Recent Advances in The Culture of The Queen Conch in Florida

ROBERT A. GLAZER, KEVIN J. McCARTHY, LONNY ANDERSON, and JAMES A. KIDNEY
Florida Department of Environmental Protection
Florida Marine Research Institute
2796 Overseas Highway, Ste. 119
Marathon, FL 33050 USA

ABSTRACT

The culture of larval and juvenile queen conch is a labor- and capital-intensive process that requires efficient systems, techniques, and protocols. We describe advances in water distribution, larval and nursery culture systems, and husbandry techniques devised to maximize efficiency in the queen conch culture program at the Florida Department of Environmental Protection. Advances in larviculture protocols include the design and implementation of software that calculates algal feed dilutions in static and flow-through systems for up to three algal species. Implementation of an ozone system to treat and condition incoming seawater resulted in larval production that approaches 20x the larval production in untreated water. Ozone injection is controlled by meters that electronically monitor the change in the oxidation-reduction potential of the seawater. A nursery system was developed and implemented for postlarval conch that includes downwelling feeding and upwelling cleaning phases. Algal culture tanks are integrated into the process in order to precondition the screens to be used as substrate for postlarval conch. A benthic diatom (*Nitzchia* sp.) isolated from local waters is used as the inoculum. After conch reach approximately 10 mm they are transferred to nursery system troughs and are fed an artificial diet developed on-site that yields growth rates approximating those observed in the wild. The juvenile conch are cleaned and fed daily and culled by size at regular intervals. Feed rations are based upon conch wet-meat weight. All nursery troughs are covered and shaded 100% to reduce intraspecific interactions implicated in reduced growth rates. These advances have enabled the State of Florida's queen conch hatchery to increase production to a maximum of 15,000 postlarval individuals per month while maintaining labor requirements at one culturist. Future research will focus on nursery system designs that will maximize production by increasing densities and, consequently, capacity without increasing labor requirements.

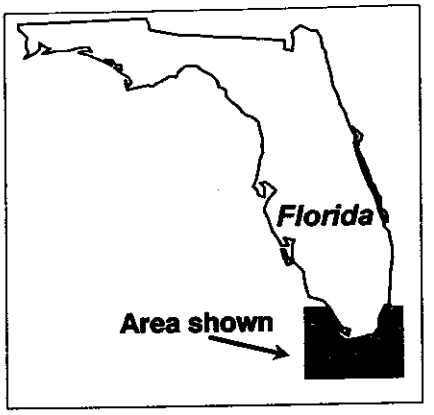
KEY WORDS: Hatchery, nursery, *Strombus gigas*

INTRODUCTION

Aquaculture of queen conch has been suggested by many investigators as a method for replenishing depleted wild populations (Berg, 1976; Brownell, 1977; Ballantine and Appeldoorn, 1983; Davis and Hesse, 1983; Hensen, 1983; Iversen, 1983; Laughlin and E. Weil, 1983; Siddall, 1984; Munoz *et al.*, 1989; Creswell and Davis, 1991; Marshall *et al.*, 1992). In 1990, the Florida Department of Environmental Protection (then Department of Natural Resources) constructed a pilot queen conch research laboratory on Long Key in the Florida Keys (Figure 1) with the goal of examining the feasibility of rehabilitating the local conch population (Glazer and Berg, 1994). The laboratory consisted of a hatchery and nursery with single-pass, nonrecirculating water flow and was designed to be operated by one person. The engineering of the hatchery was based in part upon the large body of literature on systems designs and culture protocols for the larviculture of the queen conch in the Caribbean (*e.g.*, Brownell, 1977; Hensen, 1983; Siddall, 1984; Heyman *et al.*, 1989; Creswell and Davis, 1991). Few precedents existed, however, upon which to base the nursery's design because the few queen conch nursery systems that had been described were not applicable to Florida's requirements and conditions (*e.g.*, Dalton, 1994) and the other marine gastropods for which large-scale nursery systems were developed have dramatically different physical and behavioral requirements (*e.g.*, abalone).

Our initial attempts at larviculture yielded mixed results due to suboptimal water conditions; the hatchery obtains seawater from Florida Bay which has been negatively affected by increased eutrophication and periodic algal blooms (Butler *et al.*, 1995). Although we were able to successfully culture larvae to metamorphosis, the densities were much lower and the times to metamorphosis were much longer than those reported in other hatcheries. After analyzing the water chemistry of the incoming seawater from Florida Bay, we concluded that poor water-quality was responsible.

