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Bringing Seaweed Cultivation into the Classroom: A Case Study in Rural Alaska

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ABSTRACT: Seaweed farming is a nascent and rapidly growing industry in the United States, particularly in Alaska. The harvest and consumption of seaweed has been practiced by Native communities in coastal Alaska since time immemorial, but more recently, challenges to the sustainable harvest of seaweed in Alaska have appeared. This collaborative project between NOAA Fisheries researchers and rural and urban classrooms in Alaska aimed to involve students and communities in seaweed education and cultivation with the three primary goals of 1) community engagement, 2) culturally responsive place-based education, and 3) promoting food sovereignty. We developed and implemented STEAM lessons detailing the life cycle, physiology, and cultural importance of red seaweed, and classroom activities including a word search, seaweed pressing instructions, and a mobile aquaculture unit assembly and maintenance guide. This work can inform other organizations and classrooms interested in culturally responsive place-based education to increase community engagement and inclusiveness in STEAM opportunities, especially as they relate to marine education.

INTRODUCTION

Interest and investment in seaweed cultivation is increasing in Western countries, driven by demands for sustainable food, fuel, and fertilizer, as well as carbon capture potential (Kim et al., 2017; Duarte et al., 2017). Interest is growing especially quickly in Alaska, where the number of applications and subsequently issued permits increased by 33% from 2017 to 2022, attributable in part by the promotion of aquatic farming by global, Federal, State and private organizations (Alaska Department of Fish and Game, 2022). In response to this growing interest, NOAA Fisheries researchers partnered with rural and urban classrooms in Alaska to introduce students and communities to seaweed education and cultivation. The primary goal was youth education and the secondary goal was community knowledge-building for potential future cultivation efforts at commercial scales.

While the direct consumption of seaweed is relatively recent in Western diets, seaweed species have been consumed since time immemorial by the Tlingit people and other Alaska Native Tribes in Southeast Alaska. For this partnership, we focused on red ribbon seaweed (*Devaleraea mollis*, formerly *Palmaria mollis*), also known as dulse, which is of high cultural importance and potentially high commercial value. Known in the Tlingit language as k'aach', red ribbon seaweed is a small (< 20 cm) red macroalgae found on beaches from northern California to the Aleutian Islands of Alaska, and in Russia (Guiry and Guiry, 2022) (Figure 1). This species, along with similar red seaweeds, is harvested during spring low tides and is consumed fresh or dried.

Challenges to the sustainable harvest of red ribbon seaweed are increasing. Housing and industry development of the nearshore zone and resulting concerns regarding contaminants such as septic leakage and petrochemicals have limited the regions where some communities feel comfortable harvesting native seaweed species (Helms, 2017;

Figure 1. Red ribbon seaweed (*Devaleraea mollis*, formerly *Palmaria mollis*), also known as dulse, growing on a semi-exposed rocky beach in Juneau, Alaska. This species is of high cultural importance and potentially high commercial value.

Starzynski-Hotch, Klukwan School, pers. comm, 2022). Furthermore, the harvest season appears to be shrinking, potentially due to warmer summers (Beier et al., 2008). Community members have observed seaweed bleaching earlier in the year; bleaching renders the red ribbon seaweed inedible (Starzynski-Hotch, Klukwan School, pers. comm, 2022). Cultivating red ribbon seaweed in an aquaculture setting could present a possible solution for maintaining sustainable access to this important resource in the face of these challenges.

Marine aquaculture comes with unique challenges that set it apart from terrestrial cultivation. One is the requirement of salt water, either *in situ* where a farm must contend with currents, storms, and accessibility challenges, or *ex situ* where salt water must be either transported or created on land and maintained at appropriate temperatures, nutrient content, light levels, and flow rates. Additionally, seaweed differs notably from plants. Seaweed species commonly have complex, multiphasic life cycles that include alterations of microscopic and macroscopic phases that must be accounted for in their cultivation. Considering these unique challenges, a knowledgeable and well-trained workforce is necessary for the successful establishment and sustainability of aquaculture.

