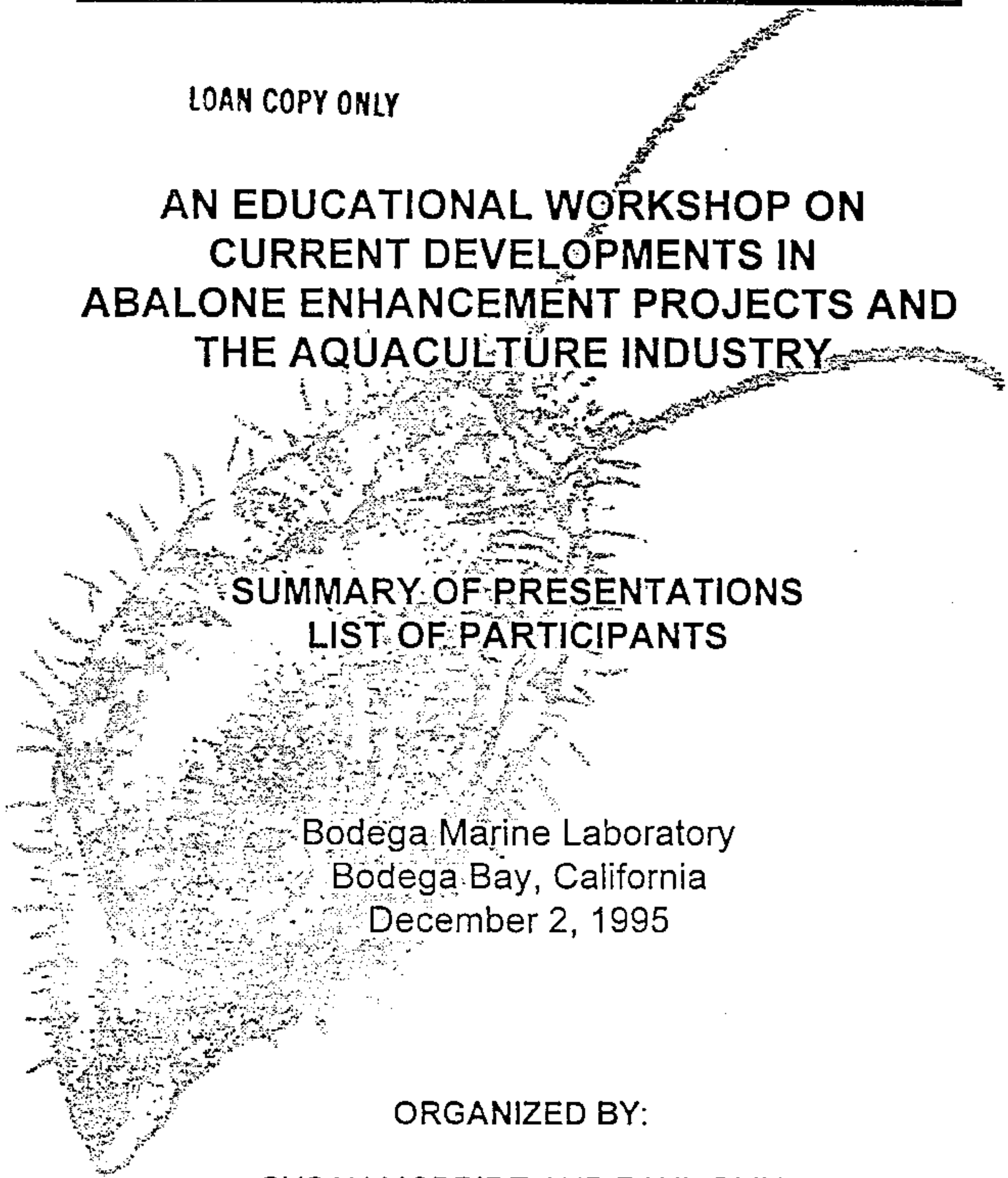
ABALONE WORKSHOP II



AN EDUCATIONAL WORKSHOP ON CURRENT DEVELOPMENTS IN ABALONE ENHANCEMENT PROJECTS AND THE AQUACULTURE INDUSTRY

SUMMARY OF PRESENTATIONS
LIST OF PARTICIPANTS

Bodega Marine Laboratory
Bodega Bay, California
December 2, 1995

ORGANIZED BY:

SUSAN MCBRIDE AND PAUL OLIN
CALIFORNIA SEA GRANT
UNIVERSITY OF CALIFORNIA COOPERATIVE EXTENSION

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ACKNOWLEDGEMENTS

We would like to thank the Director and staff of the U.C. Davis Bodega Marine Laboratory for their support and assistance in planning and organizing this workshop. The new lecture hall and other facilities allowed us to accommodate the large audience interested in California abalone. Special thanks go to the cafeteria staff for their excellent help with the refreshments and lunch menu.

Support for this workshop from California Sea Grant is greatly appreciated.

INTRODUCTION

Interest in the California abalone fishing and aquaculture industries continues at a high level and from a diverse audience. As we will hear today, aquaculturists, commercial and recreational fishermen continue to increase their understanding of the abalone resource through research and improved technologies.

The California Sea Grant College System supports these efforts both by providing educational programs and by funding university research on abalone growth, culture, and disease. Collaborative projects involving the California Department of Fish and Game, commercial abalone growers, and the abalone fishing industry also contributed to our growing understanding of this valuable resource. The presentations at this workshop represent results from several of these projects, as well as independent endeavors.

The abalone aquaculture industry has embraced innovative production technologies using cages and barrels attached to floats or long-line systems. Land-based production systems also reflect an improved understanding of the biological requirements of abalone held in tank systems. In onshore and offshore production systems, animal density, oxygen availability, and feed quality are elements that must be understood for efficient production. At this workshop, both types of production systems will be described by culturists who operate such facilities.

Many people, including some participants at the first Sea Grant-sponsored Abalone Workshop in Fort Bragg, October 1994, asked how one achieves the goal of operating an abalone farm. The lead agency for aquaculture in California is the Department of Fish and Game. The state aquaculture coordinator will explain the permit process and requirements. Presently more than 10 abalone farms are operating in California and at least 4 farms have started the permit process. Continuing in a highly practical vein, we will also hear a discussion of the marketing and economics of cultured abalone, an important consideration for all culturists.

After lunch, we will hear about recent developments in the abalone aquaculture industry and about an abalone enhancement research project using methods new in California.

One objective under investigation in abalone-producing countries is development of commercially produced abalone diets, which will result in improved growth rates, less reliance on harvesting natural diets, and increased understanding of nutritional requirements. We will be hearing a description of artificial diet feeding trials with juvenile abalone.

Until recently, the abalone aquaculture industry was fortunate in not facing serious problems with disease and parasites. But we will hear a description of a devastating polychaete, thought to be nonindigenous, which infests abalone shells and affects the animals' growth. This relatively new pest is under investigation by Sea-Grant funded scientists from the University of California in Santa Barbara and the Los Angeles County Museum of Natural History. Aquaculturists are also developing a variety of husbandry techniques to address this problem.

Reseeding and enhancement of abalone populations in California was tried during the 1970' s and 1980's by a variety of methods . Adult abalone have been relocated to improvespawning success, juveniles have been cultured and placed in the near shore habitat, and larvaeready to settle on subtidal rocks have been released. An overview of these projects and ideas foruse of cultured abalone to replenish abalone populations reduced from disease or other pressureswill be presented. One current, large-scale abalone enhancement project in northernCalifornia using abalone tagged with a fluorescent marker is testing a method used successfullyin New Zealand. This exciting project is an example of a collaborative research projectinvolving University of California scientists, the California Department of Fish and Game, Bodega Farms, and the commercial fishing industry.

