

Noyo Harbor

Aquaculture Feasibility Study

As part of the Blue Economy Visioning, Resiliency and Implementation
(BEVRI) Plan

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Acknowledgements:

The Aquaculture Feasibility Study and Blue Economy planning initiative in Fort Bragg were made possible through the support and collaboration of individuals and organizations within the community and across California. We are grateful to all who contributed their time, knowledge, resources, and enthusiasm.

Jami Miller extends special thanks to her mentors—Sarah McCormick, Luke Gardner, Kevin Johnson, Laurie Richmond, and Laura Engeman—for their guidance and encouragement throughout her fellowship. She also thanks the teams at California Sea Grant and the City of Fort Bragg for their support, and the California Coastal Commission for funding the BEVRI Plan.

Field research in Noyo Harbor relied on the generosity of local partners. We thank Harbormaster Anna Neumann, Scott Hockett at Noyo Fish Company, and Jim Hurst at Silver's at the Wharf for providing locations to install water quality instrumentation. We also appreciate the technical support from In-Situ, LakeTech, and Aquatic Resources Management.

We are grateful to Grant Downie, North Coast commercial urchin diver; Noah Kolander at Moss Landing Marine Laboratories; and the team at Hog Island Oyster Co. for providing the urchin, abalone, and oysters used in this study. Special thanks to Tristin Anoush McHugh at The Nature Conservancy for her partnership on Blue Economy initiatives, guidance throughout the permitting process, and coordination in sourcing bull kelp. We also thank Scott Hamilton, Bennett Bugbee, and Laney Hall at Moss Landing Marine Laboratories for providing the sporophytes needed for this research.

Thank you to the Noyo Center—Sheila Semans, Katherina Audley, Lynne Sullivan, Trey Petrey, Sarah Grimes, Reesha Katcher, Richard Millis, Lauren Nutt, Crans Squire, Leah Shirley, Sara Sundberg, and Debra Jones—for their partnership and commitment to advancing marine science and education.

Community engagement was central to the BEVRI planning process. We thank the BEVRI Community Outreach Team—Domenick Weaver, Josh MacDonald, Peter McNamee, George Reinhardt, Patti Opatz, Kathleen O'Connell, and Q Norwood IV—and BEVRI interns Lydia Lapporte and Charles Bowen. Numerous organizations hosted events and shared their platforms, including the Noyo Ocean Collective, The GrassRoots Institute, Larry Spring Museum, Overtime Brewing, Tall Guy Brewing, Otsuchi Cultural Exchange Program, Point Cabrillo Light Keepers Association, Leadership Mendocino, Rotary Club of Fort Bragg, Coastal Mendocino Realtors Association, Healthy Mendocino Coastal Connections, Mendocino College, Fort Bragg Unified School District, Noyo Women for Fisheries, Noyo Food Forest, Salmon Restoration Association, KZYX, Mendocino Voice, and Word of Mouth Magazine.

Thank you to the educators and partners who participated in the Blue Economy Youth Leadership Pilot Program and opening night of North Coast KelpFest! 2025, including Mendocino High School, City of Fort Bragg, Noyo Harbor District, Noyo Center, Mendocino College, Primitives Biodesigns, The Nature Conservancy, California Ocean Protection Council, and Wild Blue Aquaculture. We are grateful to artist Deth Sun for his creative contributions and the First Friday galleries and businesses that celebrated kelp. Finally, we thank Tim Karas and Brianna Zuber at Mendocino College and the Pacific Coast Ocean Restoration (PCOR) network for their collaboration in building pathways into the Blue Economy.

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1. Background

The Mendocino Coast is a rural region overlooking the Pacific Ocean, characterized by rugged mountains, traversed with rivers, home to magnificent redwood and kelp forests, and the cultural and ancestral homelands of Indigenous communities, including the Northern Pomo, Coastal Pomo, Cahto, and Yuki Peoples. Beginning in the mid-19th century, the regional economy centered on logging and fishing. The Georgia-Pacific lumber mill was prominently located on the Fort Bragg headlands and occupied one third of city land, while Noyo Harbor thrived just south of town.

Over time, these natural resource industries declined. The mill site closed in 2002, and economically and culturally important fisheries, such as salmon and red abalone, followed suit. Currently, the City of Fort Bragg is home to nearly 7,000 residents and serves as the commercial center for surrounding communities along the Mendocino Coast. The City's need for an economic driver has led to a reliance on tourism. However, the compounding effects of climate related stressors (e.g., drought, fire, and kelp forest loss), demographic shifts, and the COVID-19 pandemic have further exposed both a vulnerable environment and fragile economy.

The City of Fort Bragg and Noyo Harbor District partnered with California Sea Grant to develop the Noyo Harbor Blue Economy Visioning, Resiliency, and Implementation (BEVRI) Plan. The BEVRI Plan provides an opportunity to gather technical baseline information about the current environmental, physical, economic, and social conditions of Noyo Harbor, as well as develop a shared community vision for coastal resiliency that balances environmental stewardship with economic vitality. Funding for the plan came from the California Coastal Commission, and findings will inform updates to both the City of Fort Bragg and County of Mendocino's Local Coastal Programs.

Noyo Harbor is located approximately 80 nautical miles north of Bodega Bay and 100 nautical miles south of Humboldt Bay – a refuge for seafarers on the North Coast of California. It's situated just south of the city limits at the mouth of Noyo River (see Figure 1). The working waterfront is an integral part of the local identity and heritage of Fort Bragg, and a valuable asset when considering future blue economy investment. In addition to supporting sustainable fisheries and existing livelihoods, the BEVRI Plan aims to identify opportunities for economic diversification that are compatible with current working waterfront activities. As part of the BEVRI Plan, the Aquaculture Feasibility Study recommends species, locations, and types of aquaculture operations that are environmentally, economically, and socially feasible for Noyo Harbor and the region.

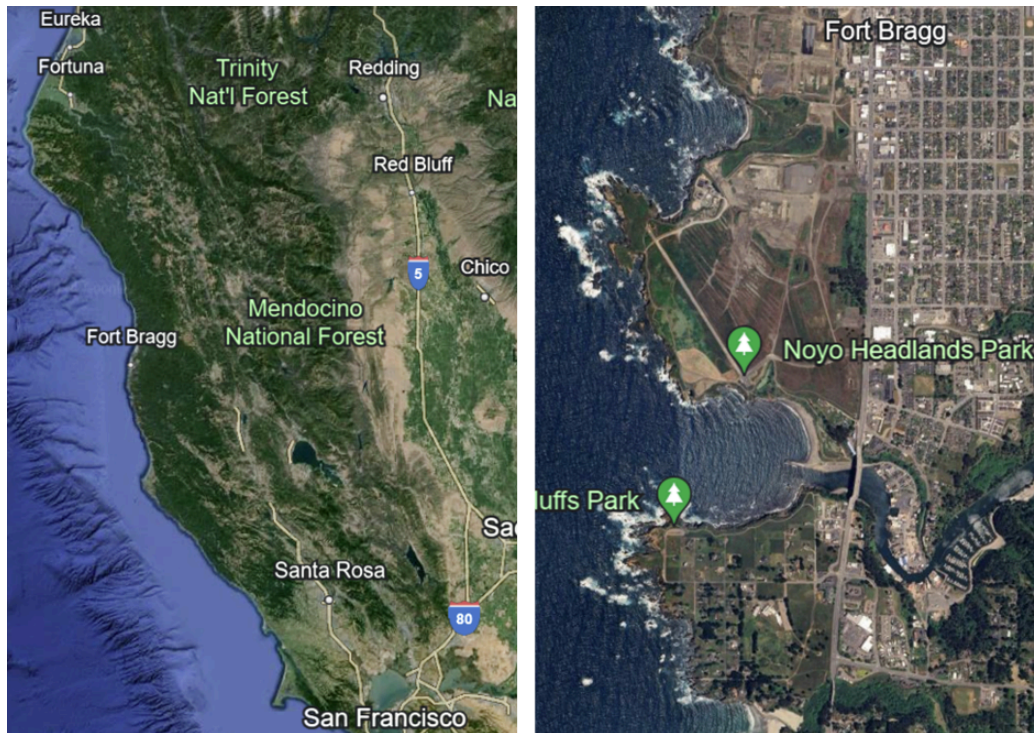


Figure 1: Google Maps images of the Mendocino Coast and the City of Fort Bragg and Noyo Harbor.

Left: Fort Bragg is located in Mendocino County on the North Coast of California, approximately a 2-and-a-half-hour drive northwest from Santa Rosa and 3 hours south of Eureka in Humboldt County. Right: Noyo Harbor and the old mill site on the Fort Bragg headlands (which occupies one third of city land and is no longer operational).

2. Project Overview

Since 2014, the 350 km expanse of the Sonoma-Mendocino coast has lost 96% of its kelp forests due to the compounded effects of warm ocean conditions and sea star wasting disease. Sunflower sea stars are the main predator of purple sea urchins in the region, and their decline has led to a boom in purple urchin populations. Purple urchins graze on kelp and are outcompeting other species, such as red abalone, for what little kelp remains. The result is an ecosystem shift from kelp forests to urchin barrens and the collapse and closure of culturally significant and economically important fisheries.

The Aquaculture Feasibility Study is a small-scale, proof-of-concept analysis to determine whether species of regional importance survive and grow in Noyo Harbor. The study includes a water quality analysis and considers future climate impacts on potential aquaculture operations. The specific objectives of the study are to: 1) locate appropriate sites and species for aquaculture operations in Noyo Harbor, for both in-water and land-based operations; 2) examine water quality for compatibility with species production; and 3) analyze the restorative and commercial opportunities of rearing these species in Noyo Harbor and the region.

The BEVRI planning team partnered with the Noyo Center for Marine Science (Noyo Center) to set-up and maintain water quality sensors and provide a robust analysis of aquaculture in the harbor. Data collection for the feasibility study is threefold. The BEVRI planning team led an in-water assessment of Pacific oysters, red abalone, purple sea urchins, and bull kelp; the Noyo Center incorporated findings from their land-based urchin ranch and dulse tumble culture; and a community survey was developed to gauge seafood consumption preferences and awareness and perceptions of aquaculture.

In-Water Operations

Fisheries closures have had a significant impact on the opportunities available to the working waterfronts of the North Coast. In light of these closures, there are emergent opportunities in aquaculture to create jobs, supplement incomes, produce local seafood products, and support restoration efforts. The species for this feasibility study were selected for either their cultural importance, economic value, or ecosystem restoration benefits – or a combination of the three.

Invertebrates

Pacific Oysters

Pacific oysters (*Crassostrea gigas*) are bivalve mollusks that inhabit sheltered intertidal and subtidal coastal waters. Native to Japan, Pacific oysters were introduced globally in the early twentieth century to restore depleted oyster stocks (FAO, 2009; Shatkin et al., 1997). They are now widespread in the eastern Pacific and are a major U.S. aquaculture product (Botta et al., 2020). They are highly efficient filter-feeders that feed on phytoplankton and remove excess nutrients from the water, improving coastal ecosystems. They are also fast-growing, generally reaching sexual maturity after one year (FAO, 2009; NIMPS, 2013). Reproduction occurs via temperature-dependent broadcast spawning, during warm summer months (>20 °C) (Troost, 2010). After fertilization, free-swimming larvae feed and grow for approximately 2 to 4 weeks before settling permanently on suitable substrates where they become juveniles, or spat (NIMPS, 2013). They are resilient and can survive through unfavorable conditions, such as large swings in temperature and salinity, by closing their shells. They often reach market size (2.5-4 in) within 18 to 30 months (FAO, 2009), although individuals can live up to 30 years and grow up to 15 inches in shell length (NIMPS, 2013). Pacific oysters are a high-value protein source and there are commercial opportunities for nursery stage operations in Noyo Harbor.

Red Abalone

Abalone are gastropod mollusks, sea snails, and red abalone (*Haliotis rufescens*) are the largest of California's seven abalone species. The shell is brick-red and has 3 to 4 open, raised respiratory pores along the left side. Beneath the shell is a broad, flat foot that allows the abalone to strongly attach to rocky substrate, an epipodium with sensory tentacles, and a mantle along the shell edge that supports shell growth. Red abalone can be found in rocky coastal waters, including tide pools and kelp forests. Individuals average 8 inches in shell length but can reach up to 12.3 inches and live for 35 to 50 years (Haaker et al., 1986). Growth largely depends on food availability, and abalone primarily graze on kelp

and attached macroalgae. They are slow-growing and late-maturing, generally maturing near 5 inches in shell length, though females may mature as small as 1.6 inches and males at 3.3 inches (around 3 to 7 years) (Giorgi & DeMartini, 1977). Abalone are broadcast spawners that require high adult densities for successful reproduction (Prince et al., 1987). In Northern California spawning typically occurs from April to July, coinciding with bull kelp availability.

Red abalone have historically been harvested for subsistence, and abalone diving represents a deeply-rooted cultural tradition, community identity, and longstanding driver of local economic activity on the North Coast. With the loss of kelp forests, came the collapse of wild abalone populations (Rogers-Bennett & Catton, 2019). The recreational red abalone fishery closed in 2018, and the ban was recently extended to 2036. There is opportunity to support recovery through aquaculture, and cultivate abalone for both restoration and food.

Purple Sea Urchins

Purple sea urchins (*Strongylocentrotus purpuratus*) are echinoderms native to the Pacific coast of North America, where they inhabit rocky intertidal and subtidal kelp beds to depths of about 160 meters (525 ft) (Parker, 2002). They have a radially symmetrical test covered by spines, pincers (pedicellariae), and tube feet; and an Aristotle's Lantern which is the mouth surrounded by toothlike plates located on the underside. Adult urchins feed on red, brown, and green algae and typically measure between 5 to 10 centimeters (2-4 in) in diameter and 4 centimeters (1.6 in) in height (Parker, 2002). They reach sexual maturity at about 2 years (25 mm) and commonly live to around 20 years. Purple sea urchins also reproduce via broadcast spawning, with peak spawning from January to March.

Purple sea urchin populations are out of balance – 60 times more abundant than normal. It might seem counterintuitive to cultivate a species whose populations are booming in the wild, but, with the limited kelp supply, these urchins are overabundant but starving. “Zombie urchins” refer to urchins that are alive but empty on the inside, with little to no roe. When there is no food in the environment, they slow down their metabolism, remain largely inactive, and all their energy goes into survival. They can live for years in this starved state. Their long lifespan, annual reproduction, and ability to survive prolonged periods of starvation make them a highly resilient species capable of outcompeting other species for resources, such as food and space. “Urchin ranching” refers to the process of removing ranch-able size urchins (>2in) from the sea floor and putting them in an aquaculture setting to fatten them up for consumption, creating market quality uni. Urchin ranching is a tool in purple urchin management, incentivizing grazer suppression activities, while developing food for consumers.



Figure 2: Invertebrates included in the feasibility study. Pacific oysters, red abalone, and purple sea urchins in 6mm mesh baskets fixed to pier pilings and floating docks in Noyo Harbor.

Bull Kelp

Bull kelp (*Nereocystis luetkeana*) are large, fast-growing brown algae that form dense canopies in rocky subtidal habitats with cold, nutrient-rich water – ranging from central California to the Aleutian Islands. Bull kelp forests provide critical habitat, food, and nursery grounds for diverse marine organisms while also attenuating wave energy and sequestering substantial amounts of carbon. They have a heteromorphic life cycle, alternating between a microscopic gametophyte stage and a macroscopic sporophyte stage. As an annual species, they complete their life cycle in one year. Sporophytes develop reproductive patches (sori) on their blades that release spores. Spores settle on the seafloor and develop into gametophytes that produce egg and sperm and, once fertilized, grow into new sporophytes. Individuals are made up of a holdfast; a long, stem-like stipe; a gas-filled, positively buoyant pneumatocyst; and blades that undergo photosynthesis. Growth and survival are strongly influenced by nutrient availability, temperature, light, wave exposure, and grazing pressure. Optimal sporophyte growth generally occurs between 10 to 14 °C (Supratya et al., 2020). Individuals can grow up to 25 centimeters (10 in) per day and reach 18 to 30 meters (60-100 ft) in a single season (Springer et al., 2010). Sporophytes develop in early spring and senesce in late summer to early fall.

Local state-supported kelp restoration efforts and campaigns are underway to protect and expand the remaining 4% of bull kelp forest habitat. In 2024, The Nature Conservancy and partner organizations launched [“Accelerating Bull Kelp Ecosystem Recovery in a Recently Deforested Location in Northern California By Using a Strategic Sequence of Restoration Techniques & Community Participation”](#) (ANCKR) with funding from the Ocean Protection Council and California Sea Grant. The ANCKR program aims to restore five acres of bull kelp forest at Big River in Mendocino County through interdisciplinary recovery techniques that demonstrate best practices and an integrated, science-based, and adaptive approach to restoration. Grazer suppression and kelp enhancement techniques are being tested, where urchins of all sizes are harvested by commercial divers and kelp is cultivated and outplanted.

There have been advances in sourcing materials and cultivation of bull kelp for restoration projects in the region and there is immense opportunity to collaborate to answer key knowledge gaps. Last year the ANCKR project closed the life cycle of bull kelp in a lab setting, meaning there is reliable culture of various life stages of kelp year-round for kelp enhancement activities (McHugh et al 2025). This is a major breakthrough considering in-water kelp enhancement practices rely on the availability of juvenile sporophytes which are spliced into lines, via Novel ARKEV modules (McHugh et al 2025). Yet, there is still a significant bottleneck, namely that bull kelp needs to be taken out of the area to be cultivated then brought back.

The Nature Conservancy (TNC) is currently working with Moss Landing Marine Laboratories (Moss Landing) to produce juvenile sporophytes via tumble culture tanks using Albion and Big River source material (McHugh et al 2025). Source material is collected in Mendocino County, taken to Moss Landing, cultivated, then brought back to Mendocino to be outplanted. To support these restoration efforts, there is a need to address if a region without saltwater intake can utilize Noyo River basin conditions to maintain outplanted bull kelp source material locally. Understanding the feasibility of growing outplanted bull kelp in Noyo Harbor will have aquaculture and restoration applications.

As a heavily impacted community, there is a shared vision of restored kelp forests and a thriving underwater ecosystem, and avenues to work together to tackle this collective crisis. With these major advances in kelp cultivation, the vision is to apply lessons learned from TNC and partner organization's previous and current research to provide a secondary source of local seed stock that will support the state's kelp outplanting initiatives and research congruent to the development of the Kelp Restoration and Management Plan (KRMP). The project team worked with The Nature Conservancy and colleagues at Moss Landing to carry out and guide this research.

Regenerative Aquaculture and Land-Based Recirculating Aquaculture System (RAS)

To evaluate the potential for regenerative aquaculture in Noyo Harbor, the Noyo Center for Marine Science designed and tested a land-based recirculating aquaculture system (RAS) at its Marine Field Station in Fort Bragg, California. With a mission to advance ocean conservation through education, exploration and experience, the Noyo Center strives to create a local blue economy. This project was supported through congressionally directed funding secured by Congressman Jared Huffman and administered through NOAA's National Ocean Service and the National Centers for Coastal Ocean Science. Funding was awarded in November 2023.

This system represents the first land-based aquaculture facility in Noyo Harbor dedicated to regenerative and restoration-focused applications. By integrating sustainable seafood production with ecosystem recovery, the project supports kelp forest restoration, strengthens environmental and economic resilience, creates local employment opportunities, and provides hands-on STEM education. Education and community engagement are core components. The Noyo Center delivers public science presentations, K–12 programs, facility tours, and engages in partnerships with Tribal communities; the red abalone captive breeding program is being developed in collaboration with the Kashia Band of Pomo Indians.

The RAS is housed in a 40-foot insulated shipping container and includes an additional five outdoor tanks. The system was intentionally designed as a low-cost, modular, and replicable platform. Land-based recirculation enables year-round production while allowing precise control over water quality, temperature, and environmental conditions. This control improves organism health, survivorship, and growth while enhancing biosecurity by reducing exposure to predators, parasites, and pathogens. The system also evaluates the feasibility of using estuarine water from the Noyo River as an alternative to direct ocean intake, providing a practical model for sites without immediate ocean access.

System performance is evaluated through a three-phase framework. Phase I (November 2023–present) focused on system design, permitting, construction, and initial operational testing to confirm feasibility for purple sea urchin ranching and Pacific dulse cultivation. Phase II (April–July 2025, in progress) evaluated system performance through stocking density trials, survivorship monitoring, and controlled feeding experiments designed to optimize gonad development and operational efficiency. Phase III (starting Spring 2026) applies these findings to restoration-oriented applications, including bull kelp cultivation and red abalone captive breeding. In collaboration with scientific partners and Tribal leadership, the facility will support broodstock conditioning, spawning, larval rearing, and kelp cultivation to support restoration and recovery efforts.

Purple Sea Urchin Ranching

Initial system testing focused on purple sea urchins (*Strongylocentrotus purpuratus*) to evaluate the feasibility of regenerative urchin ranching. Population increases in purple sea urchins over the past decade have contributed to widespread kelp forest loss along the west coast of North America. In barren habitats, urchins often exhibit poor nutritional condition and low commercial value. Targeted removal of these urchins, coupled with gonad enhancement through aquaculture, presents an opportunity to convert an overabundant grazer into a marketable seafood product while simultaneously supporting kelp forest restoration efforts (Williams et al., 2021). Our pilot project has shown that through aquaculture-based conditioning, undernourished urchin can recover gonad development and become a viable seafood product within 12-weeks.

Regenerative aquaculture supports a blue economy by removing overabundant grazers from degraded ecosystems while creating economic opportunities for coastal communities. Historically, Noyo Harbor supported a productive red sea urchin fishery, which declined following kelp forest collapse linked to marine heatwaves, sea star wasting disease, and purple urchin population expansion (Rogers-Bennett & Catton, 2019). Regenerative purple sea urchin ranching provides a pathway to diversify local fisheries, support economic recovery, and contribute to ecosystem restoration. Testing the system with this overabundant urchin helps us further understand how to use aquaculture as a restoration tool for the rearing of endangered and vulnerable species such as bull kelp, abalone, and sunflower sea stars.

Feed Trial and Nutritional Conditioning

A primary operational challenge for urchin ranching is identifying an efficient, low-cost, and sustainable feed that meets nutritional requirements while maximizing roe quality within commercially viable timeframes (Onomu et al., 2020). During the initial phase of the urchin ranch, specially formulated pellet feeds supplied by Urchinomics and The Nature Conservancy were evaluated but showed limited efficacy.

Pellets were frequently rejected by urchins and rapidly disintegrated, contributing to increased bacterial growth and organic waste accumulation that degraded water quality. Although multiple pellet formulations exist, no standardized diet has demonstrated consistent performance for purple urchin feed. In response, the Noyo Center investigated macroalgal tumble culture of Pacific dulse (*Palmaria mollis*) as an alternative feed source; however, permitting requirements and increased maintenance limited its practicality at scale.

A 14-week feeding trial evaluated agricultural produce as a sustainable and cost-effective alternative to conventional feed pellets. Approximately 700 urchins were collected from local barren habitats and assigned to feed treatments consisting of kale, purple cabbage, spinach, or Pacific dulse (control). Leafy greens and cabbage are widely available, economically scalable, and nutritionally dense, providing elevated levels of protein, essential vitamins, minerals, and carotenoid pigments. Carotenoids are known to enhance gonad coloration and potentially improve sweetness while reducing bitterness, which are important determinants of marketable uni (Robinson et al., 2002; Shpigel et al. 2006). The gonadosomatic index (GSI) was used to measure gonad growth and assess marketability.

All feed treatments supported gonad recovery, with kale and purple cabbage producing the most consistent improvements and achieving or approaching marketability thresholds. Spinach produced moderate but lower gains, while dulse showed variable performance. While these findings demonstrate that widely available agricultural produce can serve as a practical and scalable feed source for regenerative aquaculture, it should be noted that the timeframe to reach marketable gonad development is longer than with nutritionally dense pellets. Partners continue to refine pellets designed for purple urchin ranching, and early results show gonad development in 8-10 weeks. It is likely that a combination of pellets and dulse or agricultural products will yield the best color and flavor profile within an economically viable timeframe.

Dulse

The system also evaluated co-cultivation of Pacific dulse (*Palmaria mollis*) with purple sea urchins as an Integrated Multi-Trophic Aquaculture (IMTA). IMTA configuration links waste remediation with biomass production, enhancing overall system efficiency and sustainability. Pacific dulse was selected due to its suitability for land-based cultivation, rapid growth rates, and value as a sustainable, high-protein feed source for herbivorous invertebrates. Dulse functions as both a feed and biological filter by assimilating dissolved inorganic nitrogen (ammonia and nitrite) and carbon dioxide, thereby improving water quality, reducing waste accumulation, and stabilizing pH (Rosen et al. 2000). While initial performance was variable due to fouling and environmental stress, system modifications improved dulse health and stability. Further research will refine IMTA integration to improve efficiency and productivity.

While this study did not evaluate the production of Pacific dulse for human consumption, this seaweed is highly regarded for its flavor and nutritional value and may represent a viable, sustainable product for human consumption as well.

