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The Feasibility and Economic Potential of Geoduck Aquaculture in Neah Bay, Washington

Yongwen Gao[1, 2], Raymond Colby[1] and Gregory Ikeda[1]

1. Makah Fisheries Management, Neah Bay 98357, WA, USA

2. College of Fisheries, Huazhong Agricultural University, Wuhan 430070, Hubei, China

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Abstract: The geoduck clam, *Panopea abrupta*, is an economically important species and mainly cultured in the Southern Puget Sound of Washington State. There are no examples of intertidal geoduck aquaculture in Neah Bay. Since 2011, the Makah Fisheries Management (MFM) has started a pilot project supported by the United States Department of Agriculture Rural Business Enterprise Grant (USDA-RBEG). The MFM aquaculture practice and results showed that the Neah Bay beaches are feasible for intertidal geoduck aquaculture, and have the proper conditions to produce high quality geoduck clams. As compared to finfish culture, there is little environmental concern for geoduck aquaculture due to the natural seawater fluctuation (no artificial feeding) and the intertidal nature (no genetic mixing). This advantage provides the opportunity for community members of all backgrounds to partake in the aquaculture process, with low investment costs for establishing a family-based geoduck farming business. Overall, the high market value and the economic potential make geoduck aquaculture an ideal candidate in development of remote and rural areas along the Washington coast.

Key words: Intertidal geoduck aquaculture, farming business, Neah Bay beaches, Makah.

1. Introduction

Located at the Northwest tip of the Olympic Peninsula of Washington State, USA, the Makah Reservation is an Indian reservation with a land area of 121.45 km^2. The Northern boundary of the reservation is the Strait of Juan de Fuca, while the Western boundary is the Pacific Ocean (Fig. 1). Archaeological research suggests that the Makah people have inhabited the area now known as Neah Bay for more than 3,800 years [1]. The Makah culture is fundamentally rooted from the Pacific Northwest Coast area. The Makah people are the southernmost of the Wakashan group, being the only member of the Wakashan group within the United States. On January 31, 1855, the select Makah Tribe representatives signed the "Treaty of Neah Bay" with the US federal government, reducing the size of their traditional lands to what it is now [2]. The treaty allowed for the establishment of the Makah Reservation and preserved the right of the Makah people to hunt whales and seals in the usual and accustomed fishing areas (U&A). In 1974, Federal District Court Judge George Hugo Boldt reaffirmed tribal treaty fishing rights and established the treaty tribes as co-managers of the fisheries resources of Washington State. Thus fishing is the dominant income source for the Makah people today, with more than 70 commercial fishing vessels for catching groundfish, salmon and shellfish. Unfortunately, many traditional fisheries have been severely depleted in recent years, and some vulnerable species has been overfished [3]. The Makah Fisheries Management (MFM) has made ecosystem-management effects to maintain a sustainable fishery. One important step is to follow the global trends to develop new fisheries such as geoduck

Corresponding author: Yongwen Gao, Ph.D., research fields: otolith geochemistry, marine science and fisheries management. E-mail: gaoy@olypen.com.

