Student Project Report To The University of Hawai‘i At Hilo Marine Option Program

Internship with Ocean Era: Hawaiian macroalgae (*limu)* culturing techniques for future offshore demonstration

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Abstract

This report outlines an ongoing internship with the mariculture company Ocean Era, formerly Kampachi Farms, which began in September of 2019 in Kona, Hawaii. One of Ocean Era's missions is to grow native Hawaiian macroalgae in an offshore demonstration project within the next few years. The biomass produced could potentially be used for food, feed, and fuel. The internship was centered around assisting staff with the macroalgae culturing site's land-based tank cultures of native Hawaiian macroalgae species, specifically *Caulerpa lentillifera*, *Gracilaria parvispora*, *Halymenia hawaiiana*, and *Sargassum aquifolium*. Work included the maintenance and upkeep of tank systems, as well as designing and carrying out algal growth trials to determine ideal growth conditions and the feasibility of meeting those conditions at the offshore site. I also assisted in the creation of standard operating procedures (SOPs) for the maintenance and calibration of the tank systems, as well as with the design of an algal condition scale to visually assess and rate the health of the biomass. The information gained from the land-based growth trials of native Hawaiian macroalgae will be applied to a future offshore demonstration project which, if successful, could lead to a large scale macroalgae farm off the Kona coast.

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Introduction

Aquaculture systems have been an integral part of many different cultures for thousands of years. Agriculture appears to have first developed around 10,000 BCE. The earliest texts mentioning aquaculture are from China from only about 500 BCE (Lucas et al. 2019), although aquaculture may have been practiced for quite some time prior to the written evidence. Despite being practiced traditionally in many countries for a few thousand years, aquaculture has only begun to be practiced commercially on a global scale in the past few centuries (Lucas et al. 2019). Aquaculture is a quickly growing industry; the worldwide total yield has risen from around 70 million tons in 2008 to over 100 million tons of aquatic organisms produced in 2017, and that same year the industry amassed almost 240 million USD (FAO 2019). Asia is by far the highest grossing producer, unmatched by any other continent when it comes to the production of aquatic organisms. In 2017 alone, Asia sold 102 million tons of product for 210 million USD, while the Americas only produced 3.5 million tons for 19 million USD. Fish farming is growing by 10% annually (Loureiro et al. 2015) and marine plant production has nearly doubled in production in the past 10 years (FAO 2019).

The two main sectors of aquaculture are land based aquaculture, where the product is held in tanks onshore or set in natural ponds or lakes, and offshore aquaculture, where the product is held in offshore coastal nets or pens designed so that there is constant water flow without the product escaping into open waters (Lucas et al. 2019). Both systems have benefits and drawbacks. Land based aquaculture allows for more variables to be controlled and minimizes the outside forces acting on the product. However, these systems occupy limited land and require a constant water supply, all while needing to remove any waste byproduct (Lucas et al. 2019). Offshore systems require less daily upkeep and input and often are regarded as a more “hands off” approach to aquaculture (Duarte et al. 2009). There are environmental ramifications, however, as in an offshore system waste products and excess food falls to the seafloor and may build up and pollute the waters around the pen (Lucas et al. 2019). Fish and bivalve culturing can also negatively impact the surrounding ecosystem by consuming the available dissolved oxygen in the surrounding waters and excreting nitrogen and phosphorous, building up nutrient levels to an oversupply and in extreme cases leaving behind an oxygen poor, nutrient rich “dead zone” (Ogden 2013). Algae’s role as primary producers can be capitalized upon to help mitigate these negative effects when used in integrated multi-trophic aquaculture (IMTA) systems. IMTA systems use these nutrient rich waters to grow large algae or seaweed cultures, which in turn provide oxygen to the surrounding ecosystem. This diversification of trophic levels can create a more sustainable system and help prevent some of the more damaging effects of a system on the surrounding ecosystems (Ogden 2013). Macroalgae aquaculture systems are highly sustainable agriculture systems.