3. Methods

In-Water Operations

Water Quality Instrumentation

The Aquaculture Feasibility Study examines water quality for compatibility with species health and performance. In all, there were five sensors in four locations in the harbor, ranging from the mouth of the river to the mooring basin (see Figure 3). The four locations were intentionally selected with aquaculture in mind, including potential areas for Floating Upwelling Systems (FLUPSYs) or saltwater intake. Animals went into the water at two of these four sites, the Noyo Center Marine Field Station and Silver's at The Wharf.

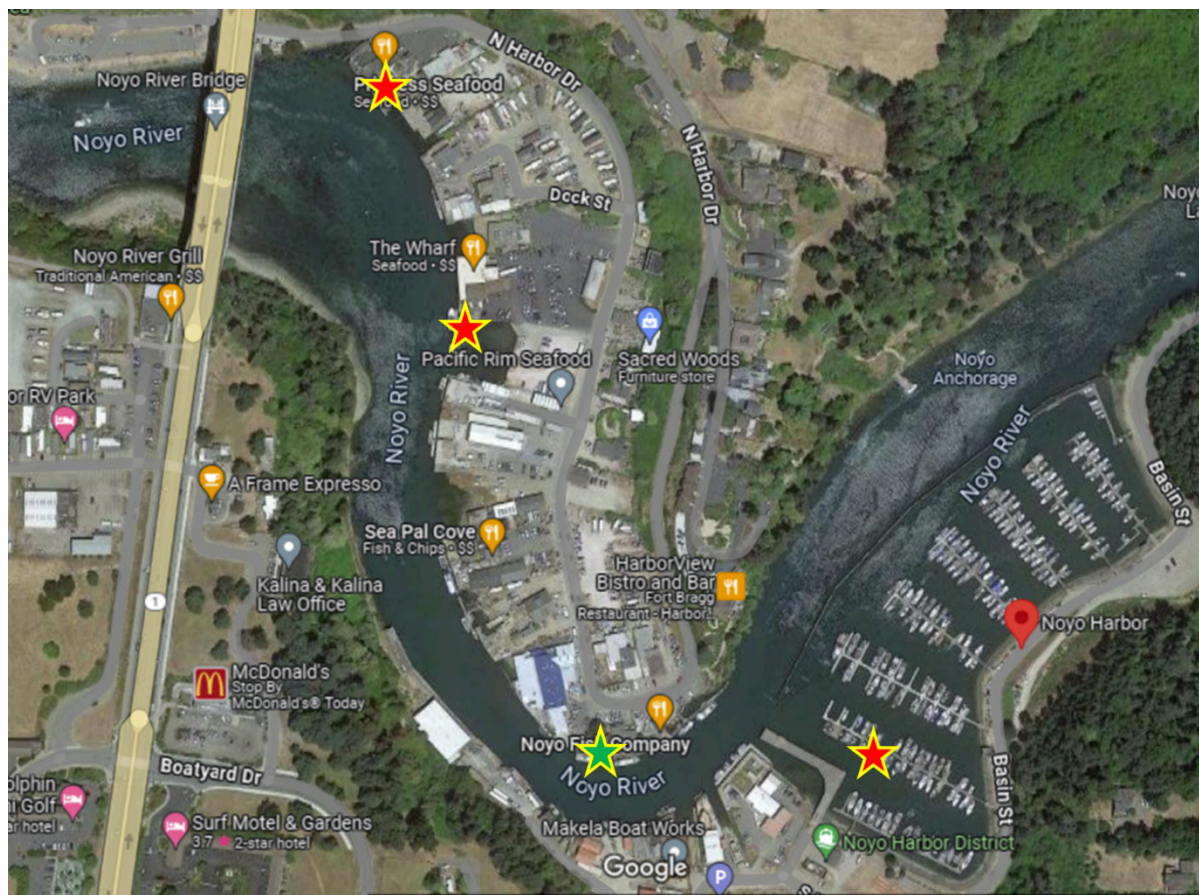


Figure 3: Map of water quality sensors in Noyo Harbor. The stars indicate the locations of water quality sensors in the harbor. The green star is the Noyo Center Marine Field Station, where there is a surface and bottom sensor.

At three of the four locations, the team installed AquaTroll 500 Multiparameter Sondes, manufactured by In-Situ. These locations are indicated with red stars on the map above. All three sensors were fixed

two feet above the seafloor and measured water temperature, conductivity, and dissolved oxygen. All bottom sensors measured the same parameters, to compare water quality throughout the entire harbor. The BEVRI planning team and Noyo Center managed this equipment, which provided an opportunity for the team and community to learn about the process of selecting equipment, installation, maintenance, and data collection, storage, and visualization through hands-on experience. These three sensors were installed in March 2024 and are still in the water.

At the Noyo Center Marine Field Station, LakeTech and Aquatic Resources Management monitored and serviced two AquaTroll 500 Multiparameter Sondes, the same equipment used at the other locations. The Field Station is located at the green star on the map above. This was the site with the majority of animals in the water, so it was important to ensure data reliability and consistency. One sensor floated at the surface and a second sensor was fixed two feet above the seafloor (see Figure 4). The top sensor measured water temperature, conductivity, dissolved oxygen, pH, and chlorophyll-a. The bottom sensor measured water temperature, conductivity, and dissolved oxygen. This set up allowed for a comparison of these environmental parameters at different depths. The sensors provided by LakeTech collected data from February 2024 to October 2025.



Figure 4: Set-up of water quality instrumentation at the Noyo Center Marine Field Station. Left: Perforated PVC pipe containing battery for telemetry system at the top and bottom sensor fixed two feet from the seafloor. Top Right: AquaTroll 500 Multiparameter Sondes with battery, manufactured by In-Situ. Bottom Right: Surface sensor hanging from floating dock.

All sensors collected real-time data every hour that was uploaded to LakeTech's public portal every four hours via telemetry software. The water quality data was publicly available on the project website, <https://noyooceancollective.org/aquaculture-feasibility/>, and directly at the following link: <https://www.my.laketechn.com/public-portal/NoyoHarborWaterQuality/>. The public portal served as a tool for community members to interact with the data for their own interests or research needs. The contract with LakeTech ended in October 2025, but a community member involved with this project is currently developing his own platform to share water quality data with the public (please visit the project website for updates).

Invertebrates

In December 2024, the Scientific Collecting Permit (S-202860001-24109-001) was approved to monitor the health, survival, and growth of Pacific oysters (*Crassostrea gigas*), red abalone (*Haliotis rufescens*), and purple sea urchin (*Strongylocentrotus purpuratus*) in an in-water setting in Noyo Harbor. All invertebrates were grown in 6mm mesh baskets deployed off the side of pier pilings or floating docks at two locations in the harbor. At the Noyo Center Marine Field Station, there were three baskets, one basket with each species, and at Silver's at The Wharf there was one basket of oysters. Data collection took place from January 2025 to January 2026.

Pacific oyster seed, approximately 20 mm in length, was sourced from Hog Island Oyster Co. in Humboldt Bay. During the 12-month data collection period, two trials were conducted, starting in January and August 2025. Oysters were divided into two baskets, and 40 oysters from each basket were tagged. All oysters were monitored weekly for health and survival. Health was assessed through observation, by looking for signs of disease and high mortality, and survival was monitored by recording mortality rates. The tagged oysters were measured for growth each month. Calipers were used to measure shell length and a scale was used to measure whole weight. The difference between the two trials was the time of year the oysters went into the water and the depth of the baskets. The baskets for the first trial were fixed to a pier piling and lowered two feet above the sea floor, and the baskets for the second trial were attached to a floating dock and submerged one foot below the surface.

Red abalone were sourced from Monterey Bay Seaweeds and tested for diseases in accordance with California Department of Fish and Wildlife (CDFW) regulation. At Moss Landing Marine Laboratories, the abalone were treated for withering syndrome (*CaXc*) with Oxytetracycline for 21 days and tested at 81 days; and, at Bodega Marine Laboratory, they were visually inspected for sabellids before arriving in Fort Bragg. Two trials were conducted, starting in January and May 2025. In both instances, the abalone were used to a water temperature of 55°F and salinity of 35 ppt and shipped in an oxygenated bag on top of seawater-soaked foam. To acclimate the abalone, water from the harbor was added to the bag for about 15 minutes. The abalone were then tagged, measured, and transferred to the basket. The basket was outfitted with additional plastic sheeting on the inside to increase the surface area for them to attach to. The abalone were fed dried dulse from Moss Landing and measured for growth (shell length and whole weight) each month.

Purple sea urchins were sourced from a local commercial urchin diver. Similar to the abalone, two trials were conducted, starting in January and May 2025. The urchins were removed from the ocean, put in a 6mm mesh basket, fed dried dulse from Moss Landing, and measured for growth each month. Growth

measurements included test length (diameter), test height, and whole weight. At the end of the study, the urchins were dissected to measure their Gonadosomatic Index (GSI) and readiness for consumption. GSI calculates what percentage of total body weight is made up of gonad weight, using the formula: $GSI = (\text{Gonad Weight} / \text{Total Body Weight}) \times 100$.

Bull Kelp

There is a need to address whether a region without saltwater intake can utilize Noyo River basin conditions to maintain outplanted bull kelp source material locally. In August 2025, an amendment to the SCP (S-202860001-24109-001-01) was approved to monitor the health, survival, and growth of bull kelp (*Nereocystis luetkeana*) in an in-water setting in Noyo Harbor. Using source material from Moss Landing that was already in culture, bull kelp survivorship and growth was tested on one, 12-foot long-line at the Noyo Center Marine Field Station (see Figure 5).

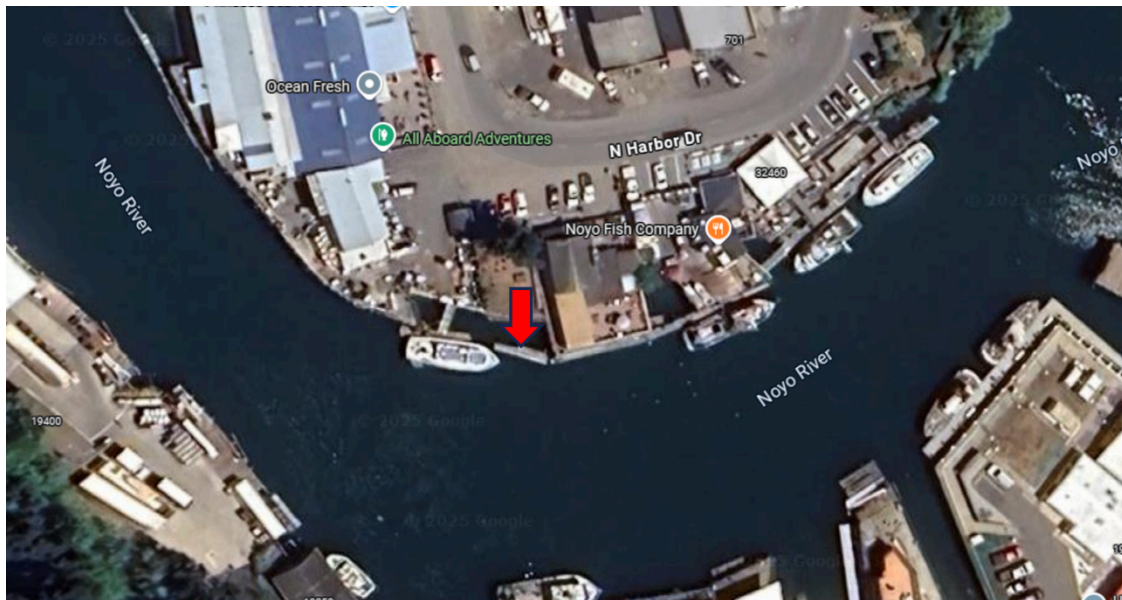


Figure 5: Bull Kelp long-line location in Noyo Harbor. The 12-foot long-line was deployed off a floating dock at the Noyo Center Marine Field Station.

From late August to October 2025, three trials were conducted. Juvenile sporophytes were received from Moss Landing, spliced onto the 12-foot culture line, and placed in the water. For trial 1, the line was attached to a floating dock 2 feet below the surface. For trial 2, the line was lowered to 4 feet, and, for trial 3, the line was fixed at the bottom between two pier pilings. Bull kelp was monitored frequently for health and survival and total length was measured twice per week. The line was also inspected for reproductive development, presence of non-permitted species, and unintended entanglements.



Figure 6: Bull kelp set-up and deployment. Juvenile sporophytes and line were received from Moss Landing. Kelp was spliced onto the line and deployed off the floating dock. The bottom photo shows deployment for Trial 1 (2 feet below the surface).

Land-Based RAS

The recirculating aquaculture system (RAS) was designed as a closed-loop seawater system housed within a 40-foot insulated shipping container at the Noyo Center Marine Field Station (see Figure 7). The container was equipped with an air conditioning unit to maintain ambient air temperature at or below 16 °C (61 °F), and energy-efficient LED lighting provided consistent illumination for routine maintenance and monitoring.

The system consisted of six fiberglass raceway troughs (100 × 28 × 12 inches), each holding two rectangular mesh baskets (36 × 22 × 11 inches) used to contain sea urchins. Filtered water was delivered from a central sump to each trough. Water exited through standpipes and returned to the sump after passing through filtration components. Directional water flow and aeration were provided by airlift bubblers, which improved circulation, oxygenation, and waste suspension.

Five approximately 300-gallon cylindrical tumble culture tanks were located outdoors adjacent to the shipping container. Each tank was equipped with a bottom aeration ring that generated an upward central flow and downward peripheral return flow, creating continuous circulation suitable for macroalgal culture.

Source water was pumped from the Noyo River estuary during peak high tide to maximize salinity stability. Salinity was measured and adjusted to 35 ppt as necessary using commercial sea salt (Instant Ocean). Water quality parameters—including temperature, salinity, dissolved oxygen, pH, ammonia, nitrite, and nitrate—were routinely monitored to maintain conditions suitable for urchin health and growth. Partial water exchanges of approximately 20% were conducted as needed to maintain water quality and reduce the accumulation of nitrogenous waste.

Total system volume was approximately 2,500 gallons. Effluent water passed through mechanical filtration media, activated carbon, and ultraviolet sterilization prior to recirculation. A fluidized biofilter containing nitrifying bacteria facilitated biological filtration and nitrogen conversion. A seawater chiller maintained the system temperature at approximately 13 °C (56 °F). System aeration was supported by a 2.5-horsepower air blower.

Waste removal was conducted using a custom vacuum system constructed from a modified filter housing and pump assembly, allowing removal of settled organic material while returning filtered water to the sump. Routine maintenance included weekly deep cleaning and interim spot cleaning using siphons or manual removal to prevent waste accumulation. Discharged water was directed to the municipal wastewater treatment system to prevent the release of cultured organisms or elevated nutrients into the estuary.



Figure 7: Recirculating aquaculture system (RAS) at the Noyo Center Field Station. Top: Interior view of the RAS showing raceway tanks arranged on a rack system with mesh culture baskets. Bottom: Exterior view of the system, including tumble culture tanks connected to the RAS infrastructure.

Purple Sea Urchin Feed Trial

A 14-week feed trial was conducted from April through July 2025 to evaluate the effectiveness of agricultural produce as a low-cost and accessible alternative feed for conditioning purple sea urchins (*Strongylocentrotus purpuratus*). The primary objectives were to assess survivorship, gonad development, and the feasibility of using widely available feeds to support commercial conditioning.

Approximately 700 purple sea urchins (≥ 5 cm test diameter) were collected from an intertidal barren habitat at Mendocino Headlands State Park. Prior to the experiment, urchins underwent a 10-day starvation period to standardize nutritional condition.

Urchins were randomly assigned to four dietary treatments:

- Kale
- Purple cabbage
- Spinach
- Pacific dulse (*Palmaria mollis*) (control)

Each treatment consisted of six replicate baskets, with 29 urchins per replicate. Pacific dulse was selected as the control because it represents a natural macroalgal component of the species' wild diet.

Baseline measurements were collected at the start of the experiment. One individual per replicate was sacrificed to measure test diameter, test height, wet body weight, and wet gonad weight. These values were used to calculate the gonadosomatic index (GSI):

$$\text{GSI} = (\text{gonad weight} \div \text{total body weight}) \times 100$$

Urchins were fed ad libitum throughout the experiment. Feed was weighed prior to introduction to quantify consumption. Every two weeks, one individual per replicate was sampled to measure growth and gonad development. Qualitative assessments of gonad color, texture, and firmness were also recorded as indicators of product quality.

Mortality was monitored throughout the trial, and deceased individuals were removed and not replaced. Survivorship was calculated as:

$$\text{Survival (\%)} = (\text{final number of individuals} \div \text{initial number stocked}) \times 100$$

Data was compiled and analyzed using Microsoft Excel. Mean GSI and standard error were calculated for each treatment over time. Scatterplots were generated to visualize changes in gonad development across dietary treatments. To make inferential conclusions about treatment effects, further data analysis is needed.

Dulse Tumble Culture

Pacific dulse (*Palmaria mollis*) was cultured in outdoor tumble tanks to evaluate integrated multi-trophic aquaculture (IMTA) performance and assess its potential as both a feed source and biofilter.

Dulse stock was obtained from Moss Landing Marine Laboratories, Monterey Bay Seafoods. Adult sporophytes were maintained in two 300-gallon tumble tanks designed to keep algal biomass in suspension. Aeration rings produced continuous rolling circulation, improving nutrient exchange and reducing fouling.

Tanks were maintained under natural light and covered with shade cloth and roofing panels to reduce excessive light exposure. Untreated effluent from urchin culture tanks was delivered directly to dulse tanks without supplemental nutrients to evaluate the feasibility of waste-driven algal production. Dulse biomass was harvested and weighed weekly to assess growth. Biomass was rinsed in freshwater prior to reintroduction to reduce fouling organisms and amphipods.

Community Survey

Survey Design

The survey consisted of 16 questions and took an estimated 6 minutes to complete. The introduction page included a few sentences on the BEVRI Plan, a one sentence explanation of what the survey is hoping to gauge, the estimated time to complete the survey, and an anonymity statement. We also included the following definition of “aquaculture,” so all respondents were starting with the same base knowledge of the term:

“The National Oceanic and Atmospheric Administration defines aquaculture as ‘the breeding, rearing, and harvesting of fish, shellfish, algae, and other organisms in all types of water environments.’ Aquaculture ranges from marine to freshwater species, in water to land-based operations, and hatchery to grow-out stages. It also varies in the type of infrastructure used, scale, and purpose. This study focuses on marine shellfish and algae, specifically: Pacific oysters, red abalone, purple sea urchin, bull kelp, and dulse seaweed. These species were selected for their commercial value, ecosystem restoration potential, and local importance.”

The survey began with two demographics questions and then split into three main sections: seafood consumption preferences, awareness and perceptions of aquaculture, and willingness to pay. Respondents were asked if they produce or consume seafood. Depending on the response, the survey took them to different sections. If they produce seafood, they were asked whether they have experience with aquaculture. If they consume seafood, the survey jumped to a series of questions on their seafood consumption preferences (e.g., how often they eat seafood, which types they prefer, etc.). The next section asked respondents how familiar they are with aquaculture, if they’ve ever purchased farm-raised seafood, whether they would support local shellfish and seaweed aquaculture production, what aspects of the industry they’d like to learn more about, and whether they have any concerns. To end the survey, they were asked how much they would be willing to pay for locally grown shellfish.

Survey Distribution

The survey was created using SurveyMonkey, and made available in digital and paper formats, in both English and Spanish. It was released for one year, from July 2024 to July 2025. Links to the digital survey were shared through the project’s website and social media accounts and through community listservs, such as the Noyo Center for Marine Science and Healthy Mendocino Coastal Connections networks. We created table tents with QR codes for the survey page of the website and displayed them at City Hall, Noyo Center locations, Mendocino College Coast Center, Mendocino Coast Botanical Gardens, and local hotels and lodgings. We also distributed postcards with QR codes to the website and had paper copies of the surveys available at tabling and community outreach events. At two community movie nights, we provided free popcorn in exchange for survey responses.

4. Results

In-Water Operations

Pacific Oysters

Trial 1

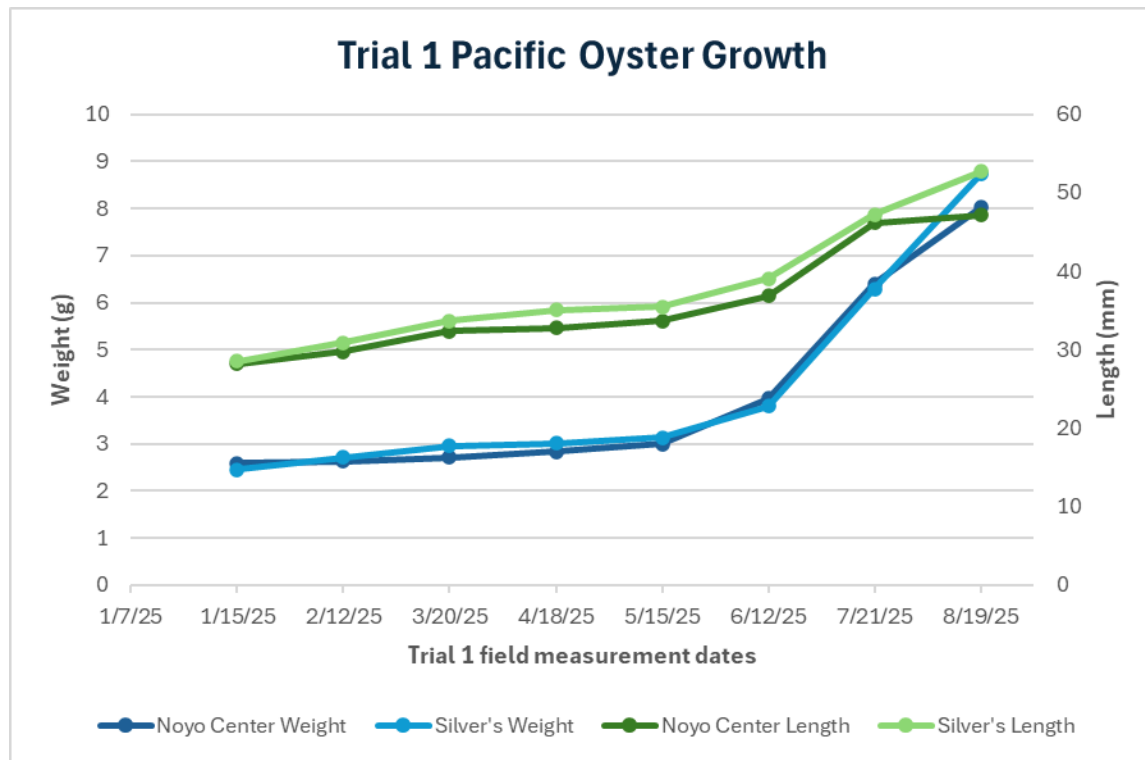


Figure 8: Trial 1 oyster growth. Average shell length and whole weight measurements from January 15 to August 19, 2025, at the Noyo Center and Silver's locations.

Two trials were conducted to test health, survivorship, and growth of Pacific oysters in Noyo Harbor. Trial 1 took place from January 7 to August 19, 2025. The oyster seeds were received from Hog Island Oyster Co. in Humboldt Bay on January 7 and placed in the water at two locations in the harbor, the Noyo Center Marine Field Station (Noyo Center) and Silver's at The Wharf (Silver's). One thousand and sixty-one oysters were divided between the two baskets (531 in the Noyo Center basket and 530 in the Silver's basket). Both baskets were attached to pier pilings and suspended two feet above the seafloor with depths ranging from 3 to 13 feet from low to high tides. For the last month of the trial, July to August, both baskets were raised to one foot below the surface.

Overall, survivorship was high (98.68% in each basket) and the oysters grew at both locations at similar rates. At the Noyo Center, oysters grew from their pre-deployment measurements of 28.2 mm and 2.59 g to 47.2 mm and 8.02 g, a total of 19 mm and 5.43 g over the 7-month period. Similarly, oysters at the Silver's location grew from 28.5 mm and 2.46 g to 52.7 mm and 8.73 g, a total of 24.2 mm and 6.27 g

(see Figure 8; [Appendix B](#)). Growth rates were steadily increasing from January to May, began to accelerate from May to June, and peaked from June to July (with the exception of oyster weight at the Silver's location which continued to grow at an accelerated rate from July to August) (see [Appendix C](#)).

From January to May 2025, there was steady but slow growth, with growth rates under 3 mm/month and 0.3 g/month at both locations. At the bottom of the harbor, water temperature ranged between 9.43 to 12.08 °C (48.97 to 53.74 °F), while salinity varied widely due to rainfall and an influx of freshwater. Salinity reached a high of 33.51 ppt and dropped to 0 ppt on three separate occasions for a maximum duration of 2 days. Pacific oysters can tolerate large changes in salinity and survive in extreme conditions (e.g., salinities of 0 ppt) for short periods of time, but optimal ranges for growth are closer to 25 ppt (Jung et al., 2025; Shatkin et al., 1997).

Peak growth rates can be seen from June 12 to July 21 for both Noyo Center length and weight and for Silver's length. Growth rates increased to 7.17 mm/month and 2.66 g/month at the Noyo Center and 6.24 mm/month and 1.90 g/month at Silver's. Mean oyster weight at Silver's continued to grow at a rate of 2.52 g/month when the basket was moved to the surface. In the summer months, water temperatures increased to between 9.97 to 14.20 °C (49.95 to 57.56 °F), and the salinity stayed between 32.74 to 36.57 ppt due to lack of rainfall. The oysters were removed from the water in August due to their size and to test survivorship and growth at the surface.