Other than water-quality problems, the greatest challenge to our hatchery and nursery production was to design and develop efficient systems and protocols that would increase production without increasing labor requirements. Each phase of production was evaluated, and appropriate innovations were adapted in order to increase efficiency. Herein, we describe recent innovations incorporated into the State of Florida's queen conch culture program that improve the water quality of seawater used for larviculture and increase efficiency.



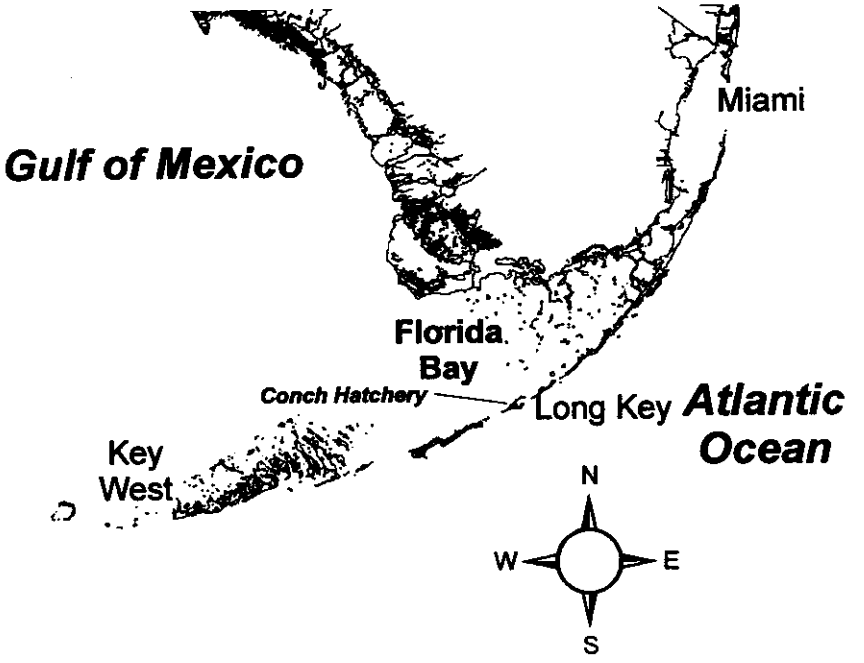


Figure 1. Location of the Florida Department of Environmental Protection's queen conch research laboratory.

SYSTEMS DESIGNS AND CULTURE PROTOCOLS

Water Treatment

In 1994, we installed a water-treatment system that uses ozone to improve water quality in our larval tanks. The current-water treatment system for larviculture is filtered through a series of sand and cartridge filters to remove particles larger than 1 μm. This water is then treated with ozone and exposed to ultraviolet light. Seawater for the juvenile nursery system may either be filtered through a sand filter to 25 μm or be unfiltered.

We used the oxidation-reduction potential (ORP) of the seawater as an indicator of the water quality. ORP is influenced by dissolved organic levels; low levels are common in eutrophic conditions. In our case, the ORP of the incoming seawater from Florida Bay more closely resembled that of polluted canals (~160 mv) than that of seawater that bathes the offshore reefs (~380 mv).

Prior to installing the ozone system, our use of filtered and ultraviolet-sterilized, but otherwise untreated, Florida Bay water resulted in larval densities as low as 1 larva/liter and a time to metamorphosis of approximately 40 days. These are considerably lower larval densities and longer times to metamorphosis than reported elsewhere (Davis, 1994).

The ozonation process enabled us to increase the ORP of the seawater, which has resulted in an increase in larval densities to 10 - 20 larvae/liter at metamorphosis and a decrease in the time to metamorphosis to approximately 20 days. The enhanced water-treatment system now includes an oxygen-generation plant, an ozone generator, a venturi injector for ozone injection, an ozone contact tower, an ozone degassing tower, a carbon filter for scrubbing dissolved toxic byproducts, ultraviolet lights to reduce ORP, and ozone on/off ORP-controlling meters (Figure 2). The controlling meters measure ORP with redundant in-line probes and prevent the ORP from increasing above 450 mv or decreasing below 380 mv. We are currently investigating the use of multiple ozone-generation plants. The advantage to having multiple plants is that different on-off set-points will reduce fluctuation in ORP and ensure continuous ozone injection which will guarantee there will be no inflow of untreated water.