In Hawaiʻi, before western influence, the native Hawaiians used at least 63 different species of *limu* (algae) as part of their diet and for medicinal and ritualistic uses (McDermid et al. 2019). While some species were grown in fishponds alongside taro and various fish species (Costa-Pierce 1987), wild *limu* were primarily collected by Hawaiian women, for whom seaweeds were an important dietary supplement due to the *kapu* (taboo) system which restricted their access to certain nutrient rich foods including coconuts, bananas, pork, turtles, and some fish species (McDermid et al. 2019). Macroalgae have remained a part of the daily diet of many people in Hawaiʻi as well as around the world. Hawaii’s 56 endemic algae species provide the opportunity for an export with little to no competition from off island (Tsuda 2014). Currently, many species of native macroalgae and seaweed growing around the Hawaiian Islands are being negatively affected by climate change and overharvesting from local sellers (McDermid et al. 2019). There has been some interest in using farmed algae for restoration of native populations. Farmed algae also have potential as an ingredient in feed for livestock or fish production (McDermid et al. 2019). On Hawai’i island, there are very few options for an inexpensive locally produced feed, and most farms ship in premade feed or feed ingredients from the mainland (Fujii-Oride 2016). An offshore system would increase biomass production without requiring the additional use of land or freshwater, and can be offshore far enough that it wouldn't be considered an "eyesore" to tourists. Developing an offshore system with tropical macroalgae native to Hawai'i has never been done before. Ocean Era (formerly Kampachi Farms LLC), is an environmentally focused mariculture research company. One of their research projects is called Blue Fields, and the purpose of the project is to grow Hawaiian seaweeds (*limu*) offshore on a demonstration farm. The biomass could be used for applications such as food, feed, and fuel (Kampachi Farms 2019). This farm would be without major competition on-island and has potential for positive local economic impacts. The keystone in this offshore farm is the use of deep seawater as fertilizer, a previously under examined resource. If successful, the farm would require no supplemental fertilization; however, before the offshore array can be deployed, a year of land based tank testing needs to take place at Ocean Era's algae site (Kampachi Farms 2019).

This MOP internship project at Ocean Era consisted of 150 hours of work centered around land-based tank cultures of *Caulerpa lentillifera*, *Gracilaria parvispora*, *Halymenia hawaiiana*, and *Sargassum aquifolium*. Work included the maintenance and upkeep of tank systems, as well as designing and carrying out algal growth trials to help inform what could be expected for an offshore farm. My objectives for the internship were to gain experience in the practice of culturing macroalgae, including monitoring nutrient balance and experimenting with different seeding methods; to become proficient in the maintenance required in a tank system, including basic plumbing; and to create an algal growth trial to assist with the land-based tank testing.

Methods

Study Site

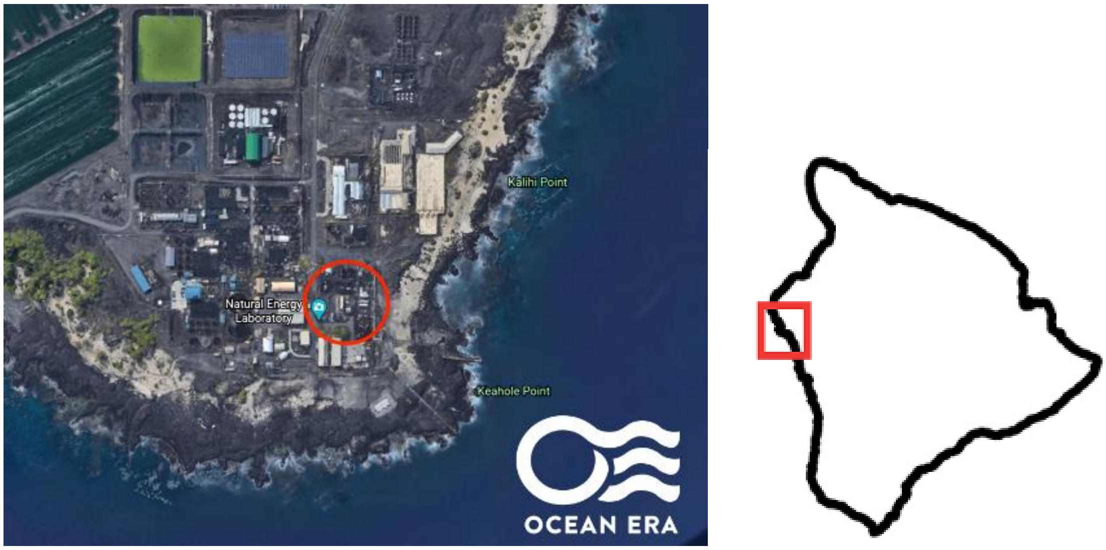

Figure 1. Study Site at Ocean Era (Google Earth, 2019)