Trial 2

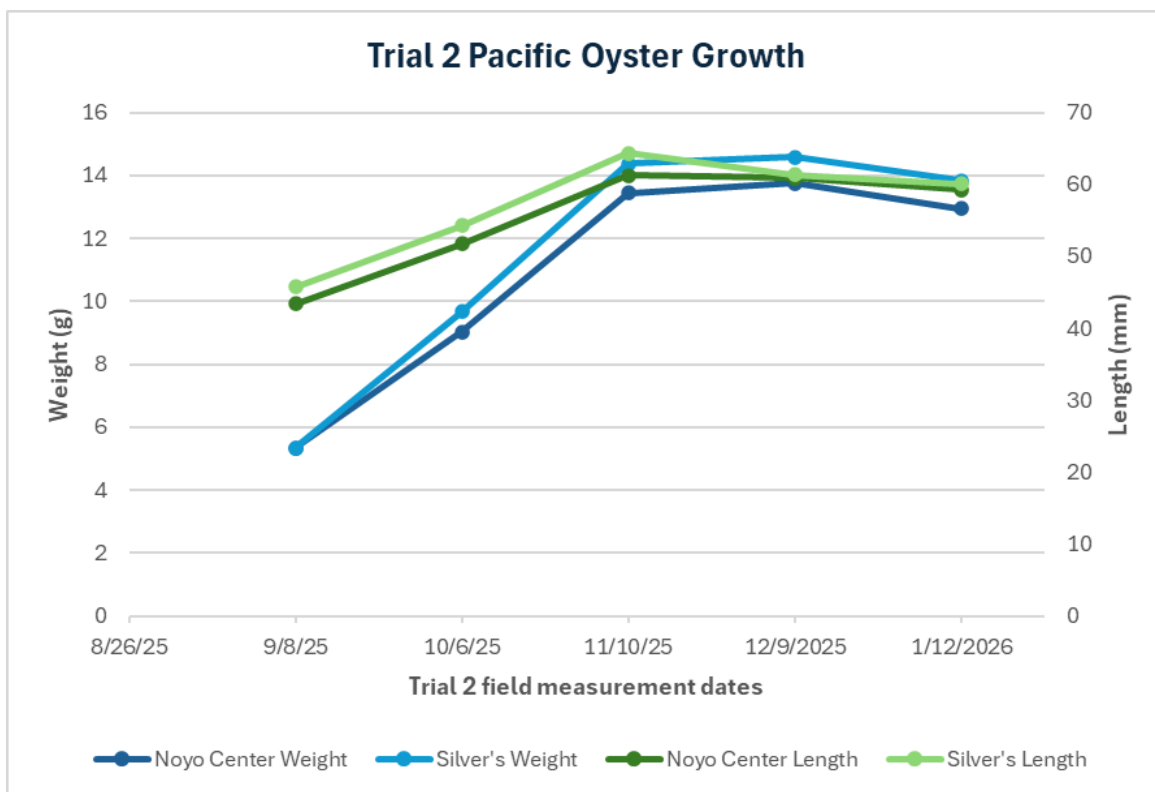


Figure 9: Trial 2 oyster growth. Average shell length and whole weight measurements from September 8, 2025 to January 12, 2026, at the Noyo Center and Silver's locations.

Trial 2 took place from August 26, 2025 to January 12, 2026. The oyster seeds were received from Hog Island Oyster Co. in Humboldt Bay on August 26 and placed in the water at the same two locations, Noyo Center and Silver's. The oysters were divided evenly, with 568 in each basket. The main differences between Trial 1 and Trial 2 were the depth of the baskets and time of year the oysters went into the water. Both baskets were attached to floating docks and lowered one foot below the surface, so they remained at one foot of depth regardless of tide. After the field measurements on November 10, the oysters were reduced to 200 per basket to lower the densities within each basket.

Overall, survivorship was very high (99.50% at the Noyo Center and 100% at Silver's), and there was rapid growth at the end of summer, going into the fall, that slowed down in the winter months. At the Noyo Center, oysters grew from 43.43 mm and 5.33 g to 59.25 mm and 12.95 g, a total of 15.82 mm and 7.62 g over a 4-month period. At Silver's, oysters grew from 45.78 mm and 5.34 g to 60.13 mm and 13.83 g, a total of 14.35 mm and 8.49 g (see Figure 9; [Appendix B](#)). Growth rates peaked in September, remained high in October, and slowed from November through January (see [Appendix C](#)).

From September to early November, the oysters grew rapidly, with peak growth in that first month. In September, oysters at the Noyo Center grew 8.9 mm/month and 4.0 g/month, and oysters at Silver's grew 9.1 mm/month and 4.7 g/month. Water temperature at the surface ranged from 13.21 to 18.21 °C (55.78 to 64.78 °F), with salinities from 23.51 to 30.06 ppt. At the Noyo Center, the surface sensor also indicated that chlorophyll-a increased from 0.03 RFU in early September to a high of 5.14 RFU by the end of the month before gradually decreasing again.

From November to December, growth rates slowed down. Temperatures cooled at the surface to between 10.87 to 13.96 °C (51.57 to 57.12 °F). There were some light rains in late October and early to mid-November, and salinity dropped to between 3.02 to 13.06 ppt. The rains increased in December, with a winter storm that brought 14.26 inches over the span of one week. The salinity dropped from 12.52 ppt before the storm to 0 ppt for the following week, reaching a maximum of 3.90 ppt in early January. The oysters were removed from the water in mid-January due to the end of study period.

Red Abalone

Trial 1

The original BEVRI planning project timeline was from November 2023 to October 2025. The plan was to get all the animals in the water by the summer of 2024 and collect one year's worth of data. For the abalone, that meant acclimating them to the new environment in the summer, when salinity is favorable, and then seeing how well they perform when there is an influx of freshwater into the system. However, the SCP was not approved until December 2024 (see [Appendix G](#)) and the abalone went into the water as soon as possible after permit approval.

Twenty-three red abalone were received on January 22, 2025 at the Noyo Center Marine Field Station and put in the water that same day. The abalone were used to a water temperature of 13 °C (55 °F) and a salinity of 35 ppt, and shipped in an oxygenated bag on top of seawater soaked foam. To acclimate the abalone, we added water from the river (51 °F, 31.7 ppt) to the bag for 15 minutes and then transferred the abalone to the basket. The basket was outfitted with additional plastic sheeting inside to increase the surface area for the abalone to attach to. In the first two days, the abalone seemed to not move

around. They were mainly clustered together near the basket openings, and strongly attached to the plastic. On January 24, they were fed 25 g of dried dulse, and by January 27 they started eating.

Throughout the weekend of January 31, Fort Bragg received light rain (<1 inch per day). The following Monday, February 3, there was 7.32 inches of rain, the river flowed with mud, and mud kept accumulating in the baskets. The project team cleaned out the basket twice per day, but the salinity dropped to 0 ppt at the bottom of the river for a two-day period (see [Appendix D](#)). The abalone did not survive under these conditions and were removed from the water on Tuesday, February 4. The project team waited until Spring to start Trial 2.

Trial 2

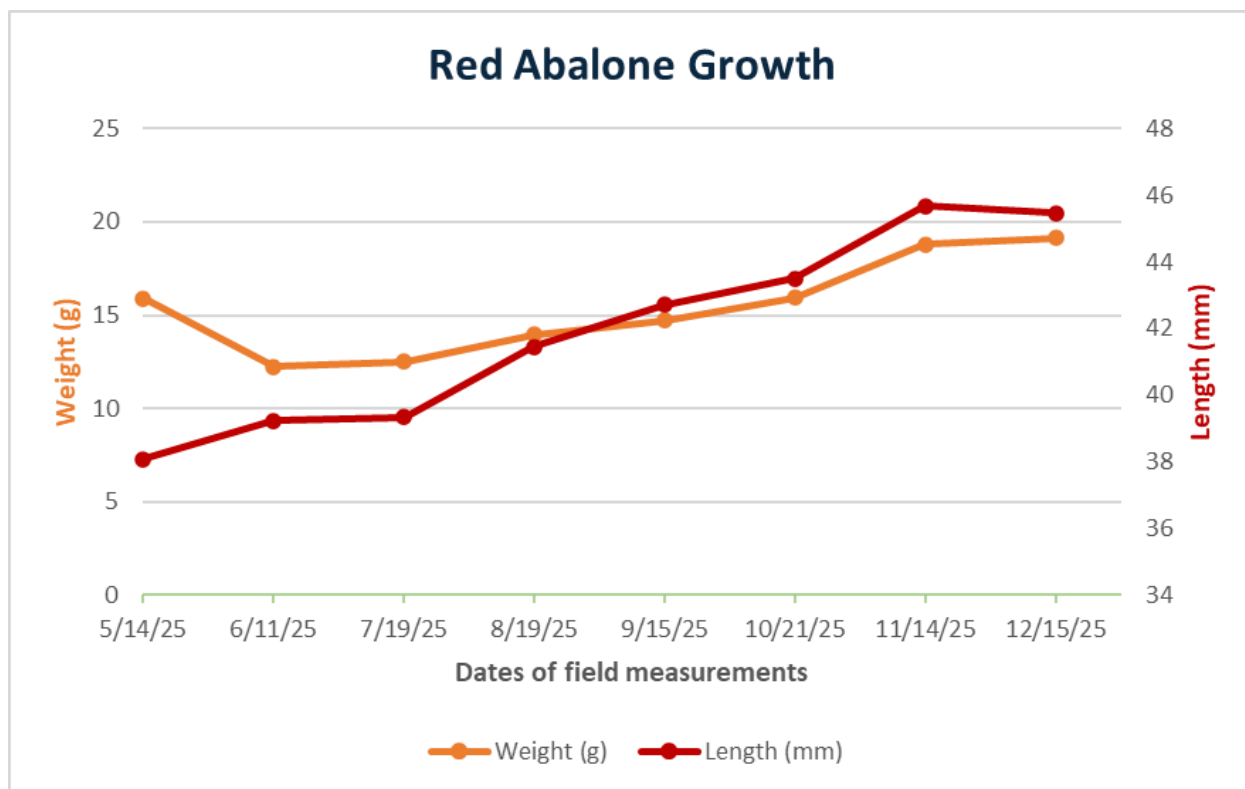


Figure 10: Trial 2 abalone growth. Average shell length and whole weight measurements from May 14 to December 15, 2025. There was steady growth throughout the study period.

For the next trial, 43 red abalone were received on May 14, 2025. Similar to Trial 1, the abalone were used to a water temperature of 13 °C (55 °F) and a salinity of 35 ppt, and acclimated by adding water from the river (52.5 °F, 32 ppt) to the bag they were transported in. The abalone were then tagged, measured, and placed in the basket. Pre-deployment measurements averaged 38.07 mm in shell length and 15.91 g in whole weight. It took the abalone a few months to consistently eat, but eventually they started eating about 25 g of dried dulse every 2 to 3 days.

From May 14 to December 15, the abalone grew to an average of 45.47 mm and 19.12 g, for a total of 7.4 mm and 3.21 g in a 7-month period (see Figure 10; [Appendix B](#)). Initially, the abalone lost weight but they gained it back. Peak growth rates for both length and weight were from October 21 to November 14 (2.76 mm/month and 3.63 g/month) (see [Appendix C](#)). Overall, the abalone maintained slow, steady growth throughout late spring, summer, and early winter.

Fort Bragg experienced about 2.5 inches of rain over a 3 day period in early November 2025. Salinity at the bottom of the harbor fluctuated between 20 to 35 ppt (surface between 8 to 12 ppt), and temperatures at the bottom ranged from 12 to 14°C (54 to 57°F). The river did not look muddy and the abalone survived and continued eating. Rain started again on December 16, and there was about 14.26 inches over the next seven days, with heavy rains (5 inches) on December 23. From the 16th through the 25th there were large salinity swings, and there was a 2-day drop to 0 ppt from December 21 to the 22nd (see [Appendix D](#)). The abalone did not survive under these conditions and they were removed on December 24, 2025.

Purple Sea Urchins

Trial 1

The original BEVRI planning project timeline was from November 2023 to October 2025. The plan was to get all the animals in the water by the summer of 2024 and collect one year's worth of data. For the purple sea urchins, the project team planned to conduct four iterations of the same experiment to test uni production in each season. However, the SCP was not approved until December 2024 (see [Appendix G](#)), so the project was adjusted and urchins went into the water as soon as possible.

Purple sea urchins were received from a local commercial urchin diver on January 29, 2025 at the Noyo Center Marine Field Station and put in the water that same day. The 25 urchins were measured, fed 100 g of dried dulse, and monitored to see how well they acclimated and how long it would take them to eat. The average test diameter and whole weight of the urchins was 58.56 mm and 60.04 g. On February 3, Fort Bragg received 7.32 inches of rain, the river was flowing with mud, and mud kept accumulating in the basket. At this time, the salinity dropped to 0 ppt from 8am to 12pm on February 3 (see [Appendix D](#)). The urchins did not survive under these conditions and were removed from the water. The rain continued for the next two days and salinity remained at 0 ppt. Similar to the abalone, the project team decided to wait until Spring to start Trial 2.

Trial 2

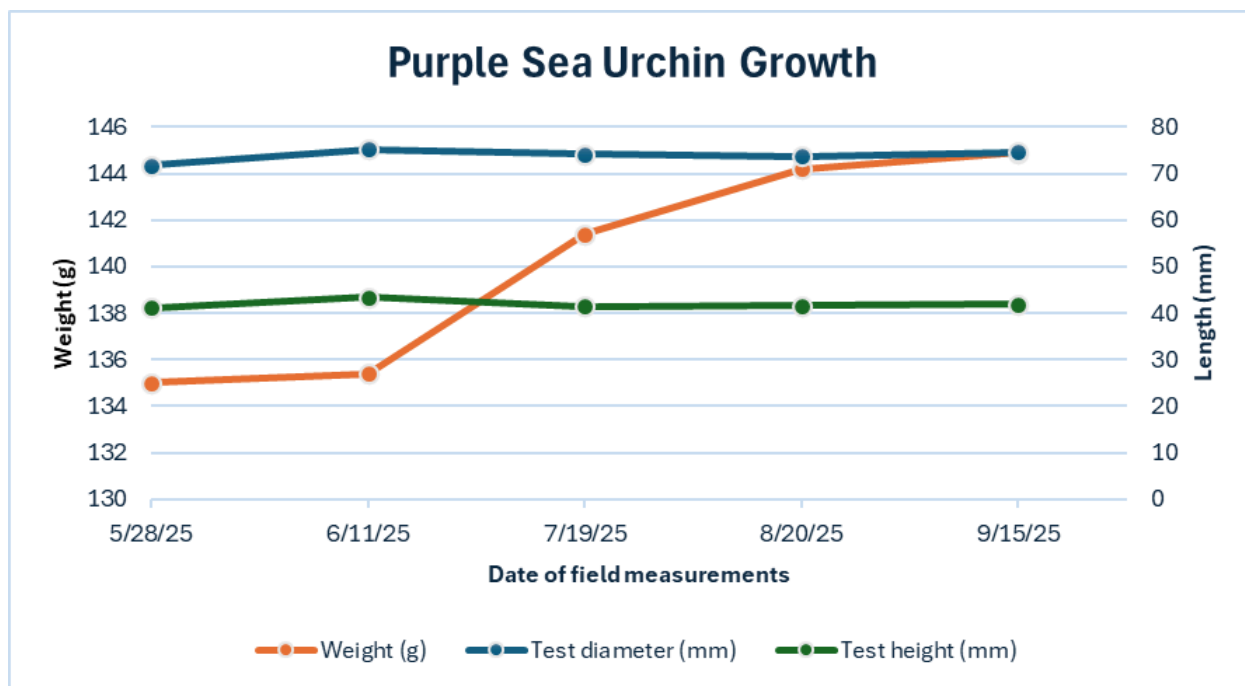


Figure 11: Trial 2 purple urchin growth. Average test diameter, height, and whole weight measurements from May 28 to September 15, 2025. Test diameter and height stayed consistent and whole weight slowly increased throughout the study period.

For the next trial, 20 purple urchins were received on May 28, 2025. Throughout the trial period, there were three mortalities - on June 17, 23, and 27 - for a total survivorship of 85% (see [Appendix A](#)). In June 2025, water temperature ranged from 9.74 to 13.13°C (49.53 to 55.63 °F). There was an issue with the bottom sensor's salinity readings. After troubleshooting, the sensor was replaced on June 18 and the issues were fixed on June 26. After the 26th, salinity ranged from 27.81 to 36.34 ppt. Both temperature and salinity are within purple urchin's tolerance ranges (Giese and Farmanfarmaian, 1963; Gonor, 1968; Ulbricht & Pritchard, 1972), however the large swings in salinity most likely caused additional stress.

The rest of the urchins were kept in the basket for 17 to 18 weeks. Three urchins were dissected on September 22, 2025, to test their GSI and the remaining 14 were removed from the water and dissected on October 4, 2025. From deployment to the end of the study, the urchins grew from an average of 71.8 mm to 74.6 mm in test diameter, 41.2 mm to 41.9 mm in test height, and 135.0 g to 144.9 g in whole weight (see Figure 11; [Appendix B](#)). Test diameter and height stayed relatively consistent with a difference of 2.8 mm and 0.7 mm respectively, and the whole weight increased by 9.9 g. For weight, growth peaked from June to July with a monthly growth rate of 4.74 g/month (see [Appendix C](#)). The urchins were eating inconsistently for the first two months but by early August they were eating, on average, 50 g of dried dulse every 2 to 3 days (at or a little more than 1 g each per day).

Gonadosomatic Index (GSI) was taken at the beginning and end of the study. Before the study, 30 urchins that were removed at the same time and from the same location as the urchins in this basket were

dissected. The roe was brown and severely shrunken, and average whole weight, gonad weight, and GSI was 127.1 g, 1.25 g, and 1.01%, respectively (see Figure 12). For low quality urchins, it typically takes 12 to 16 weeks of ranching to improve the uni to market quality, which is variable but generally considered a minimum GSI of 10% based on red and green urchin fisheries (Walker et al., 2015). After 17 to 18 weeks in the basket, the remaining urchins (17 out of 20) were removed from the water and the GSI was measured. The GSI ranged from 8.27 to 16.42% (an average of 12.05%), with only 3 out of the 17 urchins not meeting the 10% threshold (see [Appendix E](#)). All urchins were pale yellow in color, and there was little to no spawning when dissected.

Overall, purple sea urchin roe was successfully enhanced to a GSI of 10% or greater within 17 to 18 weeks. The uni had a similar GSI from week 17 to week 18 which suggests they could have been removed even sooner. By comparison, other roe enhancement studies saw faster results with different types of feed. Gardner et al. (2021) found that roe with a GSI of <0.5% could be enhanced to 10% in 6 weeks with a formulated feed diet and 9 and 13 weeks with an ogo and kelp diet. Angwin et al. (2022) increased GSI from $6.8 \pm 0.7\%$ to a mean GSI of >15% after 9 weeks with Urchinomics feeds and to a GSI of $11.7 \pm 1.2\%$ with kelp.

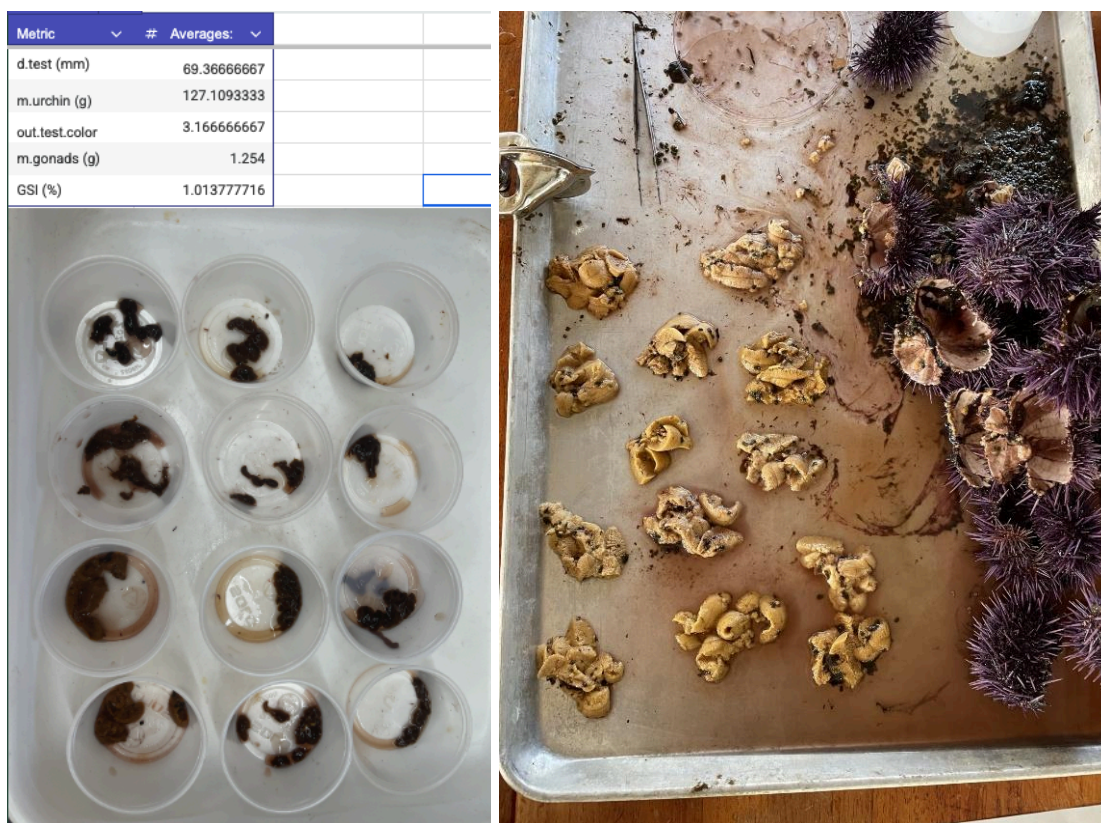


Figure 12: Comparison of uni from the beginning and end of the study. Left: Average GSI at the beginning of the study was 1.01% (photo from Moss Landing Marine Laboratories). Right: Average GSI at the end of the study was 12.05%.

Bull Kelp

Trial 1

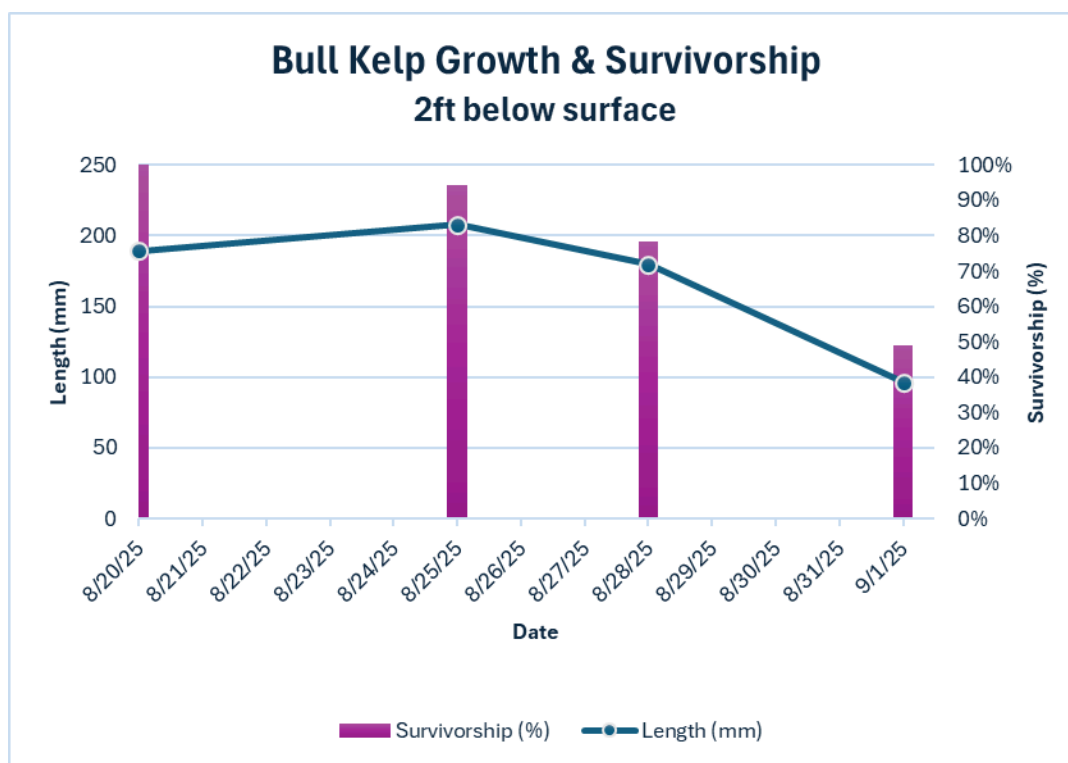


Figure 13: Trial 1 bull kelp growth and survivorship. Bull kelp grew for the first five days in the water, then both growth and survivorship declined.