In response to local needs and interests in the Tlingit Chilkat community of Klukwan, this project involved the creation of culturally responsive lessons and activities for seaweed education and a transportable and adaptable system to grow red ribbon seaweed in a classroom. While we only had funds sufficient for the development and installation of one mobile aquaculture unit, which we installed with our original collaborators in Klukwan, we expanded lesson plans and activities with students in Juneau, the capital city of Alaska. Throughout the development of this project, we emphasized food sovereignty, community partnerships, and culturally responsive place-based education. Western science typically emphasizes objective empirical thought and thus can diminish the role of place. In comparison, a sense of place holds great importance for Alaska Native peoples. The places that make up their traditional homelands are strongly reflected in their cultural and educational philosophies. Understanding this relationship can offer unique biological insights and provide multicultural and multigenerational perspectives (Kimmerer, 2002; Semken, 2005).

Disparity in representation in higher education is more pronounced for historically excluded groups in the United States, such as Alaska Native students. Among the U.S. 2009 cohort of 9th graders, rates of attending college within three years of scheduled high school graduation was the lowest among all racial and ethnic groups for American Indian/Alaska Natives (47%), compared to 62% for Black/African- Americans, 64% for Native Hawaiian/Pacific Islanders, 66% for Hispanics, 70% for “More than One Race,” 73% for Whites, and 84% for Asians (Calahan et al., 2021). Since place is key to learning in the Indigenous context, culturally responsive education can be a tool for successfully engaging Alaska Native students (Kuwahara, 2013; Sutherland and Swayze, 2012). Current research presents a compelling case for including culturally responsive practices in the classroom as it can increase student engagement, motivation, sense of belonging, and strengthen student identities, reading comprehension, and mathematical thinking (Bui and Fagan, 2013; Dee and Penner, 2016; Fulton, 2009; Lemus, 2018). Additionally, this educational approach can increase attendance, GPAs, and credits earned. This is partly because students tend to learn new information best when it is linked to what they know, as culture drives how the brain processes information (Hammond, 2014).

In this paper, we outline the methods used to construct the mobile aquaculture unit and the associated lessons with the goal that it could be easily replicated in other classrooms and communities. While this work was tailored to the specific cultural, ecological, and historical contexts of the Chilkat Valley region, and Southeast Alaska more broadly, all aspects of the project are easily customized for culturally responsive place-based learning in other locales. It can be adapted to meet the community needs of different regions, including changes to the species and ecosystems of interest and the materials available for constructing the mobile aquaculture unit.

METHODS

Mobile Aquaculture Unit Design. The mobile aquaculture unit was designed as a tumble culture in which seaweed is grown suspended in the water and prevented from settling on the bottom due to high turbulence (Werner and Dring, 2011). The unit was constructed using primarily low cost, readily available materials available in most hardware stores (Appendix A, pp. 5-6). It was designed to replicate growing conditions in the wild. The key inputs needed to maintain the seaweed in a classroom setting were salt water, low water temperature, nutrients, turbulence, and light (Figures 2, 3). In brief, seaweeds were held in five-gallon buckets filled with artificial seawater. These buckets were placed into a freshwater bath and temperature was maintained by circulating the freshwater bath water through a chiller. Vinyl tubing was attached inside on the bottom of the five-gallon buckets using adhesive-backed mounting disks and connected to an air pump to create turbulence in the system. Light was achieved by suspending daylight-balanced fluorescent or LED lights above the buckets using a lightweight PVC tube frame (Figure 2; Appendix A, pp. 1-4). The system was installed in a classroom in the Klukwan School (Mile 22, Haines Hwy, Klukwan, AK 99827).

Salinity. As a marine species, saltwater is critical to seaweeds. In locations immediately adjacent to the coast, seawater can be used provided it is sufficiently clear of contaminants (e.g., pollutants, fecal pathogens, excess sediment, excess nutrients from terrestrial runoff, excess or insufficient salinity) and collection complies with local regulations. Contaminants can be assessed visually (e.g., oil sheen on the water surface, opaque water from high turbidity), with monitoring tools (e.g., refractometer for salinity), or with commercially available testing kits (e.g. Water Test Education Kit by Lamotte Company). Users may also choose not to use natural seawater to reduce the growth of non-target species in the system (e.g., diatoms, *Ulva*, bacteria). In more inland locations or where natural seawater is considered unsuitable, seawater can be created using commercially available aquarium supplies. In this case study, saltwater was created using commercially available artificial seawater mixes to achieve a salt content of 30 to 33 PSU to mimic ocean salinity levels (Demetropoulus and Langdon, 2004). Salt concentration was monitored using a handheld refractometer (e.g. Vee Gee Refractometer). Water was changed on an as-needed basis based on growth of diatoms and other undesired algal species.