The abalone aquaculture and fishing industries are linked through a common strong interest and concern for maintaining healthy abalone populations. Workshops such as this oneare one method of bringing enthusiasts together to present, discuss, anddevelop new ideas and methods for sustaining and increasing the abalone resource. Strongsupport for abalone will also benefit other marine resources by increasing awareness ofvaluable coastal habitats. Those of use associated with California Sea Grant will continue to seek opportunities in research and education to promote understanding of coastal and marine resources. We value your participation in this meeting and look forward to continued relationships.

Susan C. McBride
Marine Advisor
California Sea Grant

A REVIEW OF THE DESIGN AND FIELD TESTING RESULTS OF SEVERAL ABALONE CULTURING BARRELS FROM CALIFORNIA, NEW ZEALAND AND MEXICO

Luc C. Chamberland
Abalone Acres

The barrel culture of abalone takes on numerous shapes and forms matched only in number by the variety of the sites where it is practiced. Each site provides a multitude of challenges that the barrel design must accomodate. In an attempt to develop a barrel most suited to its farming site in Tomales Bay, Abalone Acres reviewed and tested several barrels from California, New Zealand and Mexico. This review comprised a thorough yet basic analysis of the following parameters:

1. Material selection: life span, cost of purchase, cost to modify, ease and cost of repair, durability and ease of procurement.

2. Barrel design: size, weight, lid and bottom mechanisms, adaptability to mechanized production, points of attachment to a long line, susceptibility to storm damage, maintenance, water flow characteristics, mesh size, ease of feeding and harvesting abalone.

3. Stocking densities: feeding frequency and kind of feed utilized.

The results of this study demonstrated that no single barrel answered all the requirements of our site but is was possible to combine elements of various designs to produce an abalone culturing barrel suited to Tomales Bay. It is fair to assume that this selection process can be duplicated for other sites with similar results.

LAND BASED GROW-OUT SYSTEM

Pete Scrivani
Pacific Mariculture, Inc.

My exposure to growing abalone onshore dates back to the mid 1970's and a small shack along Cannery Row in Monterey, California. An individual named George Lockwood was beginning his abalone growing company, Monterey Abalone Farm. Since then I have visited most of the onshore farms in California and have been fortunate enough to travel to Australia, Mexico, Japan, and China for tours of their abalone facilities. Within any given year, visitors from these and many other countries stop by and tour our site in Santa Cruz, California.

Common themes with regard to abalone, which have not changed with time, are the lack of supply, high demand and the difficulty of farming abalone, whether its onshore or in cages etc. offshore. This is a capital intensive business with long production times before significant inventory is available for marketing and therefore requires significant working capital as well.

A look at a "typical" scenario for starting an onshore abalone farm brings the high up-front costs into perspective. The design for a fully integrated (hatchery, nursery, grow-out, sales/shipping) onshore abalone farm in California will require at least one to two years to secure all of the necessary permits. These permit costs must be incurred with no guarantee of success and usually after signing a land lease or purchasing property and paying for architectural and engineering plans. Permits for harvesting kelp and a lease for kelp beds, if there are any available, must also be included. This permit process is by no means impossible, just expensive and it is the cost of the process that will be used by any groups that oppose the project. Be sure to work closely with the planning staff of the local, state and federal agencies since they can save you both time and money when it comes to responding to project complaints and scheduling public hearings.

After securing all of the necessary permits, you will need to allow months to construct the infrastructure before the first crop of abalone is spawned. These lead times can be mitigated by operating a pilot facility at another location, such as leased space at a marine lab, while wading through the permit process. There are some locations of abandoned aquaculture facilities that can be leased or purchased and these can reduce the lead times for permits and construction.