The SCP amendment to include bull kelp was approved on August 7, 2025, which meant there was a limited window to test bull kelp growth in-situ in the Noyo River basin. On August 20, 2025, juvenile sporophytes were received from Moss Landing Marine Laboratories, spliced onto one 12-foot long line, measured, and placed in the water at the Noyo Center Marine Field Station. The culture line was connected to two metal pipes that were attached to a floating dock, so the line always remained two feet below the surface (see Figure 6 in the Methods section).

There was an average pre-deployment measurement of 189.31 mm in total length. The bull kelp started to grow for the first five days (to an average of 207.71 mm with a daily growth rate of 3.68 mm/day). After five days, the blades began to fray and tear (see Figure 14), and both growth and survivorship declined (see Figure 13). From August 25 to August 28, growth declined to an average of 179.78 mm (daily growth rate of -9.31 mm/day) and survivorship of 78.43%. From August 28 to September 1, growth declined to an average of 96.6 mm (with a daily growth rate of -20.80 mm/day) and survivorship of 49.02% (see [Appendix A](#), [B](#), and [C](#) for survivorship, length, and growth rate tables).

At this depth in late August, there was high sun intensity and an increase in surface temperature. In those first five days, from August 20 to 25, surface temperature ranged from 13.59 to 16.05°C, and from August 25 to September 1 the range increased, from 14.75 to 17.96°C. During this trial period, surface

salinity ranged from 23.95 to 29.78 ppt and bottom salinity ranged from 32.05 to 36.15 ppt. The depth of the culture line was closer to the surface sensor, so, after a rapid decline in survivorship, the kelp was removed from the water and the line was moved deeper to reduce sun intensity and increase salinity for the next trial.

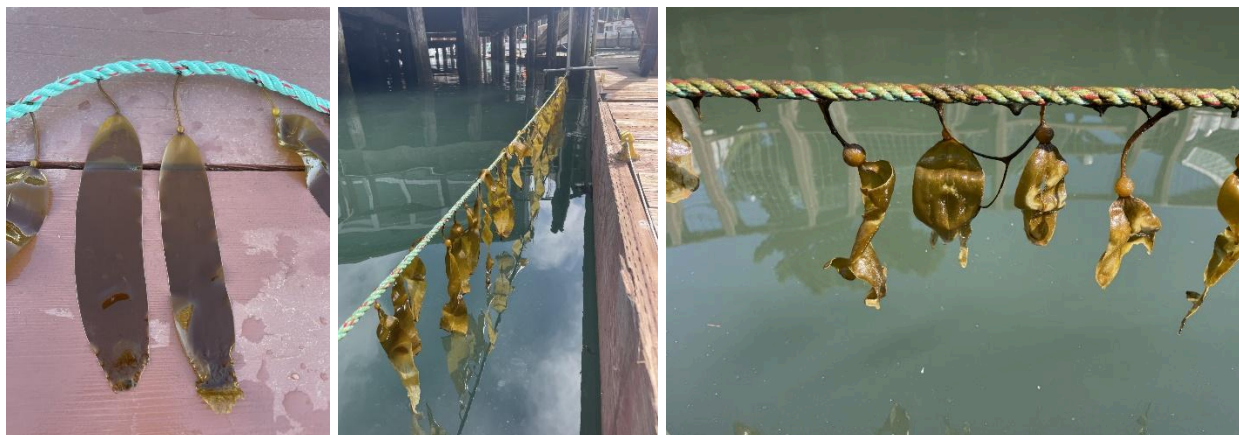


Figure 14: Bull kelp on the long line during Trial 1, from August 20 to September 1, 2025. Left: Kelp is sliced onto line and ready to go in the water, taken on August 20. Center: Most of the kelp is growing, taken on August 25. Right: Kelp is fraying, taken on August 28.

Trial 2

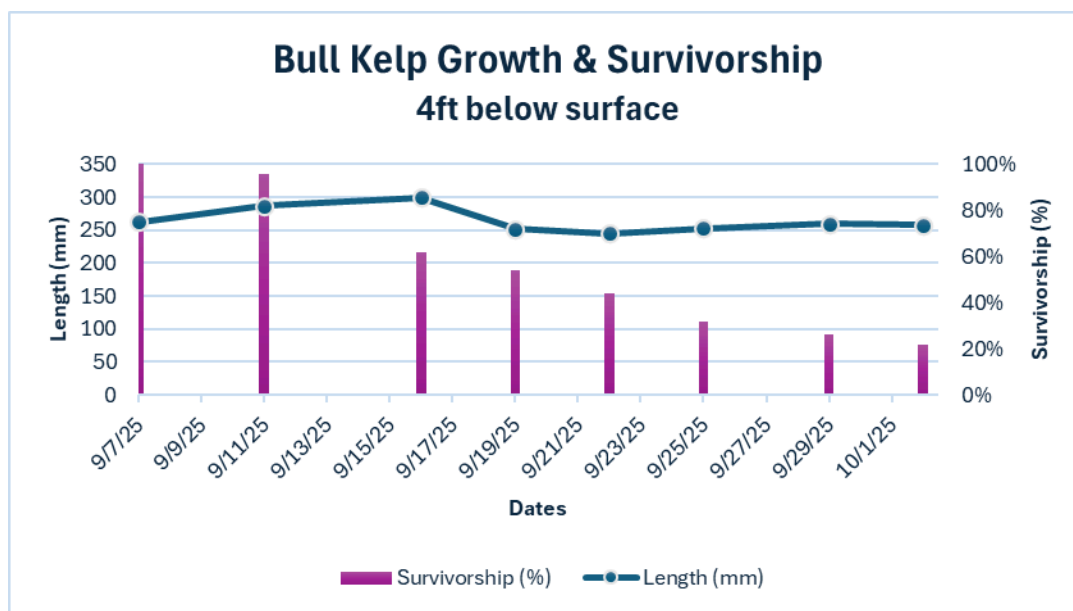


Figure 15: Trial 2 bull kelp growth and survivorship. Bull kelp grew for the first nine days in the water, then both growth and survivorship declined.

The second round of bull kelp was spliced on to the same 12-foot long line, measured, and placed in the water on September 7, 2025. The only difference being the culture line was connected to two PVC pipes that were attached to the floating dock and lowered 4 feet below the surface (see Figure 16). In early September, low tide depths receded to 5.30 feet at the site, so the line was lowered to 4 feet to reduce stress from sunlight, while also keeping the line suspended and the infrastructure from hitting the bottom.

There was an average pre-deployment measurement of 262.66 mm. The bull kelp grew for the first nine days to an average of 299.13 mm. From September 7 to 11, kelp grew with a daily growth rate of 6.06 mm/day, and from September 12 to 16 with a daily growth rate of 2.45 mm/day (see [Appendix C](#)). On September 10, there was a spike in surface temperature to 18.21 °C (bottom temperature of 17.24 °C) and multiple subsequent days of surface temperatures reaching 17 °C (see [Appendix D](#)). On September 16, the end of the blades started to look more translucent, and by September 19, many of the blades were tearing or visibly shorter. There were also small holes throughout the blades, possibly from amphipods. By September 22, most blades were shredded and a European green crab was spotted on the line as it was pulled up. There had been sightings of these crabs throughout the entire summer. Overall, growth declined to an average of 245.45 mm with tears and holes throughout the blades, and survivorship consistently declined (see Figure 15; [Appendix A](#), and [B](#)). For the last trial, the line was fixed to the bottom to keep the kelp as deep as possible to minimize temperature and salinity swings between low and high tides.

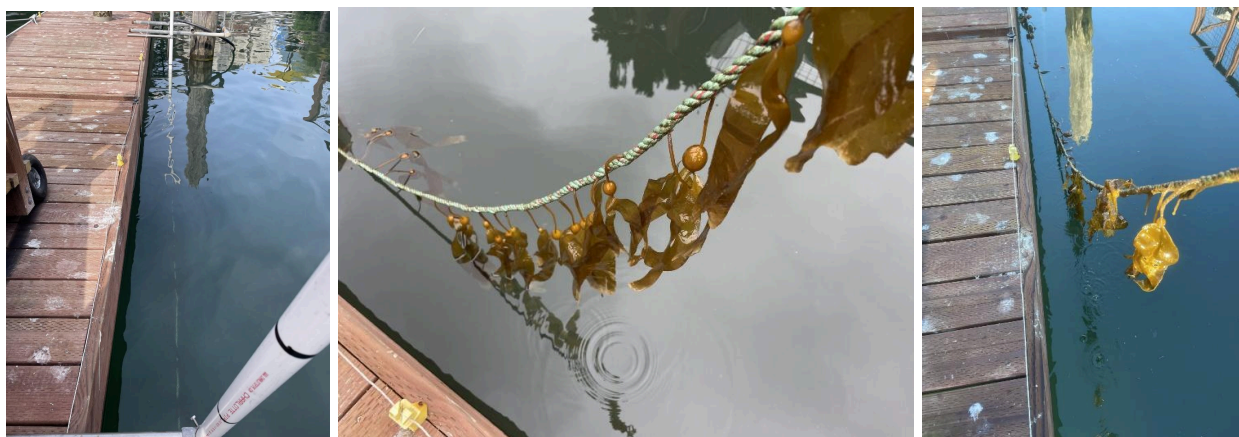


Figure 16: Bull kelp on the line during Trial 2, from September 7 to October 2, 2025. Left: Bull kelp lowered 4 ft below the surface of the water, taken on September 7, 2025. Center: Bull kelp growth, taken on September 11, 2025. Right: Frayed and torn bull kelp, taken on September 22, 2025.

Trial 3

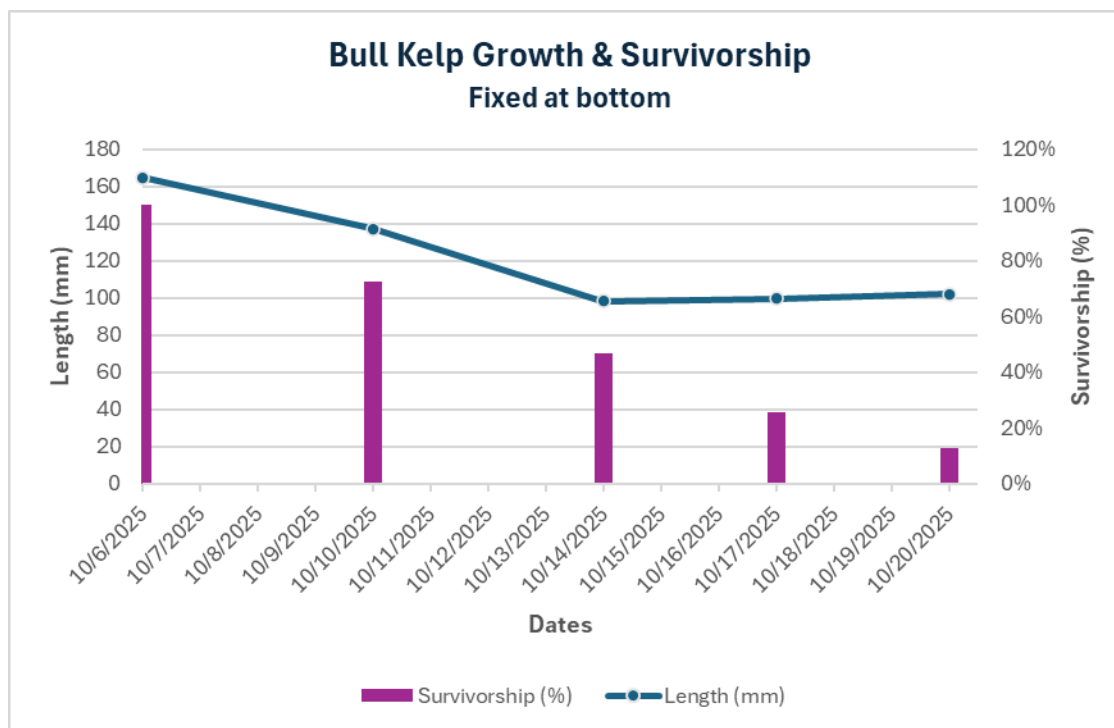


Figure 17: Trial 3 bull kelp growth and survivorship. Bull kelp were in the water for 14 days, and growth and survivorship declined from day 1.

The third round of bull kelp was spliced and placed in the water on October 4, 2025, and measured on October 6, 2025. Unlike the previous two trials, the culture line was attached to two pier pilings rather than the floating dock, to keep the line at the bottom. Two metal pipes were fixed to two pier pilings (see Figure 18). The culture line was connected to the metal pipes via carabiner. The line was weighed down on each end to keep it taught, and an additional rope, attaching the carabiner to the top of the pier piling, maintained the line at a specific depth and allowed it to be pulled up. The depth of the line during this trial ranged from 4.73 to 13.14 feet.

There was an average first measurement of 164.74 mm. The bull kelp were in the water for 14 days, and both growth and survival started to decline from day 1 (see Figure 17). Within the first four days, average length decreased to 137.15 mm (a daily growth rate of -6.90 mm/day), and survivorship decreased to 72.34%. Within eight days, average length decreased to 98.36 mm (a daily growth rate of -9.70 mm/day), and survivorship decreased to 46.81%. The bull kelp immediately started to fray, and survivorship declined at a faster rate than previous trials. For the 14-day period, water temperature ranged from 12.35 to 14.91 °C. There were also a couple drops in salinity. On October 6, bottom salinity dropped to 24.25 ppt (see [Appendix D](#)). Seeing as trials could not begin until late August due to permitting challenges, the next recommendation would be to put sporophytes in the water in early Spring.



Figure 18: Bull kelp on the line for Trial 3, from October 6 to 20, 2025. Left: The culture line was connected to metal pipes that were fixed to pier pilings. Center: Bull kelp sporophytes one day after first measurement, taken on October 7, 2025. Right: Bull kelp sporophytes after 4 days in the water, taken on October 10, 2025.

Land-Based RAS

System Performance and Operational Lessons Learned

The RAS successfully demonstrated the technical feasibility of conditioning purple sea urchins in a land-based system using estuarine source water. Once stocking densities and system balance were optimized, the system maintained stable water quality and supported high urchin survivorship and gonad recovery. Estuarine water from the Noyo River proved to be a viable water source alternative to direct seawater intake. However, seasonal variability presented operational challenges. Winter conditions increased freshwater input and turbidity, reducing intake reliability and requiring more frequent monitoring and adjustment. When forecasted river conditions raised concerns, clean river water was stored onsite as a contingency.

Stocking density was identified as a critical factor influencing system stability. Initial stocking densities exceeded biofiltration capacity, resulting in elevated mortality. Survivorship improved substantially after stocking densities were reduced to approximately 18 individuals per basket, allowing the biofilter to adequately process nitrogenous waste. This however, lowers the economic potential of the system.

System design influenced maintenance efficiency. Waste accumulation in flat-bottom troughs required frequent manual removal, highlighting the importance of incorporating sloped bottoms or dedicated solids removal systems in future designs. Adequate circulation was also critical; replacing standard bubbler aeration with airlift systems improved water movement and overall performance.

Biosecurity also emerged as an important consideration. Once disease or stress responses were introduced, spread occurred rapidly within the closed system. Careful screening and gradual acclimation during stocking are recommended to minimize risk.

Energy demand associated with chilling, aeration, and pumping represents a significant operational cost. Improving insulation, optimizing equipment efficiency, and reducing heat gain may improve economic feasibility.

Overall, the RAS provided a stable and effective platform for regenerative aquaculture but required iterative adjustment to achieve optimal performance.

Purple Sea Urchin Feed Trials

Overall survivorship across all feed treatments was 61.5%. An initial mortality event occurred across all treatments, likely due to elevated stocking densities and acclimation stress. Mortality stabilized after densities decreased, suggesting that density management is critical for survivorship.

Initial mean GSI was 3.50%, consistent with nutritionally depleted urchins from barren habitats. All feed treatments supported gonad growth, demonstrating that conditioned recovery is achievable under controlled aquaculture conditions.

Kale produced the most consistent and reliable results, with mean GSI increasing to 10.02% at week 10 and remaining near marketability thresholds through week 14. Purple cabbage showed greater variability but achieved its highest peak GSI (11.67% at week 12), exceeding the minimum commercial threshold.

Spinach supported moderate gonad growth but did not consistently reach commercial thresholds, with peak GSI of 9.12%. Pacific dulse, used as a control, showed the greatest variability. Dulse achieved the highest single GSI value (12.45% at week 10) but declined thereafter.

These results indicate that agricultural produce—particularly kale and purple cabbage—can effectively support gonad conditioning and may represent practical, low-cost alternatives to specialized aquaculture feeds.

Qualitative observations indicated that kale produced the most desirable gonad color, firmness, and texture. However, additional quantitative evaluation is needed to confirm these trends.



Figure 19: Mean ($\pm$ SE) gonadosomatic index (GSI, %) of purple sea urchins (*Strongylocentrotus purpuratus*) fed four dietary feed types (spinach, kale, purple cabbage, and dulse) over a 14-week feeding trial. Urchins were sampled from six replicate baskets per dietary feed type at two-week intervals. Points represent the feed type GSI means. Initial GSI (Week 0) represents the baseline value prior to feeding. Error bars indicate $\pm$ standard error (SE).

Dulse Tumble Culture

Integrated culture of Pacific dulse produced mixed results. Initial performance was limited by fouling algae, which repeatedly overgrew and suppressed dulse growth. Between initial deployment and November 2025, the system required three restocking events due to biomass loss. Dulse exhibited physiological stress responses, including tissue paling, suggesting environmental stress related to light exposure, nutrient availability, temperature, or water chemistry. Following system modifications—including partial isolation and nutrient supplementation—dulse health and stability improved. These findings indicate that while IMTA integration is feasible, stable macroalgal production requires careful management of environmental conditions and nutrient balance. Additional research is needed to optimize integrated macroalgal culture under regenerative aquaculture conditions.

Community Survey

The Aquaculture Survey received a total of 164 responses, 160 in English and 4 in Spanish, with a 95% completion rate.

Demographics

Question 1

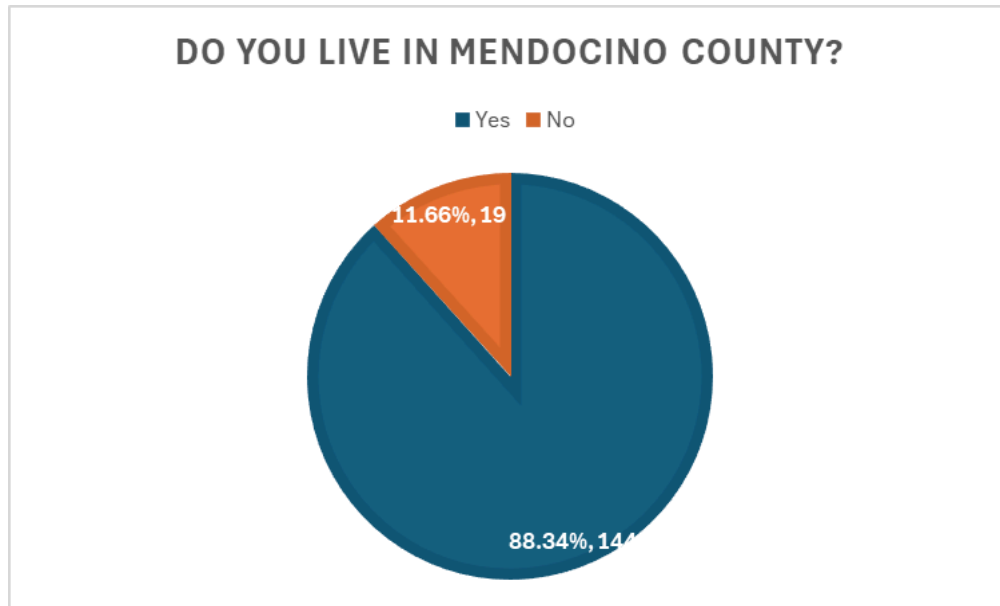


Figure 20: The number of respondents that live in Mendocino County. Most respondents (88.34%, 144 people) live in Mendocino County.

In the first of two demographics questions, respondents were asked whether or not they live in Mendocino County. This question was added to determine if we were reaching local residents. Of the 164 respondents, 163 people answered and 1 person skipped this question. One hundred and forty-four people said they live in Mendocino County (88.34% of respondents), and 19 people said they do not live in Mendocino County (11.66% of respondents).

Question 2

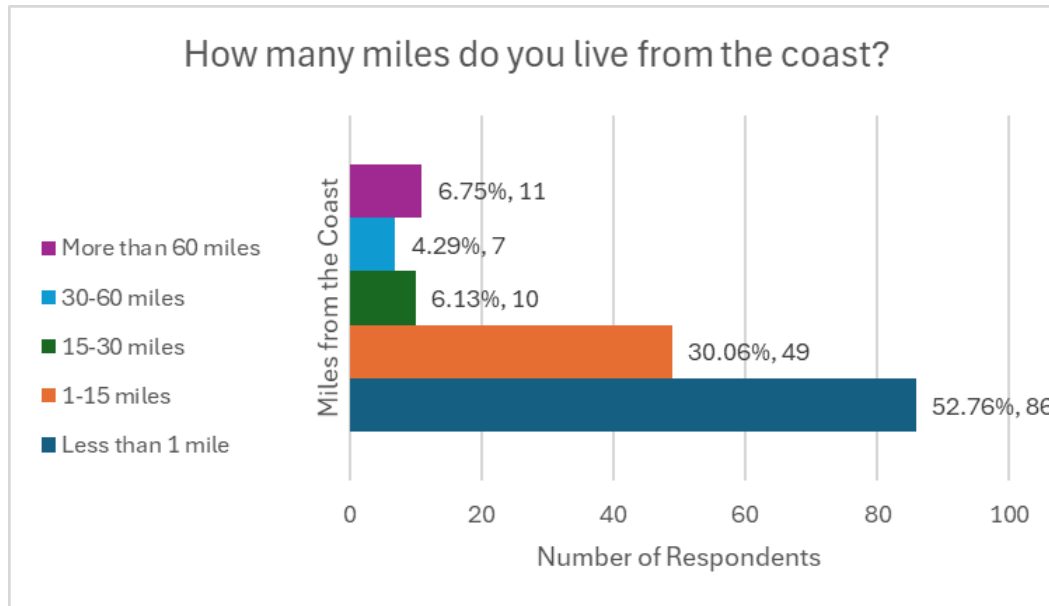


Figure 21: The number of miles respondents live from the coast. More than half of respondents live less than 1 mile from the coast.

In the second demographics question, respondents were asked how far they live from the coast. This question was added to better understand if distance to the coast plays a role in seafood consumption preferences and access to seafood (e.g., potential barriers and how people get their seafood). Of the 164 respondents, 163 people answered and 1 person skipped this question. Of note, more than half of respondents (52.76%) live less than 1 mile from the coast and 80.82% of respondents live within 15 miles of the coast. This makes sense considering residents of Fort Bragg were primarily targeted. Only 6.75% of respondents live more than 60 miles from the coast, all outside of Mendocino County.

Seafood Consumption Preferences

Question 3

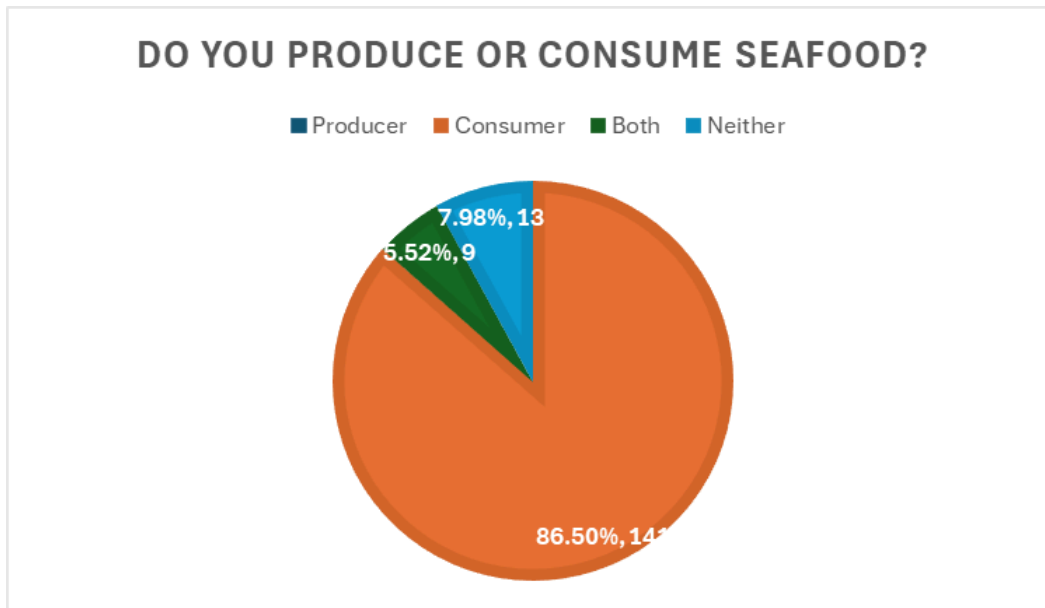


Figure 22: The number of respondents that produce and/or consume seafood. Most respondents eat seafood, while 9 people both eat and produce seafood, and 13 people do neither. No one is solely a seafood producer.

