

NARRAGANSETT BAY WATERSHED ECONOMY

The ebb and flow of natural capital



Aquaculture Overview

Owing to the climate, geology, and various biological characteristics, shellfishing and aquaculture—the farming of aquatic organisms—have a rich and important history in the Narragansett Bay watershed (NBW). Humans have been harvesting wild shellfish of the Narragansett Bay and surrounding waters for at least 2,700 years and privately farming oysters for over 200 years (Figure 1).¹

The story of aquaculture and shellfishing contains multiple oscillations, but overall embodies a successful story of resurgence. In the past, aquaculture was a booming industry in the NBW due to the desirable flavors the waters produced in the shellfish. However, the bubble burst and aquaculture faced risks of collapse due to the rise of the industrial fishing, technology improvements, and market imperfections. Overcoming the various ebbs and flows, aquaculture has persevered during the past two decades, especially in Rhode Island (RI). Today, aquaculture farms in the watershed are flourishing. In 2016 in the NBW, 36 aquaculture farms on 140 leased acres existed with 90 employees generating \$2.81 million in sales.²

In addition to high profitability, shellfish aquaculture is a sustainable method of food production that provides affordable, healthy, and locally raised protein; it also provides important ecosystem services such as fish habitats and water purification.³ Today, the aquaculture industry is thriving globally due to increasing world populations and the demand for seafood to feed the masses, with aquaculture filling that need.⁴ Over the last three decades, world aquaculture production has been expanding and by 2030 is expected to supply over 60% of fish destined for direct human consumption.⁵

This growing trend of aquaculture can also be seen within NBW with aquaculture farms increasing in number more than tenfold and overall employment increasing threefold in the last two decades. In addition, RI is looked to as a national model for “boat to table” seafood direct marketing initiatives and leads the country in the number of farms that sell products directly to consumers.⁶ With increasing global demand for fish and shellfish through farming as well as growing demand for local food at restaurants, farmers markets, and retailers, the aquaculture industry in the NBW is well positioned to attract investment in the future.



Figure 1: Ancient Oyster Shell

Credit: Prentice Stout

History

There is a long history of consumption and production of shellfish in the NBW, particularly in RI (while shellfishing does play an important role in MA, it is mostly along Cape Cod; a majority of the MA portion of the NBW is not adjacent to the ocean and, as a result, this report focuses on aquaculture in RI). Roger Williams noted in his 1643 treatise that the Narragansett Tribe would wade in and dive for shellfish, eating the meats and using the shells in a similar fashion to currency.⁷ These quahog shells, known as wampum, were sacred objects to Natives given as a tribute, but Europeans mistakenly thought they were equivalent to money. In later years, precious metals decreased, which did lead to wampum filling in as a replacement for coins.⁸ The trend of harvesting wild oysters for consumption and using the shells as raw material continued through the early colonial period. In the early 1700s, oyster shells were so plentiful that they were burned whole and ground down for use in masonry mortar as limestone was not readily available in southern New England. However, this practice was outlawed in 1734 for being a wasteful use of marine resources.⁹

As colonial populations grew and technology improved, and as no aquatic property rights existed, wild oyster beds fell victim to the problem of overfishing. Realizing the seriousness of the issue, lawmakers acted to reverse depletion through statutes and mandates such as the 1798 law closing oyster beds to harvesters during the spawning season.¹⁰ A grant of exclusive private harvesting rights was also issued in 1798, establishing RI's first recognized oyster aquaculture farm and shifting interests from shellfish harvesting to farming.¹¹ Private aquaculture farms increased in acreage yet farmers paid no lease fee, creating tension between aquaculturists and wild shellfish fishermen.¹² This market imperfection led to the Oyster Act of 1844, establishing an annual fee structure for leases. Unfortunately, problems persisted and by 1859 no more oyster aquaculture leases existed, due in part to poaching from fishermen and pollution of oyster grounds.¹³ To revive the aquaculture industry, the Oyster Act was amended in 1864 and lease fees collected increased in response. By 1869, when the average rate of laborers was less than \$0.16/hour, almost \$2,000 was collected in aquaculture leases, equivalent to \$36,000 in 2016.¹⁴