The Ocean Era site (Fig.1) is based at the Natural Energy Laboratory of Hawaii Authority's (NELHA) Hawaii Ocean Science and Technology research park on the west side of Hawai'i island. This site was chosen because of the availability of both surface seawater and deep seawater pumps. The surface seawater is filtered through 600 and 300 micron FSI filters and a heat exchanger is used to account for fluctuating surface seawater temperatures and maintain a temperature of 25.5°C. The algae site contains 32 tanks, ranging from two ton bulk tanks to 25 gallon aquariums. The main three tank types I worked with throughout my internship were the two ton bulk tanks used to house *Gracilaria*, raceway tanks mainly used for trials, and holding tanks for algae not currently used in a trial.

Tank System Maintenance/Calibration

During the internship I assisted Ocean Era's macroalgae technician Keelee Martin with the maintenance of the system. All tank systems on site are open systems, and the constant introduction of new seawater into the system causes the tanks to be susceptible to epiphytes and biofouling. In order to mitigate these effects, the tanks are cleaned daily and precautions are set in place to prevent cross contamination of the tank systems, such as bleaching all cleaning tools between tanks. My duties also included building shading structures for each tank and basic data collection for light levels and temperature of the tanks, as well as daily calibrations. Ocean Era uses nutrient rich deep seawater as fertilizer, with no additional outside supplementation. This is done by maintaining a specific ratio of deep seawater to surface seawater, usually between 1-10% depending on what is needed for a specific trial. In order to keep that ratio steady, the input valves must be calibrated at around the same time each day.

Ocean Era is a fairly small company with only four employees working the algae site one or two at a time. As the company grows, it is important to standardize methodology as well as make training new employees easier. I was tasked with writing standard operating procedures (SOPs) for the maintenance and calibration of the tanks. I created species and tank type specific SOPs which are now on site for future use. I also assisted with seeding the algae for its use in a fish feed trial at Ocean Era's fish site. This meant weaving algae (specifically *Sargassum* and *Gracilaria*) into a nylon line so it could be easily transported. We created about ten of these lines a week for six months of my internship.

Growth Trials

Algal growth trials are at the heart of Ocean Era's algae project. The purpose of these trials is usually to answer one or more of four questions: what algae species can be grown with the resources available; what is the growth rate of that species; how little nutrients can that species survive on; and what substrate type is ideal for the growth of that species. My specific duties included monitoring the growth rates of the algae throughout the trial by performing biomass weigh-ins. Throughout multiple trials, my mentor and I noticed that the algae near the deep seawater input was growing faster than algae further down the tank. It was decided that different deep seawater introduction methods needed to be tested and it became my job to design a pilot trial to test a new method.

Deep Seawater Diffusion Trial

I designed a six week growth trial examining two variables. The first was a new way of introducing deep seawater to the system using an air diffusion tube. The tube would be run the length of the tank, ideally making the introduction of deep seawater consistent throughout the entire tank. The trial was also used to compare the growth rates of two different substrate types, a small square mesh and a larger hexagonal mesh. Six packets of *Caulerpa lentillifera* were made by sandwiching the algae between two layers of mesh, three packets for each mesh type. Two packets, one for each mesh type, were placed alternating at three locations down the length of the tank. The trial ran for six weeks, with a weigh-in every week to calculate the specific growth rate of the algae that week. After six weeks we found that the algae near the input valve had a consistently higher growth rate then the algae near the middle and far end of the tank (Fig. 2). The diffuser line was not effective. The hexagonal mesh also appeared to be a better substrate for the *Caulerpa* then the square mesh (Fig. 2), although more testing with replicated trials is necessary.