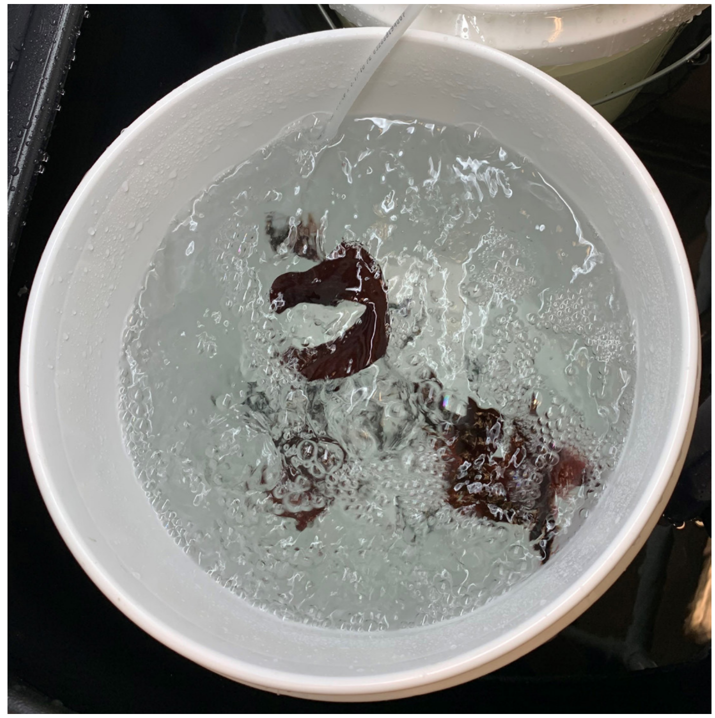

Figure 3. Red ribbon seaweed tumbling in a bucket filled with Instant Ocean® and receiving aeration through 1/8” vinyl tubing with holes cut into the tubing every 3 cm that was attached to the base of the buckets using cable mounts. The diameter of the vinyl tubing was determined by the dimensions of the air pump and may differ in other set-ups from hoses connected to an air pump.

Figure 2. Red ribbon seaweed tumbling in buckets filled with Instant Ocean® and receiving aeration from hoses connected to an air pump (EcoPlus Commercial Grade Air Pump). The temperature of the freshwater bath was regulated by pumping the fresh water (Iwaki MD-20RXT - 822 GPH) through a chiller (TradeWind Chillers IL-15-S) set at 10° C. The recirculating freshwater bath held the water temperature of the saltwater in the 5-gallon buckets constant at the set temperature. This design minimized the movement of corrosive saltwater, making the system easier to maintain.

Temperature. Red ribbon seaweed is a cold-water species, with optimal temperatures for growth between 8 and 12°C, that begins to bleach and degrade when exposed to water temperatures that exceed 15°C (Werner and Dring, 2011). Appropriate temperatures were achieved by placing three, five-gallon buckets containing saltwater and seaweed into one 48-gallon container filled with fresh water. The temperature of the freshwater bath was regulated by pumping the fresh water (Iwaki MD-20RXT - 822 GPH) through a chiller (TradeWind Chillers IL-15-S) set at 10° C. The recirculating freshwater bath held the water temperature of the saltwater in the 5-gallon buckets constant at the set temperature. This design minimized the movement of corrosive saltwater, making the system easier to maintain.