Aquaculture continued to flourish in the late 1800s and early 1900s. Due to the geology of the area (pockets of the NBW accumulate mud and sand, which creates model habitats for shellfish), the NBW became an ideal region for the cultivation of shellfish, producing a palatable *terroir*.¹⁵ This desirable

flavor of oysters from the waters led to Connecticut growers rushing to claim leases in the Narragansett Bay. During this period, aquaculture became the third largest industry in RI, employing over 1,000 people with an annual output of 1.4 million bushels of oysters and 1.3 million gallons of shucked meats worth over \$100 million in 2016.¹⁶ Between 1899 and 1902, oyster farming leases increased in acreage more than 300% and at the industry's peak in 1911, leased plots covered almost 2,000 acres (Figure 2) or more than 20% of the entire bottom of Narragansett Bay.¹⁷

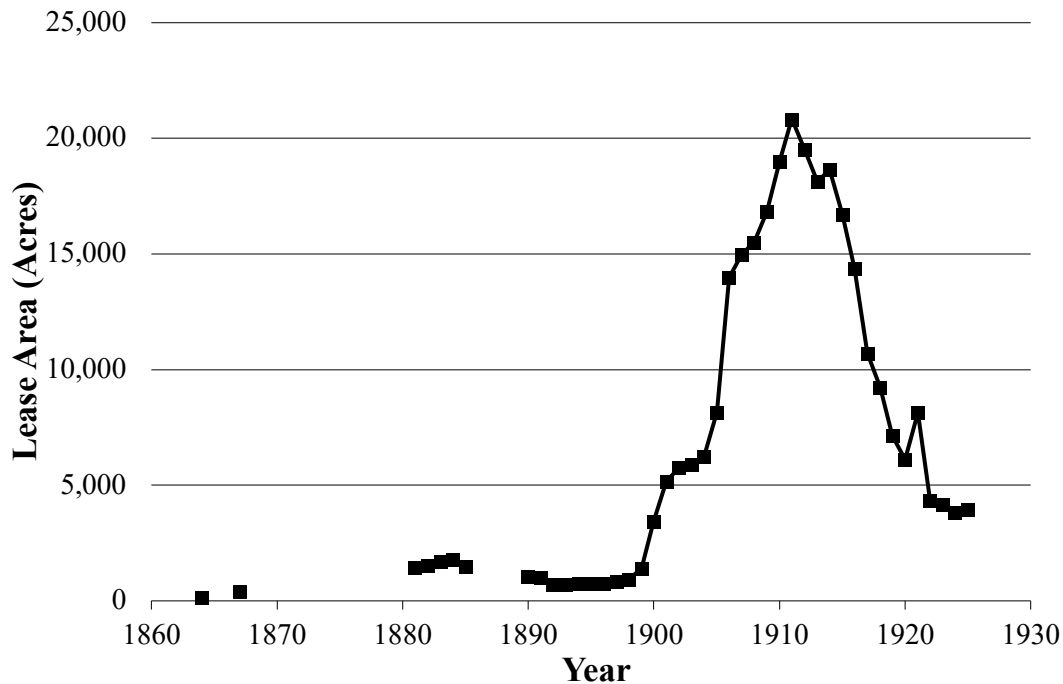


Figure 2: RI Aquaculture Industry by Area of Oyster Farming Leases, 1864-1925
Source: Rice, 2006

As the aquaculture industry was growing and leased acreage increased, industrialization was also gaining ground, and dumping chemicals, metals, and sewage into the very waters where shellfish were being farmed became increasingly common. With pollution levels in the upper bay increasing, farmers were forced further south into the deep waters and sandy bottoms of the lower bay, which are not naturally productive areas for oysters.¹⁸ Unfortunately, the rise of industrial shellfishing and the absence of consideration for long-term environmental effects aided in the downfall of the aquaculture industry. In the early 1900s, the oyster aquaculture bubble burst, immensely decreasing the number of leased acres and collapsing the industry after 1920 (Figure 2) due to factors including increase in raw sewage inputs, factories discharging metal effluents, and effects of soil erosion. The last oyster aquaculture farm gave up its leases and ceased operations in 1954, officially ending the industry's heyday.¹⁹