Respondents were asked if they produce or consume seafood. Depending on the response, the survey took respondents to different sections. If they produce seafood, they were asked whether they have experience with aquaculture. If they consume seafood, the survey jumped to a series of questions on their seafood consumption preferences (e.g., how often they eat seafood, which types they prefer, etc.). If they selected “both,” they would go through all the questions; and if they selected “neither,” they would jump to the series of questions on awareness and perceptions of aquaculture. Of the 164 respondents, 163 people answered and 1 person skipped this question. One hundred and forty-one people said they consume seafood (86.50% of respondents), 9 people said they produce and consume seafood (5.52% of respondents), and 13 people said they neither consume nor produce seafood (7.98% of respondents). No one is solely a producer of seafood.

Question 4

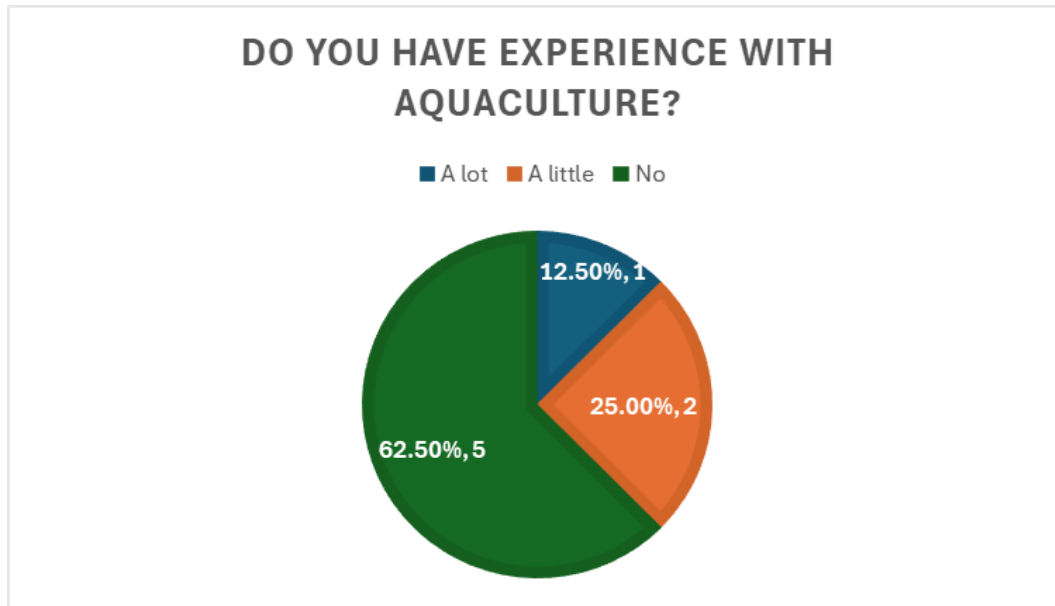


Figure 23: The number of seafood producers that have experience with aquaculture. Three respondents, who are seafood producers, have experience with aquaculture (either a lot or a little).

The 9 respondents who selected that they both produce and consume seafood in the previous question were asked if they have any experience with aquaculture. Of these 9 respondents, 8 people answered and 1 person skipped this question. One person said they have a lot of experience with aquaculture, 2 people have a little experience, and 5 people have no experience. That means three seafood producers that responded to this survey have some degree of experience with aquaculture. It should be noted that people who have experience in a non-commercial (e.g., research or academic) or informal setting, may have selected that they are not seafood producers and didn't respond to this question.

Question 5

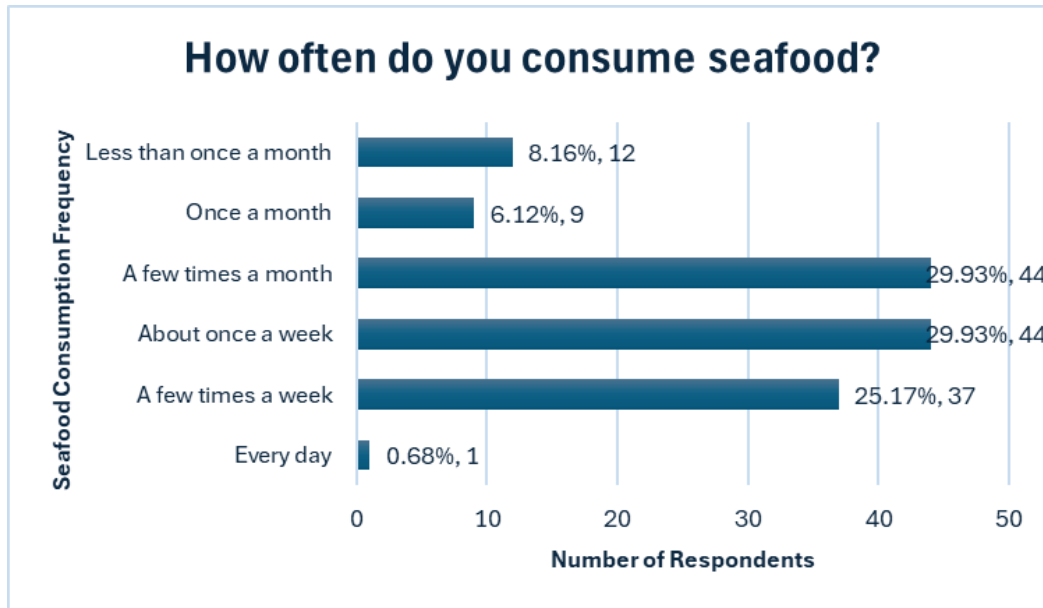


Figure 24: How often respondents eat seafood. Most respondents eat seafood between a few times a month and a few times a week.

The 150 people who said that they eat seafood in Question 3 were taken to the following series of questions on their seafood consumption preferences. First, respondents were asked how often they consume seafood. Of the 150 respondents who consume seafood, 147 people answered and 3 people skipped this question. The majority of respondents eat seafood anywhere between a few times a month to a few times a week (85.03%, 125 people). One person stated that they eat seafood every day.

Question 6

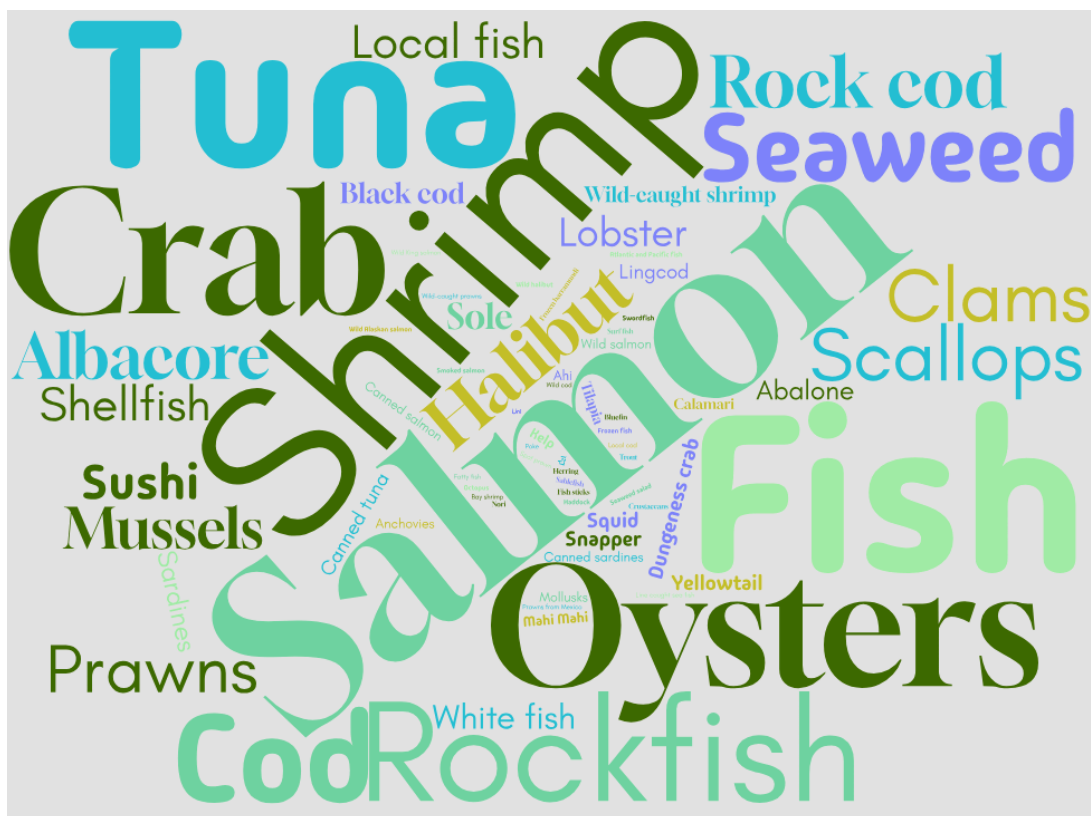


Figure 25: Word Cloud of the types of seafood respondents usually eat. The wording reflects the language that respondents used, and the size of the word represents the frequency with which it was mentioned.

Second, respondents were asked which types of seafood they usually eat. Of the 150 respondents who consume seafood, 147 people answered and 3 people skipped this question. This was an open-ended question, so respondents could list as much or as little seafood as they wanted and reference it however they preferred. The Word Cloud above reflects the language that respondents used, which included the broad categories of “fish” and “shellfish,” general terms for the type of seafood, specific species, locality or region, specifying wild-caught, and different processing, preparation, and cooking methods. The size of the word in the Word Cloud represents the frequency with which it was mentioned. Salmon was by far the most highly mentioned seafood. Respondents also mentioned eating: shrimp (40), fish (38), crab (34), oysters (31), tuna (30), rockfish (28), cod (18), seaweed (14), clams (11), and scallops (11) (see [Appendix F](#) for a tallied list of responses). A few respondents added some commentary on where they get the seafood they like to eat, which included:

- “blackened cod sandwich from Princess,”
- “whatever they try at SeaPal,”
- “fish caught by neighbors and friends,”
- “fish as available at Princess for home and shellfish dining out,” and
- “previously locally caught abalone.”

Question 7



Figure 26: Word Cloud of the types of seafood respondents wish they could eat more often. The wording reflects the language that respondents used, and the size of the word represents the frequency with which it was mentioned.

Respondents were then asked which types of seafood they wished they could eat more often. Of the 150 respondents directed to this question, 124 people answered and 26 people skipped the question. Again, this was an open-ended question to give respondents as much freedom to answer as possible, without leading or biasing responses. The Word Cloud above reflects the language that respondents used. Similarly to the previous question, responses included the broad categories of “fish” and “shellfish;” general terms for the type of seafood; specific species; specifying local, wild-caught, and sustainable; and different preparation and cooking methods. Respondents also answered with “All of it,” “No,” and “I don’t know” (see [Appendix F](#)). Salmon was the most frequently mentioned seafood that respondents wished they could eat more often. Followed by abalone and crab. A few respondents added some anecdotes to their responses, including:

- “ALL! Dying to try abalone!”
- “I would consume any seafood that was affordable. However I would pay a bit more for local seafood”
- “Oysters, Mussels (living inland right now, it is harder to source real fresh stuff)”

- “Abalone! We used to dive for it & loved it, but more for our ecosystem I hope they recover so well that we can eat them again (I would consider eating farmed abalone)” and
- “I really don't know a lot about seafood.”

Question 8

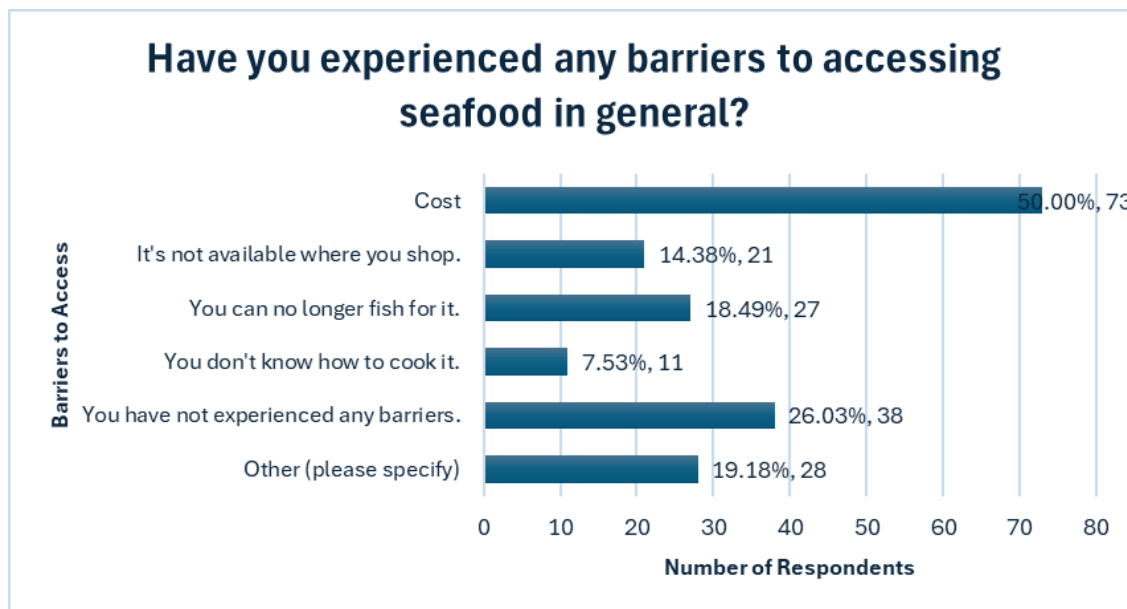


Figure 27: Barriers to accessing seafood. Half of respondents selected cost as a barrier, more than a quarter of respondents said they have not experienced any barriers, and just under 20% of respondents opted to provide a comment.

After thinking about the types of seafood they wish they could eat more often, respondents were asked if they've experienced any barriers to accessing seafood. Of the 150 respondents directed to this question, 146 people answered and 4 people skipped the question. This was a multiple-choice question to give respondents a sense of different types of barriers, but there was also a comment section for respondents to fill in any gaps. Half of respondents (73 people) selected cost as a barrier to accessing seafood, and more than a quarter of respondents (38 people) said they have not experienced any barriers (see Figure 27).

In the comment section, respondents highlighted barriers, often interconnected, that reflect their values as seafood consumers. Three common themes included: trouble sourcing the types of seafood they want to eat, limits due to seasonality and fishing regulations, and self-imposed dietary restrictions out of concerns for the environment. The first two themes relate to the answer choices “It’s not available where you shop,” and “You can no longer fish for it,” which 21 people (14.38% of respondents) and 27 people (18.49% of respondents) selected and agreed with, respectively. Regarding regulations, one respondent expanded on that sentiment and stated: “Sometimes cost, but mostly availability. However, I’m okay with the restrictions, so while availability is a restriction, I can live with it.”

Many respondents stated that the seafood they want to eat is not always available or easy to access. These preferred seafood characteristics included a combination of local, wild, fresh, high quality, and/or reasonably priced. One respondent commented that it's "hard to find [a] fresh quality source," and a few other respondents expressed a lack of trust in whether the seafood they buy from grocery stores is actually fresh. Another respondent said they would "like to buy directly from fishermen," and a third respondent mentioned that they end up back at grocery stores because it's more convenient and reliable.

Question 9

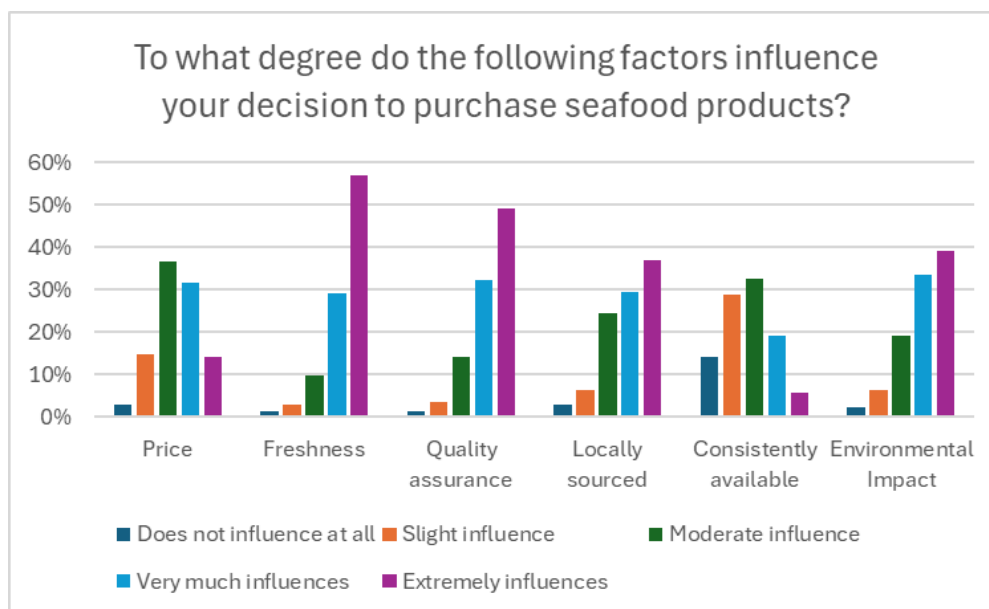


Figure 28: Factors that influence respondents' decisions to purchase seafood products. Freshness, quality assurance, and environmental impact are major considerations when purchasing seafood.

In the following question, respondents were given six characteristics of seafood and asked to what degree these factors influence their decision to purchase seafood products. The characteristics included price, freshness, quality assurance, locally sourced, consistently available, and environmental impact; and the options ranged from "does not influence at all" to "extremely influences." Of the 150 respondents, 146 people answered and 4 people skipped this question. Of note, more than half of respondents (56.94%, 82 people) say that freshness **extremely** influences their decision to buy seafood. In addition, the majority of respondents (over 80%) say that quality assurance and environmental impact very much influence or extremely influence their decisions, and 66.43% are very much to extremely influenced by locally sourced seafood. Price and consistently available are slightly skewed normal distributions with price leaning towards influential and consistently available leaning towards less of an influence. Fifty percent of respondents selected price as a barrier to accessing seafood in the previous question and we see that 45.77% of respondents selected it as influencing their purchases to some degree here.

Respondents were able to add any additional comments. There were a total of 5 comments, which were almost all health related. One respondent mentioned concern for mercury levels in general and antibiotics in farmed seafood. Another said they are “not educated deeply on the environmental impact but always try to buy locally.” There was one concern about the chemicals used to treat store-bought fish, such as formalin, and another respondent mentioned prioritizing nutritional value and lack of toxins.

Question 10

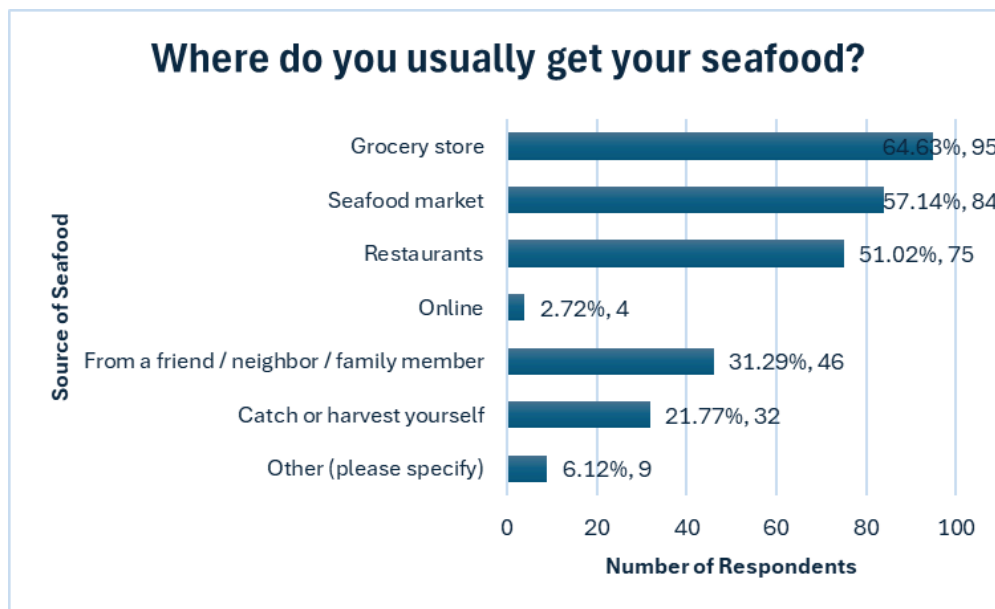


Figure 29: Places respondents get their seafood. Many respondents get their seafood from grocery stores, seafood markets, and restaurants.

In the last question on seafood consumption preferences, respondents were asked where they usually get their seafood from. Of the 150 respondents, 147 people answered and 3 people skipped this question. The top three places where respondents get their seafood are at the grocery store (64.63%, 95 people), seafood market (57.14%, 84 people), and restaurants (51.02%, 75 people). Just under a third of respondents (31.29%) get their seafood from a friend, neighbor, or family member (i.e., through informal pathways), and 21.77% of respondents catch or harvest their seafood themselves.

Of the respondents who selected “Other,” most referenced purchasing their seafood off the docks in Noyo Harbor. One person specifically mentioned an off-the-boat subscription. Other respondents said:

- “I work in Alaska and usually get my seafood up there,”
- “very rarely, we harvest mussels // too old to do other stuff,” and
- “Locals.”

Awareness and Perceptions of Aquaculture

Question 11

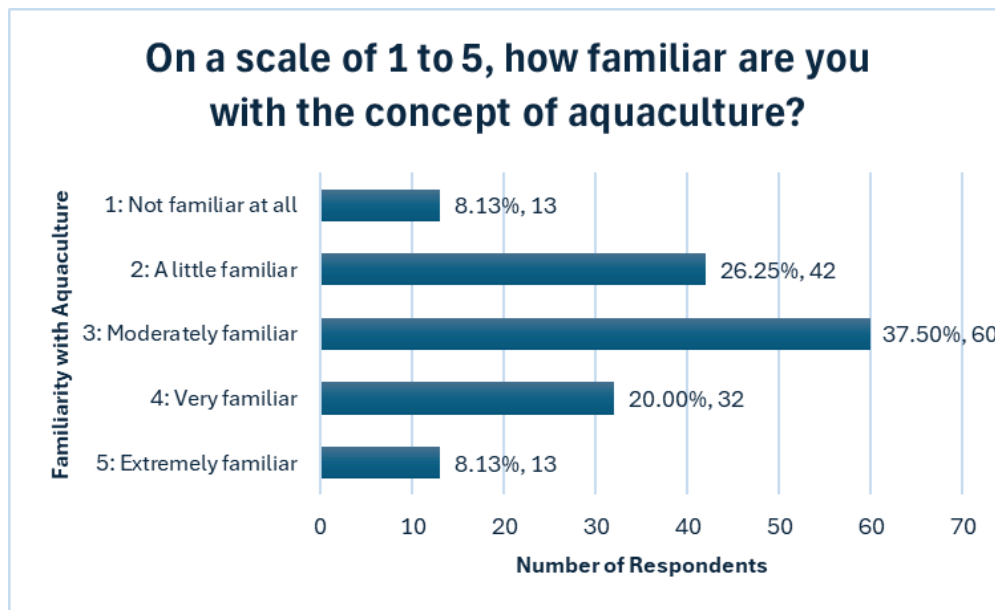


Figure 30: Respondents' familiarity with aquaculture. On average, respondents are moderately familiar with the concept of aquaculture.

In the first of six questions in this section, respondents were asked how familiar they are with the concept of aquaculture, on a scale of 1 to 5. This question was added to gauge the community's awareness of aquaculture. All respondents were directed to this question and all following sections of this survey. Of the 164 respondents to the survey, 160 people answered and 4 people skipped this question. The bar graph above is close to a normal distribution, meaning respondents, on average, have a moderate familiarity with aquaculture. Seeing as 26.25% of respondents are less familiar and 20.00% of respondents are very familiar with aquaculture, there is a slight skew towards less familiarity.

Question 12

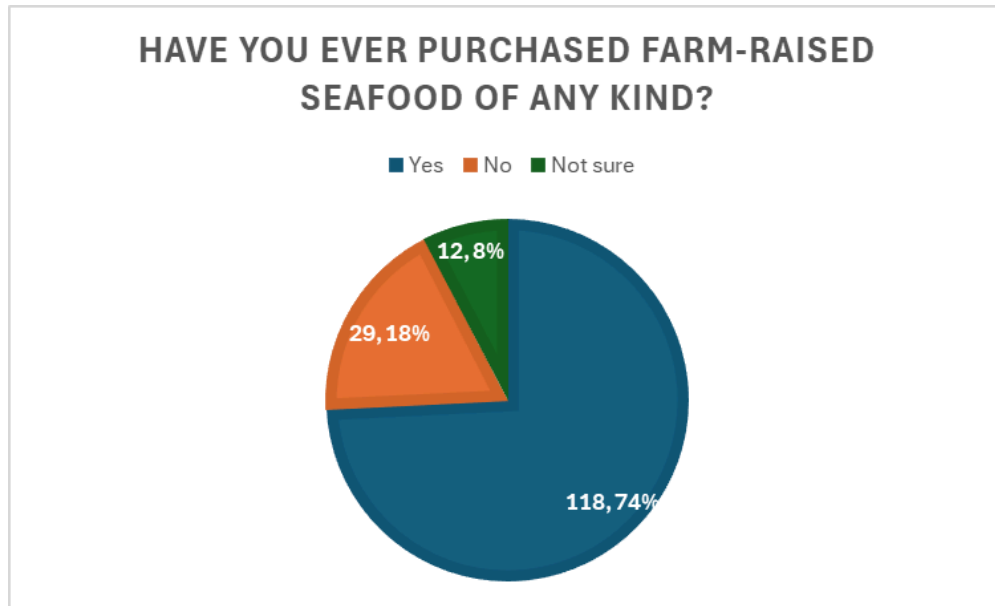


Figure 31: The number of respondents who have purchased farm-raised seafood. The vast majority of respondents have purchased farm-raised seafood.

