Transplanting as a Test Procedure Before Large-Scale Outplanting of Juvenile Queen Conch

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ABSTRACT

Field experiments were conducted to test site variation in mortality and growth rates of juvenile queen conch (*Strombus gigas*) near Lee Stocking Island, Exuma Cays, Bahamas. Enclosures (19.6 m^2) were set up in seagrass meadows with moderate and low biomass, three sites for each biomass level. One site in each biomass level had a naturally occurring conch population. Survivorship and growth rates were independent of seagrass biomass and site specific. Survivorship was highest at sites where conch occur naturally. Only one unpopulated site had good potential for conch outplanting, indicated by low mortality and high growth rates. Sites with a moderate seagrass biomass indicated a carrying capacity of 2.0 conch /m^2. Densities of juvenile conch greater than 2.0 conch/m^2 resulted in reduced survivorship and growth rates.

Transplanting is an easy and effective means of testing quality of habitats for juvenile queen conch. The mechanisms of spatial variation in habitat quality are not yet understood; therefore, we recommend that small-scale transplanting be conducted prior to large-scale outplanting of queen conch for stock enhancements.

INTRODUCTION

Populations of the commercially important gastropod *Strombus gigas* (queen conch) have been declining in the Caribbean region for many years, attributed largely to increasing fishing pressure (Adams, 1970; Brownell *et al.*, 1977; Weil and Laughlin, 1984; Appeldoorn *et al.*, 1987). A solution to the problem is stock enhancement via outplanting of hatchery-reared juveniles. Hatchery production of queen conch has become a successful venture in recent years, especially in the Turks and Caicos Islands (Davis *et al.*, 1987), but experimental outplantings in the field have met with mixed success. Past studies showed that mortality is great for small juveniles. In most cases, difficulties have related to high predation rates (Iversen *et al.*, 1986; Jory and Iversen, 1983). This is particularly true for very early stages (20 - 50 mm), for which the optimal natural habitat is not known (Appeldoorn and Ballantine, 1983; Appeldoorn, 1984). On one hand, future success of outplanting rests on developing lower cost hatchery and dependable mass-rearing methods. On the other hand, predation could be reduced by installing predator-protection means and releasing juveniles in optimal nursery habitats (Iversen *et al.*, 1987). Two factors are important for successful outplanting of queen conch: high survivorship and normal growth. In this report, the results of two field experiments will be discussed relative to practical testing procedures for field sites being considered for conch stock enhancement.

METHODS

Two experiments, involving the enclosure of juvenile queen conch, *Strombus gigas*, were conducted in localities near Lee Stocking Island, Exuma Cays, Bahamas. Animals used in both experiments were one-year old *S. gigas* collected from seagrass meadows near Children's Bay Cay. At the beginning of the two experiments, all of the conch were between 82 and 105 mm total shell length. Animals introduced after the beginning of the experiments to replace lost or killed individuals were of a size similar to the mean conch size in that treatment. All animals were individually marked with vinyl spaghetti tags (Floy Co.) tied to the shell. For both experiments, test animals were held in topless, circular field enclosures 5.0 m in diameter and 30 cm in height, constructed of 1.9 cm black plastic mesh.

Growth was examined, both in the wild and in enclosures, by change in size of the animals over two growth periods in each experiment. Exact growth rate was calculated on the basis of mm/d. Any missing or dead animals were replaced in enclosures at each of the measurement times and invading invertebrates were recorded and removed. Low immigration of untagged *S. gigas* into the enclosures and few unaccounted losses over the experimental period showed that the pens were relatively effective in retaining the test animals.

Site Variation Experiment

Animals for this experiment were transplanted and enclosed at six different sites in the vicinity of Lee Stocking Island. These sites included two which have natural populations of queen conch juveniles, Children's Bay Cay site 1 (C-1) and North Bock Cay site 1(N-1). N-1 has low biomass turtlegrass and C-1 has a moderate seagrass biomass. Conch were transplanted to two sites with characteristics similar to C-1, but with no resident conch, one about 300 m away from C-1 but in the same seagrass bed (C-2), and a second to the west of Lee Stocking Island (L-1). Seagrass biomass, detrital loads, and sediment organics and grain size were equivalent among all of the three sites (Stoner and Sandt, unpubl. data). Transplants were also made to two sites similar in macrophyte cover and sediments to N-1, one site to the north of Lee Stocking Island (L-3), and a second near Windsock Cay (W-1).

