

Advancing Pinto Abalone Farming in Alaska:

Pilot Study to Develop Protocols for an Efficient Transition from Laboratory Nurseries to Ocean-Farmed Growth Systems.



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Final Report to Southeast Conference: the Alaska Mariculture Cluster

Introduction:

In the United States, mariculture production has steadily increased during the last decade (NOAA, 2020). However, the U.S. remains a relatively small mariculture producer, importing over 80% of its seafood, 60% of which is farmed (FAO, 2018). Shrimp and abalone nearly double the volume and value of imported fish and fish products, highlighting the potential for culturing high-value species as part of the array of products offered by the domestic shellfish mariculture industry.

The northern or pinto abalone *Haliotis kamtschatkana* Jonas 1845 is found from Baja California (Mexico) to Southeast Alaska where it inhabits rocky intertidal and sublittoral areas along the open Gulf of Alaska coast avoiding inshore waters of the Inside Passage (Neuman et al, 2018). It is the only abalone species found in Alaska, where it has been harvested commercially since the 1960s, peaking at 379,000 pounds in 1979-1980. Although there was a relatively stable fishery, a steady decline in wild populations throughout its range between the late '70s and early '90s, (Woodby et al., 2000; Rogers-Bennett, 2007; Rothaus et al. 2008) prompted the closure of commercial harvest along the entire U.S. West Coast since 1996. Several attempts (Bamfield Huu-Ay-Aht Community Abalone Project and Puget Sound Pinto Abalone Restoration Project) to restore natural pinto abalone populations have been undertaken, resulting in the development of techniques to produce large numbers of juvenile ("seed") abalone under controlled conditions at shellfish hatcheries (Lemay & Boulding, 2009, Carson et al., 2019).

Abalone, which are cold-blooded animals, grow faster in warmer temperatures, presenting a challenge for cost-effective farming in colder regions. Research on wild pinto abalone indicates that the best growth for young animals (35-50 mm length) occurs at temperatures between 13-14°C, with growth inhibited below 5.5°C (Paul & Paul, 1981). Under optimal conditions, it takes around 18 months for the abalone population with a length of approximately 30 mm to reach a harvestable size of about 75 mm (Paul et al., 1977). In contrast, captive-bred juvenile pinto abalone (mean shell length ~25 mm) transplanted into

Washington State waters take about 56 months to reach a harvestable size at an average temperature of 8-11°C. However, they must find their food and avoid predators during this period (Carson et al., 2019). Coastal water temperatures in Southeast Alaska typically range between 3-15°C throughout the year depending on the location and raise above 10°C only during summer (NOAA NCEI Coastal Water Temperature Guide, <https://www.ncei.noaa.gov/products/coastal-water-temperature-guide>). Given the thermal conditions, it is reasonable to suggest that abalone farmed in Southeast Alaska with abundant food supply would take approximately 36 months to reach a marketable size, a timeframe similar to oysters (NOAA News 2022, https://www.fisheries.noaa.gov/feature-story/sustainable-pacific-oyster-farming?utm_source).

Pinto abalone feeds exclusively on benthic microalgae and seaweed (e.g. Paul et al., 1977). Thus, they do not face the risk of paralytic shellfish poisoning common in filter feeders like oysters. Pinto abalone are an excellent choice for an ocean polyculture farming system growing a mix of seaweed and shellfish. This system aims for zero input, sequesters carbon, and rebuilds fjord ecosystems (Fang et al., 2009; Jiang et al., 2022). Additionally, farming pinto abalone exclusively on shellfish farms creates a demand for locally grown seaweed, providing new markets. Rearing pinto abalone in Alaska while feeding them with locally farmed seaweed offers a unique opportunity to enhance sea farm resilience and promote diverse and effective mariculture practices in the State.

The project focuses on efficiency of pinto abalone spat transfer from laboratory-based nursery to ocean-based rearing arrays depending on animal's age/size and location. Our overarching goal is to provide prospective Southeast Alaska abalone farmers with clear instructions for setting up and maintaining pinto abalone spat rearing systems to help plan and manage their mariculture efforts.

Methods:

Cultivating abalone spat

Abalone tank production and cultivation facility was built at UAF CFOS Department of Fisheries in Juneau, Alaska, as a part of a larger abalone research project, "**Pinto Abalone Mariculture Potential (PAMP)**" funded by the North Pacific Research Board (NPRB Project #2214, \$342,403) for 2022-2026. The project ran by the same team of researchers has been focused on optimizing spawning and culturing larval and early juvenile pinto abalone in captivity using a variety of seaweed diets. The facility (Fig. 1) comprised broodstock holding, larvae hatching, and spat and juvenile rearing modules, capable of handling millions of larvae at a time. During a single abalone spawning effort in October 2023, we produced over 1 million fertilized eggs with 80% hatching success.



Figure 1. The pinto abalone hatching and rearing facility at CFOS Department of Fisheries in Juneau (UAF)

Spawning of all adults was induced following methods successfully used in prior pinto abalone studies (e.g., Standley 1987), other mariculture facilities for pinto abalone (Puget Sound Restoration Project), and in the White Abalone Captive Breeding Program (Rogers-Bennett et al., 2016; Morse et al., 1977). Briefly, animals are divided by sex and placed in containers with seawater and a hydrogen peroxide solution to induce spawning. After a few

hours, they will be rinsed with fresh seawater, and any spawned eggs or sperm are siphoned and used to create within-diet-treatment progeny. Spawning rates are calculated by comparing the proportion of females and males in each treatment who spawn, as well as the total estimate of gametes spawned per animal (calculated by measuring the concentration of gametes in a known volume of seawater) and the fertilization success (proportion of eggs that cleave when exposed to sperm). Larval survival is estimated with larval counts at days 4 and 7 post-fertilization. The settled larvae were maintained in follow-through holding tanks (troughs) under controlled condition (~14°C) to maximize development and growth and were initially fed with a mix microalga (Paul and Paul, 1977) replaced later by cultivated seaweed. Removable PVC plates are placed on the bottom of the troughs providing settling substrate for easier experimental manipulations with attached abalone spats.