Respondents were then asked if they have ever purchased farm-raised seafood of any kind. Of the 164 respondents, 159 people answered and 5 people skipped this question. The vast majority of respondents have eaten farm-raised seafood (74%, 118 people), while 18% of respondents (29 people) are sure they have not, and 8% of respondents (12 people) are not sure.

Question 13

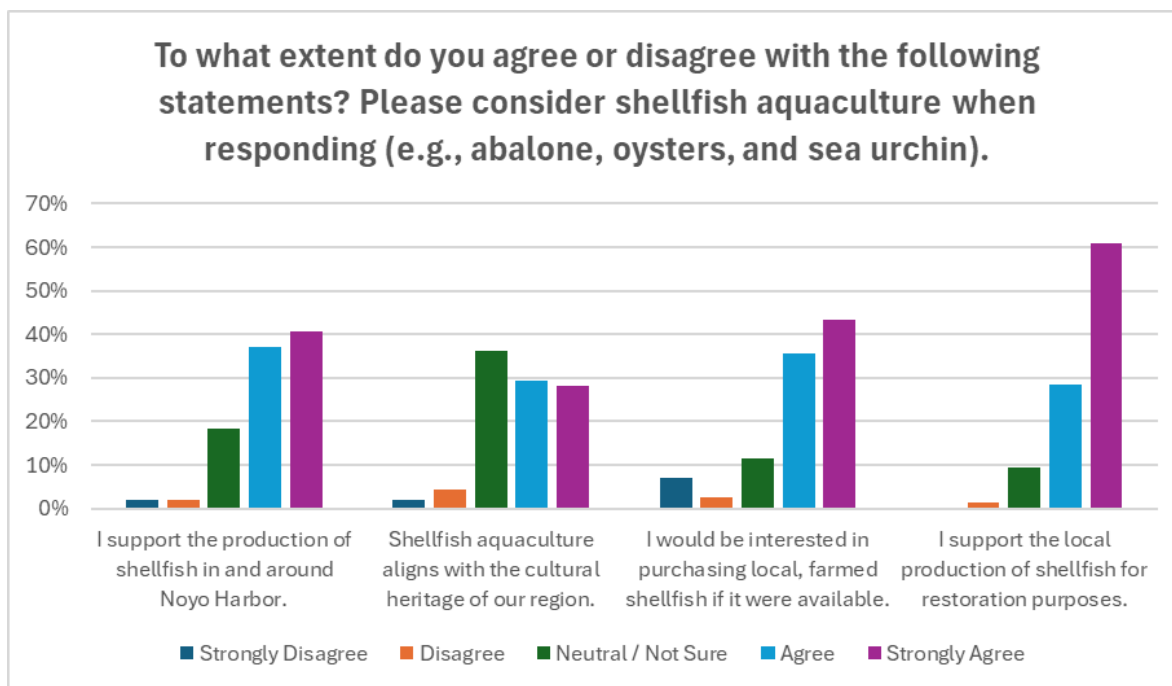


Figure 32: Perceptions of shellfish aquaculture given various scenarios. The majority of respondents support shellfish aquaculture for restoration and commercial purposes.

In the next two questions, respondents were asked the extent to which they agreed or disagreed with a series of statements. This question asked respondents to consider shellfish aquaculture when responding and provided abalone, oysters, and sea urchins as examples. The statements included: 1) I support the production of shellfish in and around Noyo Harbor; 2) Shellfish aquaculture aligns with the cultural heritage of our region; 3) I would be interested in purchasing local, farmed shellfish if it were available; and 4) I support the local production of shellfish for restoration purposes. Of the 164 respondents, 158 people answered and 6 people skipped this question.

The fourth statement was the most positively skewed distribution. 60.76% of respondents (96 people) **strongly** support the local production of shellfish for restoration purposes, and 89.24% of respondents (those who agreed and strongly agreed) are in support. Zero respondents strongly disagreed with this statement and two respondents said they disagreed. Two more statements are skewed positively: 78.71% of respondents agreed or strongly agreed that they are interested in purchasing local, farmed shellfish if it were available, and 77.70% agreed or strongly agreed they support the production of shellfish in and around Noyo Harbor. The most neutral responses were attributed to the statement: Shellfish aquaculture aligns with the cultural heritage of our region; but, even still, 57.33% of respondents answered in the affirmative (agreed or strongly agreed) and 6.37% of respondents said they disagreed or strongly disagreed. It is important to note that all of these statements were written as positive statements (i.e., “I support” rather than “I do not support”) which has the potential to introduce some bias.

Question 14

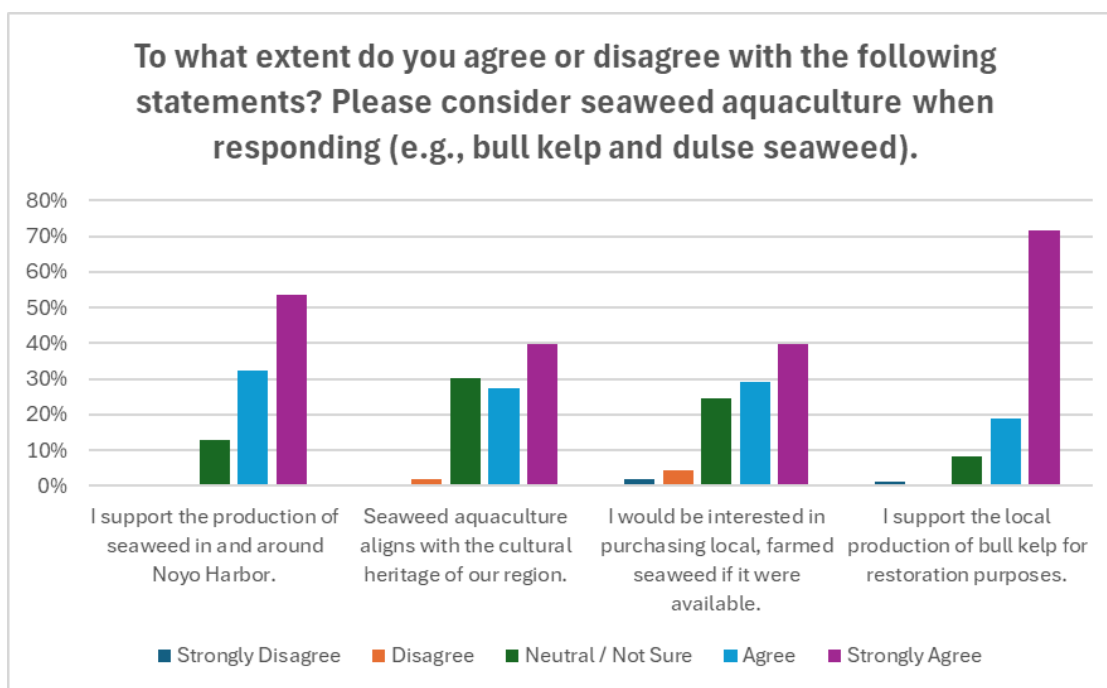


Figure 33: Perceptions of seaweed aquaculture given various scenarios. Almost all respondents support bull kelp aquaculture for restoration and the majority support commercial seaweed aquaculture.

In the next question, respondents were also asked the extent to which they agreed or disagreed with a series of statements. For this series, respondents were asked to consider seaweed aquaculture when responding and provided bull kelp and dulse seaweed as examples. The statements included: 1) I support the production of seaweed in and around Noyo Harbor; 2) Seaweed aquaculture aligns with the cultural heritage of our region; 3) I would be interested in purchasing local, farmed seaweed if it were available; and 4) I support the local production of bull kelp for restoration purposes. Of the 164 respondents, 158 people answered and 6 people skipped this question.

Responses to this question regarding seaweed production were similar to the above question about shellfish. The most skewed distribution is the fourth statement referencing restoration. 71.52% of respondents (113 people) **strongly** agree they support the local production of bull kelp for restoration purposes, and 90.51% of respondents (those who agreed and strongly agreed) are in support. Only two people strongly disagreed and zero disagreed with this statement. The two statements, “I support the production of seaweed in and around Noyo Harbor,” and “I would be interested in purchasing local, farmed seaweed if it were available,” were also positively skewed. 85.98% of respondents agreed or strongly agreed they support the production of seaweed in and around Noyo Harbor. Only 1.28% of respondents disagreed or strongly disagreed. 68.98% of respondents agreed or strongly agreed they are interested in purchasing local, farmed seaweed if it were available. Lastly, 30.38% of respondents were neutral about whether seaweed aquaculture aligns with the cultural heritage of our region, with 67.09% of respondents in the affirmative and 2.53% (4 people) strongly disagreed or disagreed.

Question 15

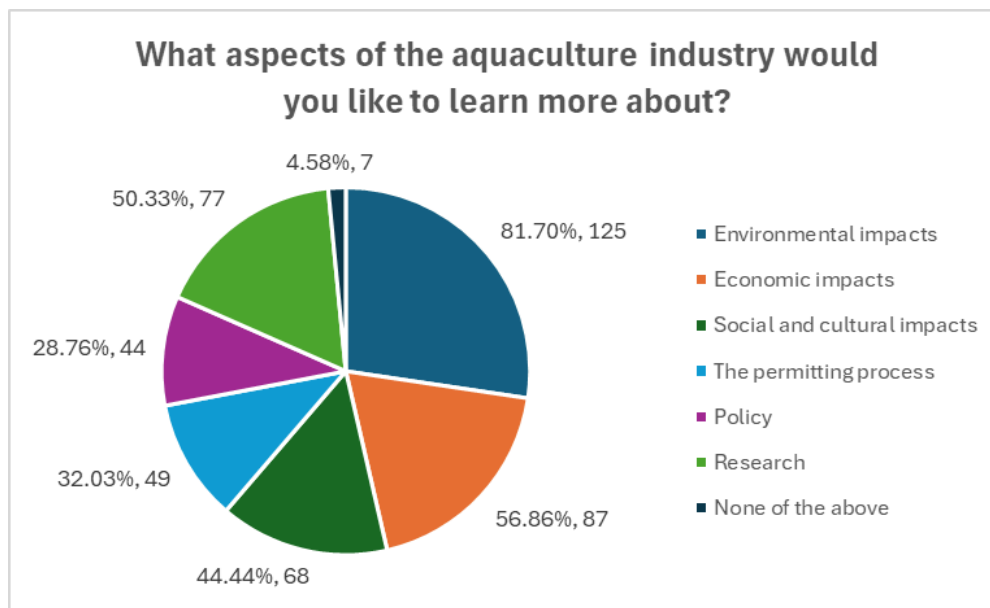


Figure 34: Aquaculture topic areas respondents want to know more about. The top two topics selected by respondents were environmental and economic impacts.

Respondents were asked what aspects of the aquaculture industry they'd like to learn more about. Answer choices were kept general to get an idea of where to focus outreach materials. Of the 164 respondents, 153 people answered and 11 people skipped this question. The top two topics selected by respondents were environmental and economic impacts, respectively.

Question 16

In the last question on awareness and perceptions of aquaculture, respondents were asked if they have any concerns about shellfish and/or seaweed aquaculture. This was an open-ended question, so respondents were free to share anything they wanted. Of the 164 respondents, 82 people answered and 82 people skipped this question. Twenty-nine respondents said they do not have any concerns, but some specified it's because they do not know enough about the topic. A couple of people simply said they are concerned and many people stated environmental impact as their main concern in general. One respondent stated, "I think aquaculture is similar to monoculture but aquatic, please change my mind." Several people referenced fish farming and either said they'd prefer shellfish and seaweed to finfish or asked how to ensure practices are more sustainable.

The three main topics of concern were water quality, impacts on wild populations, and public health. Many people were concerned about pollution, specifically what types of food go into the water, whether chemicals, pesticides, or fertilizers are used, and effluent. Some respondents said they think the river is already too polluted and want to know more about the potential contaminants in the water. One

respondent stated: “Noyo Harbor doesn’t seem very clean because of all the boats. Want my oysters and seaweed coming from a very unpolluted place. This is why I said “neutral” about supporting aquaculture in Noyo Harbor.” Others stated they didn’t want production to increase pollution and “further disrupt ecosystems.” There were also concerns that poorly managed and densely populated farms would spread disease to wild species. Salmon farming was mentioned multiple times in this regard as well as with concerns for public health. One respondent said, “We eat oysters; but I avoid farmed trout, shrimp, or salmon because of the possible use of chemicals/injections/pesticides in the production process. Would NOT knowingly eat farmed products unless purity/health could be guaranteed. And sustainable practices for the ecosystem.”

Other topics of concern included: co-existence with the existing commercial and recreational fishermen and harvesters, whether it is economically worthwhile, accessibility of permitting, loss of public coastal access, and unforeseen impacts of scaling up operations. Individual respondents also mentioned concerns for gentrification, aesthetics, industrialization, and harm to animals. Specific questions that respondents had are listed below:

- “There is already abundantly harvested WILD local seaweed. How would farming affect these harvesters?”
- “According to the Monterey Bay Aquarium, there are big risks with farmed fishing. How would we be sure not to create negative impacts on biodiversity and the environment?”
- “How clean is the river?”
- “What chemicals are used in production? Synthetic, pesticides, types of fertilizer, food.”

Willingness to Pay

In this series of questions, respondents were asked how much they would be willing to pay for locally grown red abalone and purple sea urchins. There was context provided for respondents for each question. For red abalone, it was noted that wild red abalone average 8 inches in shell length and weigh about 1lb, while farmed red abalone are commonly sold at 3-4 inches and weigh about 1/4lb. This information was provided so respondents could consider size when considering price. For purple sea urchins, a description of the shift from kelp forests to urchin barrens and a definition of urchin ranching was provided to highlight the conservation element of farming urchins. Both questions were multiple choice with a range of prices and “None of the above” and “Other (please specify)” options. Of the 164 respondents, 154 people answered the question regarding red abalone and 153 people answered the question regarding purple sea urchins. Responses were similar for both questions.

Roughly half of respondents opted to provide an alternative answer in the comments section or selected “None of the above.” Several respondents said they either do not eat abalone or urchin or weren’t sure how much they would pay. A few respondents mentioned being unfamiliar with pricing because they had never purchased them before, while others had never eaten them before. Additionally, several respondents said it depends on quality, environmental conditions, and the growing process, and they would most likely eat abalone for special occasions. A few other respondents said they would purchase them at whatever the market price is, while others said they would prefer to dive for and harvest abalone and urchin themselves. One respondent shared, “I probably wouldn’t buy it due to cost, especially after 25 years of eating abalone I harvested for free.”

Question from Fishermen's Survey

In a separate survey designed specifically for commercial and recreational fishermen and fish processors in Noyo Harbor, respondents were asked whether they would be interested in working in aquaculture or other ocean-based industries to supplement fishing incomes. In total, 241 people responded to this survey. Of the 241 respondents, 215 people answered and 26 people skipped this question. Overall, 69 people responded "Yes" (about 32.09% of respondents), 138 people responded "No" (about 64.19% of respondents), and 8 people responded "N/A" (about 3.72% of respondents). The "N/A" answer choice was included for recreational fishermen who are not selling their catch. There was also a "Depends on" comment box.

To further understand the sentiments of commercial fishermen, a filter was added to only show responses from those who stated in a previous question that they were commercial fishermen or both commercial and recreational fishermen. There were a total of 58 commercial fishermen who took this survey. From those responses, 48 people answered and 10 people skipped this question. 24 commercial fishermen (50%) responded "Yes," they are interested, and 24 commercial fishermen (50%) responded "No," they are not interested.

Next, a second filter was added on top of the first filter. We wanted to know how many commercial fishermen who live within 50 miles of Fort Bragg were interested in working in aquaculture or other ocean-based industries to supplement their fishing income. Of the 46 respondents in this pool, 36 people answered and 10 people skipped this question. Sixteen people (44.44%) said they are interested and 20 people (55.56%) said they are not interested.

There were 7 comments from commercial fishermen. Two respondents selected "Yes" and used the comment box to add either they were already involved in urchin ranching or needed more information. Two respondents selected "No" and stated, "too old" and "big no." Three respondents used the "Depends on:" comment box. They weren't sure, wanted to be able to use their boats, and wanted to know specifics on the industry.

5. Opportunities & Next Steps

Oyster Nurseries

Oysters ranked among the top five seafoods that respondents regularly eat and wish they could eat more often, and findings from both trials revealed that Pacific oysters can survive and grow in Noyo Harbor. Currently, oysters are grown in Humboldt Bay, Tomales Bay, Morro Bay, and San Diego Bay in California. These areas are approved aquaculture areas, meaning they have gone through extensive environmental, social, and economic review and are suitable for commercial aquaculture. Noyo Harbor has not undergone the process to become an approved area, but there is still opportunity to develop oyster nurseries that provide oyster seed to grow-out operations in those areas. Hatchery-reared oyster spat can be grown out to seed, then sold to companies for the remainder of the grow-out process to market size. Having an additional source of oyster seed stock is an important risk-management measure for

farms, providing redundancy to ensure a consistent supply and contingencies in the case of disease or biosecurity risks.

Urchin Ranching

There are options for both in-water and land-based urchin ranching due to their seasonal production. It typically takes 12 to 16 weeks to condition uni to market quality. In Trial 2 of the in-water experimentation, the project team found that urchin roe can be successfully enhanced to a GSI of 10% or greater within 17 weeks. These findings suggest that there could be two production cycles in-water before the winter rains, and urchin can be transferred to a land-based facility for another production cycle during the winter months. Future studies can focus on minimizing conditioning time to add another in-water production cycle to potentially reach four production cycles per year. Alternatively, purple urchins can be ranched entirely in a land-based facility.

The major practical lessons learned from the Noyo Center's land-based RAS system, urchin ranching feed trials, and dulse tumble culture include:

- estuarine water can support land-based aquaculture but requires monitoring and adjustment,
- conservative stocking density is essential for system stability,
- biofiltration capacity must be scaled gradually with biomass,
- agricultural feed can effectively support urchin conditioning,
- system design strongly influences maintenance efficiency, and
- integrated macroalgal culture is feasible but requires careful environmental control.

While agricultural produce feed types demonstrated effectiveness in supporting gonad growth, they may function better as a supplemental or short-term finishing diet rather than the primary feed. Using or supplementing with pellets during the initial conditioning phase may further reduce time to market and result in a higher GSI. The Noyo Center plans to implement a mixed or phased feeding trial in summer 2026, using pellets as the primary growth diet followed by finishing feeds of kale or dulse to enhance gonad texture and coloration.

Research is still needed to help establish best management practices that minimize spawning to maintain continuous marketable gonad quality once urchins reach market size. Establishing a profitable urchin ranch will also require developing strategies for a year-round supply of urchin, with reliable collection being difficult in rough weather during the winter months. Commercialization is further challenged by the lack of an established market for purple sea urchin. Developing a viable supply chain will require collaboration with the Sea Urchin Commission, processors, and buyers. Marketing “restorative seafood” that supports kelp restoration has a strong potential but is in a nascent phase currently.

Culturing red abalone for restoration and food

Red abalone ranked among the top three seafoods respondents wish they could eat more often. However, the species is classified as critically endangered by the International Union for Conservation of Nature, and the recreational fishery closure has been extended to 2036. Currently, abalone farms

provide the only red abalone available to eat. Given ongoing restoration needs, there are restoration and commercial opportunities for red abalone aquaculture.

In late 2024, California Sea Grant launched “Engaging North Coast Communities in Red Abalone Restoration: A Feasibility Study,” to gauge interest in a community-driven restoration project. As a reference point, the project team looked into the Ocean Resources and Enhancement Hatchery Program’s (OREHP) white seabass stocking program in Southern California and how that might be reimagined for red abalone in Mendocino and Sonoma counties. An informational flyer was developed with an explanation of what happened to red abalone in California, and a survey was circulated to gather community perspectives on the overall concept of a community-driven restoration project and preferences for how the project should be carried out. Insights from the study are coming soon and will help inform prospective next steps. The goal is to develop strong partnerships, identify the scope of the project, infrastructure and resources needed, potential sources of funding, and how to integrate a community-driven project into state restoration initiatives (e.g., CDFW red abalone recovery plan).

In terms of production in Noyo Harbor, there are options for hybrid in-water and land-based operations or completely land-based operations. Red abalone survived and grew in suspended culture in the river for 7 months, from when they were put in the water in late spring to early winter. Fort Bragg typically receives heavy rainfall in early winter, with an influx of freshwater into the river and salinity levels that drop to 0 ppt, in some cases for multiple days. Seeing as these conditions are not conducive to abalone survival, abalone would need to be transferred to a land-based facility for winter and early spring. Alternatively, red abalone can be cultured entirely in a land-based facility, in either a flow through or recirculating aquaculture system.

Support local bull kelp restoration activities by building local capacity

The vast majority of survey respondents strongly support bull kelp aquaculture for restoration. When provided with a series of statements about seaweed aquaculture and asked the extent to which they agreed or disagreed, 71.52% of respondents (113 people) strongly support the local production of bull kelp for restoration and 18.99% of respondents (30 people) support the idea, for a total of 90.51% (143 people). The majority of respondents also supported the production of seaweed in and around Noyo Harbor and would be interested in purchasing local farm raised seaweed if it were available. Overall, these findings suggest there is strong public support for these initiatives.

To support restoration efforts, there is a need for increased scientific understanding and infrastructure development to know what is possible in the harbor and region. Throughout this process, the project team was able to obtain a permit to test bull kelp survivorship and growth in-situ in the Noyo River basin and gain a better understanding of survivorship and growth requirements. Results from the bull kelp trials suggest that bull kelp should be tested earlier in the year. Due to permitting challenges, bull kelp went into the water in late August, but future trials should be conducted in early Spring, more closely following bull kelp’s natural life cycle. In the short term, there is opportunity to continue in-situ studies in the Noyo River basin as well as obtain permits for land-based tanks, to continue experimentation and provide a place to hold kelp before it is outplanted. The long term vision is to build local capacity and

provide a secondary source of local seed stock. This could include the development of a hatchery, nursery tanks, and space to grow kelp to outplanting size that will support the state's kelp outplanting initiatives.

Saltwater Intake

The region does not have a saltwater intake system, which significantly limits opportunities for land-based aquaculture. Saltwater intake refers to a system that draws seawater from the ocean to land-based facilities through a system of pipes, pumps, and filtration. This infrastructure provides a consistent and reliable source of seawater, independent of tide and weather availability. Currently, water for the Noyo Center's land-based RAS installation is pumped from the bottom of the river at high tide to retrieve the most saline water. During winter months, when there is an influx of freshwater into the river, instant ocean (i.e., salt) is added to the water to increase salinity. A saltwater intake system near the mouth of the river or open ocean would reduce operational complexity and costs. The system would benefit many stakeholders and provide an opportunity to scale up operations in and around the harbor.

Pre-permitting structure to reduce barriers to enter the industry

Permitting in California is a time-consuming, expensive, and complex process, and can be a significant barrier to entry for small-scale aquaculture businesses and operations that do not have these resources. To begin addressing this challenge, four ports in California have pioneered a pre-permitting structure, where the Port or Harbor District holds the permit and sub-leases space to farmers to streamline regulatory review (California Sea Grant, 2025). For example, in 2016, the Humboldt Bay Harbor, Recreation and Conservation District obtained subtidal permits in three zones of the bay (about 6-9 acres) and now leases out space to four aquaculture operations cultivating oysters, bull kelp, sugar kelp, and red seaweed. Noyo Harbor is significantly smaller than Humboldt Bay, but there is still opportunity for Noyo Harbor District to hold permits in areas within its jurisdiction to support small-scale commercial ventures and restoration initiatives - streamlining the process and reducing barriers.

Invest in local workforce

As part of the Pacific Coast Ocean Restoration (PCOR) Initiative Workforce Development Workstream, the City of Fort Bragg is working with The Nature Conservancy, Mendocino College, and Noyo Harbor District to support the development of marine science curriculum and physical infrastructure needed to support careers in marine restoration. PCOR is a statewide initiative that primarily focuses on bull kelp restoration, white abalone production and outplanting, sunflower sea star captive breeding, and piloting a workforce development program in Mendocino County, California. The City plans to continue working with the PCOR network on public outreach and applied learning opportunities. To learn more about the PCOR Initiative and network, visit <https://noyooceancollective.org/rocky-reef-restoration-workforce/>.

