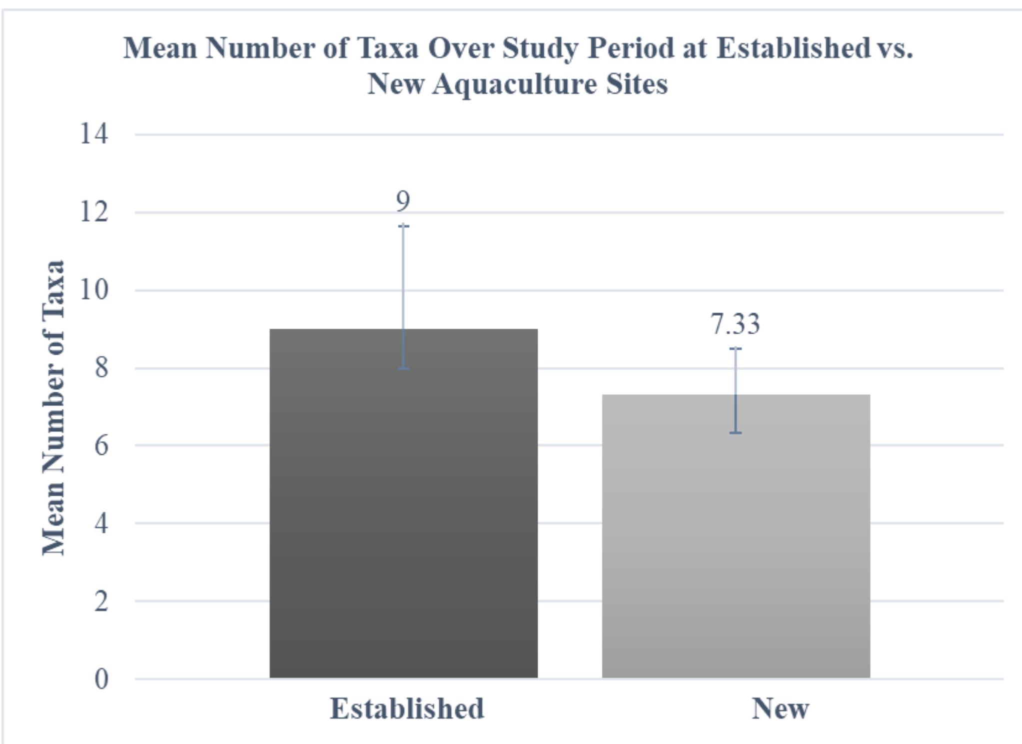

Figure 2. The mean total taxa that was recorded were closely related. In the established site, there was a mean of 9 taxa. In the new site, a mean of 7.33 taxa was observed.

A total of 19 species were found between the two testing sites. The phylum, Chordata, was 60% of the species recorded at both testing sites and was the most prevalent (Appendix C: Table 3). The phylum, Cnidaria, was 0.05% of the total species found and was the least prevalent (Appendix C: Table 3). A 2-tailed t-test was used to determine the numerical differences between the taxonomy at the new site and the established site, concluding with t-test p= 0.413.

The values of the Shannon index are generally in-between 1.5 and 3.5 in most ecological studies, rarely having a value greater than 4 (Kerkhoff, 2010). The values calculated here show that there was a richer community in the newly established oyster site at the Mattaponi River compared to the older, more established oyster site in the Morris Bay.