For this project, we expanded our abalone hatching facility to maintain abalone spat hatched in March 2024 and to accommodate new spat produced in the fall 2024. The developing spat had transformed to mainly kelp-feeding stage by 2025, which made them ready for outplanting.

Outplanting System

Holding cages were designed and built for the abalone outplanting efforts. The materials were obtained from Ketcham Supply (New Bedford, MA, <https://ketchamsupply.com>), as well as sourced locally. The prototype contained two plastic Aquapurse AP6 (72x25 cm) baskets secured by removable stainless rods inside the protective metal cage and lined with 1000 µm Nitex mesh. Rectangular plastic inserts were attached to the upper and lower sides of the baskets to provide smooth surface for attachment of the abalone. The assembled cage was equipped with four cables attached to the cage corners on one end and a stainless swivel on the other end (Fig. 2). In addition, each cage was equipped with an HOBO TidbiT MX temperature logger (<https://www.onsetcomp.com/products/data-loggers/mx2203>) pre-programmed to record water temperature every 10 minutes at the start

of each deployment. The prototype successfully underwent a month-long initial sea trial (empty, no live abalone) before being deployed.

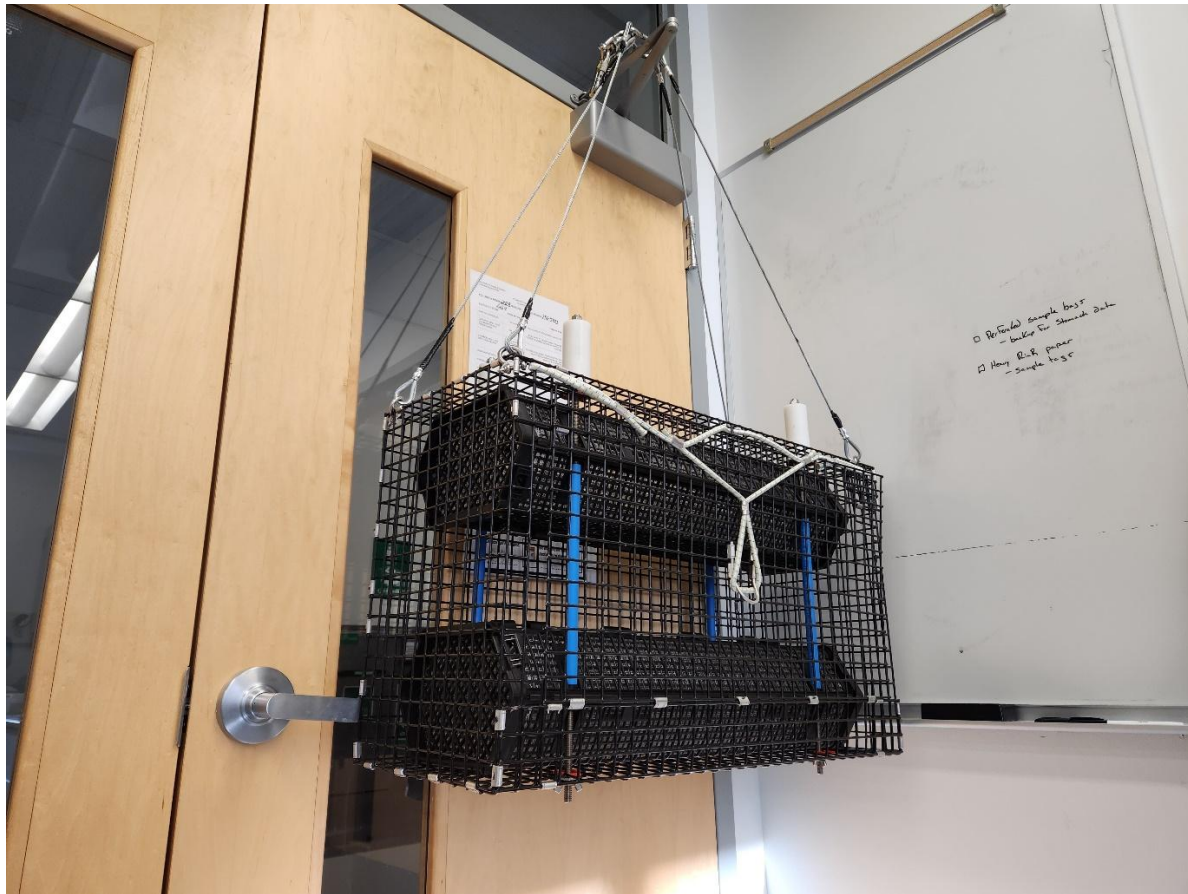


Figure 2. Fully assembled abalone rearing cage ready for deployment.

Outplanting Deployments

Oceanographic conditions substantially differ over the latitudinal expanse of Southeast Alaska rugged coasts and coastal embayments (NOAA NCEI Coastal Water Temperature Guide, <https://www.ncei.noaa.gov/products/coastal-water-temperature-guide>). To test the potential effect of regional environmental differences, we selected two locations for our experimental deployments: Sea Quester Farms (<https://www.seaquesterfarms.com>) site in

northern Stephens Passage near Juneau, and Metlakatla Indian Community (MIC) (<https://www.metlakatla.com>) at Annette Island near Ketchikan (Fig. 3).