Nutrients. Like plants, seaweeds need nutrients for growth and photosynthesis. Unlike plants, seaweeds take up nutrients in all of their tissues rather than through roots. A range of nutrients is essential for seaweed growth, and can it be divided into macro-nutrients (e.g., nitrogen, phosphorus, potassium, calcium, magnesium) which are required in higher concentration, and micro-nutrients (e.g., cobalt, iron, manganese, zinc, vitamins) which are needed in only very small amounts. If artificial seawater is used, macronutrients must be added but micronutrients are likely already present in the commercial mix. Once per week, we added a commercially available algal growth medium (Fritz Pro Aquatics F/2 Part B) so that growth was not limited by a shortage of any nutrient. The application of nitrogen especially, in the form of either nitrate or ammonium or both, has a visible effect on the appearance of k'aach': it increases the pigmentation of the fronds and thus intensifies the color of the tissue to a darkish purple-red (Schmedes and Nielsen, 2020).

Aeration. Aeration is essential for good growth and health of seaweed. The turbulence created by aeration fulfills two important tasks: a) movement of seaweed in the water to enhance nutrient uptake and thus growth, and b) movement of seaweed in a circular flow from the surface to the bottom and up again to minimize exposure to both high- and low-light intensities (Lüning and Pang, 2003; Norton, 1991). Without aeration in tanks, seaweed will rapidly decay. In our system, aeration was distributed into each 5-gallon bucket that held the seaweed from an air pump (EcoPlus Commercial Grade Air Pump) through 1/8" vinyl tubing with holes cut into the tubing every 3 cm that was attached to the base of the buckets using cable mounts. The diameter of the vinyl tubing was determined by the dimensions of the air pump outlets and may differ in other set-ups.

Lighting. As photosynthetic species, appropriate light levels for the seaweed species of focus are critical. An irradiance of 60 µmol photons m-2 s-1 (measured at the top of the five-gallon buckets with an Apogee Instruments Full Spectrum Quantum Sensor, though HOBO Pendant® MX Temperature/Light Data Logger can be a more economical alternative) and a light-dark cycle of 16:8 hours was suitable for achieving relatively high growth rates and healthy growth for the high-latitude species targeted (Demetropoulos and Langdon, 2004; Werner and Dring, 2011). Opportunistic seaweeds that may compete with red ribbon seaweed require high-light (Demetropoulos and Langdon, 2004; Werner and Dring, 2011), although such competitors should not be a problem if the initial stocking densities of the target seaweed are high in a commercial setting, or if the algae is monitored and water is changed as needed in a classroom setting. Sufficient light was achieved in our set up using a single fluorescent bulb hung 30 cm above the buckets.

Initial Setup and Stocking. Due to the time of year and available harvest locations, initial set up and stocking of the mobile aquaculture unit was done with stiff red ribbon seaweed (*Palmaria hecatensis*), a closely related and morphologically similar species to *D. mollis*. Specimens were collected from the intertidal zone and screened carefully before use to ensure that the fronds were healthy, in good condition, and did not carry other organisms on their surface. Young plant material (i.e., the tips of newly grown fronds) was especially targeted because these parts of the seaweed have the greatest potential for rapid growth and lower likelihood of having high epiphyte or endophyte loads. Large fronds were torn into smaller fragments so that the youngest, apical parts, which contain the growth meristem at the edges of the frond, could be used. We worked with state agencies to ensure seaweed collection permits were acquired as needed.

Seaweed Lessons and Activities. Lessons were designed for elementary school level students (ages 5-11) and were aligned with Ocean Literacy Principles (OLP) (Halversen et al., 2021) and Next Generation Science Standards (NGSS) that integrated Science and Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CC) (National Research Council, 2013). Activities emphasized using movement, art, visual observations, discussion, and reflection to achieve learning objectives. Student learning objectives were to (1) explore real seaweed samples and record observations (in words and drawings), (2) compare and contrast seaweeds with true plants based on their structures and specific needs (e.g., nutrients, aeration, turbidity, salinity, pH, dissolved oxygen), (3) provide examples of how seaweed grows and changes throughout its life cycle, and (4) reflect on the cultural significance of seaweed (Appendix B, p. 2).

Lessons and activities were used with the mixed 3rd and 4th grade classroom at the Harborview Elementary School in Juneau, Alaska, and the mixed 3rd to 5th grade classroom at the Klukwan School in Klukwan, Alaska. Classrooms were divided so that there were 5-10 students in each group. Each module lasted approximately 15 minutes. While seaweed was necessary for the seaweed pressing module, all other modules could be achieved in the absence of access to the intertidal. However, working with local seaweeds added to the place-based cultural and educational components.