At each of the six sites, two enclosures were constructed and loaded with 24 individually tagged and measured conch (1.2/m^2). This experiment was begun on 26 April 1988, and remeasurements were made at 35 and 75 days. Animal losses were examined and replacements were made every two weeks. The first 35 days of the experiment are referred to as Period 1. Growth and mortality for Period 2 were determined from day 35 to 75.

Carrying Capacity Experiment

The second experiment was conducted at the Children's Bay Cay site (C-1) in a seagrass meadow of turtlegrass, *Thalassia testudinum*. This particular seagrass bed characteristically contains high densities of juvenile queen conch, and has a mean depth of 3.5 m with a tidal amplitude of 1.0 m.

A random-block design was employed to examine the effects of animal density on growth rates. Three treatments replicated in three blocks, included:

1. 40 juvenile queen conch per pen (equivalent to 1.0 times the natural density of juveniles in the seagrass meadow surrounding the pens in May 1987,
2. 80 conch per pen (2.0 times natural density), and
3. 160 conch per pen (4.0 times natural density).

Animal density in the 4.0 X treatment was high, equivalent to 8 conch/m^2, but lower than the density in an aggregation of juveniles observed during the experimental period near the test site (to > 300 conch m^2 (Stoner *et al.*, 1988)).

At the beginning of the experimental period, mid-May 1987, three blocks of the three treatments were laid out in a uniform stand of *Thalassia testudinum*. There were no significant differences among the blocks or individual plots in conch density, green seagrass biomass, macrodetritus loads, sediment organic content, or sediment grain size (Stoner, unpubl. data). Treatments were randomly assigned to each of the three experimental blocks and pens were constructed at each plot. Four days following construction of the cages, they were cleared of all large invertebrates and the specified number of juvenile *S. gigas* were introduced after individual marking and measurement. All cages were loaded by 30 May 1987, and remeasured at 28 and 57 days. Growth and mortality were determined for the first 28 days (Period 1) and for the last 29 days (Period 2).

At the initiation of the experiment, 813 individually tagged and measured juvenile queen conch were released in the vicinity of the enclosures for examination of growth rates in wild individuals. Between June and September 1987, 927 additional one year old conch were tagged and distributed at the experimental site. Recapture and measurements were made for each of the two growth periods described above.

RESULTS

Site Variation

During the first five weeks of the experiment (Period 1), no animals held in sites with moderate (M) seagrass biomass died, but mortalities at low (L) biomass stations L-3 and W-1 were 14.6 and 16.7%, respectively (Fig. 1). During period 2, no mortality was observed at the two sites with natural conch populations (C-1) (M) and N-1 (L)) as was true during the first growth period. Relatively few animals were lost at sites with moderate seagrass biomass, but mortality was high at L-3 (L) and W-1 (L). A total of 37 animals died by the end of the experiment at L-3 (of an original 48) and 12 were lost at W-1. Despite large differences in mortality at the six field sites, the differences were not significant (Kruskal-Wallis test, $p < 0.05$). This was a result of large variation in the two cages at station W-1, and a large number of zeros in the data.

Growth rates varied with location and period (Fig. 2). Analysis of variance indicated significant site variation in growth rates ($F = 28.74$, $p < 0.001$), where W-1 (L) and C-2 (M) had similar rates, L-1 (M) and C-1 (M) were similar, and N-1 (L) and L-3 (L) were similar to no other sites (Newman-Keuls test, $p < 0.05$). During Period 1, two areas without natural populations of conch, W-1 (L) and C-2 (M), had highest growth rates, exceeding 0.15 mm/day.

During Period 2, growth rates increased slightly at stations C-1 (M), C-2 (M), and N-1 (L), but decreased by at least 50% at the other three sites. Station differences were highly significant (ANOVA, $F = 119.34$, $p < 0.001$) and all stations had statistically distinct growth rates ($p < 0.05$), except L-3 (L) and W-1 (L) where the rates were near zero ($p > 0.05$). Overall, the pattern of growth rates appeared to be opposite that of mortality (*i.e.*, where mortality was high, growth was low).

Carrying Capacity

In this experiment, mortality of conch was less than 2.0% of the sample treated in each of the experimental densities during the first 28 days (Fig. 3); there was no significant difference among densities (Kruskal-Wallis test, $X^2 = 0.57$, $p > 0.05$). During the next 29 days (Period 2), however, mortality rates differed significantly by density ($X^2 = 6.21$, $p < 0.05$), with zero losses at 1-X density, 0.8% mortality at 2-X density, and 9.8% mortality at 4-X density.