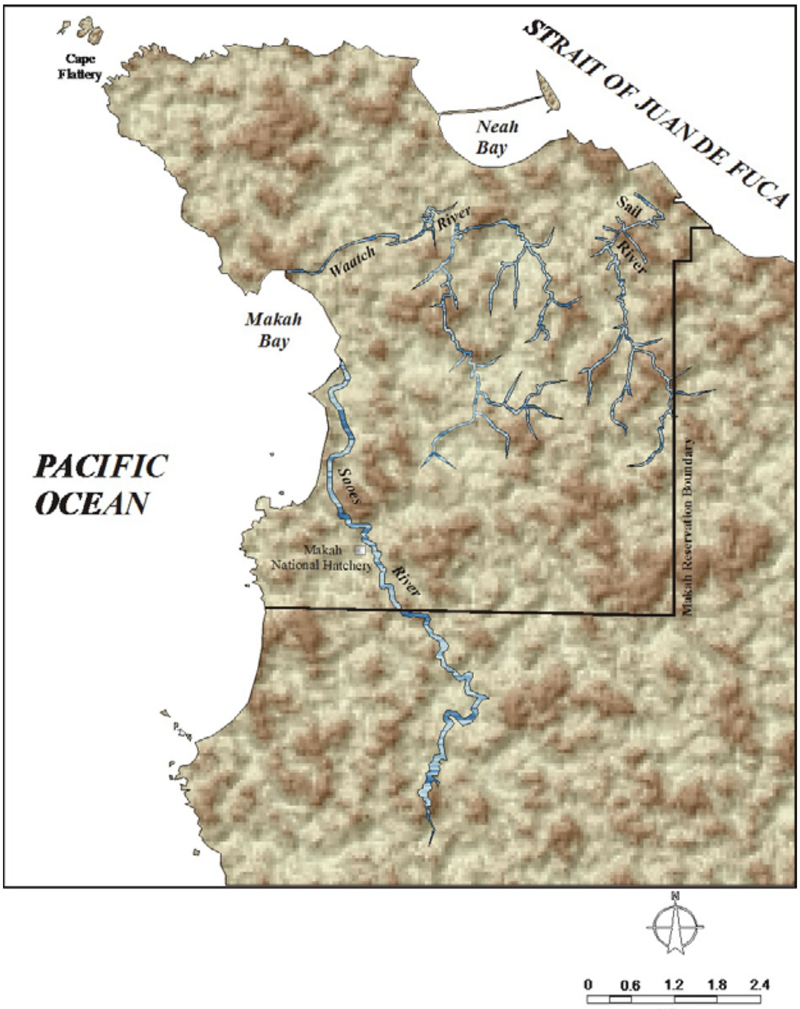

Fig. 1 Area map showing the Makah Reservation at the Northwest tip of the Olympic Peninsula of Washington State and its boundaries.

clam aquaculture.

The geoduck clam (*Panopea abrupta*, Conrad 1849) is one of the largest burrowing clams in the world [4]. Commercial geoduck stocks occur from Alaska to the Gulf of California in the Northeast Pacific Ocean, from the intertidal zone to depths of about 110 m [5, 6]. They bury themselves up to 1 m deep in sand, silt, gravel and other soft substrates, with an average weight of 0.91-1.36 kg in adults [7, 8]. Since 2005, the Washington State Department of Natural Resources (DNR) has released aquatic lands (both intertidal and subtidal) statewide for geoduck aquaculture. Because geoduck clams are fast growing animals (early maturity at 4-5 years) with high market values (currently over $66/kg; Department of Health, personal communication), it is very attractive for MFM to start intertidal aquaculture in the Neah Bay beaches.

Geoduck farming and business are popular in the southern Puget Sound of Washington State. Although historically a small subtidal geoduck fishery occurred in the deeper sea-flat near Sekiu, no example of intertidal geoduck aquaculture has been reported in Neah Bay. Thus the fundamental questions are raised: (1) Can we grow geoduck clams in Neah Bay remote and rural areas as growers did in Southern Puget Sound? (2) If yes, under what conditions will we successfully establish a geoduck farming business? Thanks to the US Department of Agriculture Rural Business Enterprise Grant (USDA-RBEG), MFM aquaculture team has successfully conducted a geoduck aquaculture project since 2011 and obtained first-hand information for answering those questions.

The main objective of this manuscript was to summarize the geoduck aquaculture results from the USDA-RBEG project. First, using the same techniques and procedures as the Southern Puget Sound farmers, we illustrated that the Neah Bay beaches were suitable for growing intertidal geoduck clams. Second, through monitoring and research programs after geoduck seed planting, we collected seawater parameters (e.g., temperature, salinity, pH and dissolved oxygen concentration) to better understand the environmental conditions that the animal encountered in Neah Bay and possible impacts on the aquaculture product. Finally, throughout the geoduck aquaculture practice from the USDA-RBEG project, we expected to call Makah people and the community's attention to the geoduck aquaculture business, particularly the economic potential in Neah Bay and other Washington coastal remote and rural areas.

2. Materials and Methods

2.1 Aquaculture Site Selection

Before selecting a location for the pilot project, possible areas around Neah Bay were surveyed, as geoduck size, density and quality had been linked to habitat conditions [6, 9]. Potential sites were visited prior to geoduck seed planting. If the substrate was too rocky or contained imbedded oysters it would not be ideal sites for geoduck aquaculture. It was also necessary to check for the abundance of predators such as sea stars and crabs.

