Translocation as a strategy to rehabilitate the queen conch (*Strombus gigas*) population in the Florida Keys

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Abstract—Queen conch (*Strombus gigas*) stocks in the Florida Keys once supported commercial and recreational fisheries, but overharvesting has decimated this once abundant snail. Despite a ban on harvesting this species since 1985, the local conch population has not recovered. In addition, previous work has reported that conch located in nearshore Keys waters are incapable of spawning because of poor gonadal condition, although reproduction does occur offshore. Queen conch in other areas undergo ontogenetic migrations from shallow, nearshore sites to offshore habitats, but conch in the Florida Keys are prevented from doing so by Hawk Channel. The present study was initiated to determine the potential of translocating nonspawning nearshore conch to offshore sites in order to augment the spawning stock. We translocated adult conch from two nearshore sites to two offshore sites. Histological examinations at the initiation of this study confirmed that nearshore conch were incapable of reproduction, whereas offshore conch had normal gonads and thus were able to reproduce. The gonads of nearshore females were in worse condition than those of nearshore males. However, the gonadal condition of the translocated nearshore conch improved, and these animals began spawning after three months offshore. This finding suggests that some component of the nearshore environment (e.g., pollutants, temperature extremes, poor food or habitat quality) disrupts reproduction in conch, but that removal of nearshore animals to suitable offshore habitat can restore reproductive viability. These results indicate that translocations are preferable to releasing hatchery-reared juveniles because they are more cost-effective, result in a more rapid increase in reproductive output, and maintain the genetic integrity of the wild stock. Therefore, translocating nearshore conch to offshore spawning aggregations may be the key to expediting the recovery of queen conch stocks in the Florida Keys.

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The queen conch (*Strombus gigas*) is a large marine gastropod harvested intensively throughout the Caribbean for its meat and shell. In the Florida Keys, conch once supported commercial and recreational fisheries, but overharvesting severely depleted the population. The harvesting of conch has been banned in Florida since 1985, but the population has not recovered to levels that can support exploitation (Glazer and Berg, 1994; Berg and Glazer, 1995; Glazer and Delgado, 2003). Intensive fishing may invoke depensatory mechanisms as densities are reduced, limiting the ability of conch to locate mates and increasing the chance of recruitment failure (Appeldoorn, 1995). This seems to be the case in Florida because the lack of recovery has been attributed to diminished recruitment due in part to small spawning aggregations (Stoner et al., 1997; Stoner and Ray-Culp, 2000).

Queen conch occur in the various oceanside habitats of the Florida Keys archipelago with the exception of Hawk Channel (Glazer and Berg, 1994). This naturally occurring deep-water channel runs parallel to the Florida Keys, between the island chain and the offshore reef tract. The substrate on the bottom of Hawk Channel is predominantly soft sediment, which is poor conch habitat; consequently, Hawk Channel serves as a barrier to migration and isolates nearshore from offshore conch aggregations (Glazer and Berg, 1994). We have been monitoring queen conch stocks throughout the Florida Keys since 1987, and despite extensive surveys, we have never observed reproductive activity among conch in nearshore aggregations (Glazer and Berg, 1994). Conversely, reproductive behavior has been commonly observed among conch in offshore aggregations (Glazer and Berg, 1994). Moreover, a preliminary histological examination of conch from these two regions indicated that the gonads of offshore conch were capable of undergoing gametogenesis, whereas the gonads of nearshore conch were nonfunctional (Glazer and Quintero,

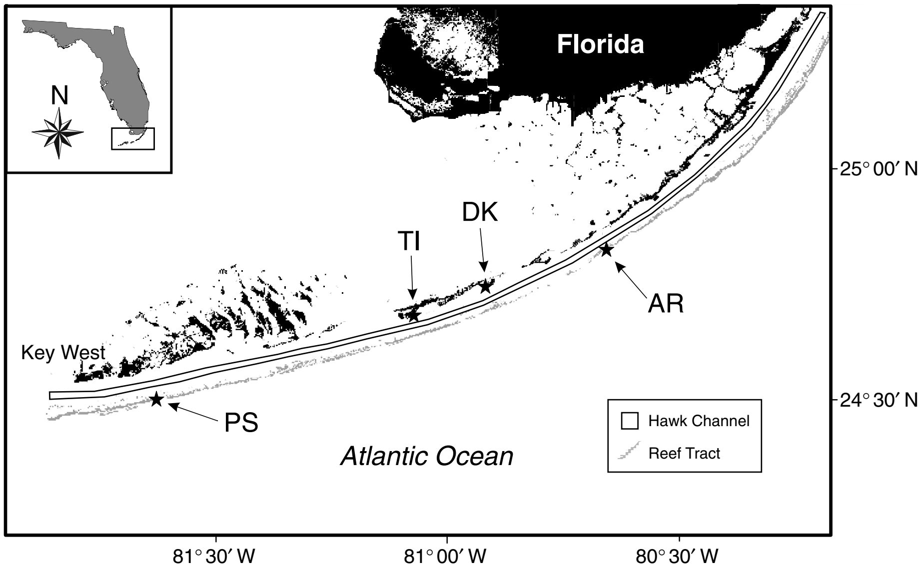

Figure 1

Queen conch (*Strombus gigas*) translocation sites in the Florida Keys (adapted from McCarthy et al. 2002). The nearshore region is the stretch of water on the landward side of Hawk Channel; the offshore region is the stretch of water on the other side of the channel, contiguous with the Atlantic Ocean. Nearshore conch were translocated from Tinglers Island (TI) to Alligator Reef (AR) and from Duck Key (DK) to Pelican Shoal (PS).