From 1954 until 1971, when the Coastal Resources Management Council (CRMC) was established, interest in aquaculture remained almost nonexistent. The CRMC was tasked with managing

aquaculture leases and by 1976 renewed interest in shellfish leases emerged. This trend continued until the 1980s when aquaculture laws were revised and lease application procedures were made more rigorous, including the implementation of public hearings and intensive application reviews. These modifications caused leaseholders to cease production or move elsewhere by 1990.²⁰

Despite the hiatus and challenges facing aquaculture farmers the industry has made a successful comeback, seeing a steady and healthy rate of growth since policy efforts in the 1990s and the incorporation of the Ocean State Aquaculture Association. The Legislative Commission on Aquaculture was also formed in the mid-1990s, studying opportunities and constraints of the industry.²¹

Since aquaculture law revisions in 1996, aquaculture has flourished in RI. In the last two decades, the industry has grown rapidly in sales value, increasing from \$84,000 in 1995 to \$5.5 million in 2016. During the same period, the number of farms has increased from five to 70 and acreage has increased from nine to 275.²²

Data Sources and Limitations

In this report, estimates are provided for the economic impact of aquaculture within the NBW, which includes market value, employment, number of farms, acres of farms, and oysters sold. These data are derived from local studies and national studies at the state level, including multiple CRMC Annual Status Reports and the United States Department of Agriculture (USDA) 2013 Census of Aquaculture.

The USDA Census of Aquaculture is beneficial for seeing statewide and countrywide trends in the aquaculture industry, but there exists a discrepancy in numbers of farms and market value when compared to the CRMC reports. For this reason, the CRMC data are used in lieu of the USDA data for RI as a local, in-depth study is more ideal for this report.

To estimate the size of the aquaculture industry in the watershed, this report only examines aquaculture operations in RI, as no aquaculture operations in Massachusetts fall within the NBW study area.²³

In addition, not all RI aquaculture operations are located within the NBW study area; many acres are in the Salt Ponds Region outside of the watershed (for a map of the NBW, please see the “Geography” section of this report). Of the total aquaculture acres in RI, 49% are located within the Salt Ponds Region. For this reason, the following assumption was made: most data are scaled by the ratio of total aquaculture acreage located within the NBW— 51%— to total figures provided by CRMC reports (unless otherwise noted). Based on this assumption, the economic impact of aquaculture is estimated for the NBW, assuming that aquaculture data (acreage, sales, and farms) is consistently distributed in the area covered by the data set (thereby allowing for 51% of these figures to proportionately represent the watershed). For additional information on methodology used in this report, please refer to the “Methodology” section.

Current Status & Trends

The growing trend of aquaculture at the global level can be seen within the NBW. In the last two decades, the aquaculture industry in the watershed has increased in market value, employment, number of farms, and total farm acres leased. Currently, oysters are the primary product cultivated by aquaculture farms in the NBW and, as a result, many figures in this report can be attributed to the cultivation and sale of eastern oysters (7.8 million oysters were sold in 2016 in RI, at least 2.2 million of which was in the NBW portion of RI). Aquaculture farms in RI also cultivate other species, although at much lower rates; it is not uncommon for farms to harvest hard clams (70,500 were sold in 2016) as well as blue mussels (27,000 pounds were sold in 2016). Furthermore, some aquaculture farms are branching out from cultivating just shellfish—a small number of farms are growing sweet kelp. From 2015 to 2016, nine more farms added kelp to their list of products with an increasing number of farms expected to produce kelp in coming years. Although oysters make up a large portion of aquaculture products, there are additional species that contribute to the diversity of the aquaculture industry in the NBW.²⁴

RI has shown rapid growth in the number of aquaculture farms, number of cultivated acres, and sales, a stark contrast compared to national trends. Between 2005 and 2013, the number of saltwater aquaculture farms in the U.S. declined by 27% and the number of acres decreased by 34% (Figure 3). During the same period, RI aquaculture farms and total acreage increased by 91% and 90% respectively. Values of sales in the same period increased by 489% in RI compared to the national trend of 26%.²⁵