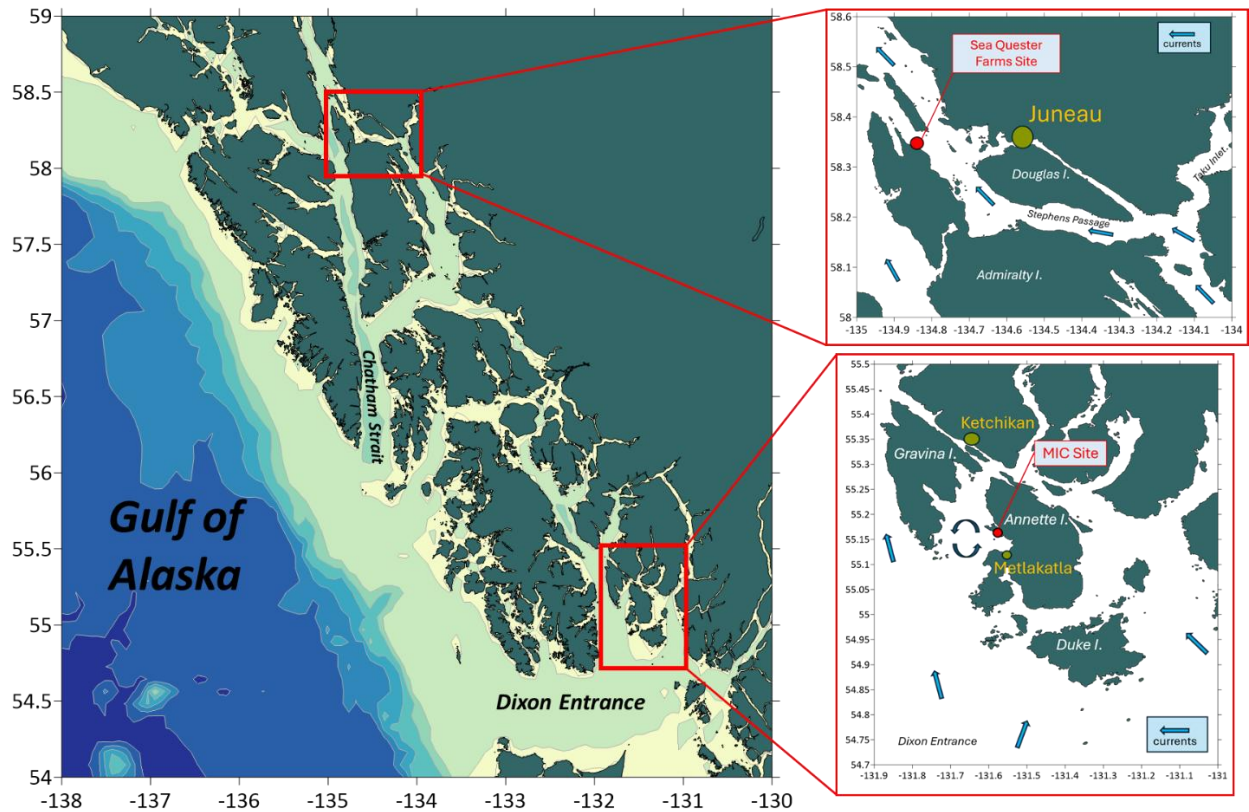


Figure 3. Locations of Sea Quester Farms and Metlakatla Indian Community (MIC) experimental sites.

Sea Quester Farm Site

A branch of the Southeast Alaska Inside Passage, Stephens Passage is a glacially carved waterway which separates the Alaska mainland and Douglas Island on the east from Admiralty Island on the west. Stephens Passage connects (via Frederic Sound) to the deep tectonically fault-originated Chatham Strait in the south and Lynn Canal in the north, thus providing an alternative inshore route for northward buoyancy flow which derives from the freshwater runoff and dominates the Inside Passage oceanographic circulation throughout most of the year. The Sea Quester Farm Site (about 10 m bottom depth) is located near the

Admiralty Island coast in the shallower north-western segment of the passage almost directly across the Auke Bay. The location while semi-protected from the winds is influenced by glacial outputs of the nearby Mendenhall River and local tidal currents. The site was selected to examine the possibility of pinto abalone farming within the Inside Passage where many operating seaweed farms are located. The other goal was to investigate potential reasons for wild pinto abalone avoidance of inshore environment. At the Sea Quester Farm Site, the Experimental Cage #1 with 20 (10 per basket) juvenile abalone ~10 mm long was deployed on May 2, 2025. After a two-week initial assessment, the Experimental Cage # 2 with 20 (10 per basket) juvenile abalone from the same size cohort was deployed on May 24, 2025. The initial mix of fresh dulse seaweed (*Palmaria palmata*) were placed into each basket as *ad libitum* food source for the abalone spat. The abalone were inspected biweekly (weather permitting) and food was replaced with fresh split kelp (*Saccharina groenlandica*) grown at the farm site (Fig.4). The experiment was run until July 8, 2025 (see Results).