Additionally, the City partnered with Mendocino High School, the Noyo Ocean Collective, Primitives Biodesign, and local industry and community members to pilot the Blue Economy Youth Leadership Program. The program was an opportunity to introduce students to different blue economy topics (e.g., aquaculture, sustainable fisheries, climate resiliency, blue technology, public access and the Coastal Act, etc.) through hands-on learning, exposure to career pathways, and by meeting local experts in the field. The program consisted of a classroom visit to introduce key concepts, a field trip to Noyo Harbor, and student research presentations. It was designed to be replicable and adaptable to teacher needs, student interests, and presenter availability, and a community-led program that is representative of the people and industry in Noyo Harbor. There are opportunities to keep this program going as well as support field trips and internships in these fields.

To gauge how many seafood producers might be interested in participating in other industries, including aquaculture, we pulled one question from the BEVRI Plan's Fishermen's Survey. This survey was designed specifically for commercial and recreational fishermen and fish processors working and recreating in Noyo Harbor. Respondents were asked whether they would be interested in working in aquaculture or other ocean-based industries to supplement fishing incomes. Findings showed that 16 commercial fishermen who live within 50 miles of Fort Bragg are interested. Given these responses, although general, there is opportunity to continue the conversation.

Public Outreach

Based on the community survey, respondents are moderately familiar with the concept of aquaculture, and the vast majority have eaten, and know they have eaten, aquaculture products of some kind. There is a lot of support specifically for local shellfish and seaweed aquaculture but still concerns that can be addressed. Concerns largely stem from potential changes in water quality, impacts on wild populations, and whether aquaculture products are safe for consumption. Some people said they did not know enough to explicitly state any concerns, and the number one topic respondents want to learn more about is environmental impacts. Therefore, there are opportunities to share information on how specific species of shellfish and seaweed are grown (e.g., inputs, outputs, and stages of production) and how these farms operate and interact with the local environment.

Respondents were also interested in learning more about the economic impact of the industry. When asked how much they would be willing to pay for local, farm-raised red abalone and purple sea urchins, many people needed more information to decide because they were unfamiliar with the market. Some respondents have never purchased or eaten these species before. Some were willing to pay the market rate but were not sure what that was, and others were willing to pay a little more if the seafood was local, sustainably grown, and did not pollute the environment. Overall, there is also opportunity to share information on the market, how commercial aquaculture plays into larger conservation efforts, and taste test some products.

6. Appendix

Appendix A: Survivorship Data

Pacific Oysters

Table 1: Trial 1 oyster survivorship from January 15 to August 19, 2025 at the Noyo Center and Silver's locations.

Date	Noyo Center Mortalities	Noyo Center Total Count	Noyo Center Survivorship (%)	Silver's Mortalities	Silver's Total Count	Silver's Survivorship (%)
1/15/25	0	531	100.00	0	530	100.00
2/12/25	0	531	100.00	1	529	99.81
3/20/25	0	531	100.00	2	527	99.43
4/18/25	1	530	99.81	1	526	99.25
5/15/25	0	530	99.81	1	525	99.06
6/12/25	0	530	99.81	1	524	98.87
7/21/25	5	525	98.87	0	524	98.87
8/19/25	1	524	98.68	1	523	98.68

Table 2: Trial 2 oyster survivorship from September 8, 2025 to January 12, 2026 at the Noyo Center and Silver's locations.

Date	Noyo Center Mortalities	Noyo Center Total Count	Noyo Center Survivorship (%)	Silver's Mortalities	Silver's Total Count	Silver's Survivorship (%)
9/8/25	0	568	100.00	0	568	100.00
10/6/25	0	568	100.00	0	568	100.00
11/10/25	0	568	100.00	0	568	100.00
12/9/25	0	200	100.00	0	200	100.00
1/12/26	1	199	99.50	0	200	100.00

Red Abalone

Table 3: Abalone survivorship from May 14 to December 24, 2025.

Date	Mortalities	Total Count	Survivorship (%)
5/14/25	0	43	100.00
6/11/25	0	43	100.00
7/19/25	0	43	100.00
8/19/25	0	43	100.00
9/15/25	0	43	100.00
10/21/25	0	43	100.00
11/14/25	0	43	100.00
12/15/25	0	43	100.00
12/24/25	43	0	0.00

Purple Sea Urchins

Table 4: Purple sea urchin survivorship from May 28 to September 15, 2025.

Date	Mortalities	Total Count	Survivorship (%)
5/28/25	0	20	100.00
6/11/25	0	20	100.00
6/17/25	1	19	95.00
6/23/25	1	18	90.00
6/27/25	1	17	85.00
7/19/25	0	17	85.00
8/20/25	0	17	85.00
9/15/25	0	17	85.00

Bull Kelp

Table 5: Trial 1 bull kelp survivorship from August 20 to September 1, 2025.

Date	Mortalities	Total Count	Survivorship (%)
8/20/25	0	51	100.00
8/25/25	3	48	94.12
8/28/25	11	40	78.43
9/1/25	26	25	49.02

Table 6: Trial 2 bull kelp survivorship from September 7 to October 2, 2025.

Date	Mortalities	Total Count	Survivorship (%)
9/7/25	0	50	100.00
9/11/25	2	48	96.00
9/16/25	19	31	62.00
9/19/25	23	27	54.00
9/22/25	28	22	44.00
9/25/25	34	16	32.00
9/29/25	37	13	26.00
10/2/25	39	11	22.00

Table 7: Trial 3 bull kelp survivorship from October 6 to October 20, 2025.

Date	Mortalities	Total Count	Survivorship (%)
10/6/25	0	47	100.00
10/10/25	13	34	72.34
10/14/25	25	22	46.81
10/17/25	35	12	25.53
10/20/25	41	6	12.77

Appendix B: Length & Weight Measurements

Pacific Oysters

Table 8: Trial 1 average oyster shell length and whole weight measurements from January 15 to August 19, 2025, at the Noyo Center and Silver's locations.

Date	Number of tagged oysters	Noyo Center Length (mm)	Silver's Length (mm)	Noyo Center Weight (g)	Silver's Weight (g)
1/15/25	NC=40; S=40	28.2	28.5	2.59	2.46
2/12/25	NC=40; S=40	29.8	30.9	2.63	2.72
3/20/25	NC=40; S=40	32.4	33.7	2.71	2.96
4/18/25	NC=40; S=40	32.8	35.1	2.83	3.01
5/15/25	NC=40; S=40	33.7	35.5	3.00	3.14
6/12/25	NC=37; S=40	36.9	39.1	3.97	3.81
7/21/25	NC=36; S=38	46.2	47.2	6.41	6.29
8/19/25	NC=32; S=38	47.2	52.7	8.02	8.73

Table 9: Trial 2 average oyster shell length and whole weight measurements from September 8 to January 12, 2025, at the Noyo Center and Silver's locations.

Date	Number of tagged oysters	Noyo Center Length (mm)	Silver's Length (mm)	Noyo Center Weight (g)	Silver's Weight (g)
9/8/25	NC=40; S=40	43.43	45.78	5.33	5.34
10/6/25	NC=39; S=40	51.72	54.30	9.03	9.67
11/10/25	NC=34; S=39	61.24	64.33	13.44	14.37
12/9/25	NC=32; S=35	60.91	61.40	13.76	14.59
1/12/26	NC=24; S=24	59.25	60.13	12.95	13.83

Red Abalone

Table 10: Abalone average shell length and whole weight measurements from May 14 to December 15, 2025.

Date	Length (mm)	Weight (g)
5/14/25	38.07	15.91
6/11/25	39.23	12.23
7/19/25	39.33	12.51
8/19/25	41.44	13.97
9/15/25	42.72	14.70
10/21/25	43.49	15.94
11/14/25	45.67	18.80
12/15/25	45.47	19.12

Purple Sea Urchins

Table 11: Purple sea urchin average test diameter, height, and whole weight measurements from May 28 to September 15, 2025.

Date	Average Length (mm)	Average Height (mm)	Average Weight (g)
5/28/25	71.8	41.2	135.0
6/11/25	75.2	43.4	135.4
7/19/25	74.2	41.4	141.4
8/20/25	73.7	41.6	144.2
9/15/25	74.6	41.9	144.9

Bull Kelp

Table 12: Trial 1 bull kelp average total length measurements from August 8 to September 1, 2025.

Date	Length (mm)
8/20/25	189.31
8/25/25	207.71
8/28/25	179.78
9/1/25	96.6

Table 13: Trial 2 bull kelp average total length measurements from September 7 to October 2, 2025.

Date	Length (mm)
9/7/25	262.66
9/11/25	286.88
9/16/25	299.13
9/19/25	251.48
9/22/25	245.45
9/25/25	252.81
9/29/25	259.46
10/2/25	257.73

Table 14: Trial 3 bull kelp average total length measurements from October 6 to October 20, 2025.

Date	Length (mm)
10/6/25	164.74
10/10/25	137.15
10/14/25	98.36
10/17/25	99.67
10/20/25	102

Appendix C: Growth Rate Data

Pacific Oysters

Table 15: Trial 1 oyster growth rates at the Noyo Center location from January 15 to August 19, 2025.

Date	Daily Growth (mm/day)	Monthly Growth (mm/month)	Cumulative Length (mm)	Daily Growth (g/day)	Monthly Growth (g/month)	Cumulative Weight (g)
1/15/25	—	—	0	—	—	0
2/12/25	+0.057	+1.71	+1.6	+0.00143	+0.043	+0.04
3/20/25	+0.072	+2.16	+4.2	+0.00222	+0.067	+0.12
4/18/25	+0.014	+0.42	+4.6	+0.00414	+0.124	+0.24
5/15/25	+0.033	+0.99	+5.5	+0.00630	+0.189	+0.41
6/12/25	+0.114	+3.42	+8.7	+0.03464	+1.039	+1.38
7/21/25	+0.239	+7.17	+18.0	+0.08851	+2.655	+3.82
8/19/25	+0.034	+1.02	+19.0	+0.05552	+1.666	+5.43

Table 16: Trial 1 oyster growth rates at the Silver's location from January 15 to August 19, 2025.

Date	Daily Growth (mm/day)	Monthly Growth (mm/month)	Cumulative Length (mm)	Daily Growth (g/day)	Monthly Growth (g/month)	Cumulative Weight (g)
1/15/25	—	—	0	—	—	0
2/12/25	+0.086	+2.58	+2.4	+0.00929	+0.279	+0.26
3/20/25	+0.078	+2.34	+5.2	+0.00667	+0.200	+0.50
4/18/25	+0.048	+1.44	+6.6	+0.00139	+0.042	+0.55
5/15/25	+0.015	+0.45	+7.0	+0.00481	+0.144	+0.68
6/12/25	+0.129	+3.87	+10.6	+0.02393	+0.718	+1.35
7/21/25	+0.208	+6.24	+18.7	+0.06333	+1.900	+3.83
8/19/25	+0.190	+5.70	+24.2	+0.08414	+2.524	+6.27

Table 17: Trial 2 oyster growth rates at the Noyo Center location from September 8, 2025 to January 12, 2026.

Date	Daily Growth (mm/day)	Monthly Growth (mm/month)	Cumulative Length (mm)	Daily Growth (g/day)	Monthly Growth (g/month)	Cumulative Weight (g)
9/8/25	—	—	0	—	—	0
10/6/25	+0.296	+8.9	+8.29	+0.132	+4.0	+3.70
11/10/25	+0.272	+8.2	+17.81	+0.126	+3.8	+8.11
12/9/25	-0.011	-0.3	+17.48	+0.011	+0.3	+8.43
1/12/26	-0.049	-1.5	+15.82	-0.024	-0.7	+7.62

Table 18: Trial 2 oyster growth rates at the Silver's location from September 8, 2025 to January 12, 2026.

Date	Daily Growth (mm/day)	Monthly Growth (mm/month)	Cumulative Length (mm)	Daily Growth (g/day)	Monthly Growth (g/month)	Cumulative Weight (g)
9/8/25	—	—	0	—	—	0
10/6/25	+0.304	+9.1	+8.52	+0.155	+4.7	+4.33
11/10/25	+0.287	+8.6	+18.55	+0.134	+4.0	+9.03
12/9/25	-0.101	-3.0	+15.62	+0.001	+0.2	+9.25
1/12/26	-0.037	-1.1	+14.35	-0.022	-0.7	+8.49

Red Abalone

Table 19: Abalone growth rates from May 14 to December 15, 2025.

Date	Daily Growth (mm/day)	Monthly Growth (mm/month)	Cumulative Length (mm)	Daily Growth (g/day)	Monthly Growth (g/month)	Cumulative Weight (g)
5/14/25	—	—	0	—	—	0
6/11/25	+0.04	+1.26	+1.16	-0.13	-4.00	-3.68
7/19/25	+0.00	+0.08	+1.26	+0.01	+0.22	-3.40
8/19/25	+0.07	+2.07	+3.37	+0.05	+1.43	-1.94
9/15/25	+0.05	+1.44	+4.65	+0.03	+0.82	-1.21
10/21/25	+0.02	+0.65	+5.42	+0.03	+1.05	+0.03
11/14/25	+0.09	+2.76	+7.60	+0.12	+3.63	+2.89
12/15/25	-0.01	-0.20	+7.40	+0.01	+0.31	+3.21

Purple Sea Urchins

Table 20: Purple sea urchin test diameter and height growth rates from May 28 to September 15, 2025.

Date	Test Diameter Daily Growth (mm/day)	Test Diameter Monthly Growth (mm/month)	Cumulative Test Diameter Length (mm)	Test Height Daily Growth (mm/day)	Test Height Monthly Growth (mm/month)	Cumulative Test Height Weight (mm)
5/28/25	—	—	0	—	—	0
6/11/25	+0.243	7.29	+3.4	+0.157	+4.71	+2.2
7/19/25	-0.026	-0.78	+2.4	-0.053	-1.59	+0.2
8/20/25	-0.016	-0.48	+1.9	0.006	+0.18	+0.4
9/15/25	+0.036	1.08	+2.8	0.010	+0.30	+0.7

Table 21: Purple sea urchin whole weight growth rates from May 28 to September 15, 2025.

Date	Daily Growth (g/day)	Monthly Growth (g/month)	Cumulative Weight (g)
5/28/25	—	—	0
6/11/25	+0.029	+0.87	+0.4
7/19/25	+0.158	+4.74	+6.4
8/20/25	+0.088	+2.64	+9.2
9/15/25	+0.027	+0.81	+9.9

Bull Kelp

Table 22: Trail 1 bull kelp daily growth rates from August 20 to September 1, 2025.

Date	Daily Growth Rate (mm/day)
8/20/25	—
8/25/25	+3.68
8/28/25	-9.31
9/1/25	-20.80

Table 23: Trail 2 bull kelp daily growth rates from September 7 to October 2, 2025.

Date	Daily Growth Rate (mm/day)
9/7/25	—
9/11/25	+6.06
9/16/25	+2.45
9/19/25	-15.89
9/22/25	-2.01
9/25/25	+2.45
9/29/25	+1.67
10/2/25	-0.58

Table 24: Trail 3 bull kelp daily growth rates from October 6 to October 20, 2025.

Date	Daily Growth Rate (mm/day)
10/6/25	—
10/10/25	-6.90
10/14/25	-9.70
10/17/25	+0.44
10/20/25	+0.78

Appendix D: Water Quality Data

Pacific Oysters

Field Station Top & Bottom (DO, Sal, Temp, Depth, Rain)

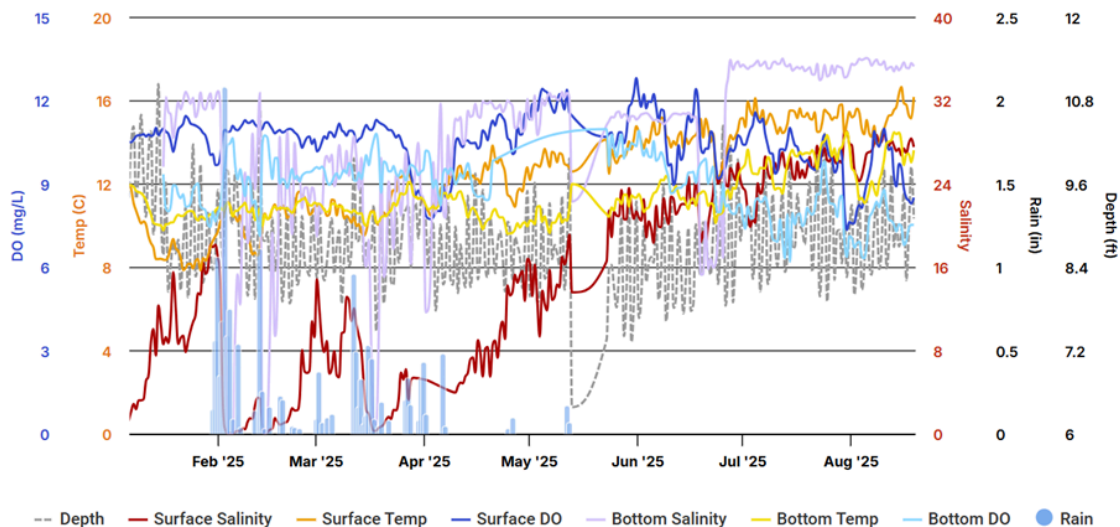


Figure 35: Temperature, salinity, dissolved oxygen, depth, and rain for Trial 1 of oysters, from January 7 to August 19, 2025.

Field Station Surface - All Parameters

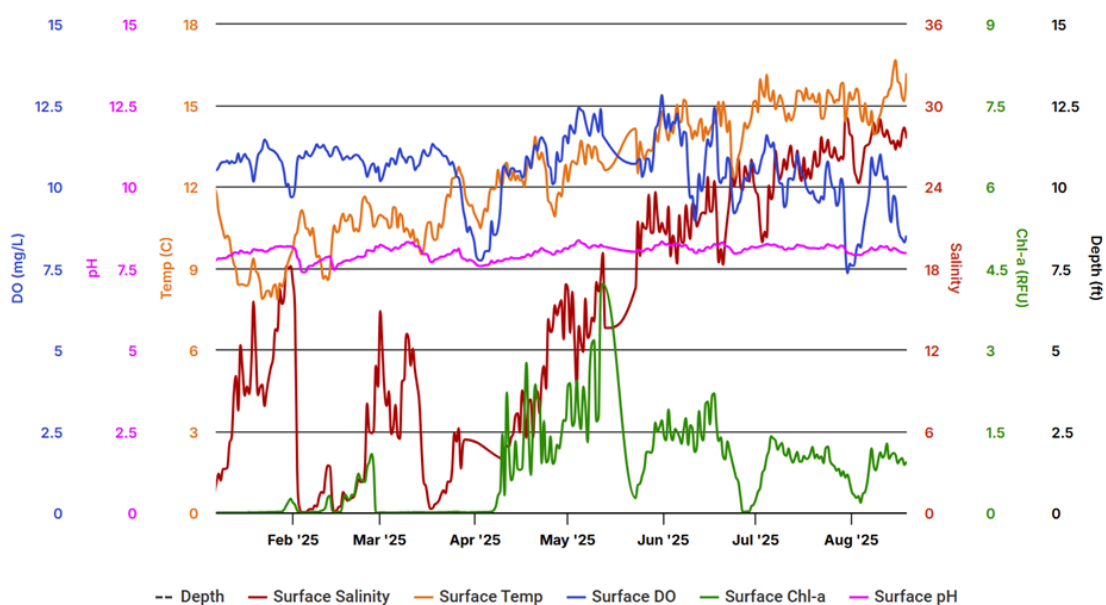


Figure 36: Surface data (temperature, salinity, DO, Chl-a, and pH) for Trial 1 of oysters, from January 7 to August 19, 2025.

Field Station Top & Bottom (DO, Sal, Temp, Depth, Rain)

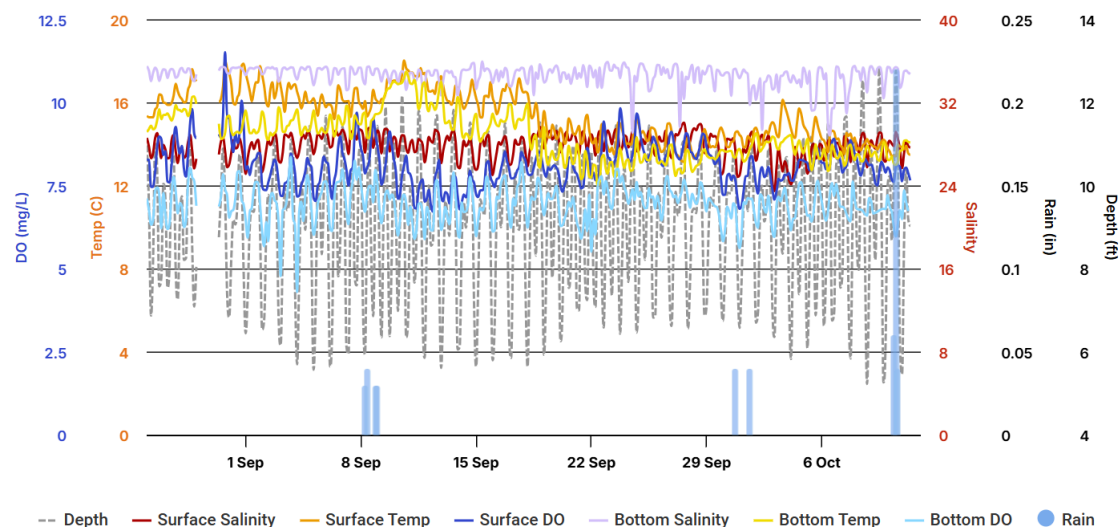


Figure 37: Temperature, salinity, dissolved oxygen, depth, and rain for portion of Trial 2 of oysters, from August 26 to October 12, 2025. The top and bottom sensors managed by LakeTech were removed from the water on October 11 and replaced with two of the sensors managed by the planning team. The remainder of the data for Trial 2 can be seen below (October through January).

Field Station Surface - All Parameters

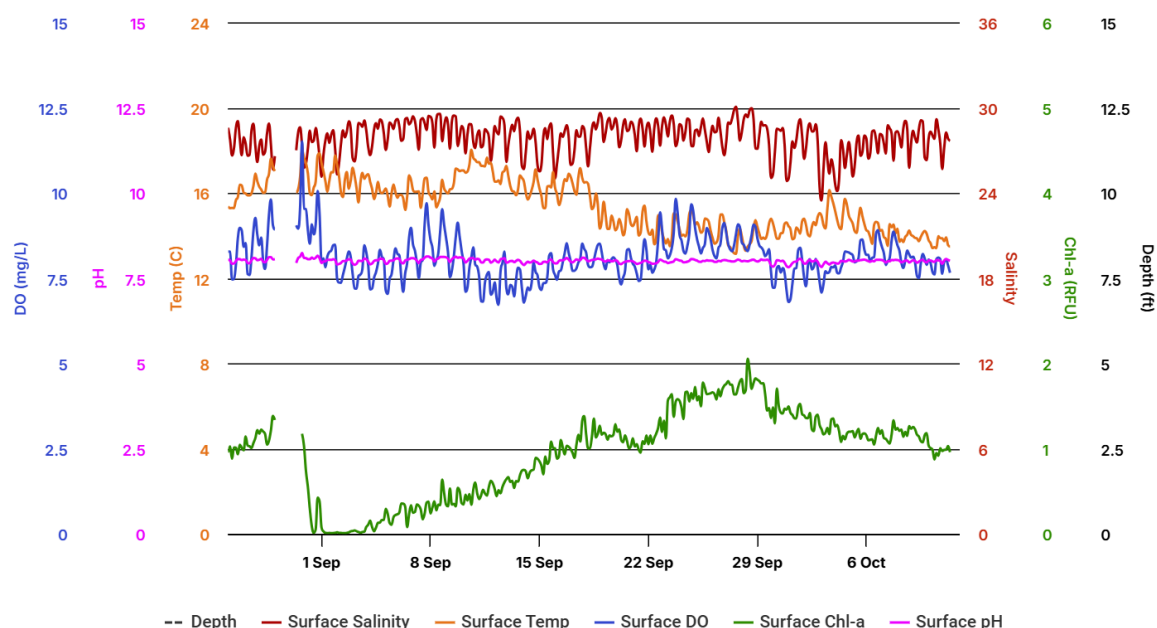


Figure 38: Surface data (temperature, salinity, DO, Chl-a, and pH) for portion of Trial 2 of oysters, from August 26 to October 12, 2025. The remainder of the data for Trial 2 can be seen below (October through January).



Figure 39: Temperature, salinity, and dissolved oxygen from October 11, 2025 to January 12, 2026. The green line is the bottom sensor and the blue line is the surface sensor.