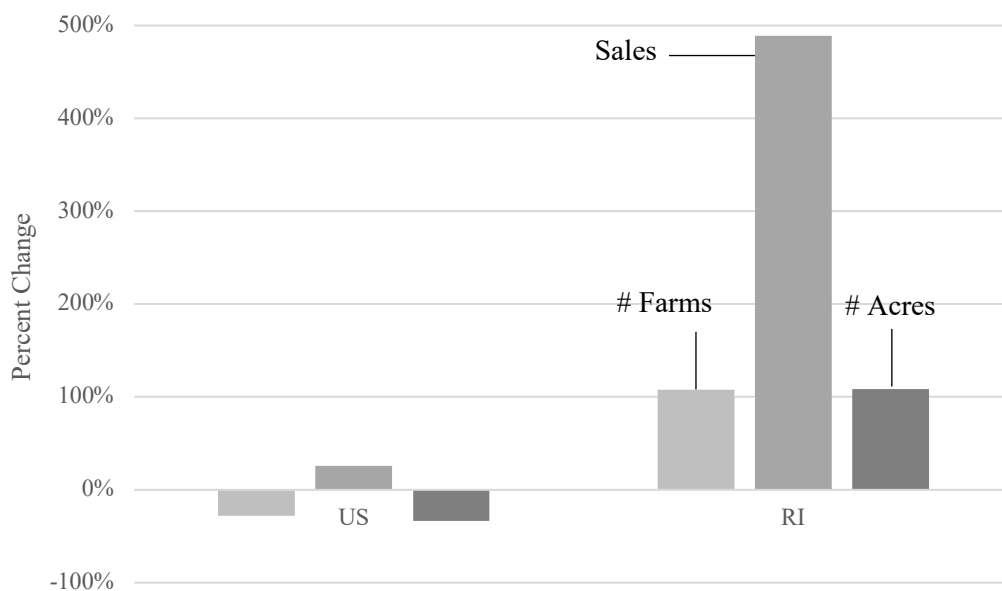


Figure 3: Percentage Change in Aquaculture Farms, Sales, and Acres in U.S. and RI, 2005-2013

Sources: Census of Aquaculture, 2013; Beutel, 2013; Alves, 2005

In all of RI in 2016, there were 70 aquaculture farms on more than 274 leased acres with 177 total employees. These farms produced nearly eight million oysters for consumption and totaled \$5.5 million in sales.²⁶ Within the NBW (Mount Hope Bay, Sakonnet River, and Narragansett Bay) during this same year, there were 28 farms on 134 acres of land. Twenty-four of these farms cultivated oysters, three cultivated blue mussels, two cultivated clams, one cultivated steamers, and one cultivated bay scallops.¹ Combined, these farms sold over 2.2 million oysters and 27,000 pounds of mussels.²⁷ Using total RI values to calculate the number of farms, employees, and sales in the NBW portion of the state using these data indicates that there were 36 farms on 140 acres with 90 employees and \$2.8 million in sales. As previously stated, the following estimates are calculated by taking the proportion of the NBW in RI (51% of total area) and scaling total RI figures by this amount. Although this is not entirely accurate, it gives some idea as to the trends and a general estimate of the importance of the aquaculture in the NBW.

These numbers are the result of remarkable growth in recent years. Since 1995, market value of sales generated by aquaculture industries in the NBW have increased by more than 4,000%, from \$67,000 in 1995 to \$2.8 million in 2016 (Figure 4).²⁸ The largest increase of nearly 200% occurred between 1996 and 1997. This jump was due to the formation of the regulatory RI Aquaculture Working Group by the CRMC (a response to the state having the lowest aquaculture production in the country), which worked in conjunction with URI and RWU to regulate and manage the state's shellfishing and aquaculture industries.²⁹