Growth rates were remarkably similar among animals within experimental treatments (Fig. 4). Analysis of variance ($F = 306.64$, $p < 0.001$) and Neuman-Keuls multiple range test ($p < 0.05$) showed that during Period 1 all treatments resulted in different growth rates. Growth was fastest for wild conch followed closely by conch at 1-X density, and lowest in animals held at highest density (4-X). During Period 2, growth rates declined in all treatments, but conch in the wild population had rates similar to those at 1-X density (Neuman-Keuls test, $p > 0.05$). Growth rates in all other treatments were

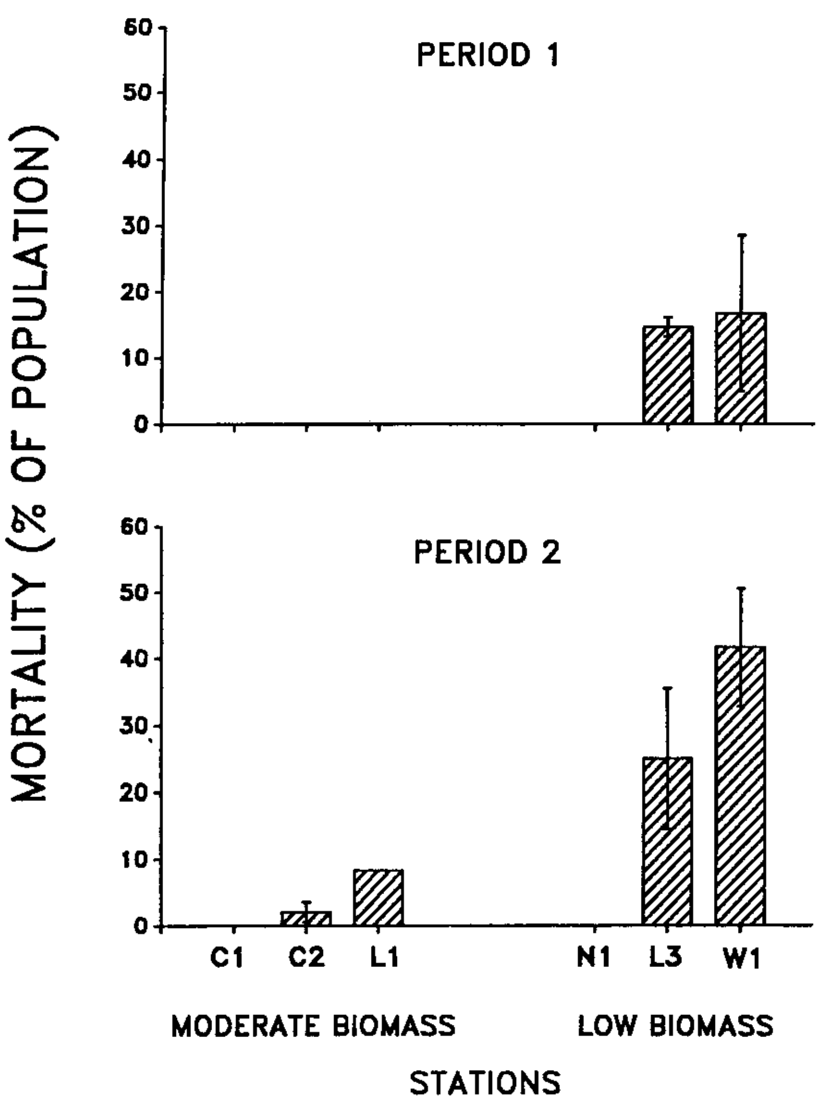

Figure 1. Mortality of juvenile queen conch transplanted to six sites near Lee Stocking Island. Values shown are mean + standard deviation. Station codes: C= Children's Bay Cay, L = Lee Stocking Island, N= North Bock Cay, W = Wind Sock Cay.