Larviculture

The complex nutritional requirements of conch veligers necessitates providing their algal feed at optimal densities and quality. Our original larval-feeding protocol involved conducting daily algal cell counts and performing manual calculations of algal dilution rates for static and flow-through systems. These procedures were tedious and time consuming.

To increase overall hatchery efficiency, we have automated these procedures. First, we used a spectrophotometer to correlate the percent light transmittance to

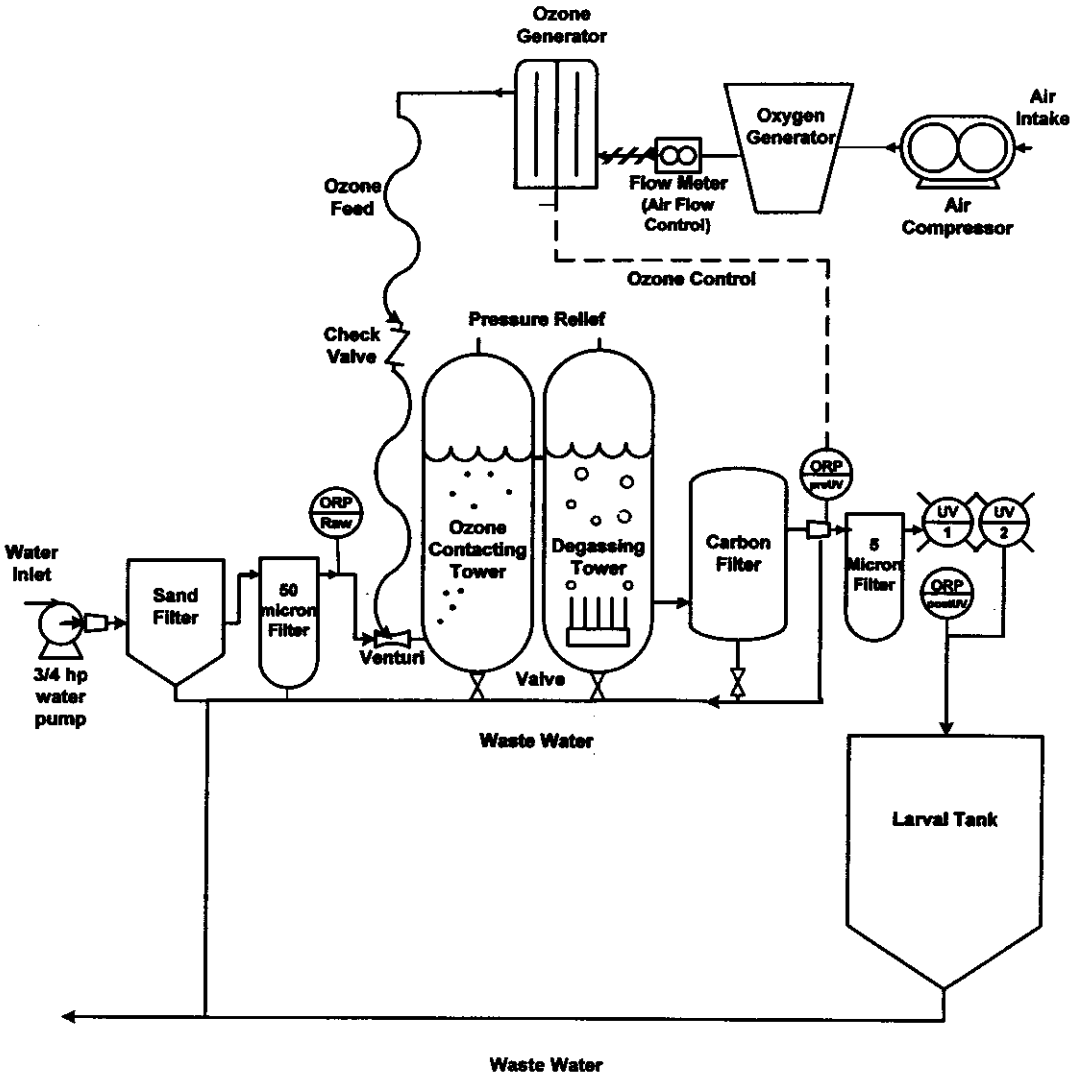


Figure 2. Water treatment schematic for the Florida queen conch hatchery detailing water flows, ozone production, ozone injection, and control. Ozone control meters maintain ozone production at a level that limits oxidation-reduction potential to 380 - 450 mv.

algal cell densities for each algal species. The percent light transmittance of the algal feed was then entered as a variable into a computer program that calculated batch feed algal volumes for initial static feeding and drip feed rates for continuous feeding in a flow-through system. In addition to percent transmittance, the program incorporates the following variables: 1) number of algal species, 2) desired feed density, 3) desired ratio of algal species, 4) seawater flow rate into tank (flow-through systems), and 5) the mix of seawater and algae in the feed reservoir (flow-through systems). The program calculates the number of drops per second at which the drip rate from the feed reservoir must be set in order to maintain a consistent density of algae in the larval production tanks. This procedure eliminated the need for manual cell counts and feeding-rate calculations.