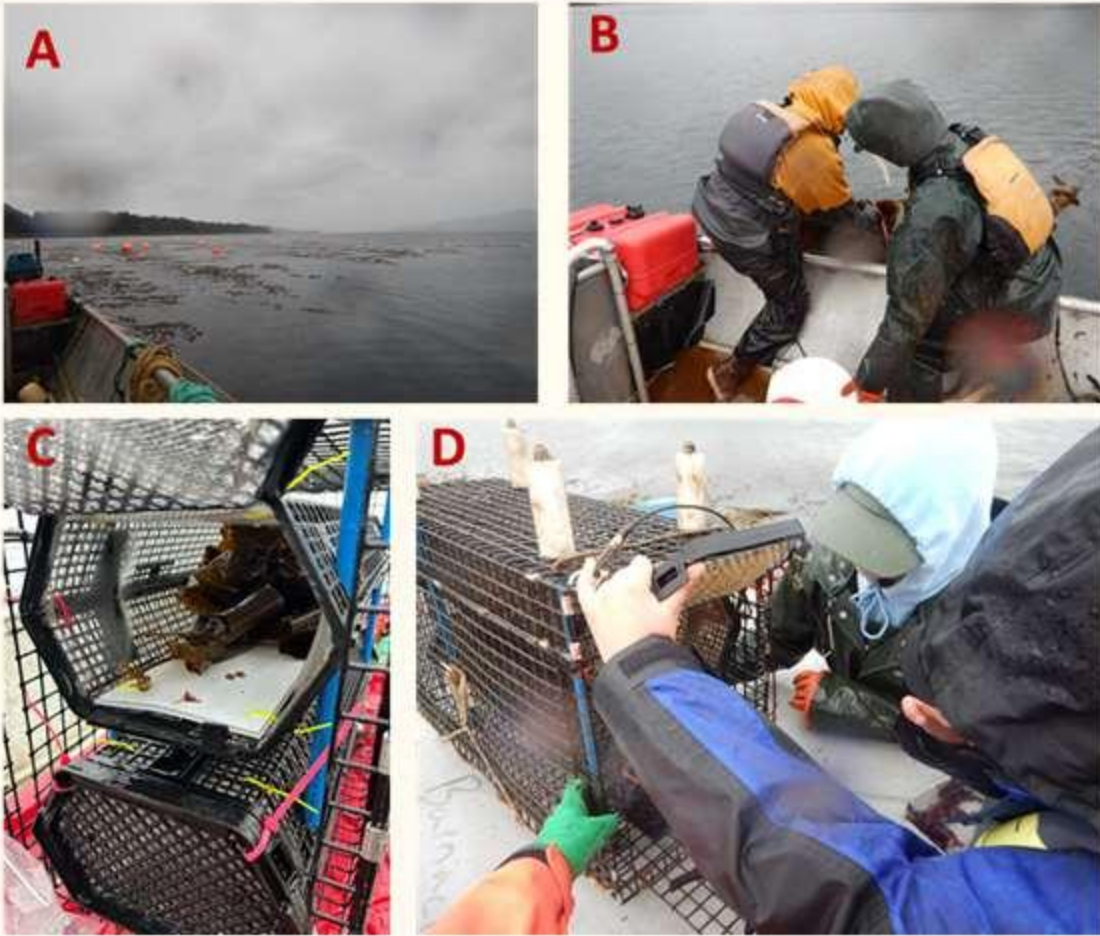


Figure 4. Operations at Sea Quester Farms site: A – farm site, B – deployment of the cages, C and D – inspection and feeding of abalone spat

Metlakatla Indian Community (MIC) Site

Annette Island is situated immediately north of Dixon Entrance on the east side of Clarence Strait at the southern end of the Inside Passage. Both waterways resulted from tectonic faulting followed by glacial carving during the Ice Age that excavated the deep marine channels seen today. The area is influenced mainly by oceanic water penetrating inland passage network through Dixon Entrance. In addition, coastal water from Hecate Strait contributes to the local oceanographic conditions especially during winter (Weingartner et al 2009). The MIC site (about 6 m bottom depth) was set up on the western shore of Annette Island in direct vicinity from Metlakatla small boat harbor and local wild groves of

bull (*Nereocystis luetkeana*) and giant (*Macrocystis pyrifera*) kelp. The location was shielded from easterly winds and the majority of inland water. The side was selected to examine the possibility of abalone farming in the southernmost Alaska where native communities of Metlakatla and Kake are particularly interested in establishing mariculture operations to provide themselves with traditional and sustainable food sources. Two experimental cages with 40 (10 per basket) juvenile abalone ~15 mm long were deployed at the site on July 10, 2025. Similarly, each cage was equipped with a temperature logger and the initial mix of fresh dulse seaweed (*Palmaria palmata*) (cultured in the UAF laboratory) to provide initial ad libitum food source for the abalone spat. The site was visited at least monthly (and bi-weekly weather permitting). During each visit, cages and spat were visually checked and counted, lengths of individual abalone were measured, and food was replaced with fresh kelp from the site (Fig. 5). The experiment was run for 295 days until May 5, 2026.

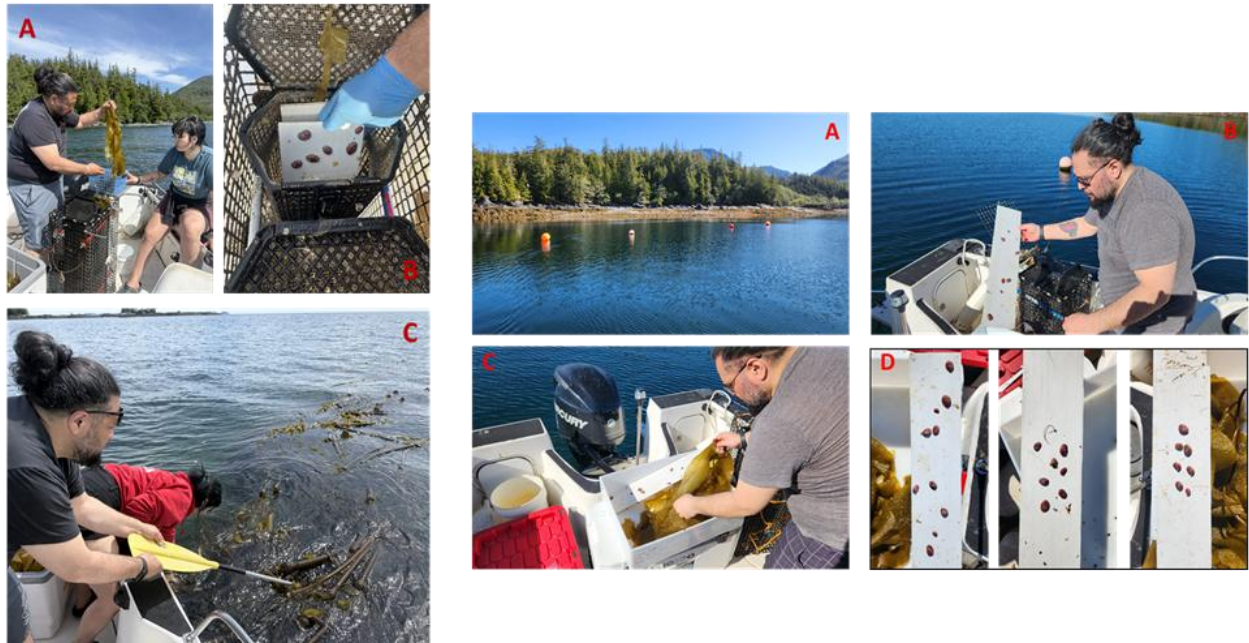


Figure 5. Operations at the MIC site: Left Panel (September 2025): A – choosing healthy kelp to feed abalone spat, B – abalone spat after ~30 days of exposure, C – harvesting wild kelp at the site; Right Panel (May 2026): A – site location; B and C – inspecting baskets in the cages; D – experimental abalone spat.

Results and Discussion:

Sea Quester Farm Site

Water temperature at the Sea Quester Farms site continually increased from ~6°C to ~12°C through the duration of the experiment (Fig. 6), indicating that most favorable conditions for abalone growth were set by the middle of June. Diurnal temperature fluctuations were relatively small rarely exceeding 2°C amplitude.