If you decide to grow a three and one half inch abalone and project growth rates of one inch per year it will take at least 39 months before the harvest of your first "crop". This means you will have many crops in production at once and explains the value of a reliable seawater and air system. These two systems are the main life support for abalone grown onshore and usually operate 24 yours a day. They need to work efficiently whether its winter or summer and under standard or backup power. Along with labor and food cost, the power to operate these two systems will be one of your largest production cast costs. The air system is the most critical from a time perspective since by definition onshore abalone growing equates to rearing systems (tanks-raceways) at high densities. Lack of dissolved gases in seawater will cause the abalone to crawl out of the tanks. The critical factors during a seawater pumping failure are usually temperature and waste products (ammonia). Depending upon the weather and the amount of feed in the tanks days can pass before mortality becomes significant if all other support systems are running.

To minimize potential spread of disease, isolate water quality problems, and maintain inventory integrity you can choose to maintain tanks with separate inflow and discharge systems, however this increases capital and operating costs. Another approach is to use a system of slacked or terraced tanks with a common inflow and discharge form one tank to the next. While such a design may save capital costs and reduce costs per gallon of seawater pumped, it can also lead to compromises on water quality and disease control. Abalone growth rates within tanks can be defined by a combination of variables such as density, water exchange, quantity and quality of feed, air, temperature and "stress factor". The design of the tanks and layout will impact the ability of the grower to alter these variables, optimize growth and survival and lower production costs per abalone.

PERMIT REQUIREMENTS

Bob Hulbrock
California Department of Fish and Game

I. California Department of Fish and Game - Lead Agency for Aquaculture in California
   A. Aquaculture Registration - Required of every private aquaculture facility in California. Reviewed for potential impacts on wildlife resources.
      1. Species approval
         a. Commonly approved species - include red, green, and pink abalone.
         b. Prohibited species listed in the Fish and Game Code and Title 14 (CCR). There are no abalone species on the prohibited species list.
         c. All other species are reviewed on a case by case basis. Fish and Game Commission policy makes introduction of non-established exotic species from out of State very difficult.
      2. Location - movement from one area where they are approved to another area may not be approved if the movement may cause negative impacts on adjacent resources in the new area either through introduction of a new species (unlikely with abalone) or because of possible disease impacts (eg the sabellid polychaete worm.
      3. Facility design
   B. State Water Bottom Lease - Fish and Game Commission
   C. As lead agency for aquaculture in California, if DFG approves an Aquaculture Registration, it should support the project with other regulatory agencies.
II. California Coastal Commission - Coastal Development Permit - for projects in the Coastal Zone
   A. If certified Local Coastal Plan (LCP) - local government agency may issue permit.
   B. If a third party objects to a permit issued by local government, the appeal is heard by Coastal Commission.
C. If no Certified LCP, Coastal Commission issues permit.
III. U.S. Army Corps of Engineers
   A. For projects in wetlands
   B. For projects in navigable waters - including territorial seas inside three miles
      1. River and Harbor Act - Section 10 Permit
      2. Clean Water Act - Section 404 Permit
IV. State Lands Commission - State Permit/Lease for pipeline over public lands (beach).
V. Regional Water Quality Control Boards - NPDES (National Pollutant Discharge Elimination System) Permit for water discharge to surface (ocean) waters.
VI. Local Government - County, Harbor District, etc.
   A. Land use and Building Permits
      1. Aquaculture is Agriculture by State Law,
   B. CEQA - California Environmental Quality Act.
      1. California's most important environmental law.
         a. Most proposals for physical development in California are subject to CEQA.
   2. May require preparation of EIR (Environmental Impact Report)
         a. Lead agency (usually local government) mlakes determination if EIR required.
VIII. Others - determined by specifics of project

MARKETING AND ECONOMICS

Bill Marinelli
Marinelli Shellfish

Marinelli Shellfish was established in July of 1982 by Bill Marinelli. The purpose of the company was to develop markets for aquacultured shellfish, primarily oysters. The product line was increased to include other under utilized shellfish. Initially the marketing and sales were focused on restaurants concerned with the highest quality and an interest in new and unusual products. Once a strong customer base was established, with steady demand for our product, the restaurants were turned over to reputable seafood wholesalers for servicing. Marinelli Shellfish now supplies the wholesalers only, acting as a distrubtor, enabling us to rapidly increase our product line and volume. Although we no longer sell directly to a restaurant we still maintain a very strong presence by providing seminars to staff on the preparation, storage, and serving of shellfish, periodic newsletters and personal demonstrations of our product line to interested chefs. Besides emphasis on our marketing, we maintain close relationships with the farms and producers that supply us. Doing more than just "placing orders", we constantly assist in maintaining and improving the quality and service our customers have come to expect. Marinelli Shellfish is active in the state, national and international associations and regulatory bodies that concern themselves in shellfish culture and we play an active part in the advancement of the industry.