Nursery Systems

Mass culture of juvenile queen conch is difficult from an economic perspective because of the high feed-conversion ratios of queen conch (Creswell, 1984; Davison, 1990) and the difficulty in obtaining natural fodder. Artificial diets have been developed to eliminate the dependence on natural food, but newly settled conch are too small to ingest the current artificial diets.

We developed a nursery system that uses a benthic diatom (*Nitzchia sp.*), isolated from waters adjacent to the hatchery, as a feed. This system consists of two inoculum troughs, within which the diatoms are cultured, and six queen conch culture tanks (Figure 3). Each culture tank holds four culture screens, each measuring 48 cm x 48 cm x 15 cm and constructed of 9.5-mm sheet PVC with nylon mesh screen bottoms. The screens are conditioned within the inoculum troughs until they are coated with a fine layer of the diatom. The screens are removed from the troughs and placed in the culture tanks. Immediate post-settlement juvenile conch are placed on 500 µm mesh screens; conch larger than 3 mm shell length are transferred to 1,000 µm mesh screens, and the seawater is downwelled to ensure that the newly settled juveniles remain on the screens. Periodically, the water flow is reversed to flush feces from the screens (Figure 4). This system accommodates juvenile conch until they are sufficiently large to accept artificial diets. The water source can be either filtered or raw seawater, water from the inoculum tanks, or a mixture of both. Over the course of one six-week period we measured mean conch growth rates of 390 µm/day in this system.

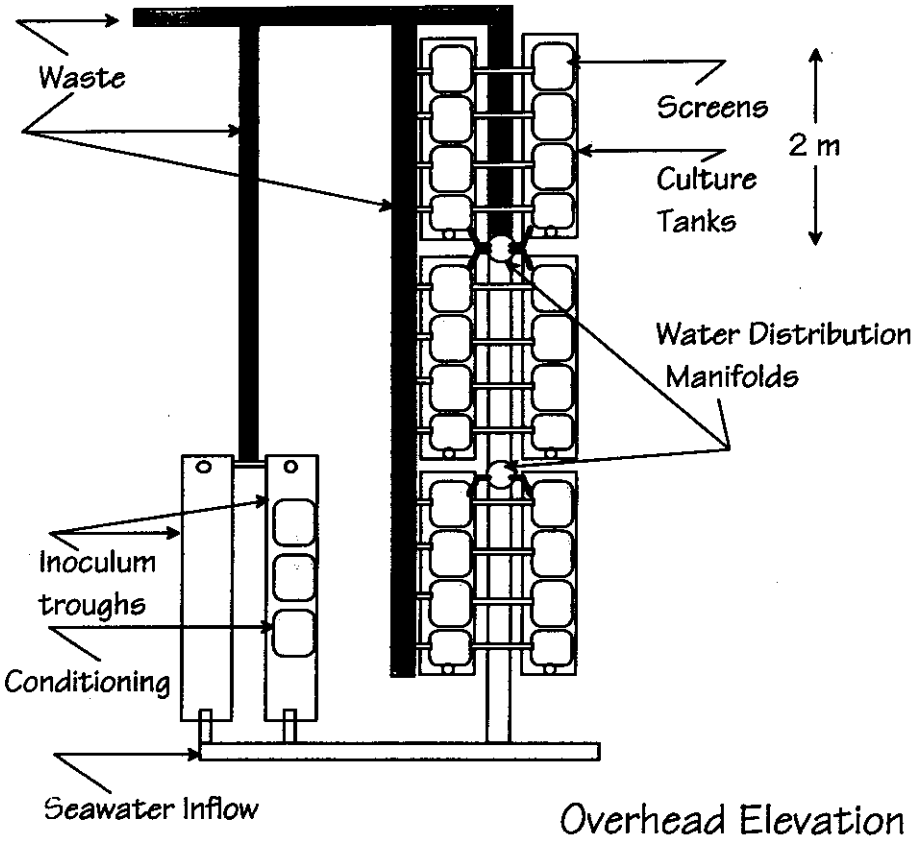


Figure 3. Conch nursery system detailing water-flow distribution. Seawater is supplied to the culture tanks from water-distribution manifolds located between tanks. Screens are conditioned in the inoculum troughs prior to use for culture.