Seaweed Anatomy and Physiology. Students explored the anatomy of red ribbon seaweed by observing collected specimens (tetrasporophytes) in conjunction with completing a handout that contained a simplified diagram of red ribbon seaweed and vocabulary words such as thallus, stipe, blade, and holdfast (Appendix C, pp. 4-5). Students also learned the differences between seaweeds and plants by looking at a specimen with their eyes and through a dissecting microscope (Appendix C, pp. 17-19). Discussions and observations about the differences between seaweeds and plants were aided by potted plants found in the classroom and wild plants found on the beach, as well as red ribbon seaweed brought in for the bookmark pressing activity. However, the comprehensive handouts would suffice to guide the discussion in the absence of live plants and seaweeds.

Ocean Literacy Principles included Grades K-2: OLP 5A.2. Many groups of organisms exist only in the ocean; Grades K-2: OLP 5A.4. Ocean organisms have a variety of different structures and behaviors that help them to survive in the ocean; Grades 3-5: OLP 5B.2. There are adaptations and life histories that exist only in the ocean, due to unique environmental and physical properties, such as salinity, pressure, temperature, light, and density, that are associated with living in a liquid environment; and Grades 3-5: OLP 5B.6. There are many groups of organisms that occur in the ocean that do not occur on land or freshwater, such as sea stars, squid, jellyfish, corals, many types of worms, and seaweeds (National Marine Educators Association, 2023; Appendix B, p. 9).

Next Generation Science Standards Performance Expectations included K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive; 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction; and 5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water. Science and Engineering Practices included Analyzing and Interpreting Data, Science Knowledge Is Based on Empirical Evidence, and Engaging in Argument from Evidence. Disciplinary Core Ideas included LS1.C: Organization for Matter and Energy Flow in Organisms; LS1.A: Structure and Function; LS1.C: Organization for Matter and Energy Flow in Organisms. Cross Cutting Concepts included Patterns, Systems and System Models, and Energy and Matter (National Research Council, 2013; Appendix B, pp. 9-11).

Seaweed Life Cycle. The life cycle of red algae is complex, consisting of a microscopic and macroscopic phase, so it is important to understand for sustainable harvest or cultivation purposes (van derMeer and Todd, 1980) (Figure 4). Using a combination of read/write and kinesthetic teaching tools, students learned about the life cycle of red ribbon seaweed. A paper handout containing simplified diagrams, written descriptions, and complex vocabulary words (e.g., tetraspore, tetrasporophyte), provided students with an opportunity to engage with the content at their own pace (Appendix C, pp. 6-7, 13-16). Students then deepened their understanding of the life cycle by acting out the different stages as a class. Students were broken up into groups and each pretended to be (1) adult seaweed (sporophyte or tetrasporophyte) waving in the current, (2) microscopic tetraspores or zoospores released from the adult drifting through the water, (3) settled out tetraspores growing into microscopic gametophytes, (4) gametophytes releasing gametes and settling into juvenile tetrasporophytes or sporophytes, and (5) juvenile tetrasporophytes or sporophytes growing into adult tetrasporophytes or sporophytes waving in the current.

