Modification of Behavior and Morphology in Hatchery-Reared Queen Conch (*Strombus gigas*, L.): A Preliminary Report

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ABSTRACT

The Florida queen conch population has remained in a state of decline, despite a 13-year moratorium on harvest; therefore, stock-enhancement using hatchery-reared juvenile conch is being evaluated. In a successful stock-enhancement program, a variety of factors that contribute to maximizing seed survival must be considered. Among these, husbandry techniques must produce seed that are well-adapted to local environmental conditions. Various studies have shown that laboratory-reared conch often have less optimal burial responses and lighter shell weights than their wild counterparts. We conducted a series of experiments to determine if hatchery-reared conch could develop behavioral and morphological characteristics in the presence of a predator, the spiny lobster (*Panulirus argus*), that would improve outplant survival. Experiments were conducted in tanks containing a calcareous sand substrate to simulate a natural environment. Conch (35-40mm SL) were exposed to caged lobsters for six hours each day for two weeks; conch in the control tanks were exposed to empty cages. Burial data for the control and conditioned conch were collected daily. Preliminary results indicate that conch exposed to the lobster buried themselves more frequently than the control group. Morphometric data (shell length and weight) indicated that predator-induced polymorphisms had occurred. The conch exposed to the lobster grew at a slower rate than the control group, but the shell weights of the two groups were not different. This implies that the conditioned conch had thicker shells than the control group, perhaps as a predator-induced defense mechanism. Further studies are needed to determine whether these behavioral and morphological modifications will translate to increased survival when the conch are outplanted.

KEY WORDS: Behavior, morphology, queen conch, stock-enhancement

INTRODUCTION

The queen conch, *Strombus gigas*, has been depleted throughout its range because of overfishing (Wells et al. 1983). In Florida, stocks began to decrease in the mid-1960s (Stevely and Warner 1978); ultimately, all harvest was banned in 1985. Because Florida stocks have not recovered to date (Berg and Glazer 1990; Glazer and Berg 1994), the Florida Department of Environmental Protection (FDEP) is evaluating the feasibility of enhancing natural stocks by releasing hatchery-reared juvenile queen conch into the wild. The purpose of this study is to:

i) Investigate behavioral and morphological abnormalities implicated in reports of decreased survivorship in field-release experiments of hatchery-reared juvenile queen conch, and
ii) attempt to mediate these abnormalities prior to the release of the hatchery-reared conch.

Many investigators have proposed stocking hatchery-reared *S. gigas* juveniles to replenish impoverished stocks (Berg 1976, Ballantine and Appeldoorn 1983, Iversen 1983, Laughlin and Weil 1983, Siddall 1983, Munoz et al. 1989, Creswell and Davis 1991, Marshall et al. 1992, Ray et al. 1994). Culture techniques are relatively routine, and raising juveniles has become commonplace (Davis 1994); however, conch restocking experiments have resulted in poor survival rates (Appeldoorn and Ballantine 1983, Appeldoorn 1985, Iversen et al. 1987, Coulston et al. 1989, Marshall et al. 1992, Ray et al. 1994).

In a successful stock-enhancement program, many variables contribute to maximizing juvenile survival. For example, husbandry techniques must produce seed that are well-adapted both behaviorally and morphologically. Various studies on the behavior of hatchery-reared *S. gigas* have shown that these individuals often have less optimal burial responses compared to their wild counterparts. Several researchers observed that released conch exhibited little or no burial activity resulting in high mortality rates (Appeldoorn and Ballantine 1983, Coulston et al. 1989, Munoz et al. 1989, Stoner and Davis 1994). Burial behavior has been hypothesized to be a survival strategy in juvenile *S. gigas* (Iversen et al. 1986).

Gastropod shell morphology may also influence survival (Norton 1988). The decreased shell weight and shorter apical spines of hatchery-reared *S. gigas* were thought to be responsible for their higher mortality rates compared to wild conch (Stoner and Davis 1994). However, other studies have shown that hatchery-reared conch have heavier shells due their slow growth (Jory and Iversen 1988, Davis 1992). Clearly, the seed stock production environment may contribute to morphological variation in queen conch.

MATERIALS AND METHODS

The experiment was conducted at FDEP's queen conch hatchery at the Keys Marine Lab on Long Key in the Florida Keys. Six tanks with a centralized, flow-through water system were used. Calcareous sand was collected from offshore reefs with resident conch populations. The sand was disinfected in freshwater and bleach and placed on under-gravel filters on the bottom of each tank.

Queen conch produced at the FDEP hatchery were used in the experiment. A total of 120 individuals (35-40mm SL) were randomly selected for inclusion in the study. These conch were then tagged so that individuals could be tracked for the duration of the experiment. Shell length was recorded to the nearest 0.1mm prior to experiment initiation.