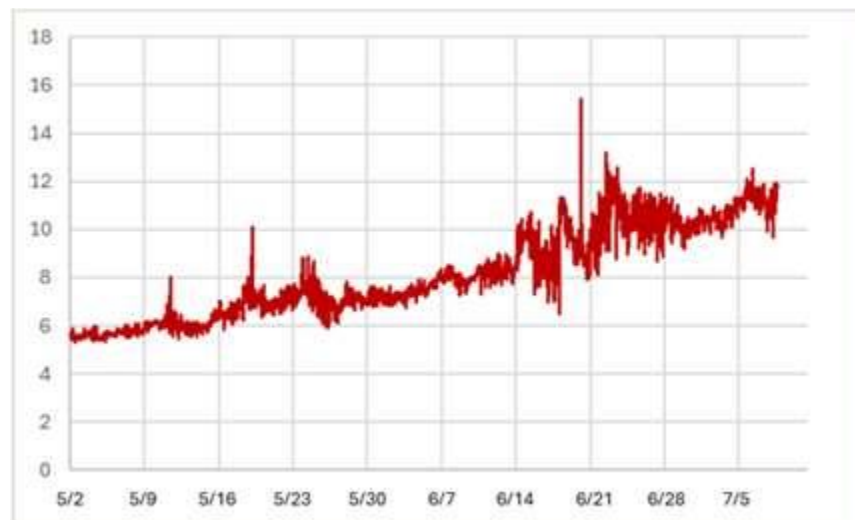


Figure 6. Water temperature (°C) at the Sea Quester Farm site

On July 8, 2025, a census accompanied with individual length measurement was done on all experimental animals. Intensive coverage of newly settled barnacles was observed on the cages and animals. In over 50% of the abalone, barnacles covered over half of the shell surface area blocking abalone respiration pores, so the animals suffocated (Fig. 7). Only 4 individuals were not affected by barnacle growth. While all the affected individuals were still alive, they barely moved and could not easily attach themselves to the surface. It was clear the future barnacle growth would not leave them any chances of survival. We decided to terminate the experiment at that point. For the period of 45 days starting on May 24, the abalone increased in length by 56% from the initial mean 10.95 ± 0.65 (95% CI) mm to the final 17.13 ± 1 (95% CI) mm length, which corresponds to $0.137 \text{ mm day}^{-1}$ at the average

temperature of ~9°C. Larger pinto abalone (40-50 mm of total length) experienced considerably lower increase in length of 8-10% over observation period of 65 days (Paul and Paul, 1981). This indicates that summer conditions for abalone spat growth in Lynn Canal are quite favorable, if the damage from barnacle settlement could be avoided.

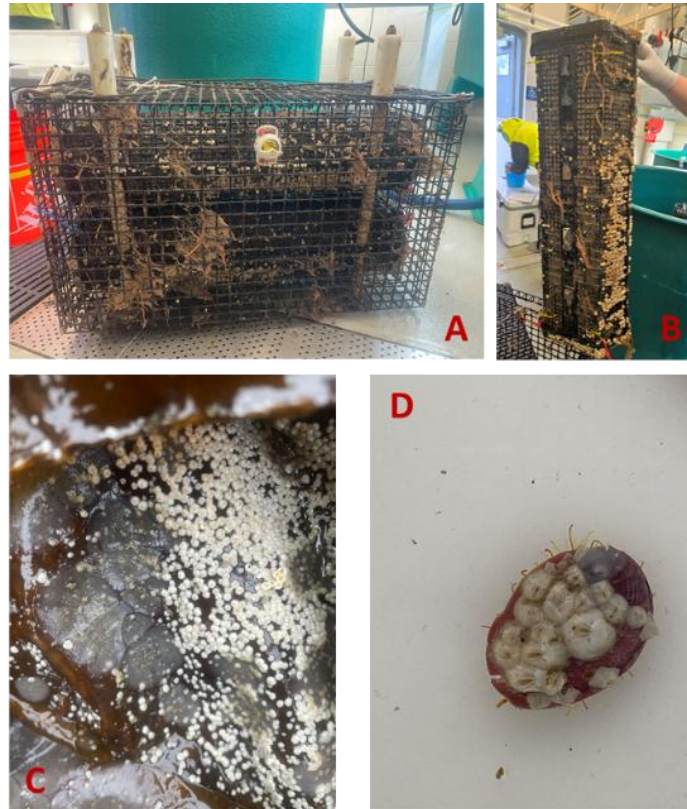


Figure 7. Barnacle colonization of the cages, kelp and abalone spat at the Sea Quester Farms site: A – Cage #1 after ~65 days exposure, B – individual basket after ~65 days exposure, C – kelp food, D - abalone shell.

Adult barnacles release their fertilized eggs into the water column where they hatch into free-swimming planktonic nauplii larvae. The nauplii feed on phytoplankton and protozoans as they undergo six consecutive molting increasing in size. After the final molt, the nauplii transform into a non-feeding cyprid larvae (Fig. 8). The cyprid larvae actively search for a suitable substrate (typically semi-submerged rocks or human infrastructure) to

settle often using chemical cues from previously settled barnacles to located a dense and safe colony. After attaching itself to the substrate it goes through a quick metamorphosis reshaping into a juvenile sedentary barnacle.