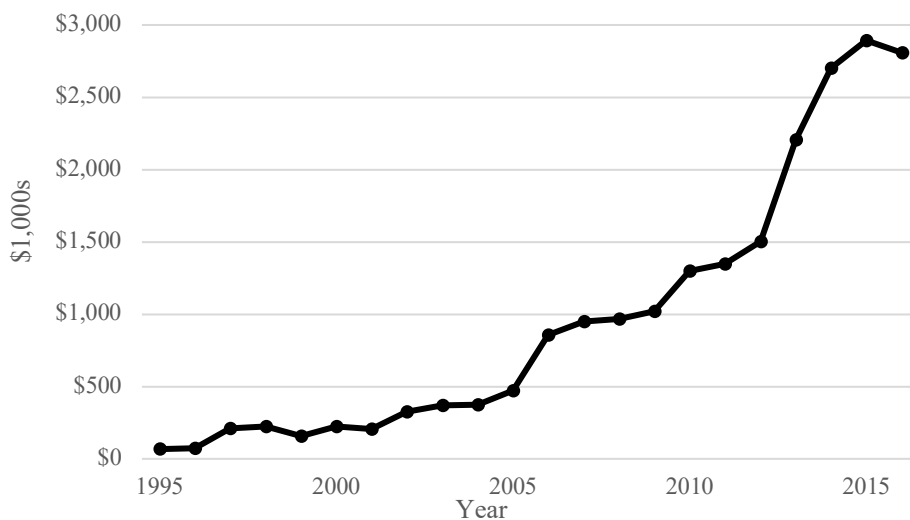


Figure 4: Inflation-Adjusted Market Value of Aquaculture Sales in the NBW, 1995-2016 (in 2016 dollars)

Source: CRMC Annual Reports, 1995-2016

¹ These figures are not from the 51% scaling, but are exact numbers extracted from aquaculture farms specifically in Narragansett Bay, Mt. Hope Bay, and Sakonnet River.

Since 2000, when the CRMC began documenting employment numbers, total employment in the watershed has increased more than 600% from 13 in 2000 to 90 in 2016 (Figure 5). The percentage increases are not as large as total sales, but the growth trend is similar with the largest increase of 43% occurring between 2005 and 2006.³⁰