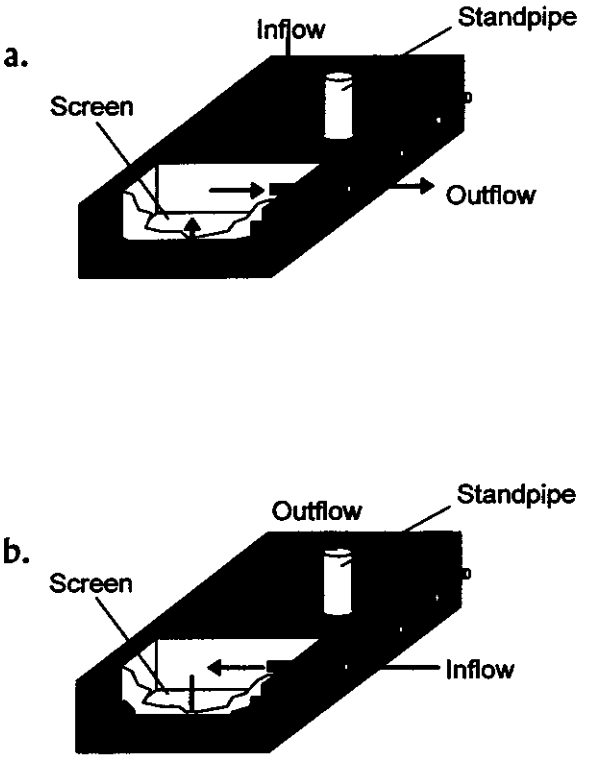


Figure 4. Cutaway view of queen conch nursery tanks showing water flow in the conch nursery screens. Water upwells through the screens during the periodic cleaning phase (a). Downwelling through the screens occurs at all other times (b).

We developed an artificial diet for conch larger than 5 mm when we were unable to obtain a commercially produced conch diet because of patent and exclusivity rights. Our diet consists of a commercially available feed (Mazuri Koi Platinum, Purina Feeds, St. Louis, Missouri, USA, 314-768-4576) with oyster shell added to equal 15% of the diet by weight. The mix is ground to a fine meal, which sinks readily and forms a fine coat on the bottom of the tank. Daily feed rations are determined based upon conch length:wet-meat weight regressions and are calculated as a percentage of the predicted wet-meat weight of the conch. This percentage is generally between 2% and 15% of the wet-meat weight.

We tested this diet in a replicated experiment by comparing the growth rates of tank-reared juveniles fed the artificial diet to the growth rates of a subgroup of the cohort placed in cages in a productive, nearshore environment. The cages permitted conch to graze on naturally occurring macroalgae without risk of predation. The experiment was conducted over a nine-week period and measurements were taken weekly of the 15 tagged conch in each replicate tank or cage. Average initial sizes ranged from 44 mm - 47 mm. Growth for the conch in the treatment fed the artificial diet was 340 µm/day; the conch in the caged treatment grew 350 µm/day. The differences between the treatments were not significant ($n = 7$, $f = 0.687$, d.f. = 6, $p = 0.66$).

In addition to conch nutritional requirements, behavioral responses to nursery systems must be addressed. Siddall (1984) demonstrated that increased conch density and light intensity increased intraspecific interactions which increased stress levels in *Strombus pugilus*. In order to minimize these potential effects, nursery tanks were covered with 100% shade cloth. We observed reduced mucous production after the addition of the shade cloth. Mucous production has been suggested to be a result of stress in queen conch juveniles (Siddall, 1984). Additionally, fewer individuals aggregated along the tank walls when shaded, whereas in uncovered tanks, conch aggregated along the sides of the tanks in the shade produced by the tank walls.

Juvenile conch in culture migrate toward the water inflow, often resulting in dense aggregations there (Glazer, personal observation). We reduced these high effective densities by incorporating spray bars that maintain uniform water inflow throughout the tanks. Without a point source of inflowing water, individuals remain dispersed throughout each nursery tank.