A. History of my experiences in selling farm raised abalone: Initially product was too small, too expensive and there was still an abundance of wild product. As market prices increased, farmers grew out larger sizes. Great success in selling the three to four inch abalone.

B. The Japanese connection: The demand for the product in Asia is rapidly increaseing as wild stocks continue to decline, expecially the production from New Zealand and Australia.

C. Marketing plans: How and why to diversify your market. There is still a very large untapped domestic market. The "romance effect" of farmed raised product.

D. The future: As wild stocks continue to decline, demand continues to increase, prices rise, the future looks very healthy for the abalone farmers. Where's the ceiling?

PRELIMINARY ARTIFICIAL ABALONE DIET TRIALS WITH THE RED ABALONE, *HALIOTIS RUFESCENS*

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INTRODUCTION

Abalone aquaculture has successfully made the transition from research and development to commercial production in the last decade. This transition was enabled by development of reliable techniques for spawning, larval rearing and grow-out, coupled with reduced wild harvest and increasing demand. Research efforts are now focused on improving culture techniques, and developing artificial diets to improve growth and survival, while reducing reliance on natural feeds.

While most commercial companies rely on natural seaweeds as the primary food source for abalone grow out, there are a number of commercially available artificial feeds on the market. These feeds have been developed in different parts of the world for a variety of abalone species and culture conditions. In California, the primary species being cultured is the red abalone, *Haliotis rufescens*, and there is little information available on the comparative performance of these diets for this species under different culture conditions. This paper will summarize some of the requirements of a successful abalone diet, and present some preliminary data on diet performance for the culture of juvenile red abalone.

A successful abalone diet must provide for good growth and survival, and be economically competitive with other feed sources. Seaweed is currently the most widely used grow-out feed because it supports good growth and survival, is readily available in many areas, can be purchased inexpensively, and has a minimal impact on water quality. There is however a considerable labor cost associated with the acquisition and delivery of seaweed to culture tanks or barrels. Seaweed abundance is also seasonally variable, and there are many regions of the world that lack seaweed resources, but which otherwise have good potential for abalone culture.

To be competitive, artificial diets must provide for growth and survival comparable to those achieved using seaweed diets, and do this on a cost competitive basis. Artificial diets must provide carbohydrate and protein for energy and growth, along with necessary vitamins, minerals and trace elements. Diets must also be chemically and physically attractive so they are readily consumed and digested.

EXPERIMENTAL TRIALS

In order to evaluate a number of commercially available diets for use in red abalone culture, experiments were set up to evaluate ABFEED, a diet developed in South Africa by Sea Plant; VEGGIE FLAKE, developed in the U.S. and marketed by AquaDine; MAKARA, a feed developed by Promak in New Zealand. These trials included starvation and kelp fed control treatments.

There were a total of five treatments with eight replicates per treatment. Experimental animals were taken from a group of juveniles with an average weight and length of 2.175g and 24.91mm respectively. Animals were raised in small plastic mesh baskets with ten animals per basket, and these baskets were placed in shallow raceways at ten per raceway. Experimental treatments were randomly assigned to baskets in the raceways. The animals were fed, and baskets were cleaned every other day. Animals were fed formulated diets at a rate of 20% body weight/day, while kelp controls were fed ad libitum. Starved animals were able to graze only on algae that grew on the basket surface. The composition of the artificial diets on a percent basis follows:

FEED	PROTEIN	CARBOHYDRATE	FAT	FIBRE	MOISTURE
ABFEED	34.6	43.3	5.3	4.2	10
PROMAK	53.3	32.0	5.3	N/A	N/A
VEGGIE	31.0	N/A	5.0	4.0	8

The diets were all accepted by the abalone but varied in their water stability. The Kelp and Abfeed diets were the most stable, and there was visible feed left following a 48 hour period. The Veggie Flake and Makara feeds were largely broken down within a 24 hour period, although there were visible residues remaining. These residues were more apparent in the Veggie Flake treatments than the Makara. The following table presents data on growth of abalone over a 60 day trial period.

ABALONE LENGTHS AND WEIGHTS WHEN FED DIFFERENT ARTIFICIAL DIETS DURING 60 DAY TRIAL

VARIABLE	ABFEED	MAKARA	VEGGIE	KELP	STARVE
INITIAL WEIGHT (g)	2.175	2.175	2.175	2.175	2.175
FINAL WEIGHT (g)	2.95	3.12	2.97	3.04	2.25*
INITIAL LENGTH (mm)	24.91	24.91	24.91	24.91	24.91
FINAL LENGTH (mm)	27.46	28.1	27.36	28.4	25.26*

* These values were collected after 30 days, at which time the starvation control was discontinued

As can be seen from these preliminary trials, each of the diets used supports growth and survival in red abalone. These trials are continuing, and further experiments conducted over a longer time frame will provide additional information on their relative performance.

CHARACTERISTICS OF CULTURED ABALONE INFESTATIONS BY AN INTRODUCED SABELLID POLYCHAETE

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A new undescribed polychaete pest, that settled on the growing edge of abalone shells, was detected in several California abalone aquaculture facilities and brought to our attention in 1993. High worm infestations significantly reduce growth rates and cause abnormal shell growth, sometimes blocking respiratory pore formation. Although the meat of the abalone is not impacted, infested abalone may take a much longer time to reach market size. Sometimes growth ceases altogether or the shells become brittle and deformed so as to be unmarketable. To date, industry surveys (both written and on-site) indicate that all producing farms have dealt with this pest, either presently or in the past. Transmission of the worm within the industry was greatly enhanced due to the interdependent nature of the business; seed and larger abalone are sold within the industry. With the problem spreading, in 1994 Sea Grant funds were obtained to initiate a six month investigation focusing on shell damage, infestation rates, and biological control of the pest. Research has since continued through funding by the abalone aquaculture industry and additional funds from Sea Grant. Recent studies, summarized here, include investigations on development/life history characteristics, host specificity, and water management.

Although first believed to be a boring organism, examination of sectioned infested abalone shells revealed that abalone shell deposition formed a tube over the worm. Presence of the worm interrupted deposition of the abalone's prismatic shell layer (needed for linear extension of the shell) and promoted nacreous shell deposition.

Transmission requirements, including contact, aeration, water direction, host size, and salinity, have also been investigated. Contact between uninfested and infested abalone is not required for transfer of larval worms. Benthic locomotion of larval worms is quite impressive, in terms of both infestation rate and distance covered. In the presence of infested abalone, uninfested abalone become infested within 24 hours. Infestation rates were influenced however by several variables, including distance between uninfested and infested hosts, presence of substrates, and use of aeration. For example, larvae could move a distance of 5 meters within a week when substrates are lacking. In comparison, with substrates present it takes 3 weeks for larvae to move the same distance. Preliminary studies suggest that aeration plays a role in dispersal. With aeration, dispersal increased. To understand the spread of this pest in culture facilities it is necessary to understand worm dispersal in the presence of unidirectional water flow. Movement of the larvae was exclusively downstream when hosts were placed both up and downstream from the source of larvae. Of additional interest is the relationship between abalone size and larval settlement. At present, we have recorded infested abalone as small as 2mm. However it appears that the very small abalone (<3mm) were either less preferred hosts or were better able to restrict the worm larvae from settling. Lastly, the ability of larvae to actively infest abalone in different salinities is being examined. Larvae were able to survive in salinity as low as 17 ppt for several days. Current experiments are examining whether these larvae can also infest a host.