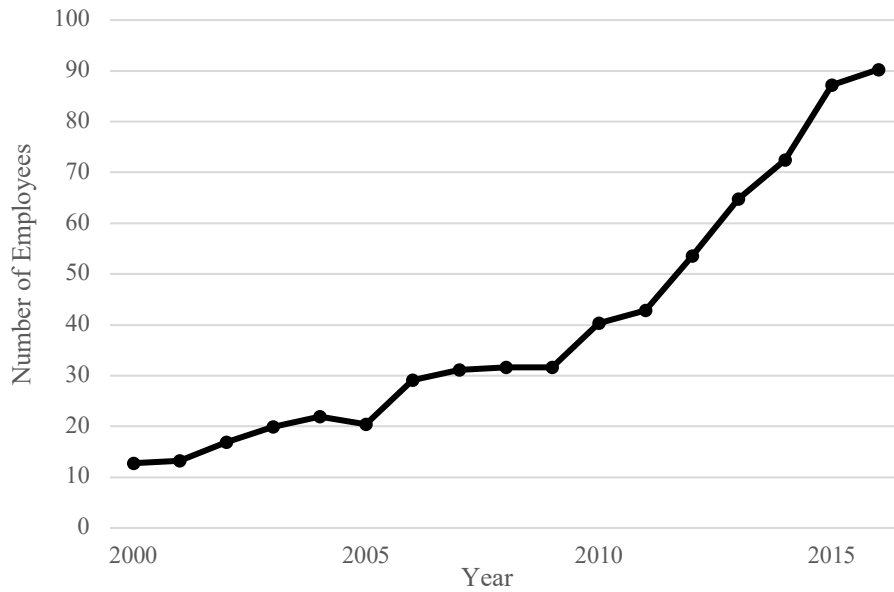


Figure 5: Aquaculture Employment in the NBW, 2000-2016

Source: CRMC Annual Reports, 2000-2016

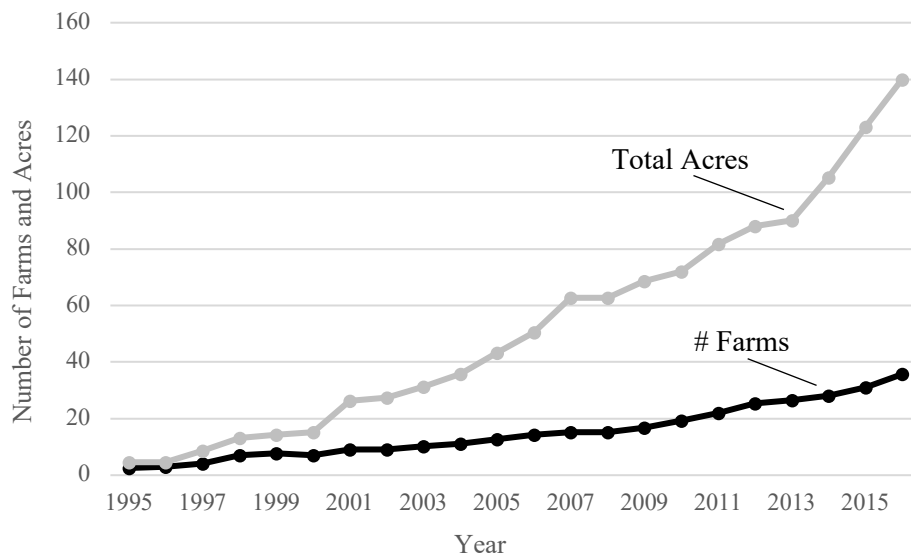


Figure 6: Aquaculture Farms and Acres in the NBW, 1995-2016

Source: CRMC Annual Reports, 1999-2016

In addition to growth in market value of sales and number of employees, total aquaculture operations and leased acres have rapidly increased in the last two decades (Figure 6). Between 1995 and 2016, total number of aquaculture farms in the NBW increased from three to 36, and total leased acres increased from five to 140.³¹

Since aquaculture law revisions in 1996, the aquaculture industry in the NBW has flourished on all fronts. In the last two decades, the industry has grown the most rapidly in sales value, increasing over 4,000% from \$67,000 in 1995 to \$2.8 million in 2016 (Figure 4). During the same period, total number of leased acres increased nearly 3,000% from five to 140, and total number of aquaculture farms in the NBW increased 1,300% from three to 36 (Figure 6). Although employment has witnessed the least amount of growth, between 2000 and 2016 it increased more than 600%, from 13 in 2000 to 90 in 2016 (Figure 5).³²

Overall, the aquaculture industry in the NBW embodies a story of resurgence and growth in the past century. Despite past challenges, aquaculture farms in the watershed have grown rapidly from almost non-existent in 2000 to a sizeable industry by 2016, with direct economic impacts of \$2.8 million in sales, 36 aquaculture farms, 140 leased acres, and 90 employees.³³ With increasing global demand for fish and shellfish through farming as well as growing demand for local food at restaurants, farmers' markets, and retailers, the aquaculture industry in the NBW is well positioned to continue growth and attract continual investment in the future.

Future Threats and Opportunities

Temperature | Population Growth | Shellfishing areas

As previously stated, aquaculture has flourished in recent years. This continued growth, however, may be threatened by the effects of climate change on aquaculture areas and cultivated species. For example, of the 70 aquaculture farms in RI, a majority cultivate oysters on coastal waters, making them susceptible to changes in marine environments that are difficult to control or prevent. Shellfishing and aquaculture in the NBW has a history of sensitivity to outside pollutants and threats. For example, in the early 1900s, residents in the area noticed problems with shellfish populations that arose from increased urbanization and fecal pathogens and pollutants entering the water. In 1925, the National Shellfish Sanitation Program was established to address this issue, although it continues to affect shellfish in the NBW. As of 2015, 76% of the NBW was open to shellfishing (either approved or conditionally approved—this “approved” status is conditional on acceptable levels of contaminants and fecal pathogens found in water). As discussed in previous sections, as human populations increase and settlements expand, water quality is threatened, and this threat is exacerbated by the effects of climate change (e.g., increased runoff from storm activity, warmer waters conducive to bacteria growth, etc.). In summary, the effects of growing population, enhanced by climate change, pose a major threat to water quality and therefore the aquaculture industry.

