



California Sea Grant College Program Progress Report

Project Information

Year _____ **Grant No.:** NA08OAR4170669
Number R/AQ-128 **Start Date:** _____ **Completion Date:** _____
Title Seaweed Strain Selection and Preservation to Optimize Harvest Yields for Abalone Culture

Project Leader

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Project Hypothesis

The overall project objective was to develop operational procedures for optimizing the culture of kelp and red algae by small to moderately sized abalone farms in central California.

Project Goals and Objectives

Our specific objectives were to (1) use intra-clone outplant selection experiments to develop strains of *Gracilaria/Gracilariopsis* with high (a) fragmentation survivorship, (b) high protein content, and (c) high resistance to epiphytism, (2) use kelp selection experiments to develop *Macrocystis* and *Nereocystis* strains with high (a) survivorship after harvesting, (b) growth rates, and (c) protein content, and (3) develop low-cost seaweed preservation techniques to support the annual production of 36,000 farmed abalone. The goals for 2010-2011 were to (1) complete development of kelp and red algal dehydration techniques, (2) complete controlled diet experiments with cultured juvenile and adult abalones to determine effectiveness of dried seaweed as abalone feed, and (3) develop an implementation plan to use selection and preservation techniques to support the annual production of 36,000 farmed abalone.

Briefly describe project methodology

We conducted standard outplant selection experiments to develop strains of *Gracilariopsis andersonii* that have enhanced biomass yields in the presence of epiphytes, transplantation, and multiple harvests. The selection experiments followed the protocols established internationally for

strain selection amongst Gracilarioid red algae and focused only on wild-harvested vegetative thalli. Additional replicate lines were established at the farm in June 2008 according to our current transplant protocols. Each clone was tagged and harvested back to 10 cm original length every 2 weeks. Harvested material from each clone was then weighed, assayed for epiphytes, tagged and sorted into (1) analytical samples for determination of protein content and (2) new 10 cm outplant lengths for re-transplantation. Harvest/retransplantation cycles continued every 2 weeks until all vegetative biomass decayed. Clone survivorship in the presence of epiphytism, transplantation, and harvesting is being tested against clone identity for overyielding strains. For the dehydration techniques and effectiveness of diet experiments, we developed a preservation methods for creating silage from 40% dry weight kelp. Kelp was harvested fresh, rinsed in seawater and airdried to 30-50% of its starting weight. The kelp was then vacuum sealed and stored for greater than 2 months. The feeding experiment utilized 40,000 experimental abalone seed. The seed were fed one of four diets: (1) fresh kelp, (2) fresh kelp and red algae, (3), silage kelp, silage kelp and red algae. There were 5 replicate cages per treatment, and 3000 abalone per cage. The abalone were counted, measured for length, and weighed every two months.

Describe progress and accomplishments toward meeting goals and objectives.

We have now completed our strain-selection experiments with Gracilariopsis. The experiment ran 6 months. Epiphytism was low and was not studied. The experiment indicated the strains could be selected for enhanced biomass growth for up to 7 months, after which time the clones deteriorated. The results suggested that lines can be propagated monthly over a year, from twice yearly collections. The silage production was excellent and we have silaged 65 tons during the three year project. The experiment was successfully completed after 6 months using our produced silage; additional silage was utilized directly in the Monterey Bay Abalone direct farm operations. Results indicated no significant differences in abalone survivorship over the 6 month experiment suggesting that kelp silage is a useful diet supplement when fresh kelp is unavailable, at least for a period of 2 seasons. Biomass growth rates were significantly lower for silage fed abalone relative to fresh-kelp fed abalone, but this appeared to be due to low water content in silage where abalone receive their dietary water. Shuck weights were equal between the two diets. Due to loss of our laboratory partner, nutritional samples have been collected and are awaiting analysis.

PROJECT MODIFICATIONS: Explain briefly any substantial modifications in research plans, including new directions pursued and ancillary research topics developed. Describe major problems encountered and how they were resolved.

Our research indicated 100% dried kelp would be a non-viable feed, so we removed that treatment from our feeding experiment, which allowed us to increase our sample size from 3 to 5. Additionally, the company that was performing our nutritional analyses went out of business and we required a no-cost extension for 2011-2012 in order to establish a contract with a new laboratory to complete the analyses.

PROJECT OUTCOMES: Briefly describe data, databases, physical collections, intellectual property, models, instruments, equipment, techniques, etc., developed as a result of this project and how they are being shared.

We have been able to successfully create kelp silage for the first time known to science. Our feeding experiments indicate that this new diet will allow abalone farmers to maintain quality product during extended (6 months) periods of poor food quality or lack of fresh kelp. Our method has been utilized by Monterey Abalone Company at a commercial scale for over 2 years. Our field culturing experiments indicated the gracilarioid red algae could be propagated for up to 7 months using single cuttings, with no decrease in growth rates and biomass yields. This new information will allow for more efficient seaweed culture methods with minimal requirements for harvesting new material as seed stocks.

IMPACTS OF PROJECT: Briefly describe how this project has contributed to a discipline; to developing human resources; to developing physical, institutional or information resources; technology transfer; and society beyond science and technology. Please notify CASG of impacts that occur after your project ends; CASG may contact you after your project ends to learn about additional impacts that occur over time.