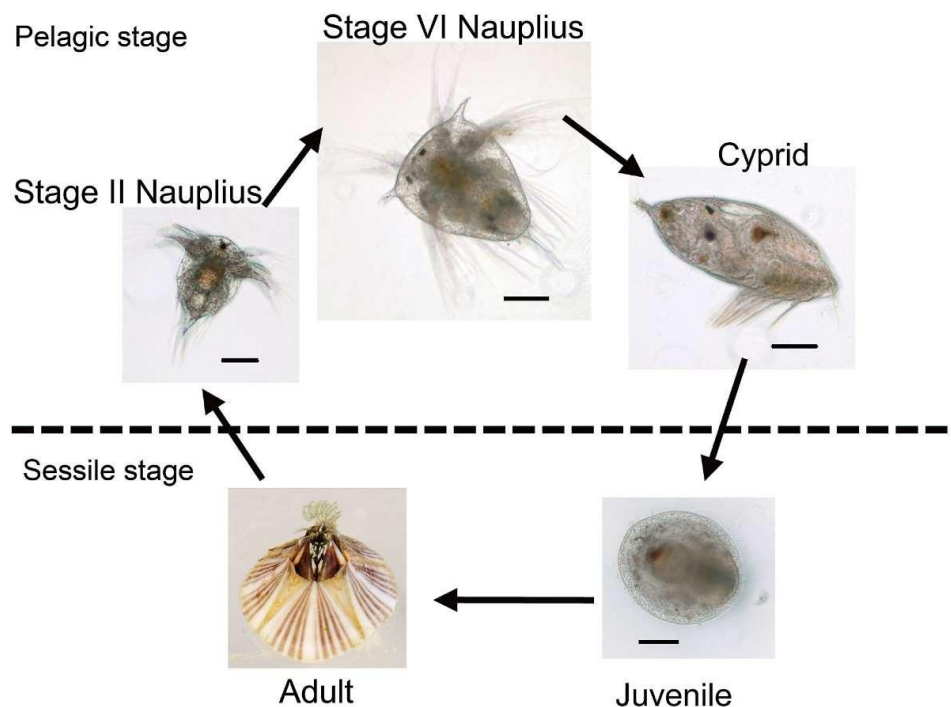


Figure 8. Barnacle life cycle (after Chen et al 2012): the cyprid is the settling stage of the barnacle.

Our oceanographic observations conducted in summer 2019-2021 indicate that a well-developed peak in barnacle planktonic larvae abundance consistently occurs in Lynn Canal fjords in late May and continues through late June (Fig. 9). The larvae take advantage of elevated temperatures and intensive spring phytoplankton bloom in the mixed layer of the upper water column which accelerate their development and metamorphosis. In addition, the narrowing Stephens Passage surrounded by rugged rocky coasts with numerous docks and pilings provide optimal conditions for mechanical accumulation of planktonic barnacle larvae in the area of our experimental site.

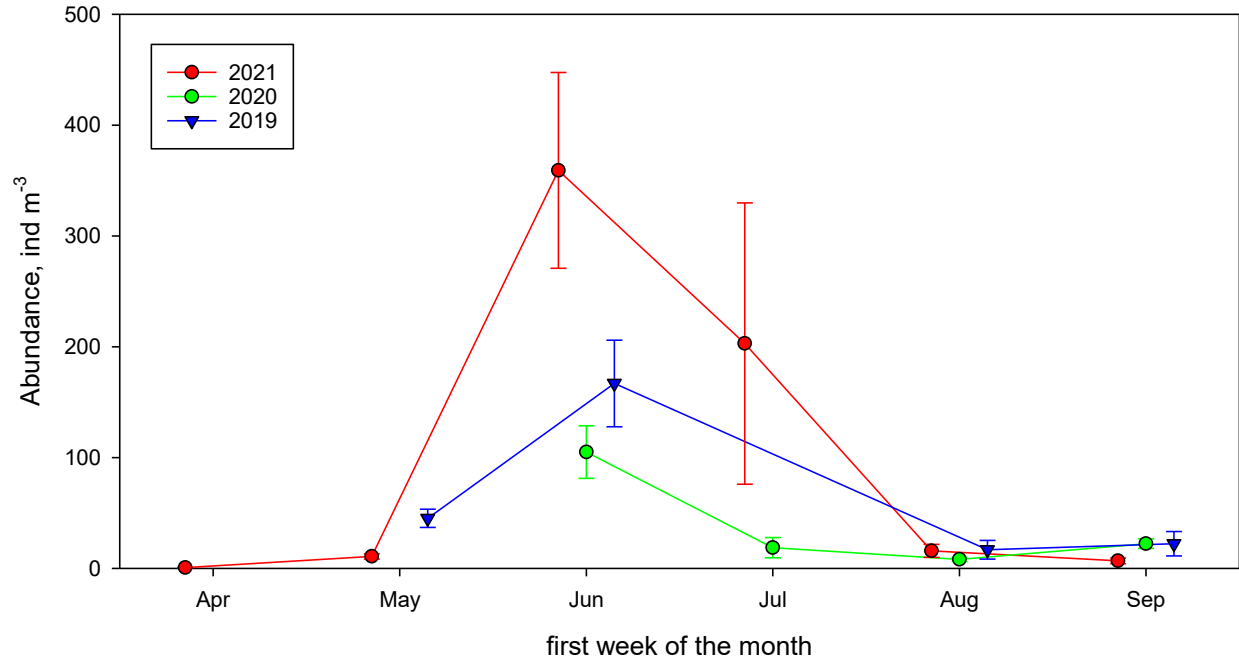


Figure 9. Interannual abundance of barnacle cyprid larvae in Lynn Canal fjords (Auke Bay, Gastineau Channel, Berners Bay combined) in 2019-2021 (vertical bars – 95% confidence intervals). Data from the EPSCOR Fire and Ice Project provided by A. Pinchuk and A. Knobloch (UAF).

While barnacles are typically commensal (e.g. harmless) to molluscs using their shells as substrate, in the case of abalone spat, they act similarly to true parasites causing damage because of the unique abalone anatomy. Despite otherwise favorable conditions, the detrimental effect of barnacle settlement on juvenile abalone shells would prevent the establishment of a self-supporting abalone population in inshore waters. This might explain why abalone natural range does not extend into the Inside Passage but spreads along the North Pacific coast (Fig. 10).



Figure 10. Distribution range of pinto abalone in Alaska and British Columbia (from Neuman et al., 2008).

Metlakatla Indian Community (MIC) Site

The abalone spat outplanted at the MIC site near Annette Island was observed for 295 days. The water temperature continually decreased from mean $13.5 \pm 0.03^\circ\text{C}$ in summer (July through September) to $7.9 \pm 0.02^\circ\text{C}$ in winter and spring (October through May) (Fig. 11), indicating that most favorable conditions for abalone growth occurred in the summer and early fall. In the summer, the site experienced substantial (5°C amplitude) fluctuations

in daily temperatures caused by diurnal insolation cycle. In contrast to the Sea Quester Farms site in Lynn Canal, the diurnal thermal amplitude at the MIC site was amplified by the shallower depth and substantial protection from wind mixing.