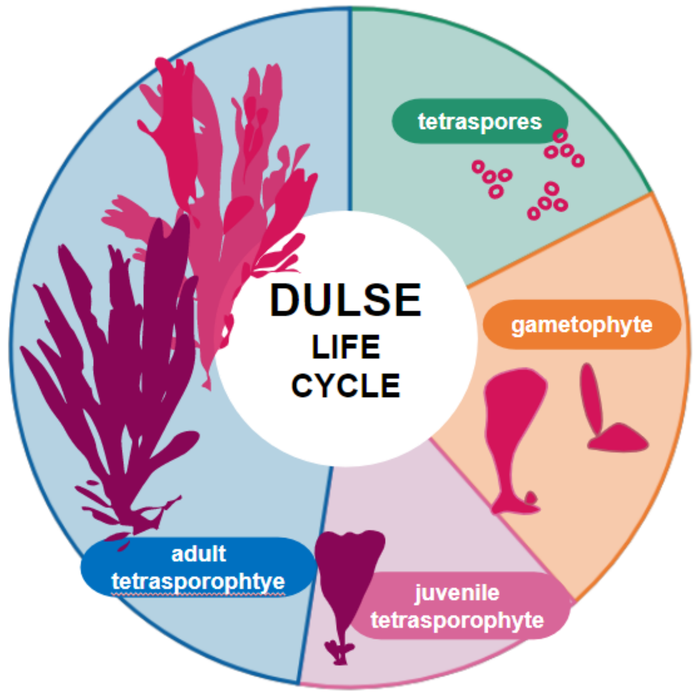

Figure 4. Simplified life cycle of red ribbon seaweed, modified from Hollarsmith et al. (2022).

Ocean Literacy Principles included Grades K-2: OLP 5A.4. Ocean organisms have a variety of different structures and behaviors that help them to survive in the ocean; Grades 3-5: OLP 5B.2. There are adaptations and life histories that exist only in the ocean, due to unique environmental and physical properties, such as salinity, pressure, temperature, light, and density, that are associated with living in a liquid environment; and Grades 3-5: OLP 5B.5. Organisms in the ocean exhibit an amazing variety of life cycles. Some undergo metamorphosis and have planktonic phases, some lay eggs, and others nurse their young (National Marine Educators Association, 2023; Appendix B, p. 14).

Next Generation Science Standards Performance Expectations included 1-LS3-1. Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents; 3-LS1-1. Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death, and 4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. Science and Engineering Practices included Constructing Explanations and Designing Solutions; Developing and Using Models; Scientific Knowledge is Based on Empirical Evidence; and Engaging in Argument from Evidence. Disciplinary Core Ideas included LS3.A: Inheritance of Traits; LS3.B: Variation of Traits; LS1.B: Growth and Development of Organisms; and LS1.A: Structure and Function. Cross Cutting Concepts included Patterns and Systems and System Models (National Research Council, 2013; Appendix B, pp. 14-16).

Cultural Education and Reflection. The students of the Klukwan School had an additional opportunity to reflect on the importance of red ribbon seaweed to the Chilkat Tlingit people. They harvested seaweed with the intent of drying it and distributing it among the community, and they spent time listening to stories from a Klukwan Elder, Guneiwtí Marsha Hotch, who shared her memories of collecting k'aach' as a child with her mother, and as an adult with her own children and grandchildren. This included how access to k'aach' has changed during her life due to the effects of colonization and coastal development. Students were prompted to reflect on their own experiences harvesting seaweed and other coastal resources, and how it tied into their family and community values. Additionally, parents and family members of students were present at harvest sites and participated with their own stories and questions, emphasizing the importance of community in cultural education.

Ocean Literacy Principles included Grades K-2: OLP 6A.2. The ocean provides much of the food we eat; Grades K-2: OLP 6C.8. Ocean resources are limited, so people need to use these resources wisely; Grades 3-5: OLP 6A.1. The ocean is an important source of food for humans; Grades 3-5: OLP 6A.2. Food from the ocean includes organisms such as fish, crabs, and oysters, as well as prepared products that contain organisms such as algae; and Grades 3-5: OLP 6C.5. Ocean resources are finite and should be respected and cared for by people (National Marine Educators Association, 2023; Appendix B, p. 20).

Next Generation Science Standards Performance Expectations included K-ESS3-1. Use a model to represent the relationship between the needs of different plants and animals (including humans) and the places they live; K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment; and 5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment. Science and Engineering Practices included Developing and Using Models and Obtaining, Evaluating, and Communicating Information. Disciplinary Core Ideas included ESS3.C: Human Impacts on Earth Systems; ETS1.B: Developing Possible Solutions, and ESS3.C: Human Impacts on Earth Systems. Cross Cutting Concepts included Systems and System Models; Cause and Effect; and Science Addresses Questions About the Natural and Material World (National Research Council, 2013; Appendix B, pp. 20-22).