The geoduck aquaculture site for the USDA-RBEG project was selected at low tide conditions in Neah Bay over the course of April to June. In addition to the water quality measurements (e.g., temperature, salinity and dissolved oxygen concentrations), locations containing these oceanic conditions in conjunction with intermediate tidal flow [10] were also considered. The general criteria for site selection included but not limited to: (1) at least 90 m away from the State Park or other recreational areas; (2) no eelgrass on the geoduck aquaculture site; (3) avoiding sites near large streams or rivers; and (4) absence of PSP (paralytic shellfish poisoning) in the historical record. Ultimately, the chosen site is confined within a breakwater that allows adequate wave motion without disturbing the aquaculture installations, and meets environmental requirements for geoduck development.

2.2 Protection and Equipment for Geoduck Aquaculture

The MFM aquaculture team purchased geoduck seeds from the Shellfish Hatchery of the Lummi Indian Tribe in Bellingham, Washington, although the Taylor Shellfish Inc. can also provide quality seeds. To protect geoduck seeds from predators such as crabs and sea birds, six-in diameter polyvinylchloride (PVC) tubes, protection nets and rubber bands were prepared. The PVC pipes were purchased from a local company in Bremerton, WA and cut by the MFM aquaculture technicians to one-ft cylinders (Fig. 2). The predator nets and the heavy, UV-resistant rubber bands were purchased from a central elastic company in Malaysia.

2.3 Tube Installation and Seed Planting

On the aquaculture day, the weather was first considered. A cloudy or cold day and moderate currents are generally good for geoduck seed planting. Proper conditions of water temperature (< 16 °C) and salinity (> 26‰) are also favorable for geoduck aquaculture [11].

During the USDA-RBEG project, the MFM aquaculture team took two steps for geoduck aquaculture: (1) installing the PVC tubes in one morning; (2) planting the geoduck seeds in the next morning. When the tide reached below -0.5 ft sea level, each tube was pressed into the substrate on 1.5 ft centers leaving three- to four-in exposed for placement of netting and rubber bands. These tubes can be removed and re-used after two or three years of growing, as the planted geoduck has generally grown large enough to avoid predation by that time [11].

Fig. 2 The 1 ft cylinders cut from the 6-in PVC pipe by the MFM aquaculture technicians.

The geoduck seeds were kept in a cooler with air pumping and elite boxes on the top with air-circle pipes, which was designed by the MFM aquaculture technicians. In general, the seeds can be kept in the cooler overnight, or 24 h maximum for transportation. Therefore, the MFM aquaculture team bought geoduck seeds from the Lummi Hatchery in the afternoon, and returned to Neah Bay for planting in the next morning. Immediately after planting geoduck seeds, 8 mm mesh nets were placed over the tube and secured with a heavy-duty rubber band. After geoduck seed planting, examination of site and tube conditions was carried out in the following day.

2.4 Scientific and Environmental Monitoring Program

The primary aim for scientific and environmental monitoring program is to determine the suitability of geoduck aquaculture in Neah Bay, the impact of geoduck aquaculture on habitat and ecological changes, and the development on species of concern in scientific research. The on-site monitoring and sampling began at the first year of geoduck aquaculture cycle. Sampling was designed to detect a 20% change over a 12 month period with 90% confidence. Repeated sampling of selected sites might be used for making pair-wise comparisons. Thus baseline sampling was used to determine the number and location of samples needed in order to make a statistically valid inference about changes.

Monitoring was conducted at low tide for sediment and plant observations and at high tide for water quality parameters. Sampling was conducted at the upper, mid and lower parts of the planted beach area for sediment and benthic infaunal and epifaunal and plant metrics. Sampling of water quality metrics (e.g., temperature, salinity, dissolved oxygen concentration and turbidity) was conducted at the lower end of the planted beach area. All data collected (such as field notes, data sheets, photographs and measured water quality metrics) were recorded on file each day. Field samples (such as water, sediment, shells, etc.) were checked each week and kept in a refrigerator for further analyses.

In the meantime, a research proposal on stable isotope analyses in geoduck shells was initiated in MFM, along with the progress and data from a previous DNR project on low dissolved oxygen in the Hood Canal of Puget Sound (cf. IAA 06-258, contract between DNR and MFM, 2006). Because geoduck clams have a long lifespan up to 160 years in Puget

Sound [12] and the shell carbonate is a good proxy in marine environmental studies [13], stable isotope analyses especially carbon isotope ratios ($^{13}C/^{12}C$ or $\delta^{13}C$), can be used in detection of the effects of ocean acidification in open and estuary waters [14].