The experiment consisted of two treatments: the conch to be conditioned by the predator and the control group. Each treatment had three tanks (replicates) containing 20 conch each. Conch and tanks were randomly assigned to each treatment. A spiny lobster (*Panulirus argus*) enclosed within a cage was placed into the tank containing the conch that were to be conditioned by the predator. The control group was exposed to an empty cage. The cage design allowed for water exchange between the predator and the conch, as well as visual contact; however, direct contact was not possible. Additional juvenile conch of similar size to those in the tank were supplied as food for the caged lobster, permitting any chemical alarm substance produced by the feed conch to contact the juveniles being conditioned. Juvenile conch were exposed to the predator for six hours each day (11am-5pm) for two weeks. Burial behavior was recorded at two-hour intervals beginning at 9am and ending at 7pm each day for two weeks. The conditioning experiment was repeated in order to determine if predator-induced polymorphisms would arise in a one-week time period as well.

At the end of the two weeks, ten randomly selected juveniles from each tank were sacrificed. The foot and viscera were removed, and the shell was placed in a drying oven for 24 hours at 70°C; dry shell weight was then recorded. Additionally, the shell lengths of the all individuals were recorded. Morphological comparisons (shell length and shell dry weight) between the conch in the two predator treatments were made using a one-way nested ANOVA.

PRELIMINARY RESULTS

The conch exposed to the caged lobster grew at a significantly slower rate than the control group ($p<0.0001$), but the shell weights of the two groups were not significantly different ($p>0.50$) at the end of two weeks (Table 1). The results from the one-week conditioning experiment were very similar. Again, the conch exposed to the caged lobster grew at a significantly slower rate than the control group ($p<0.05$), and the shell weights of the two groups were not significantly different (p>0.50) (Table 1).

Table 1. Growth (mean ± std. dev.) of the juvenile queen conch and the dry weight of the shell (mean ± std. dev.) at the end of the two-week experiment and the one-week experiment. An asterisk (*) indicates that the one-way nested ANOVA was significant at p<0.05; two asterisks (**) indicate that the test was significant at p<0.0001.

		2 WEEKS	
	with predator	without predator	f
growth (mm)	0.753 ± 0.312	3.17 ± 0.809	295.1**
shell dry weight (grams)	3.48 ± 0.469	3.46 ± 0.458	0.128
		1 WEEK	
	with predator	without predator	f
growth (mm)	0.610 ± 0.475	2.30 ± 1.10	40.7 *
shell dry weight (grams)	3.61 ± 0.573	3.57 ± 0.442	0.013

Analysis of the burial data revealed that the juvenile conch exposed to the caged lobster buried themselves more frequently than the control conch, and that the burial frequency increased from 43.2% to 55.7% during the second week of the experiment (Table 2).

Table 2. Percentage of buried juvenile queen conch for the two predator treatments during week 1 and week 2.

	with predator	**without predator**
week 1	43.2%	16.4%
week 2	55.7%	11.8%

DISCUSSION

Despite a moratorium on the harvest of queen conch in Florida for the last 13 years, stocks have not recovered, so the FDEP has been investigating the feasibility of stock-enhancement. A successful stock-enhancement program requires a hatchery that can produce not just high quantities of seed, but also high quality seed. However, numerous authors have shown that hatchery-reared juvenile conch have many deficiencies compared to their wild counterparts. Slower growth rates, lighter shells, decreased predator avoidance behavior, and decreased burial rates lead to abysmal survival rates when hatchery-reared individuals are released (Appeldoorn and Ballantine 1983, Coulston et al., 1989, Munoz ***et al.*** 1989, Stoner and Davis 1994). Therefore, optimal culture and release strategies are essential if a stock-enhancement program is to be successful. By altering the culture environment one can induce the expression of different phenotypes (phenotypic plasticity). Several authors have shown that shell structure in queen conch is plastic, depending on environmental conditions (Alcolado 1976, Stoner and Davis 1994, Martin-Mora et al. 1995).

Our experiments have shown that by exposing juvenile queen conch to a spiny lobster, predator-induced polymorphisms (thicker shells) can occur in as little as one week. The conditioned conch grew at a slower rate than the control group, yet the conditioned conch had slightly heavier shells (although not significantly different). The shell's primary function is protection (Vermeij, 1993), and as a protective structure, the molluscan shell must be able to resist breakage. Therefore, exposure to a predator prior to release may have a positive impact on survival as juvenile queen conch with thicker shells may be able to resist shell-crushing predators.

Analysis of the burial data showed that conch exposed to the predator buried themselves more frequently than the control group, and that the burial frequency of the conditioned conch increased during week two. This implies that conditioning occurs in approximately two weeks and that these individuals may be able to avoid detection by predators through their burial behavior.

Stock-enhancement via mariculture may be the only way to restore queen conch populations in the Florida Keys. Because of the high mortality rates and the high monetary costs associated with stock-enhancement, it is crucial to release well-adapted individuals in the appropriate habitat. Further studies are needed to determine whether the behavioral and morphological modifications documented in this study will translate to increased survival rates when hatchery-reared juvenile conch are released to enhance natural stocks.

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