Seaweed Pressing Activity. To deepen their cultural connection to the lessons and inspire their imagination and creativity, students made seaweed bookmarks following traditional herbarium pressing methods. Materials used included 140 lb watercolor paper cut into bookmark sizes, paintbrushes and teasing needles for manipulating the seaweed on the paper, weed cloth or wax paper and cardboard to absorb water during pressing, and heavy materials such as large books to flatten and press the seaweed.

Seaweed was gathered prior to the classroom visit to Harborview Elementary School and during the Klukwan School's field trip to Haines, Alaska. We collected a diversity of seaweed species so students could capture the kaleidoscope of the intertidal zone in their bookmark creations. When students were ready to make the pressing, they rinsed the seaweed in freshwater, then either immersed a piece of watercolor paper into a shallow tub of freshwater and arranged the seaweed on top or removed seaweed from the water and arranged them on the paper. Students then drained excess water from the paper, used a paintbrush or teasing needle to position the seaweed into desired arrangements, and placed weed cloth or wax paper over the seaweed. They then sandwiched the seaweed between two pieces of cardboard and placed weights on top to preserve it. Pressings were removed after one week and, if dry, laminated for long-term preservation.

The seaweed pressing instruction handout included background on the importance of seaweed, the history of seaweed pressing, and introduced students to the Tlingit names of common seaweed species found in Southeast Alaska (Appendix C, pp. 10-12).

Word Search Puzzle. Our lessons also included a word search puzzle that contained 14 vocabulary words students had been exposed to in the various modules. The word search included Western terminology and the Tlingit names of common seaweed species (Appendix C, pp. 8-9).

RESULTS

Seaweed Lessons and Activities. Students at both the urban and rural schools were highly engaged with the lessons and activities. At the beginning of the exercise when students were asked what they knew about seaweeds, common responses included, “slimy, green, and plant.” However, after participating in the lessons and activities kids realized seaweeds are not plants, and there are multiple types (green, red, brown). Student engagement was assessed based on the degree of attention, curiosity, interest, and passion that was exhibited. Additionally, after the students rotated through all of the activities, students were asked content-specific questions to reflect their engagement and retention of the material. Classroom teachers reported that many of the students retained the information and were able to speak in detail about the lifecycle and ecological and cultural importance of seaweed after the activities. Completing all of the activities took approximately 1.5 hours at Harborview Elementary School and 5 hours at the Klukwan School with the field trip. The activities took longer with the students from the rural school in Klukwan because we incorporated more exploration and observations in the classroom, as well as a field trip to a local beach for intertidal collections.

The field trip with the Klukwan School provided one of the most valuable aspects of the project, a space where educators, children, scientists, families, and elders could model collective learning. Everyone contributed to the learning environment and we were able to value and share knowledge from all parties. It was more than learning about one species, it was learning about the ecosystem, community, and history intertwined with that species. As a Chilkat Indian Village school, the Klukwan students learned more deeply about the cultural history and importance of sustainable harvesting of k’aach’. In addition, we fostered cross-school exchange using the seaweed pressing module, in which students from each school made extra bookmarks that they exchanged between classrooms. The hands-on nature of this project allowed students to feel, smell, and taste the seaweeds they were learning about.

Mobile Aquaculture Unit. The students at the Klukwan School successfully stocked and operated the mobile aquaculture unit for two months (May and June) with minimal labor required for upkeep. After an unexpected power outage caused the chiller to stop working for a week when no one was available to monitor the unit, it was found that buckets containing raw seawater became extremely overgrown with bacteria, diatoms, and other organisms, while buckets containing artificial seawater remained largely free from overgrowth. The seaweed in the artificial seawater medium survived the power outage and were able to persist in the aquaculture unit while the seaweed in the raw seawater buckets did not survive. The unit also had to be moved from the original installation location because the chiller was unable to maintain low water temperatures in the warm and sunny room, highlighting the importance of considering other factors in the classroom setting such as ambient temperature and light.

DISCUSSION

The design and implementation of this project was a collaborative effort among scientists, community members, educators, and students. Both urban and rural classrooms proved to be excellent case study locations for our culturally responsive place-based seaweed lessons. Growing up in Southeast Alaska, many students already have strong ties to the marine and coastal environment. They also have experience with subsistence, recreation, and commercial fishing and harvesting. Each lesson was developed to build on the student’s own experiences with the natural world and emphasized the importance of food sovereignty, community engagement, and place.