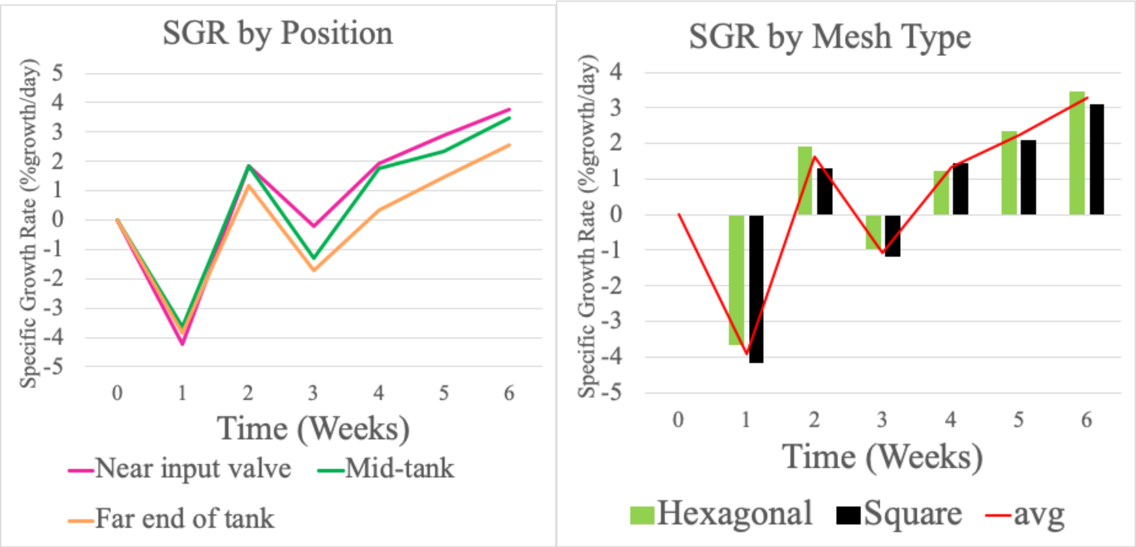

Figure 2. The specific growth rate of *Caulerpa lentillifera* over six weeks based on position in the tank and mesh type.

Algal Condition Scale

As more trials took place, my mentor and I noticed that although algae had positive growth rates, the algae was not at optimum health. Some algae were bleaching and dying or had a strange hollow texture. We decided that it was important to create a system to quantify the algal heath of our tanks other than just biomass. The quantified values could then be tracked overtime to evaluate the overall health of the system. In order to quantify what we saw, we created a visual algal condition scale. The four species on site were individually evaluated for four variables: color, thallus texture, epiphyte presence, and general morphology. Each variable was then split into five levels, with level one signifying algae that is dead or beyond saving and level five signifying optimal health. When evaluating a piece of algae, each level was assigned an estimated percent per total biomass that when added together would total one hundred percent. These values were then recorded so the estimated health of the tank could be monitored.

Results

I succeeded in achieving my initial objectives coming into this internship. I gained 150 hours of experience working with land-based algae cultures and learned what conditions are optimal for the growth of the four species on site. I also gained experience with the technical side of the site, learning what filtration and heating implements are necessary to run a site that size as well as how to maintain a clean environment for algal growth. I also designed my own algal growth trial and assisted in the design and implementation of several others which will all be used to inform how to set up the offshore array.

Discussion/Conclusion

Ocean Era is finishing its initial year of land-based tank testing and plans to deploy the offshore array later this year (2020). The information gained from the growth trials of native Hawaiian macroalgae will be applied to the future offshore demonstration project. If successful, this could lead to a large-scale offshore macroalgae farm. This farm would be without major competition on-island and has potential for positive local economic impacts. A larger biomass yield from an offshore farm could be sold locally for food, as well as livestock feed (McDermid et al. 2019). As the impact of climate change on land based farming conditions increases, implementing more sustainable ways of producing biomass such as macroalgae culturing will become essential (Lucas et al. 2019). The work of Ocean Era can be used to determine the possibility of future multi use sustainable algae farms all around the Hawaiian Islands.

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