Control, as one would expect, is a key issue for the aquaculture industry. Chemical treatment was initially sought at by the industry. These ad hoc procedures included air exposure for extended periods of time, freshwater, chlorine treatment, and several insecticides. In all cases, either no impact occurred or the abalone were more negatively effected than the worms. We examined biological controls, assuming that in culture worm populations increased because natural predators were excluded from the tanks. Various native Californian fishes and invertebrate predators were placed in aquaria with infested abalone and worm density was monitored. Of the 6 fish and 9 invertebrates tested, none were capable of reducing the worm populations. To date, the only means of control is coating the shell with wax or other non-toxic substances. This effectively smothers the adult worms and closes the tubes so any remaining larvae can not be released.

The failure to identify an effective natural enemy was not surprising since the pest has now been recognized as an introduced species. Co-investigator Kirk Fitzhugh of the L.A. County Museum of Natural History recognized that a worm native to South Africa was conspecific to the pest of cultured California abalone. In South Africa this worm has now been reported in both native and cultured abalone. This polychaete worm is in the family Sabellidae and co-investigator Fitzhugh is preparing its formal description. Its life cycle is as follows: eggs are brooded within the tube, producing benthic larvae. The larvae, once active, leave the parent tube. Upon settlement, they undergo metamorphosis into juveniles which possess the branchial crown, used for filter feeding. The worms mature within the tube. This species is a simultaneous hermaphrodite.

The development time for each phase of the life cycle is currently under study. Preliminary evidence indicates that within two days post-settlement, crawling larvae begin metamorphosing into juveniles. This process is completed in approximately a week, depending on temperature. Maturity is reached in about one month, although it is still unclear when reproduction is initiated.

In conjunction with development, the issue of larval survivorship is currently being examined. Initially we believed that the sabellid required a live host to become established. Recently, we have found this to be only partially true. The sabellids do not infest empty shells, even those that have established, empty tubes. However, in more than one instance the larvae secreted a sheath on the bottom of the experimental container. The worm not only survived in these conditions, but also continued to develop through metamorphosis.

Upcoming research will involve determining the relationship between abalone shell growth and worm population growth as a function of temperature. Preliminary observations indicate that worm populations increase tremendously at high temperatures when abalone growth is normally slow. Contrarily, the worms minimally impact abalone growth at cooler temperatures. Maximizing abalone growth while minimizing worm infestation rates through the use of temperature will be investigated.

In addition, as this pest is introduced to California other native molluscs may be at risk. Initial findings, based primarily on surveys of other molluscs found in heavily infested aquaculture facility tanks, indicate that gastropods in general are susceptible to sabellid infestations. Bivalves do not become infested. Research will be expanded to more critically examine host preference among molluscan species.

A LARGE SCALE JUVENILE RED ABALONE ENHANCEMENT EXPERIMENT IN PROGRESS IN CENTRAL AND NORTHERN CALIFORNIA

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INTRODUCTION

Red abalone, *Haliotis rufescens*, are harvested by both recreational and commercial divers in California. The commercial fishery is centered in southern California, San Francisco and the Farallones. Stocks along the north coast support an even larger recreational fishery. Despite the importance of the north coast abalone population, comparatively little work has been done in northern California. Elsewhere in the world, abalone enhancement has had mixed success. In Japan, studies of large scale outplanting experiments report survival rates from 1 - 80% (Saito, 1984; Tegner & Butler, 1985). Large scale seeding experiments in New Zealand using Paua, *Haliotis iris*, reports 7 - 53% survival from 8 locations with growth rates ranging from 13 - 22 mm per year (Schiel and Mercer, 1993). However, in southern California outplants of red abalone, even at large sizes (mean 71 mm), have been mostly disappointing with high mortality rates (99%) (Tegner & butler, 1985).