Red Abalone & Purple Sea Urchins

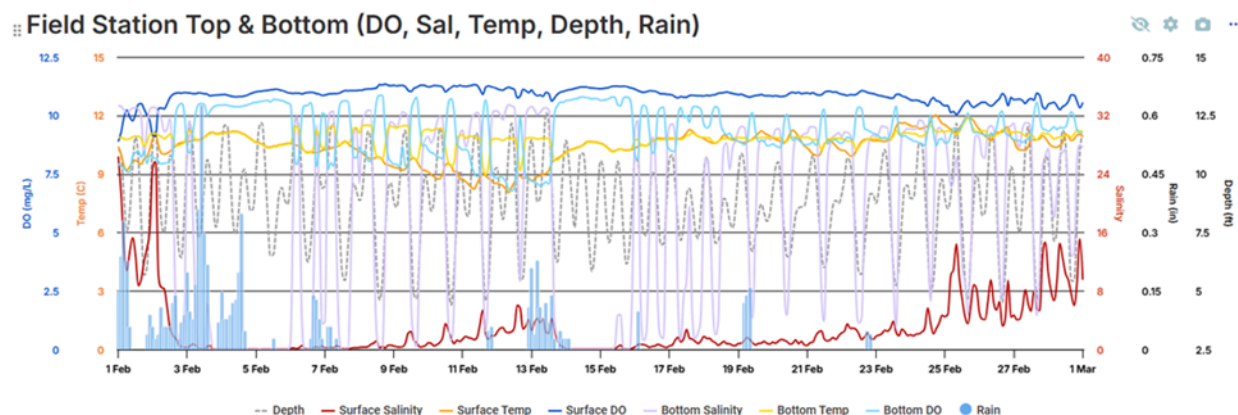


Figure 40: February 2025 rainfall event. During heavy rains, the salinity at the bottom of the harbor dropped to 0ppt on 2/2 from 8-10pm, 2/3 from 8am-2pm, and from 2/4 to 2/6 (a 3-day period).

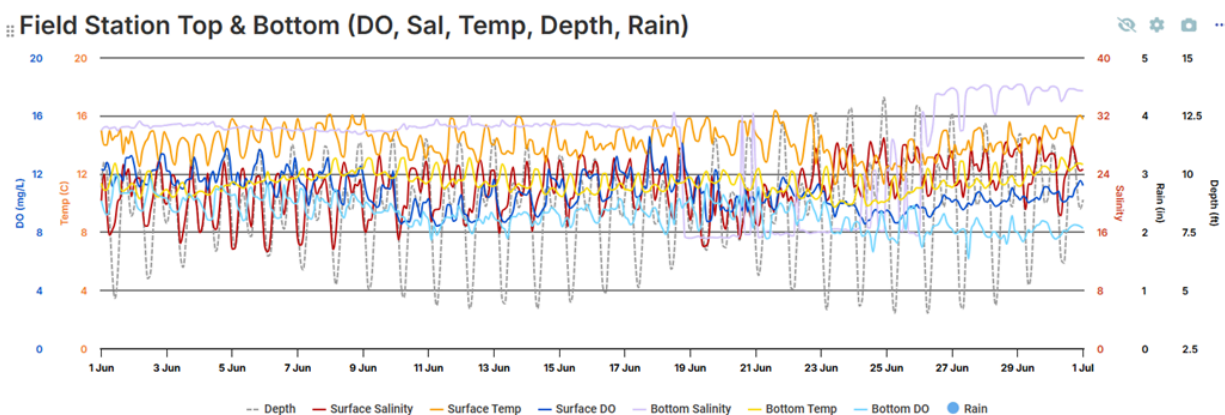


Figure 41: Temperature, salinity, dissolved oxygen, depth, and rain for the month of June 2025. There was an issue with the bottom sensor's salinity readings. After troubleshooting, the sensor was replaced on the 18th and the issues were fixed on the 26th. The three urchin mortalities occurred on June 17, 23, and 27.

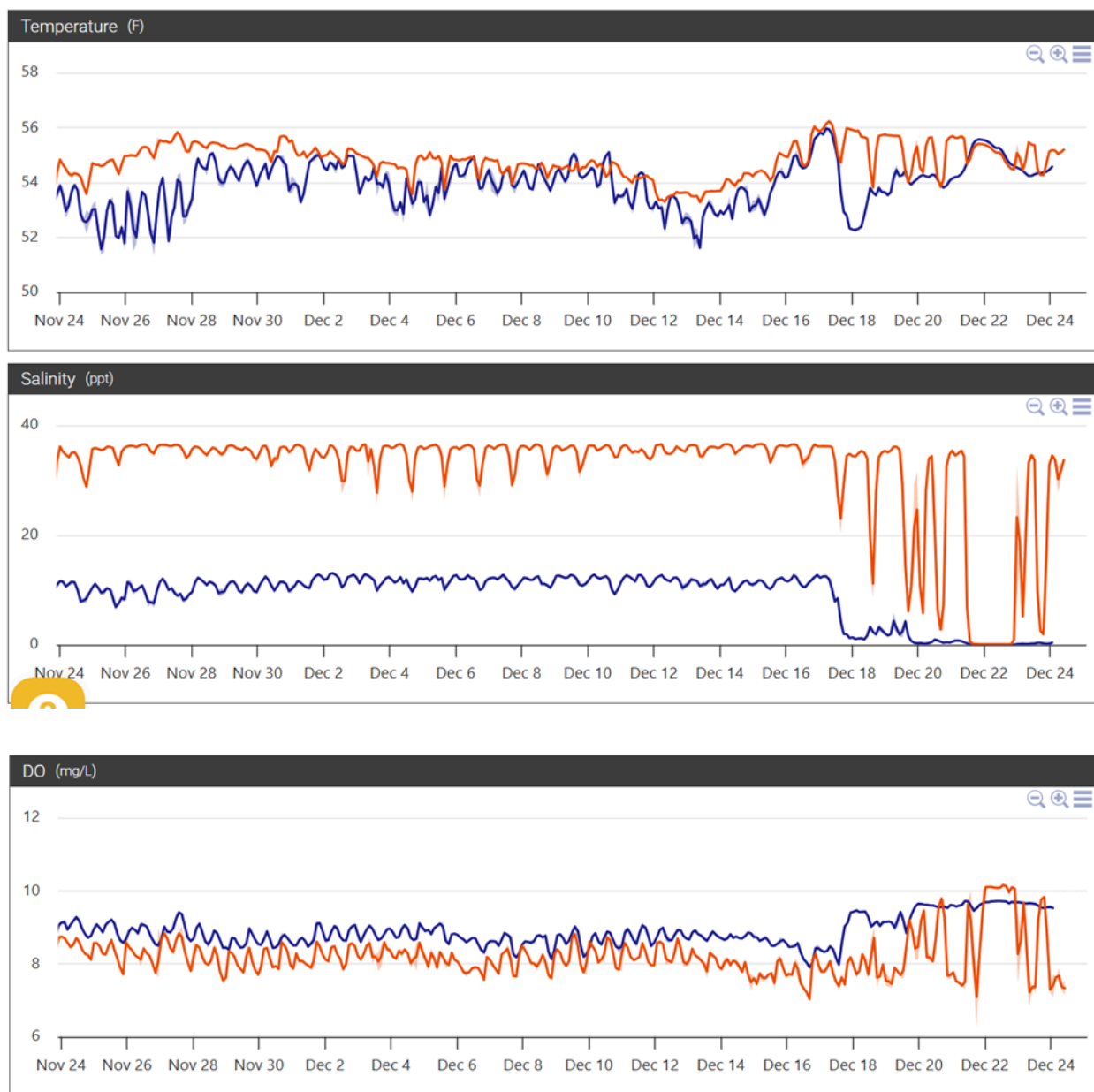


Figure 42: Temperature, salinity, and dissolved oxygen from November 24 to December 24, 2025. The orange line is the bottom sensor and the blue line is the surface sensor. Fort Bragg experienced approximately 14.26 inches of rain (5 inches on December 23), leading to large fluctuations in salinity, including a 2-day period of 0 ppt.

Bull Kelp

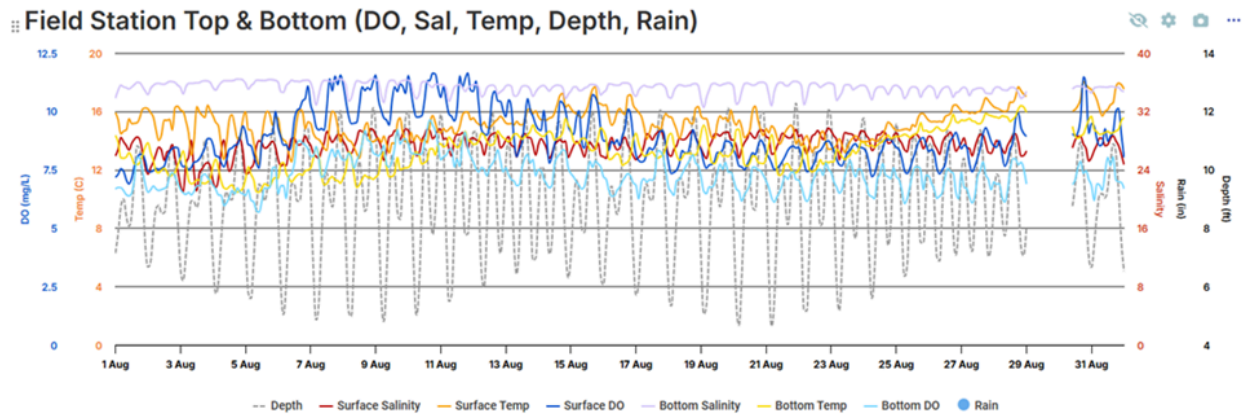


Figure 43: Temperature, salinity, dissolved oxygen, depth, and rain data for the month of August 2025. Water temperatures increased in late August.

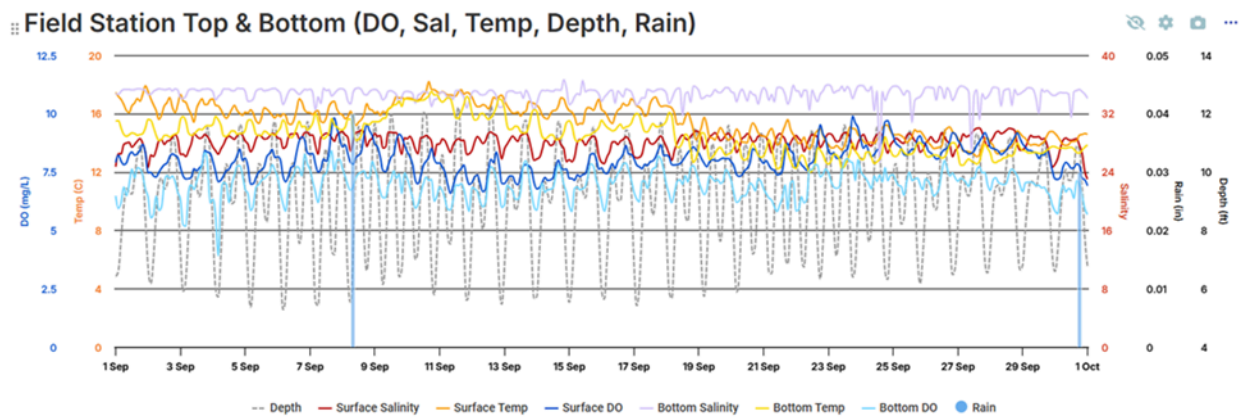


Figure 44: Temperature, salinity, dissolved oxygen, depth, and rain data for the month of September 2025. Water temperature increased on September 10.

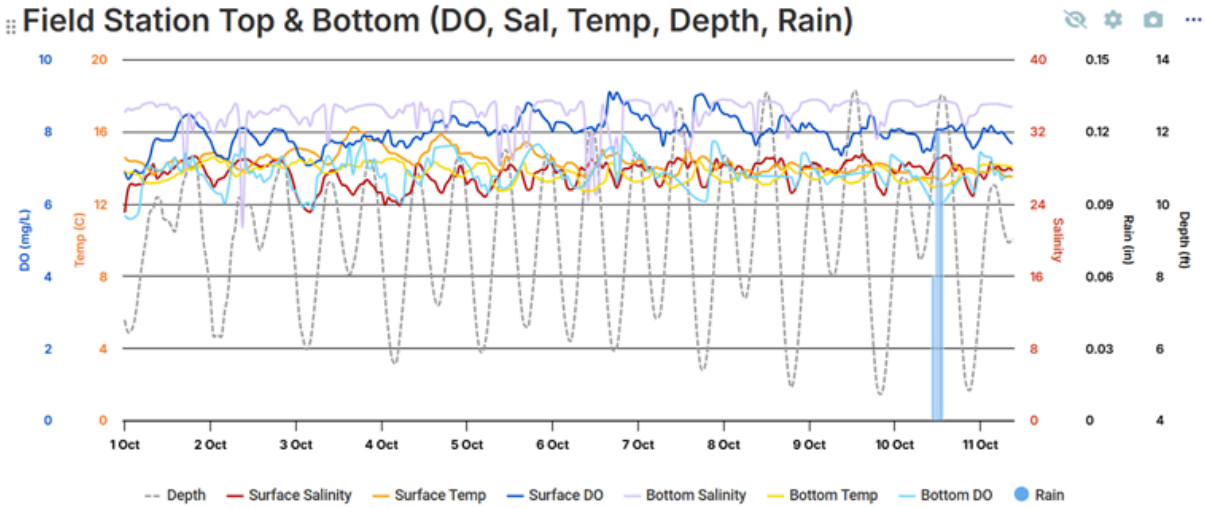


Figure 45: Temperature, salinity, dissolved oxygen, depth, and rain data from October 1-11, 2025. The top and bottom sensors managed by LakeTech were removed from the water on October 11 and replaced with two of the sensors managed by the planning team. Data visualization was transferred to In-Situ's platform, HydroVu; and the remainder of the data for October 2025 can be seen in the Figure below.

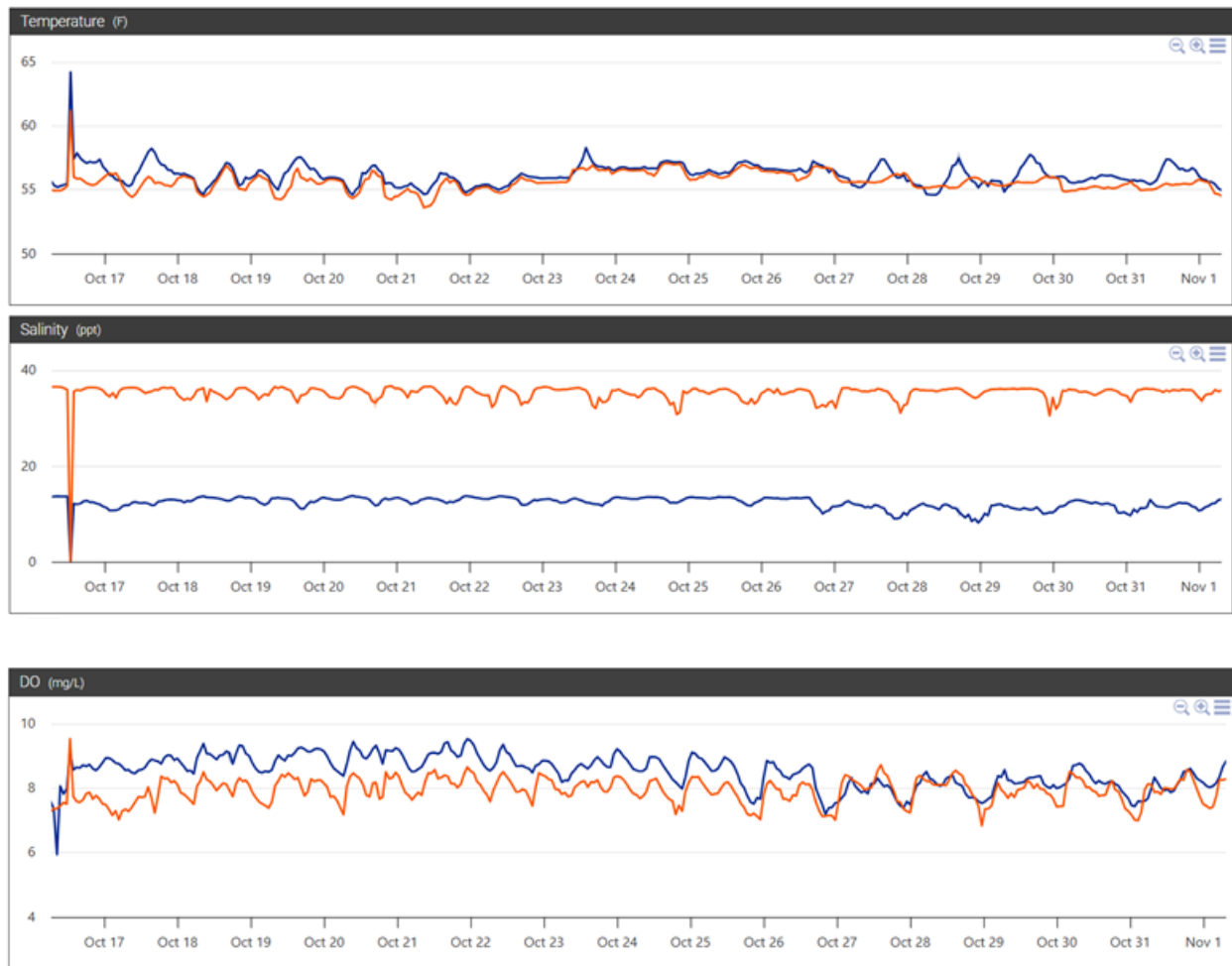


Figure 46: Temperature, salinity, and dissolved oxygen from October 16 to November 1, 2025. The orange line is the bottom sensor and the blue line is the surface sensor.

Appendix E: Purple Sea Urchin GSI Data

Table 25: Purple sea urchin gonadosomatic index (GSI). GSI ranged from 8.27% to 16.42%.

Date	Whole Weight (g)	Gonad Weight (g)	Gonadosomatic Index (%)
9/22/25	139.3	15.6	11.20
9/22/25	131.9	18.4	13.95
9/22/25	152.6	18.9	12.39
10/4/25	134.2	17.8	13.26
10/4/25	148.6	23.3	15.68
10/4/25	110.0	12.9	11.73
10/4/25	137.2	18.4	13.41
10/4/25	139.3	18.5	13.28
10/4/25	146.7	12.3	8.38
10/4/25	137.6	12.9	9.38
10/4/25	216.3	23.1	10.68
10/4/25	139.0	14.0	10.07
10/4/25	163.0	17.4	10.67
10/4/25	200.7	16.6	8.27
10/4/25	152.6	20.9	13.70
10/4/25	126.5	15.7	12.41
10/4/25	120.0	19.7	16.42



Figure 47: Purple sea urchin dissected on September 22, 2025. The urchins were weighed, opened, cleaned, and the uni collected and weighed on the scale.

Appendix F: Tables from Question 6 & 7 of Community Survey

Table 26: Types of seafood respondents usually eat, ranked in order. The most frequently mentioned seafood that respondents eat includes salmon, shrimp, fish, crab, oysters, tuna, and rockfish.

Frequency	Percentage (%)	Type of Seafood
58	39.46	Salmon
40	27.21	Shrimp
38	25.85	Fish
34	23.13	Crab
31	21.09	Oysters
30	20.41	Tuna
28	19.05	Rockfish
18	12.24	Cod
14	9.52	Seaweed
11	7.48	Clams, Scallops
10	6.80	Halibut, Prawns, Rock cod
9	6.12	Albacore
8	5.44	Mussels
7	4.76	Local fish, Shellfish, Sushi
6	4.08	Lobster
5	3.40	Sole, White fish
4	2.72	Abalone, Black cod, Sardines
3	2.04	Canned tuna, Dungeness Crab, Lingcod, Snapper, Squid, Wild-caught shrimp, Yellowtail
2	1.36	Ahi, Anchovies, Calamari, Canned salmon, Canned sardines, Kelp, Mahi Mahi, Mollusks, Tilapia, Wild salmon
1	0.68	Atlantic and Pacific fish, Bay shrimp, Bluefin, Crustaceans, Eel, Fatty fish, Fish sticks, Frozen barramundi, Frozen fish, Haddock, Herring, Line caught sea fish, Local cod, Nori, Octopus, Poke, Prawns from Mexico, Sablefish, Seaweed salad, Smoked salmon, Spot prawn, Surf fish, Swordfish, Trout, Uni, Wild Alaskan salmon, Wild cod, Wild halibut, Wild King salmon, Wild-caught prawns

Table 27: Types of seafood respondents wish they could eat more often, ranked in order. The most frequently mentioned seafood respondents wish they could eat more often includes salmon, abalone, crab, and all of it in general.

Frequency	Percentage (%)	Type of Seafood
24	19.35	Salmon
18	14.52	Abalone, Crab
12	9.68	All of it
11	8.87	No
9	7.26	Oysters
6	4.84	Scallops
5	4.03	Shellfish
4	3.23	Lobster, Local fish, Seaweed, Tuna
3	2.42	Fish, Shrimp
2	1.61	Albacore, Dungeness Crab, I don't know, Mussels, Rockfish, Sushi
1	0.81	Black cod, Calamari, Clams, Cod, Halibut, Herring, Kelp, King crab, Local, Local salmon, Locally caught abalone, Locally caught crab, Locally caught seaweed, Mollusks, Red abalone, Sardines, Stone crab, Sustainably fished abalone, Sustainably fished salmon, Sustainably fished local mussels, Sustainably fished local shrimp, Tilapia, Wild King salmon, Wild-caught fish, Yellowfin

Appendix G: Permitting Blueprint

Scientific Collecting Permit (SCP)

The permitting process took approximately eight months, with the SCP application submitted in April and approved in December 2024. The review included three meetings: one pre-application meeting to go over project details and two species-specific follow-up meetings focused on the proposed seaweed (Pacific dulse and bull kelp) and red abalone. There were also four rounds of agency questions and requested revisions. To stay within the project timeline, the project team elected to remove bull kelp from the SCP to expedite permit approval, with the intention of submitting a SCP amendment to re-incorporate bull kelp at a later stage.

11/1/23 – 1/3/24	CASG/City of Fort Bragg project team designed project.
1/3/24	Met with harbor stakeholders (Noyo Harbor District, Noyo Center) to introduce project ideas and discuss potential locations.
1/5/24	Follow-up meeting to map out water quality sensor locations.
1/8/24	Filling out SCP application.
1/16/24	Circulated application internally for review.
2/9/24	Finalized project location and scope.
2/15/24	Began collecting water quality data in Noyo Harbor.
2/22/24	CASG/City of Fort Bragg project team reached out to CDFW to review project details prior to SCP application submission.
3/7/24	CASG/City of Fort Bragg project team met with CDFW. CDFW suggested a more detailed procedure section (e.g., expand on timeline, add exact number of animals, be specific on source of animals).
3/13/24	Entering information into CDFW's online portal and adding necessary attachments.
4/19/24	Submitted SCP application.
7/9/24	Received first round of reviewers' questions re: feed, origin of seaweeds, source and ages of red abalone, ploidy of oysters, maintenance and monitoring of baskets, and whether there has been preliminary water quality monitoring.
7/16/24	Submitted responses to first round of reviewers' questions.
8/30/24	CASG/City of Fort Bragg project team met with CDFW to discuss the seaweed component. Options are to install our own tumble culture operation or use dried seaweed from MLML as feed. CDFW let us know that the review of bull kelp will take a long time. We decided to remove bull kelp from the application to hopefully expedite approval of the other species.
9/6/24	Red abalone tested negative for CaXc, abalone wasting disease.
9/24/24	Received another round of reviewers' questions re: source and origin of oysters, red abalone, and purple urchin, and source for water quality data.
9/25/24	Submitted responses to second round of reviewers' questions.
10/29/24	Red abalone tested negative for CaXc again. Dr. Colleen Burge confirmed that we've met the red abalone health check. The project team will physically take the abalone to the Shellfish Health Lab at Bodega Marine Laboratories for a visual sabellid inspection en route to Fort Bragg.
10/30/24	CDFW sent list of requested edits.

11/1/24	CASG/City of Fort Bragg project team requested meeting with CDFW to discuss red abalone.
11/1/24	CASG/City of Fort Bragg project team met with CDFW. CASG project team clarified origin of red abalone. The project team will edit the application to clarify the movement of abalone and send Sara Briley a schematic of tank locations and uses at MLML. CDFW will speak with Colleen Burge to go over details of the sabellid health check.
11/5/24	Re-submitted SCP application with all requested edits.
11/7/24	Sent in required materials to Sara Briley.
11/13/24	A few more questions re: year of transfers and ages of abalone.
11/22/24	Sent in responses to reviewer's questions.
12/17/24	SCP approved with conditions.

Amendment to SCP to Include Bull Kelp

The amendment process to incorporate bull kelp into the SCP took approximately four months, with the amendment submitted in late March and approved in early August 2025. Prior to submission, the project team coordinated with local stakeholders and restoration partners to establish a shared vision for kelp aquaculture in the Noyo River basin. Agency review included two rounds of reviewer questions and requested revisions. Ultimately, the process of including bull kelp into the feasibility study took 12 months when considering SCP and amendment timelines.

2/13/25	CASG/City of Fort Bragg project team met with local stakeholders (The Nature Conservancy, Noyo Center) to discuss shared vision and coordinate efforts.
3/18/25	CASG/City of Fort Bragg project team met with The Nature Conservancy (and ANCKR partners) and Scott Hamilton's Lab at MLML to discuss sporophyte availability.
3/31/25	Submitted amendment application.
6/19/25	Received first round of reviewers' questions re: clarifying language.
6/25/25	Submitted responses to first round of reviewers' questions.
7/1/25	Received second round of reviewers' questions re: tumble culture options.
7/16/25	Submitted edits to amendment application re: removing tumble culture from project design.
8/7/25	Amendment to SCP approved.

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