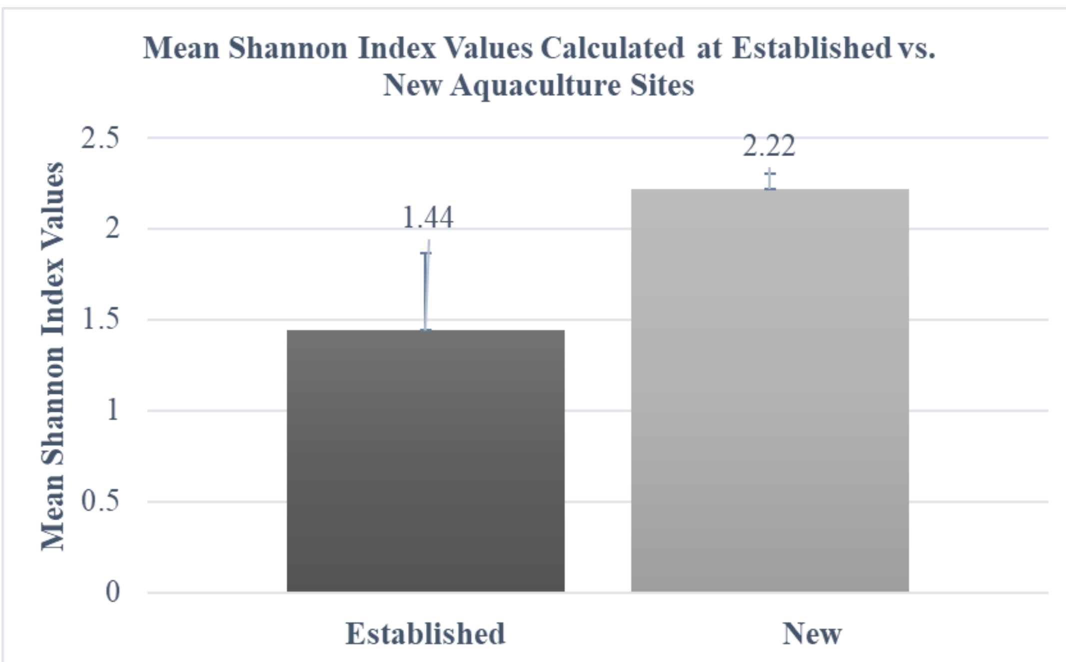

Figure 4. The Shannon index values of the established site resulted in a mean of 1.44. The Shannon index values calculated for the new site resulted in a mean of 2.22.

Conclusion

The results demonstrate that oyster aquaculture provides ecosystem services in the Chesapeake Bay by providing organisms a favorable habitat. There was a greater number of organisms found at the established site in Morris Bay compared to the new site in the Mattaponi River. This rejects the null hypothesis that, H_o: *Organisms commonly found in association with natural oyster reefs will not be found in similar abundance in aquaculture oyster systems.* There is no statistical difference (p= 0.216) between the diversity and abundance of oyster aquaculture at the established site compared to the new site. The established site also had a constant biodiversity throughout the study. As the oysters began to grow at the new site, organisms that are commonly found in a natural reef began to come to the area. Based on the data, the null hypothesis, H_o: *Chesapeake Bay oyster reef taxa will not colonize oyster aquaculture systems*, can be rejected. There is no statistical difference between the biodiversity from oyster aquaculture at the established site compared to the new site, p =0.413. It can be inferred that over time the oysters at the newer site will continue to attract more organisms and create a richer habitat. There was also a larger taxonomic value at the established site compared to the newer site. This was expected in the study since the established site has been in the same area for about four years, whereas the new site had just been created. The findings of the study agree with research from other areas, which shows a positive influence on the usage of oyster aquaculture. A study conducted in Long Island Sound in New York found that oyster cage farms provided a functional habitat that is relatively similar to oyster habitats that are found on a natural rock reef in the Long Island Sound (D'Anna and Murray, 2015).

Any collaborative effects between oyster aquaculture and a marine environment will project several benefits in the ecosystem. In an older research study conducted by the Virginia

Institute of Marine Science, manmade *Crassostrea virginica* reefs were observed in the York River over a period of time to determine if the oyster species would attract other species into the habitat (Marshall et al., 2010). The research from VIMS resulted in a Shannon Index value of 2.08 with a standard deviation of 0.25. The Shannon Index values found from this study were a mean of 1.44 in Morris Bay, and a mean of 2.22 in the Mattaponi River. The research values given from the VIMS project are closely related to the data collected in this experiment; thus, concluding that *Crassostrea virginica* helps create a rich and diverse habitat. Research in the Baynes Sound of British Columbia showed that shellfish aquaculture helped the ecosystem by cleaning the water and by enhancing the abundance and diversity of species found in the Baynes Sound (Mercaldo-Allen et al., 2019). This research also helps support the study that oyster aquaculture will help to create a cleaner and more diverse habitat for the species that inhabit the area.

Previous studies have been conducted in areas where aquaculture is most prevalent, however, there is limited research in how oyster aquaculture could benefit the Chesapeake Bay. Further, most of the research that has observed aquaculture affecting biodiversity was conducted more than over 10 years ago. Since then, the Chesapeake Bay has greatly changed due to climate change effects. If more oyster aquaculture businesses were allowed in the Chesapeake Bay, the ecosystem could be restored creating a diverse and high-quality habitat for the neighboring organisms. When understanding the positive effects that oysters provide for estuaries, the Chesapeake Bay community should push towards establishing more oyster aquaculture businesses to greatly benefit the biodiversity of the bay.

Appendix

Appendix A:

Date	Location	pH	Temp.	Salinity	Nitrite	Nitrate	Ammonia
7/10/2019	Morris Bay	7.1	28º C	10ppt	0ppm	0ppm	0.50 ppm
8/11/2019	Morris Bay	7.5	27.8º C	17ppt	0 ppm	0ppm	0.50 ppm
9/1/2019	Morris Bay	7.8	26.7ºC	15 ppt	0ppm	0ppm	0.50 ppm
9/28/2019	Mattaponi River	7.5	25.5º C	5 ppt	0 ppm	0ppm	0.50 ppm
10/13/2019	Mattaponi River	8.2	21.1º C	20 ppt	0 ppm	0 ppm	0.25 ppm
10/26/2019	Mattaponi River	7.4	16.6ºC	15 ppt	0ppm	0 ppm	0.50 ppm

Table 1. Water testing data recorded at the established site and the new site.

Appendix B:

Date	Location	Total Number of Organisms Found	Number of Taxa
7/10/2019	Morris Bay, VA	180	12
8/11/2019	Morris Bay, VA	110	7
9/1/2019	Morris Bay, VA	952	8
9/28/2019	Mattaponi, VA	72	8
10/13/2019	Mattaponi, VA	153	8
10/26/2019	Mattaponi, VA	121	6

Table 2. Total organisms and total taxa recorded at both sites.