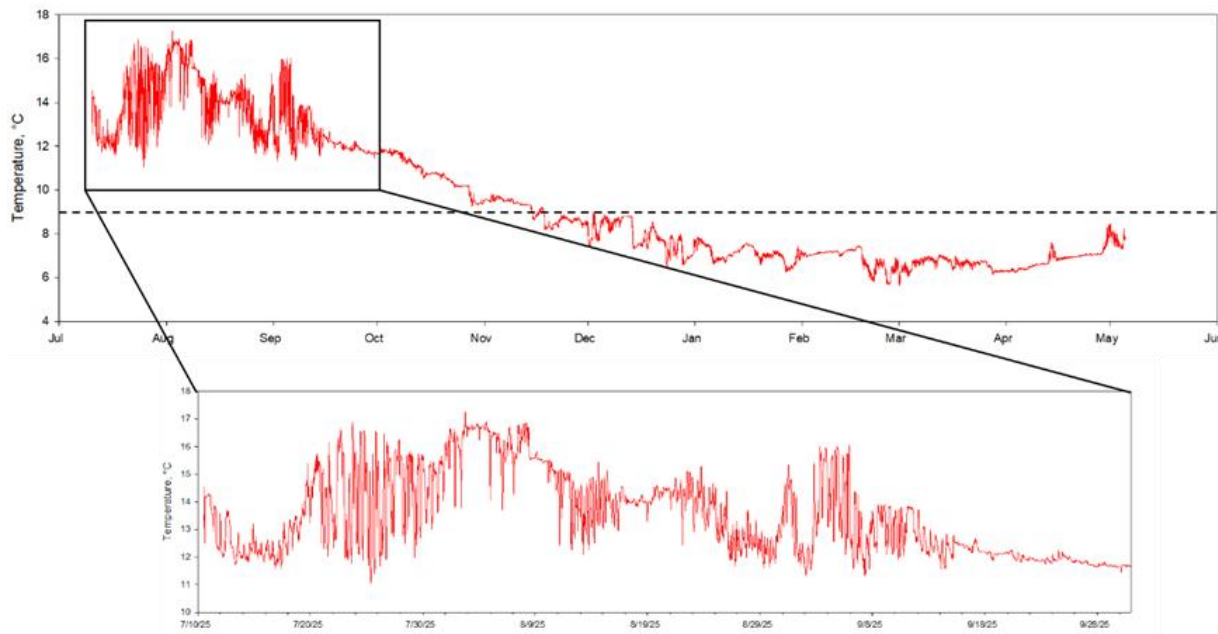


Figure 11. Water temperature (°C) at the MIC site during the entire period of observations (the upper graph). The reference line indicates the temperature below which pinto abalone growth dramatically slows down (according to Paul and Paul (1981)). The lower graph shows daily temperature fluctuations during summer.

The spat survival throughout the duration of the experiment was relatively high averaging 75% and ranging between 100% and 60% among the baskets. However, according to the site manager, most of the mortality was probably due to human operation errors, e.g. occasional crashing of abalone shells during measurements and missing them while inspecting and replacing old kelp thalli with fresh under inclement weather. In any case, all mortality ($n=10$) occurred from October 11, 2025 through January 3, 2026, during the period preceding the coldest and darkest time of the year, suggesting that winter conditions have little impact on abalone spat survival.

For the period of 295 days starting on July 10, the abalone increased in length by 63% from the initial mean 14.95 ± 0.47 (95% CI) mm to the final 24.43 ± 1.53 (95% CI) mm length, which corresponds to $0.032 \text{ mm day}^{-1}$ at the average temperature of $\sim 9^\circ\text{C}$. However, the growth pattern was highly seasonal with elevated rate of $\sim 0.056 \text{ mm d}^{-1}$ in July-September followed by retardation to $\sim 0.02 \text{ mm d}^{-1}$ in October-December. The growth almost completely stopped from January through March and picked up again in April to $\sim 0.04 \text{ mm d}^{-1}$ (Fig. 12). There was substantial individual variability in abalone growth marked by increasing 95% confidence intervals as the experiment progressed. At the end of observations, 13% of the abalone population were under 20 mm length, 10% were over 30 mm, and 77% fell within 20-30 mm range.

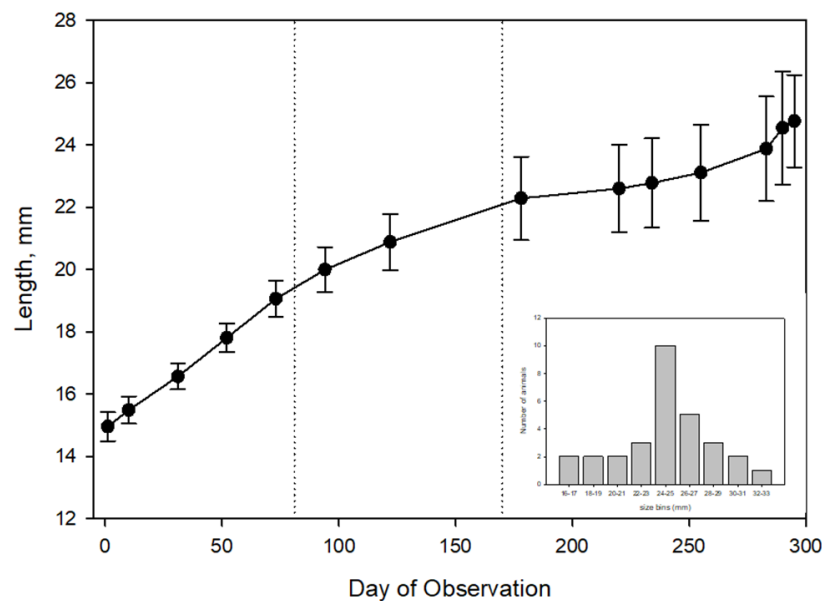


Figure 12. Growth in length of spat abalone at the MIC site during the period of observations starting on July 10, 2025 and ending on May 5, 2026 (vertical bars – 95% confidence intervals). Inserted plot shows length distribution of the experimental abalone population at the end of the experiment.

Abalone spat experienced relatively low mortality during winter time and demonstrated intense growth through late summer, fall and spring with little growth during mid-winter.