Nursery Culture Protocols

Regular culling and redistribution of juveniles into groups of uniform-sizes resulted in faster growth relative to those in unculled treatments (McCarthy *et al.*, in press). Culling by size is now a regular procedure in our nursery and is conducted approximately every eight weeks. Culling provides more accurate feed

rationing because the variance of the mean size of conch in culled treatments is less than the variance of that of conch in unculled treatments. Additionally, the uniform size of juveniles within a tank reduces potential size-specific competitive advantages for food.

DISCUSSION

The primary goal of Florida's queen conch restoration program is to evaluate alternative strategies for rehabilitating the state's depleted conch population. One mechanism under consideration is enhancing the native spawning stock with hatchery-raised juvenile conch. To maximize cost-effectiveness, development of efficient culture systems is critical.

The hatchery and nursery were designed to be operated by one individual. To increase production in this one-person operation, modifications were required to reduce labor requirements, increase culture densities, and increase conch growth rates. Modifications that increased efficiency and production included the following: improved water quality, increased efficiency in calculating algal densities, improved nursery system design and procedures, and development of an artificial diet. As in most aquaculture facilities, many of these modifications were made because we noted problems in our operation and made changes to correct them without conducting definitive scientific experiments.

An initial problem in our hatchery operation was the limited larval production due to poor water quality. Considerable capital investments were necessary to improve water quality. A complete ozone-treatment system was required to condition seawater to a quality sufficient for the survival and growth of conch larvae. Larvae are now cultured at densities (10 to 20/l) similar to those at other hatcheries (*vide* Creswell, 1994). We will further improve water quality with the addition of a second ozone-generating plant. Two ozone-generating plants, with different on-off set-points, will reduce fluctuations in the ORP and will ensure continuous ozone treatment of inflowing water. The cost of this ozone system will be offset by the reduced labor costs associated with more efficient larviculture.

Investment in relatively inexpensive equipment has led to considerable savings in labor costs. Before we began using the spectrophotometer and before we developed the computer program to calculate algal feed rates, we used a hemacytometer to determine the densities of each algal species (Guillard, 1975) and, based upon this information, then manually calculated algal:seawater dilutions. This daily procedure was laborious and time-consuming, but with the aid of the new equipment, now requires a minimal amount of time.

In most cases, decreasing the labor requirements of an operation necessitates a concomitant increase in capital expenditures. Although this has been the case for some aspects of our hatchery improvements, other advances have reduced

both operational and capital requirements. For example, development of an artificial diet drastically reduced the labor required to collect wild fodder and the capital commitments to culture macroscopic algae.

Postmetamorphosis is an especially critical stage in the culture of queen conch because postlarval conch will not accept the current artificial diet formulations. Other postlarval grow-out systems require that a diet of flocculated algae be prepared or that macroalgae be collected and that trays of sand containing the postlarval juveniles be maintained (Davis, 1994). Our system requires very little daily maintainence. Additionally, growth of juvenile conch in our system compares favorably with the growth rates reported by other researchers (Davis *et al.*, 1992; see review by Creswell, 1994).

Some improvements involved little cost or labor. Improved seawater distribution in the nursery tanks resulted in the dispersion of individuals throughout the tanks. Although we do not quantitatively know the effect of dispersion on growth, we hypothesize that the more uniform distribution of conch within the nursery troughs reduced intraspecific interactions and, therefore, reduced stress (Siddall, 1984). In addition, directed movement of animals due to water flow is presumably decreased with the use of spray bars because water inflow is no longer so strongly unidirectional. Improved water flow, coupled with the use of shade covers, has caused the conch juveniles to be more uniformly distributed throughout the culture trough and has maximized food availability to each individual. Experiments examining the effects of water flow and light level on conch growth and dispersion are planned.

Future research will focus on the development of nursery systems that include stacked trays so that the entire water column of culture troughs can be used. We anticipate that this will dramatically reduce production costs by decreasing the amount of land and the number of tanks required. Operational costs associated with pumping water should remain constant.

Additionally, husbandry practices and systems development will focus on producing juvenile conch for reseeding that are morphologically and behaviorally similar to wild conch. We have conducted preliminary experiments that have indicated behavioral differences between conch exposed to predators and 'naive' conch that have not been exposed to predators. We have observed morphological differences in shell growth between conch exposed to predators over a period of months and conch that were isolated from predators. Those results could have important implications for conch survival after outplanting in the Florida Keys restocking effort.

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