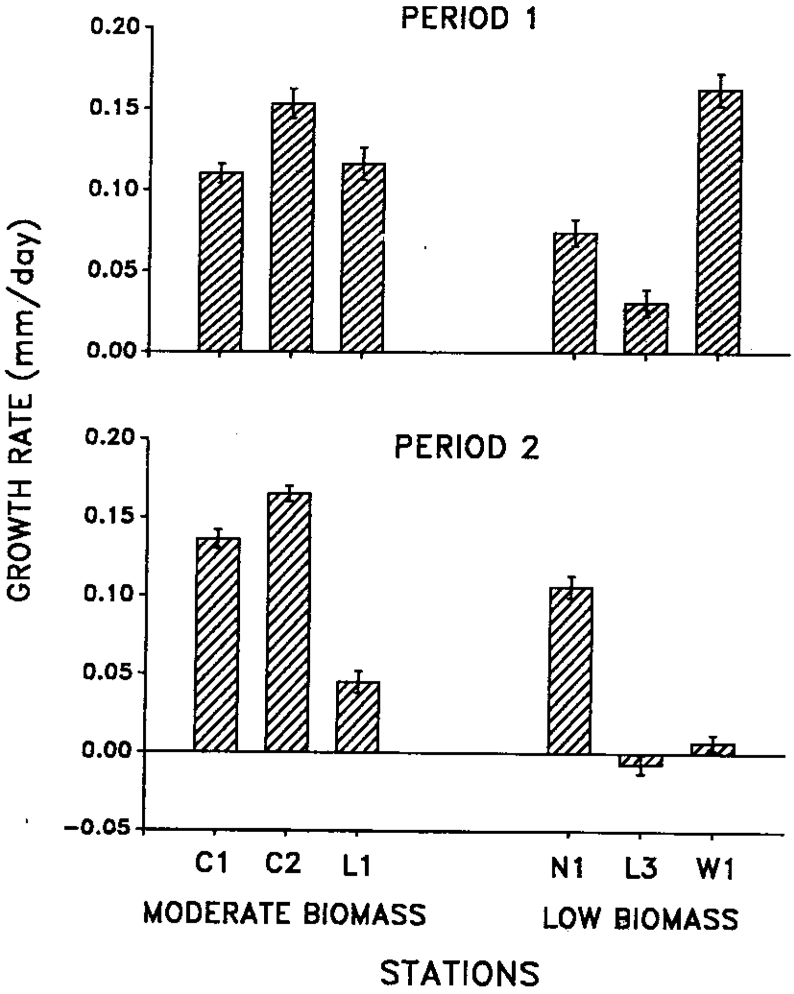

Figure 2. Growth rates of juvenile queen conch transplanted to six sites near Lee Stocking Island. Values are mean + standard error. Station codes are the same as in Fig. 1.