We incorporated the theme of food sovereignty through education about harvesting and cultivating red ribbon seaweed. Klukwan students learned how to grow and maintain red ribbon seaweed through the mobile aquaculture unit and collected red ribbon seaweed for consumption by members of their community. Klukwan students also learned from Guneiwtí Marsha Hotch, an Elder in the community, to hear a first-hand account of her experience gathering k’aach’ as a child with her mother, and as an adult with her own children and grandchildren. Reduced access to traditional foods has implications for the well-being of rural Alaska Native communities, through impacts on food security and food sovereignty (Ibarra, 2021; Walch, et al., 2018). Food insecurity is a growing public health concern in Alaska, and individuals and households in rural Alaska Native communities are at greater risk (Walch, et al., 2018). This project sought to contribute to ongoing efforts to ensure community food sovereignty and maintain and revitalize access to local and traditional resources for current and future generations.

Community engagement was achieved in tandem with culturally responsive place-based education. In many ways, the two quickly became indistinguishable because the process of creating culturally responsive place-based lessons required close engagement with community members. The mobile aquaculture unit and associated lessons were designed with frequent communication between scientists and educators to ensure it met the educational level and needs of the students. Before scientists visited the Klukwan School to introduce the lessons and to install the mobile aquaculture unit, students participated in a video tour of the Alaska Fisheries Science Center aquarium and lab space. During the video tour, students had the opportunity to engage with the scientists, ask questions about seaweed, and drive the discussion to further influence the finalized lesson plans. In the urban classroom, students completed a unit on plant anatomy and physiology and grew geraniums and sweet peas in containers on their desks. Scientists were able to incorporate student knowledge on plants and the plant visual aids into the seaweed lessons, further promoting understanding of comparable structures in plants and seaweed that support survival, growth, behavior, and reproduction. Furthermore, the seaweed pressing activity allowed the students to make extra bookmarks to exchange between the two classrooms, providing an additional opportunity for inter-school community building.

The mobile aquaculture unit and seaweed lessons were both designed for red ribbon seaweed, chosen because of its high cultural and subsistence importance in the region. Only small modifications would be necessary to adapt the materials for different seaweed species in the same region, such as kelp species (Laminariales), or in a different region entirely. Likewise, the mobile aquaculture unit could also be adapted for use as an aquarium to house intertidal invertebrates or small fish, if the educational goal does not include aquaculture and following regional permitting requirements. Future adaptations could include a lesson plan where students design their own tumble culture and make adjustments to environmental variables that suit the needs of the species being housed in the tumble culture. This lesson could be centered on OLP #5: The ocean supports a great diversity of life and OLP #7: The ocean is largely unexplored and NGSS Performance Expectations 2-LS2-1. Plan and conduct an investigation to determine if plants need water and sunlight to grow; 3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all; 5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water; K-2-ETS1-1. Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool; K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs; 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost; and 3-3-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved (National Research Council, 2013).

The students in both classrooms were highly engaged during the learning activities, and enthusiasm from teachers has resulted in plans for implementation of the curriculum in additional classrooms. The mixture of art, movement, and discussion across the different activities allowed students to express themselves in different ways, draw comparisons from their surroundings, and stay focused on the lessons. There is continued communication between the scientists and the Klukwan School as they maintain and adapt the mobile aquaculture unit to suit their evolving educational and food needs. Additionally, educators and students at the Klukwan School have plans to adapt the mobile aquaculture unit to accommodate other seaweed species by manipulating aeration, light intensity, and salinity, while Juneau teachers have expressed interest in developing a mobile aquaculture unit for their classrooms. Efforts are already underway to improve upon the original design, based on feedback from teachers in both communities. This project has laid the groundwork for a continual flow of ideas between researchers and community leaders and educators in both rural and urban schools in Alaska.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this manuscript.

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ABBREVIATIONS

CC: Crosscutting Concepts; DCI: Disciplinary Core Ideas; NGSS: Next Generation Science Standards; OLP: Ocean Literacy Principles; SEP: Science and Engineering Practices

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