Furthermore, the effects of climate change on marine waters, including increasing water temperatures, changes in ocean currents, acidification, and increased storm activity near coastal areas, can have a direct impact on aquaculture in the NBW. For example, warmer waters may increase the likelihood of harmful algal blooms, outbreaks of bacteria, or increased instances of toxic algal blooms, known to be harmful to humans if consumed. In 2016, RI experienced its first *Pseudo-nitzschia* (toxic algae) bloom in the state's history. The algae produce a neurotoxin called domoic acid, which affects shellfish and migrates up the food chain in the marine environment (potentially spreading to humans if they consume contaminated shellfish). This outbreak led to a temporary shellfishing ban and no humans tested positive for the toxin. Although this was the first outbreak of its type in RI waters, a subsequent outbreak occurred in spring 2017, less than a year later. Scientists believe that toxic algal blooms may become more common in the area as sea temperatures rise, creating a welcoming environment for algae to grow.³⁴ Warmer waters also increase the spread of diseases that affect marine life. These two factors—harmful algal blooms and disease/pathogens/bacteria—are believed by the Food and Agriculture Organization of the United Nations to be the biggest risk factors affecting aquaculture in temperate regions.³⁵ Additionally, there are other environmental factors that, although may not be as threatening as those mentioned above, will still impact aquaculture in the NBW. Ocean acidification leads to a depletion of available calcium carbonate, the main element that comprises shelled mollusks' shells. Reduced levels of available calcium carbonate as a result of ocean acidification may be a limiting factor for the growth of future shellfish populations; RI is especially vulnerable to ocean acidification, as a recent study found that the state is one of the top 15 at-risk areas for ocean acidification in the country.^{36 37}

Although some of these risk factors cannot be prevented, there are some preventative measures that can be taken to reduce the impact of these threats. For example, disease-resistant oysters can be used and proper handling techniques by shellfishermen (such as flash freezing and placing oysters on ice immediately after harvest) can help reduce the occurrence of vibrio.³⁸ In addition, constant monitoring will be key to ensuring the health of farms and species involved.

Overall, a culmination of factors in the future, ranging from population growth to an increase in ocean temperatures, may have an impact on the current state of shellfishing and aquaculture in the NBW. The exact impacts may be difficult to predict, although it seems highly likely that the industries will experience shifts and potential problems in the future due to these effects.

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Appendix

Table A.1: Aquaculture Farms, Sales, and Acres in U.S. and RI, 2005-2013 (in 2016 dollars)

	US	RI
Number of Farms, 2013	3,093	52
Number of Farms, 2005	4,309	25
Sales, 2013 (\$1000s)	\$1,411,236	\$4,511
Sales, 2005 (\$1000s)	\$1,357,125	\$924
Total Acres, 2013	462,729	177
Total Acres, 2005	693,053	85

Sources: Census of Aquaculture, 2013; Beutel, 2013; Alves, 2005

Table A.2: Aquaculture Sales, Farms, Acres, and Employment in RI, 1995-2016

	Sales (\$1000s)	Number of Farms	Total Acres	Employment
1995	\$131.6	5	9	-
1996	\$140.4	6	9	-
1997	\$410.8	8	17	-
1998	\$435.4	14	26	-
1999	\$308.4	15	28.25	-
2000	\$442.1	14	30	25
2001	\$405.9	18	51.5	26
2002	\$639.7	18	53.75	33
2003	\$725.4	20	61.13	39
2004	\$733.0	22	70.3	43
2005	\$924.7	25	85	40
2006	\$1,611.1	28	99	57
2007	\$1,858.5	30	123	61
2008	\$1,899.3	30	123	62
2009	\$2,003.0	33	134.5	62
2010	\$2,544.1	38	141	79

2011	\$2,646.3	43	160.3	84
2012	\$2,950.4	50	172.55	105
2013	\$4,325.9	52	176.55	127
2014	\$5,296.2	55	206.2	142
2015	\$5,673.2	61	241.4	171
2016	\$5,508.7	70	274.53	177

Sources: CRMC Annual Reports, 1999-2016

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