3. Results and Discussion

Throughout the USDA-RBEG project, the MFM aquaculture team has installed about 1,800 PVC tubes and planted geoduck seeds near the Western Makah Senior Center in Neah Bay (Fig. 3). The results showed that the survival rate of geoduck seeds was about 80%, and that the Neah Bay beaches are suitable for aquaculture and able to produce high quality geoduck clams (Fig. 4). As an educational process, many Makah and community members participated in geoduck aquaculture, and learnt the aquaculture techniques and methods. In particular, several Makah members (e.g., John J. Ides, Mike Shaw and Deanna Buzzell-Gray) showed their interests for establishing a family-based geoduck farming business in Neah Bay, which is exactly the expectation of the USDA-RBEG funding.

Why do we think these results are important? From the business point of view, geoduck aquaculture will create jobs and make a great advance in economic development for the rural areas such as Neah Bay. Because the intertidal geoduck farming is more productive than the subtidal aquaculture [15], the Neah Bay beaches have a great potential for aquaculture business. Over a geoduck aquaculture cycle (generally 5-6 years), the average annual income for a geoduck farming business in Southern Puget Sound is from $150,000 to $200,000 (Taylor Shellfish Inc., personal communication). We can expect similar income for the geoduck farmers in Neah Bay. Assuming there are 30 acres of aquatic lands in Neah Bay, the commercial geoduck farming will bring at least six families to business and create 18-24 jobs in shellfish fisheries. The aquaculture area may be extended to the East to the Strait of Juan de Fuca, where wild geoduck clams have been found along the Strait in Clallam County. If successful, the potential for the economic development along the Western Clallam County will be prospective. Therefore, the geoduck aquaculture in Neah Bay is not only a fishery business, but a social activity to promote rural community development as well.

Based on the Treaty Rights [2] and the Boldt Decision (US vs. Washington, 1974), MFM must manage their fisheries in Makah's U&A so that the environmental impact would be a paramount consideration for any aquaculture program. As compared to finfish farming such as Atlantic salmon

Fig. 3 The geoduck beds located on the beaches near the Makah Seniors Center in Neah Bay.

Fig. 4 The geoduck size and growth at different stages in Neah Bay beaches (from the bottom to the top: 6-12 months geoduck; 18-24 months geoduck).

and rockfish with ocean pens [16-18], fortunately, there is little environmental concern for geoduck aquaculture due to the natural seawater fluctuation (adult geoduck grow for 4-5 years without artificial feeding) and the intertidal nature (no genetic mixing; [19, 20]). This advantage provides an opportunity for Makah community members of all backgrounds to partake in the aquaculture process. With the goal of establishing family-based small businesses in the future, the relative simplicity of geoduck aquaculture makes it an ideal candidate. In addition, high selling price coupled with low investment costs provide high returns compared to other aquaculture species.

Results from the MFM sampling and monitoring program illustrated optimal seawater conditions on temperature, salinity and pH variations in Neah Bay. From July to September, 2011, the temperature in seawater ranged from 10-13 °C (Fig. 5) whereas the salinity ranged from 28-33 psu (practical salinity unit [21]). The salinity decreased dramatically in late September, 2011, due to the onset of the rainy season (Fig. 5). In contrast, the pH values were stable and did not change much over the November observations (Fig. 6).

These first-hand observations and other reference information are very helpful for the MFM ongoing scientific research project on shell carbonate studies. Geoduck clams deposit annual growth rings in shells and these annuli can be used for age determination [5, 8, 22, 23]. Geoduck shells are composed of calcium carbonate (aragonite + calcite), thus they can be potentially used as proxies for long-term marine environmental studies like other bivalves and fish otoliths [24-26]. The principle is that carbonate shells are precipitated in oxygen isotopic equilibrium with the ambient seawater [27-29], so the $^{18}O/^{16}O$ ratios of geoduck shells record the environmental conditions that an individual clam encountered. The $^{13}C/^{12}C$ ratios of geoduck shells do not reach isotopic equilibrium conditions, but they are still useful because they reflect metabolic status of the animal and may show trophic level changes as geoduck clams grow [30-32]. Noakes and Campbell [33] identified the potential to use geoduck clams as indicators of climate change. Strom et al. [12] has developed methods for ageing geoduck clams and demonstrated that the growth patterns in geoduck shells may relate to sea surface temperature changes in North Puget Sound. The geochemical methods that combine stable $^{18}O/^{16}O$ and $^{13}C/^{12}C$ ratios in shell carbonate will provide a powerful new tool in geoduck research and