However, the initial growth was substantially slower than that of abalone outplanted at Sea Quester Farms site earlier in the summer. The observed growth retardation might have resulted from the large amplitude (between 14-16°C) of diurnal fluctuations in water temperature at the MCI site during summer. In contrast, the diurnal thermal variation Sea Quester Farms was typically within 1-2°C through the observation period. Temperature instabilities were detrimental for small (3-5 mm length) pinto abalone spat dramatically reducing their survival (Stapelton, 2023). While we did not record any mortality during summer, it is possible that growth rates were affected. Another reason might be the difference in diet. Abalone at the MIC site were fed primarily wild bull and giant kelp, while spat at the Sea Quester Farms site consumed commercially grown split kelp. Further studies are needed to evaluate nutritional benefits of these kelp species and their effect on pinto abalone spat growth and development.

Perspectives for harvesting

Abalone growth as a function of time can be modeled with a number of functions among which the von Bertalanffy model (VBGM) proves to be most useful (Rodgers-Bennet et al 2007). In the simplest form the model is written as $L_t = L_\infty (1 - e^{-k(t-t_0)})$ for length and $W_t = W_\infty (1 - e^{-k(t-t_0)})^b$ for weight increase, where L_t and W_t are individual length and weight at time t respectively, L_∞ and W_∞ are maximal individual length and weight that can be reached by an individual, $(t-t_0)$ is the time period, b is allometric constant from $W=aL^b$ relationship between weight and length, and k is the growth constant. In excess of food, the growth constant depends on temperature and is calculated by fitting to observed growth increments either graphically (Walford 1946) or using standard statistical procedures (e.g. Rodgers-Benner et al 2007). If temperature does not change during the duration of the experiment, k remains temperature-specific and can be applied only to populations exposed to the same temperature. Alternatively, if ambient temperature changes, k would incorporate the temperature fluctuations during the observation period and becomes applicable only to similar thermal environment.

Southeast Alaska nearshore is a highly seasonal environment with water temperatures staying below 8°C for the half of the year. Therefore, a modification of the traditional VBGM that allows for seasonal oscillations in length within each growth year needs to be used to describe and predict abalone growth. Among many proposed models, Somers' modification (Somers 1988) gained certain popularity in fisheries science. The model is expressed as the equation

$$L_t = L_\infty \left(1 - e^{-k(t-t_0) - S(t)+S(t_0)} \right)$$

with

$$S(t) = \frac{CK}{2\pi} \sin(2\pi(t - t_s)),$$

where L_t is the expected or average length at time (or age) t ; C modulates the amplitude of the growth oscillations and corresponds to the proportion of decrease in growth at the depth of the oscillation (i.e., "winter"); t_s is the time between time 0 and the start of the convex portion of the first sinusoidal growth oscillation, and L_∞ , k , and t_0 are as defined above.

In order to build a robust model and estimate the time required for abalone spat to reach harvestable size, we need additional multi-year observations. For now, we can make only very rough estimates based on the results from the first year of exposure, and on our knowledge of their biology. The average daily increase in length of captured abalone (started at 30 mm total length and kept at 13°C for 1080 days) measured over eight 90 days intervals was nearly constant averaging 0.053 mm d⁻¹ until they reached 80 mm in total length (Paul 1977). After that, the growth slowed down and only 5 mm in total length was gained for the following 360 days as the animals reached their maximal size. The former rate (0.053 mm d⁻¹) is comparable to our observations during the first three months of exposure (0.056 mm d⁻¹), when water temperature on average was similar to 13°C. This suggests that abalone growth is nearly constant until they reach near maximal size, providing stable optimal thermal conditions and ad libitum food supply.

Over the duration of our experiment (starting in mid-July), the abalone gained ~ 10 mm in total length (with "a pause" in the dead of winter). Assuming they maintain the same growth rates the following year, one might expect to see them gaining ~14 mm after additional 365 days of exposure starting in May. Thus, it should take about 56 months for spat abalone to grow from 14 mm to presumably harvestable size of ~70 mm. Harvesting them at 60 mm would reduce the exposure time by one year.

Another way to reduce ocean exposure would be rearing newly hatched spat under controlled conditions to a larger size (e.g. 30 mm). The 30 mm spat outplanted in the ocean would reach the harvestable size of 75 mm in about 36 months. The main advantage of rearing them in the hatchery is that they can be kept at constant elevated temperature (~13°C) all the time, so they reach 30 mm size much faster than in the outplanting cages. The disadvantages are the amount of resources (space, energy) and labor for maintenance in the lab. The need for better estimates of abalone growth parameters warrants future experimental and modeling studies.

Conclusions:

We confirmed that abalone spat of ~ 10 mm total length can be safely outplanted and reared in customized holding cages in Alaskan waters using locally produced or harvested kelp as food.

We found that large concentrations of ready-to-settle barnacle larvae directly threaten abalone farming in semi-closed coastal embayments such as sites within the Southeast Alaska Inside Passage. One way to counter this threat in the future would be to outplant abalone spat later in the season (July) after most of the planktonic barnacle larvae settled and disappeared from the water column. Alternatively, outplanting older animals with larger respiration pores might decrease detrimental effect of the barnacles on abalone growth.

In contrast, abalone spat performed well in a coastal environment directly influenced by oceanic water from the Gulf of Alaska, making seaside communities like Metlakatla and Kake excellent locations for pinto abalone farming.

Overall, the study emphasizes the importance of oceanographic settings and data when choosing potential farm sites and planning abalone farming operations.

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Appendix 1. Outreach Efforts:

- Members of the MIC were provided with printed and video materials on abalone culturing.

- Information about the project was submitted to Alaska Mariculture Research and Training Center web-site (<https://amrtc.org/>), as the most appropriate web resource for sharing the results.
- A presentation “***Investigating abalone farming in Southeast Alaska: comparison of spat development and survival from open-ocean growth systems in the Inside Passage and coastal Gulf of Alaska***” by A. Pinchuk, S. Umanzor, M. Montiel, K. Booth, J. Antoni and O. Duner was delivered at Alaska Mariculture Conference held in Anchorage on February 9-13, 2026.
- A scientific manuscript is in preparation for submission to an international mariculture journal.