Appendix C:

Scientific Name	**Common Name**	**Species Type**	**Reef Obligate**	**Location(s)**
Panopeus herbstii	Mud Crabs	Arthropoda	Yes	Morris Bay, Mattaponi River
Callinectes sapidus	Blue Crabs	Arthropoda	Yes	Morris Bay, Mattaponi River
Menippe mercenaria	Stone Crabs	Arthropoda	Yes	Morris Bay, Mattaponi River
Brevoortia tyrannus	Juvenile Menhaden	Chordata	Yes	Morris Bay
Opsanus tau	Oyster Toad	Chordata	Yes	Morris Bay
Ictalurus furcatus	Juvenile Catfish	Chordata	No	Morris Bay
Ictalurus furcatus	Adult Catfish	Chordata	No	Mattaponi River
Morone americana	Juvenile White Perch	Chordata	Yes	Morris Bay, Mattaponi River
Lepomis auritus	Sunfish	Chordata	No	Mattaponi River
Anguilla rostrata	Eels	Chordata	No	Morris Bay
Molgula manhattensis	Sea Squirts	Chordata	Yes	Mattaponi River
Gobiosoma ginsburgi	Gobies	Chordata	Yes	Morris Bay
Morone saxatillis	Rockfish	Chordata	No	Mattaponi River
Geukensia demissa	Mussels	Mollusca	Yes	Morris Bay
Clemmys guttata	Turtles	Chordata	No	Mattaponi River

Aurelia aurita	Jellyfish	Cnidaria	No	Morris Bay, Mattaponi River
Polychaete	Worms	Annelida	Yes	Morris Bay, Mattaponi River
Argulus foliaceus	Fish Lice	Arthropoda	No	Morris Bay
Palaemonetes pugio	Grass Shrimp	Arthropoda	Yes	Morris Bay, Mattaponi River
Micropogonias undulatus	Juvenile Croaker	Chordata	Yes	Morris Bay

Table 3. Species list of the new and established site.

Reef obligate determination according to: (NOAA, 2019).

Literature Cited

Peer Reviewed Sources:

D'Anna, L., & Murray, G. (2015). Perceptions of shellfish aquaculture in British Columbia and implications for well-being in marine social-ecological systems. Ecology and Society, 20(1). Retrieved from www.jstor.org/stable/26269746

Hernandez, A.B., Brumbaugh, R.D., Fredrick, P., Grizzle, R., Luckenbach, M.W., Peterson, C.H., & Angelini, C. (2018). Restoring the eastern oyster: how much progress has been made in 53 years? VIMS Articles. 1368. https://scholarworks.wm.edu/vimsarticles/1368

Kellogg, M. L., Turner, J., Dreyer, J., & Massey, G. M. (2018) Environmental and Ecological Benefits and Impacts of Oyster Aquaculture Chesapeake Bay, Virginia, USA. Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.25773/hdb1-xf91

Marenghi, F.P. & Ozbay, G. (2010). Floating Oyster, Crassostrea virginica Gmelin 1791, Aquaculture as Habitat for Fishes and Macroinvertebrates in Delaware Inland Bays: The Comparative Value of Oyster Clusters and Loose Shell," Journal of Shellfish Research 29(4), 889-904. https://doi.org/10.2983/035.029.0422

Marshall, D., Lebreton, B., Palmer, T., De Santiago, K., & Pollack, J. (2019) Salinity disturbance affects faunal community composition and organic matter on a restored Crassostrea virginica oyster reef, *Estuarine, Coastal and Shelf Science*, 10.1016/j.ecss.2019.106267.

Mercado-Allen, R., Clark, P., Liu, Y., Meseck, S., Milke, L., & Redman, D. (2019). Macrofaunal Assemblages on Oyster Aquaculture and Rock Reef Habitat in Long Island Sound. North Am J Aquaculture. doi:10.1002/naaq.10127

Ozbay, G., Reckenbeil, B., Marenghi, F.P., Erbland, P. (2014). Eastern oyster (Crassostrea virginica) Aquaculture and Diversity of Associated Species.

Wijsman J.W.M., Troost K., Fang J., Roncarati A. (2019) Global Production of Marine Bivalves. Trends and Challenges. In: Smaal A., Ferreira J., Grant J., Petersen J., Strand Ø. (eds) Goods and Services of Marine Bivalves. Springer, Cham.

Non-Peer Reviewed Sources:

Chesapeake Bay Program, 2015. https://www.chesapeakebay.net/issues/oysters.

Kerkhoff (2010). Measuring Biodiversity of Ecological Communities. http://biology.kenyon.edu/courses/biol229/diversity.pdf

National Oceanic and Atmospheric Administration (NOAA). 2019. Oyster Reef Habitat. https://www.fisheries.noaa.gov/national/habitat-conservation/oyster-reef-habitat

Young, T. (2020). Biodiversity Calculator. https://www.alyoung.com/labs/biodiversity_calculator.html