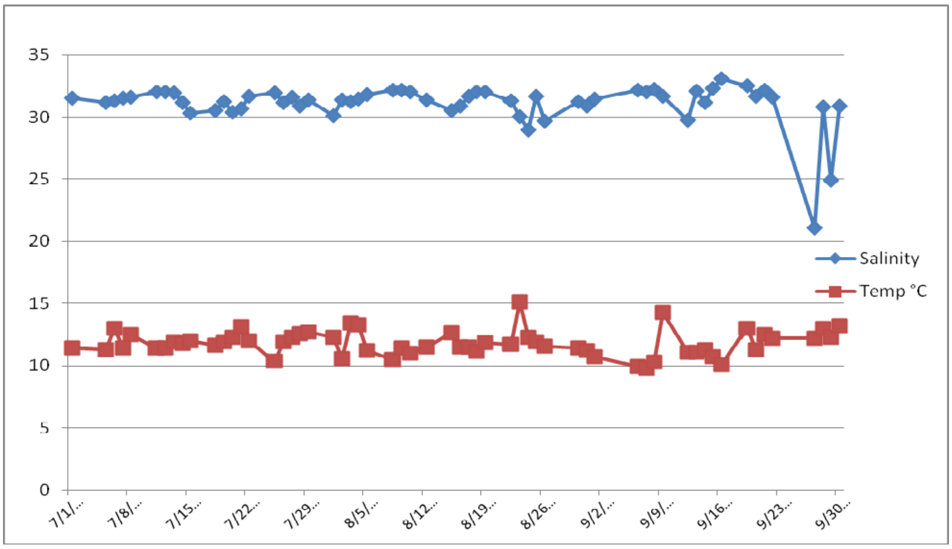

Fig. 5 Weekly low tide survey in Neah Bay geoduck beds from July to September, 2011.

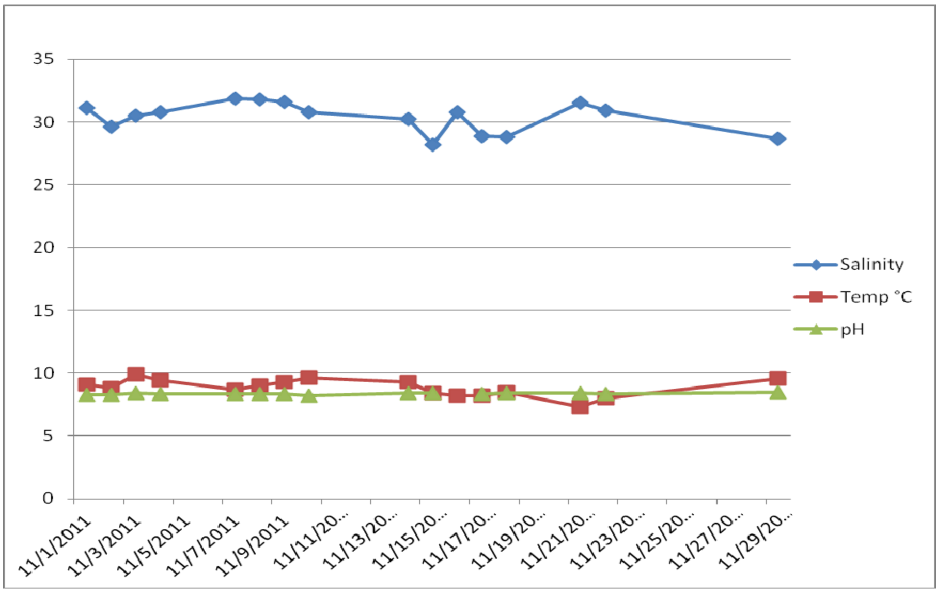

Fig. 6 The pH records during the low tide survey in November, 2011.

provide independent chemical records on ocean climate changes that the animal experienced. The MFM research projects that target geoduck shells and otoliths for ocean acidification in Neah Bay and Washington coast are currently underway.

4. Conclusions

By completing the USDA-RBEG project, we have demonstrated that the Neah Bay beaches are feasible for intertidal geoduck aquaculture, and have the proper conditions to produce high quality geoduck clams. Establishing effective geoduck farms has the potential to bring great economic benefits to the Makah people and the Neah Bay community, providing stable jobs and income to supplement traditional fisheries. These techniques and benefits may be further expanded to other rural communities along the Washington coast. In addition to the economic development and benefits, the geoduck shells and the natural seawater fluctuations can provide excellent proxies for coastal environmental studies.

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