Outplant success in northern California may be more promising. First, northern California has few red abalone predators (e.g., sea otters *Enhydra lutris*, spiny lobsters *Panulirus interruptus*, and rainbow star *Astrometis sertulifera*). Second, the dramatic increase in the red sea urchin fishery in northern California has inadvertently increased the abundance of bull kelp *Nereocystis*, an important abalone food resource. Finally, red sea urchins in shallow habitats in some areas (e.g., Bodega Bay) may provide important spine canopy microhabitats for juvenile red abalone because they reside in "home scars" and appear to be relatively stationary. Therefore, the unique habitat features in northern California suggests that specific outplant strategies must be tested locally to determine the success of enhancement efforts.

EXPERIMENT IN PROGRESS

We have outplanted 50,900 juvenile red abalone in 6 sites in central and northern California. The vast majority of these abalone, 50,000, averaged 8 - 10 mm with 900 in the 18 and 28 mm sizes. These juveniles were spawned from northern California broodstock and reared in the Bodega Farms hatchery. Juveniles were tagged in the Bodega Marine Laboratory internally with Tetracycline and Alizarin red. Densities of wild juvenile abalone and abalone predators were determined along three 30 m transects at each site prior to the outplant. In addition, the degree of substrate rugocity (unevenness) and substrate composition was recorded along the transects. Juvenile urchins were outplanted over the course of an 11 day period in mid October 1995 at all the five sites. Sites were selected in Fort Bragg, Salt Point, and Bodega Bay, and Half Moon Bay. Juvenile abalone were placed in sites paired with and without sea urchins.

We will test whether juvenile red abalone survival in northern California is enhanced by the presence of urchin spine canopy. Red urchin spines are known to provide canopy shelter for juvenile red and purple sea urchins (Tegner & Dayton, 1977) and have been suggested as important nursery microhabitats for juvenile red abalone. Abalone may gain the same kinds of benefits hypothesized for juvenile urchins including protection from predation and increased access to macroalgae captured by red urchins.

We will also test which method of outplanting yields the best survival. To examine this second question, abalone were outplanted using two techniques. The first method was that of hand planting by divers in which juveniles on macroalgae were carefully placed in cryptic microhabitats. The second method employed concrete abalone modules (Ebert & Ebert, 1988) within which juvenile abalone were placed. Following an 18 hour acclimation period, the box doors opened allowing the juveniles to escape. Finally, temperature loggers were also placed at 4 of the 6 sites. Each logger records subtidal water temperature every hour and will be in place for the duration of the outplant. We propose to examine the relationship between water temperature and abalone growth, and survival in central and northern California.

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ABALONE ENHANCEMENT: PAST AND FUTURE

Peter L. Haaker, Associate Marine Biologist
California Department of Fish and Game

Abalone enhancement has been suggested as a means of maintaining abalone landings, which have declined in recent years. The Department of Fish and Game has investigated various methods which may be used to increase populations of abalones along the coast and at the Channel Islands. Each method has benefits and liabilities in the usefulness for enhancement of abalone stocks. Transplantation of large abalones taken from native populations offer the quickest, most efficient means to increase spawning concentrations of abalones at an area, but is not usually feasible because of the lack of source stocks, and susceptibility to illegal harvest. Using small (5 to 50 mm) hatchery raised abalone for outplanting solves the availability problem, but high mortality, and moderate to high cost may limit its effectiveness. Dispersal of pre-settlement larvae is an inexpensive way to get millions of larvae into an area, but assessment and effectiveness are difficult to assess. Area closures that protect spawning populations have some merit as they allow all stages of the abalone to exist without harvest, and encourage the necessary aggregation of abalone that maximizes fertilization. Area closures are not well received by the public, but several de-facto closed areas can be used as evidence of their effectiveness. Current abalone management practices used in California are not effective and are not maintaining either the resource or the fishery. We discuss possible research into ways to better manage California's abalone resources.

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