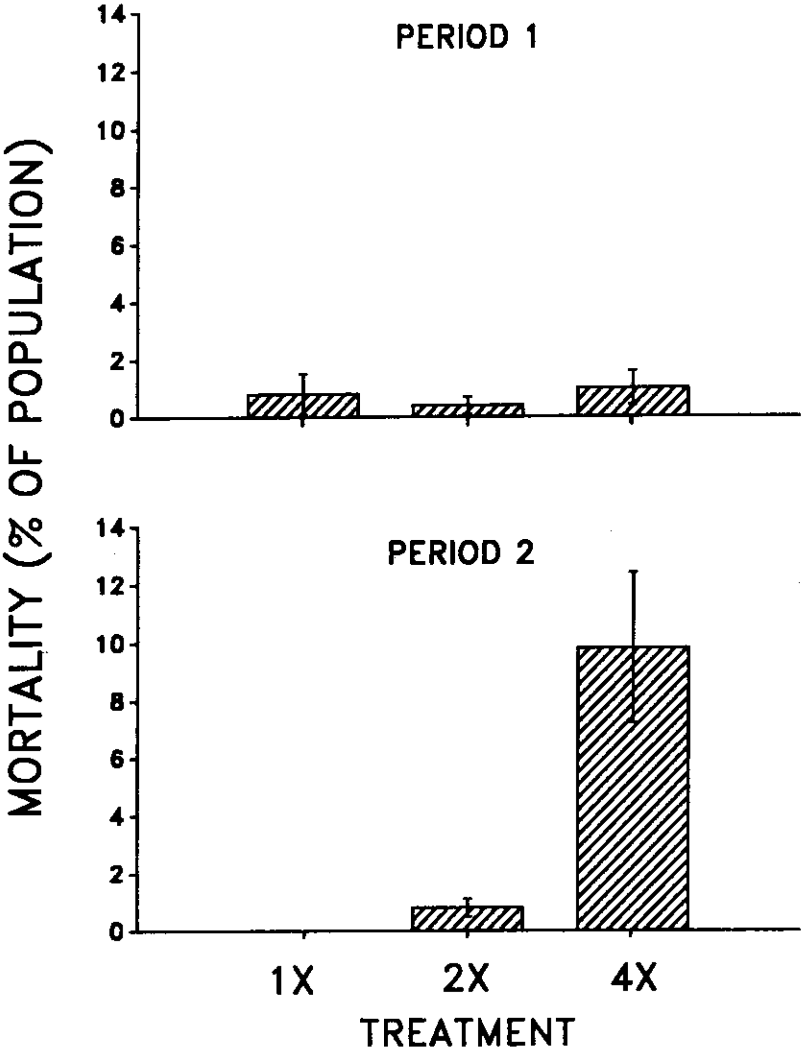

Figure 3. Mortality of juvenile queen conch held in the field at three different densities. Values are mean + standard deviation. 1X = 2.0 conch/m^2, 2X = 4.0 conch/m^2, and 4X = 8 conch/m^2.

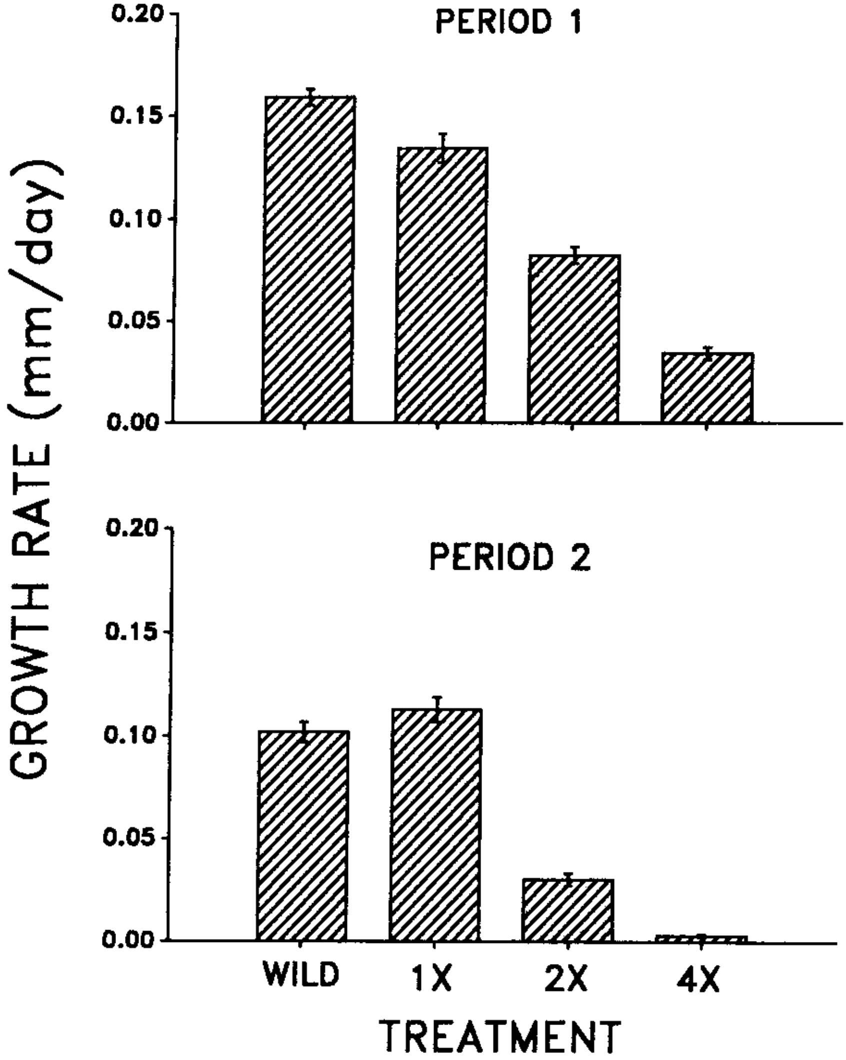

Figure 4. Growth rates of juvenile queen conch held in the field at three different densities. Values are mean + standard error. Codes are the same as in Fig. 3.

significantly different ($p < 0.05$) (ANOVA, $F = 420.05$, $p < 0.05$), and near zero at 4-X density.