The results of this project have directly impacted the operational plan of the Monterey Abalone Company allowing them to maintain abalone farming operations during two consecutive poor winters. We have given numerous presentations of our research at scientific meetings, and through that dissemination two additional abalone farms in California, and 3 additional abalone farms internationally have become aware of our silage production methods and our feeding results. The silage results have also been utilized by two additional firms exploring storage of kelp for biofuel production.

BENEFITS, COMMERCIALIZATION, AND APPLICATION OF PROJECT RESULTS: Please list any companies, agencies, organizations or individuals who have used your project results, scientific/technical advice, etc., and provide names, emails and phone numbers. Briefly describe how results were used and quantify results and socioeconomic benefits, if possible.

The results have already been utilized at a commercial scale in the operational plan of the Monterey Abalone Company, which has silaged over 50 tons of fresh kelp for their operations.

ECONOMIC BENEFITS generated by discovery, exploration and development of new, sustainable coastal, ocean and aquatic resources (i.e., aquaculture, marine natural products, foods, pharmaceuticals).

Although we have not conducted an economic analysis, the use of silage by Monterey Abalone Company has completely negated their costs of buying fresh kelp from other harvesters during the winter, and has decreased the fuel, salary, and maintenance costs of harvesting kelp directly during periods of low kelp abundance.

Issue-based **forecast capabilities** to predict the impacts of a single ecosystem stressor, developed and used for management (i.e., climate change, extreme natural events, pollution, invasive species, and land resource use).

We anticipate that all California kelp farms will utilize silage as a feed stock during some time of the year. Also, our final implementation plan will allow for the design of abalone farms dependent 100% on silage feed, potentially allowing for more cost-efficient expansion of abalone farms in California, as well as additional business opportunities for companies interested in producing silage for sale.

Tools, technologies and information services developed (i.e., land cover data, benthic habitat maps, environmental sensitivity index maps, remote sensing, biosensors, AUVs, genetic markers, technical assistance, educational materials, curricula, training).

Kelp ensilagement is a novel technology

Publications (list in appropriate category below) Each listing should be a stand-alone bibliographic reference, including all authors' names. For each Publication type, specify title, authors, date and journal details, where appropriate (repeat headers as necessary).

Technical Reports

Title	Authors	Date
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Conference Papers, Proceedings, Symposia

Peer-reviewed journal articles or book chapters

Non-peer Reviewed Reprints

Publications, Brochures, Fact Sheets

Books & Monographs

Handbooks, Manuals, Guides

Electronic publications: (non-print formats).

Maps, Charts, Atlases

Theses, dissertations

Newsletters, periodicals

Program reports (annual/biennial, strategic plans, implementation plans)

Educational Documents

Topical Websites and Blogs

Miscellaneous documents (not listed above).

MEDIA COVERAGE: Select 'Yes' or 'No'. If yes, describe any radio, TV, web site, newspaper, magazine coverage your project has received. Send original clippings or photocopies to the Sea Grant Communications Office.

Our work has been described in a Sept 17 2009 article in Monterey Herald entitled "Moss Landing scientists study seaweed as a key to sustainability", which was later carried in the Santa Cruz Sentinel

MEDIA NOTES: Brief description of the type media coverage your project has received.

DISSEMINATION OF RESULTS: List any other ways in which results of your project have been disseminated. Indicate targeted audiences, location, date and method.

Results have been disseminated at 3 scientific meetings.

International Seaweed Symposium, Ensenada, Mexico, Feb 2010

California World Oceans, San Francisco, Oct 2010

Western Society of Naturalists, San Diego, Nov 2010

And 3 University seminars.

WORKSHOPS AND PRESENTATIONS: A brief description of location, date, time, topic, number of attendees and name of presenter.

No workshops, all presentations listed under results dissemination

COOPERATING ORGANIZATIONS: List those (e.g., county or state agencies, etc.) who provided financial, technical or other assistance to your project since its inception. Describe the nature of their cooperation.

Federal Organizations

Monterey Bay National Marine Sanctuary

Regional Organizations

State Organizations

California Department of Fish and Game

Nongovernment Organizations

International Organizations

International Seaweed Association

Industry Organizations

Monterey Harbor District

Monterey Abalone Company

Academic Organizations

Moss Landing Marine Laboratories

Universidad de Los Lagos, Chile

Sea Grant Organizations

Other Organizations

INTERNATIONAL IMPLICATIONS: Does your project involve any colleagues overseas or have international implications?

The kelp silage methodology is current being considered as a mechanism to support expansion of abalone farming in Chile where kelp populations are distant from the center of abalone farming.

AWARDS: List any special awards or honors that you, or any co-project leaders, have received during the duration of this project.

KEYWORDS: List keywords that will be useful in indexing your project.

kelp silage, abalone farming, red algae

PATENTS: Please list any patents or patent licenses that have resulted from this project, and complete the patent statement form available on the web site.

NOTES: Please list any additional information in the notes area

FOR ALL STUDENTS SUPPORTED BY THIS GRANT, PLEASE LIST:

Volunteer Count 6

Graduate Student Info

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Degree Program	MS				
Thesis Title	Effect of competition and dispersal on the recruitment of the annual kelp <i>Nereocystis luetkeana</i>				
Supported by Sea Grant	Yes	Start Date	2/1/2009	End Date	1/31/2010
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Degree Program	MS		
Thesis Title			
Supported by Sea Grant	Yes	Start Date	2/1/2009
		End Date	1/31/2011