DISCUSSION

Basic habitat associations and requirements for queen conch have been reported in the literature (Randall, 1964; Brownell and Stevely, 1981). Seasonal movements and ontogenetic shifts in habitat, and preferred foods are also known (Hesse, 1976; Weil and Laughlin, 1984; Stoner *et al.*, 1988). However, little is known about variation in habitat carrying capacity and other qualities or mechanisms which mediate survivorship and growth in natural conch populations. Lack of this information may be responsible for low survivorship in juveniles hatched in the laboratory and released in the field (Appeldoorn and Ballantine, 1983; Appeldoorn, 1985).

Transplant data reported here and in another study (Stoner and Sandt, unpubl. data) show that survivorship and growth of juvenile queen conch are highly variable in space, even among sites that have similar seagrass, detritus, and sediment characteristics. Seagrass detritus is an important component of the diet of juvenile conch in the study area (Stoner, unpubl. data); thus, abundance of detritus undoubtedly represents an important characteristic of habitat quality for conch growth. However, growth and survivorship were high at the North Bock Cay site (N-1) where seagrass biomass and abundance of detritus were low. Therefore, components such as epiphyte abundance or benthic diatoms (not measured in this study) may play important roles in habitat quality for juvenile conch. Basic research is needed to evaluate other habitat characteristics contributing to high survivorship and growth rates.

Laboratory and hatchery studies have shown that animal density affects conch growth (Laughlin and Weil, 1983; Appeldoorn and Sanders, 1984; Siddall, 1984). Our field experiments indicated that a habitat can support limited numbers of juvenile conch. Results also indicated that the natural animal density in two established nursery areas were close to their carrying capacities. For example, a density of animals greater than 2.0 /m^2 may not be sustained for long periods of time in seagrass meadows similar to those near Lee Stocking Island. The fact that growth rate and survivorship crashed at some of the test sites after the first month of the transplant experiment indicates that even 1.2 conch/m^2 soon remove a large portion of the usable food.

Sites such as C-1 (M) and N-1 (L), which have supported juvenile conch populations over many years, probably have characteristics that accumulate larvae, and provide abundant food and shelter from predators. For these reasons, restoration of populations by outplanting will be most successful in habitats which supported natural conch populations in the past, provided that the habitat has not been disturbed. Unfortunately, historical data on juvenile distribution is often unavailable.

Growth rates were relatively consistent among animals within treatments, so large numbers of test animals may not be needed for transplant experiments. Similarity of growth rates for wild and enclosed animals at the natural density suggests that the caging technique is a valid means of examining conch growth.

The short walls of the enclosures allowed easy passage of large, mobile predators, and predatory gastropods. Tulip snails and apple murex were frequently found in the enclosures. Where tethering experiments (Lipcius *et al.*, this volume) were conducted at our sites, spatial patterns in mortality rate were similar; therefore, we conclude that mortality rates provided through the enclosure experiments are good estimates.

Although the mechanisms which mediate habitat quality for juvenile conch are unknown, transplanting provides an empirical measure of habitat quality easy to apply prior to large-scale outplanting. The experimental growth period should run for at least eight weeks, as suggested by the frequently observed crash of survivorship and growth after the first month of testing. However, when experiments were run longer than eight (Stoner, unpubl. data) or twelve weeks (Stoner and Sandt, unpubl. data), both site and density effects became even more pronounced. In several cases, replacement of conch exceeded 100% of the original number stocked and growth rates in poor habitats became negative because of shell erosion. Appeldoorn (1985) found that conch mortality was greatest during the warmer summer season. For this reason, testing of field sites for outplanting should be conducted during that season.

Determination of habitat carrying capacity is not a simple procedure, and a standard density of animals could be tested during transplanting experiments. If carrying capacities are less than a standard test density of 1.0 juvenile/m^2, outplanting is probably not recommended.

Only one of the four sites without a natural conch population yielded high juvenile survival and growth, although all had appropriate seagrass, detritus, and sediment characteristics. Two conclusions can be drawn: 1) There are areas not inhabited by juvenile queen conch that may provide high survivorship and growth. 2) Preliminary testing of habitat quality for conch should be made prior to large-scale outplanting efforts. This should include testing for animal survival and growth. This supports the idea that local fisheries can be enhanced by outplanting of juveniles in pretested areas.

ACKNOWLEDGEMENTS

This research was supported by a grant from the Office of Undersea Research of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Ana Bardales, Kevin McCarthy, and Edward Wishinski assisted in field and laboratory analyses. The manuscript was reviewed by Isabelle Boidron-Metairon, Bori Olla, and Robert Wicklund.

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