1998; McCarthy et al., 2002). In a metapopulation context, the nearshore region in the Florida Keys can be considered a "blackhole sink" for larval recruitment because conch that settle there do not spawn and thus do not contribute to the reproductive output of the stock (*sensu* Morgan and Botsford, 2001).

In 1990, the Florida Fish and Wildlife Conservation Commission's (FWC) Florida Marine Research Institute constructed an experimental hatchery to test the feasibility of rehabilitating queen conch stocks in the Florida Keys by releasing hatchery-reared juveniles. A series of experiments to determine the best size of juveniles, time of release, and area to release hatchery-reared juvenile conch were conducted, and a cost-benefit analysis was performed. Unfortunately, the high mortality of conch after release, coupled with high production costs, caused us to examine alternate strategies (Glazer and Delgado, 2003).

Translocation is defined as the intentional introduction or reintroduction of animals in an attempt to establish, reestablish, or augment a population in order to aid in the recovery of a native species whose numbers have been reduced by overharvesting or habitat loss (or both) (Griffith et al., 1989). This method of population recovery has been used to facilitate the recovery of numerous species of birds and mammals (Griffith et al., 1989) and several aquatic species, including cutthroat trout (Harig et al., 2000) and corals (Edwards and Clark, 1999; Rinkevich, 1995; van Treeck and Schuhmacher, 1997). Nest translocations have also proven effective in efforts to recover sea turtles (Garcia et al., 1996).

The present study was initiated to determine the potential of translocating nonspawning nearshore conch to offshore sites as a method to augment spawning aggregations and as an aid in the recovery of the queen conch population in the Florida Keys. However, this strategy will be beneficial only if the translocated conch regain their reproductive capacity. To test this approach, we translocated adult conch from the nearshore region into existing offshore breeding aggregations and examined changes in reproductive behavior (i.e., mating and spawning) and gonadal development.

Materials and methods

Translocations and reproductive behavior

During March 1999, we translocated adult conch from nearshore aggregations to aggregations offshore. Nearshore aggregations were located at Tinglers Island (24°41′N, 81°05′W; water depth <1–2 m) and Duck Key (24°45′N, 80°55′W; water depth <1–2 m) (Fig. 1). The habitat at the two nearshore sites was characterized as a matrix of hard-bottom and *Thalassia testudinum* patches. Offshore aggregations were located at Alligator Reef (24°51′N, 80°37′W; water depth 9–11 m) and Pelican Shoal (24°30′N, 81°37′W; water depth 5–7 m) (Fig. 1). The habitat at the offshore sites consisted of back-reef rubble, sandy plains, and patches of *Thalassia testudinum*.

We tagged 44 adult conch at Tinglers Island; 23 were translocated to Alligator Reef, and 21 were rereleased at

Table 1

The number of gonadal tissue samples taken from resident nearshore, resident offshore, and translocated nearshore queen conch, by sex and season.

	Spring		Summer		Fall	
	Females	Males	Females	Males	Females	Males
Resident nearshore	13	12	14	12	10	6
Resident offshore	22	20	19	20	25	15
Translocated nearshore	—	—	12	12	13	4

Table 2

Index and definitions used to quantify gonadal maturity in queen conch. This index is patterned after the maturity scale developed by Egan (1985). The dashed line separates the scores 1–5 from 6–8 that were combined for statistical analyses.

Gonadal condition	Score	Definition
Early development	1	primary and cortical alveolar oocytes in females; spermatogonia and spermatocytes in males
Mid development	2	vitellogenesis beginning in females; spermatozoa present in males
Late development	3	fully developed oocytes in females, none in oviduct; all stages of spermatogenesis, no spermatozoa in vas deferens
Ripe	4	oocytes in oviduct for females; spermatozoa in vas deferens for males
Spent	5	reabsorption of vitellogenic oocytes in females; empty lobules, residual spermatozoa in males
Atresia	6	reabsorption of oocytes and no vitellogenesis in females; reabsorption of spermatozoa in males
Regressed	7	only primary oocytes in females; only primary spermatogonia in males
No tissue	8	no gonadal tissue development and no germ cells present; this is an abnormal condition in adult females and males

Tinglers Island. We also tagged 132 adult conch at Duck Key; 73 were translocated to Pelican Shoal, and 59 were re-released at Duck Key. In addition, 100 resident offshore conch were tagged *in situ* at both Alligator Reef and Pelican Shoal. Conch were tagged with individually numbered tags that were secured to the shell spires by Monel wire; in addition, colored flagging tape was similarly attached to facilitate recapture.

Reproductive behavior of tagged queen conch was monitored at each of the four sites on a weekly basis, weather permitting, from March 1999 through November 1999. Offshore sites were surveyed by using SCUBA; nearshore sites were surveyed by snorkeling. Mating activity was quantified by counting the number of tagged individuals (both males and females) copulating; spawning activity was quantified by counting the number of tagged females laying egg masses. Data from the two nearshore sites were pooled and data from the two offshore sites were pooled. Data were also pooled by season: spring consisted of March, April, and May; summer consisted of June, July, and August; and fall consisted of September, October, and November.

Histological examinations

Gonadal tissue samples from adult conch were collected for histological examination at the initiation of the study (spring; the start of the breeding season), during July–August (summer; breeding season), and during October (fall; the end of the breeding season) in order to assess gonadal development in relation to time after translocation. We collected approximately 40 resident offshore conch during each season (Table 1). However, because of the small size of the nearshore aggregations and the small number of nearshore conch translocated offshore, we collected about 20 individuals from these two groups each season (Table 1). We did not determine the sex of the animals before sample collection; therefore the breakdown by sex is not exactly even (Table 1).

A one-cm^3 piece of tissue from the middle of the gonad of each animal was placed in a labeled plastic cassette and preserved in 10% neutral buffered formalin. After 7 to 14 days in fixative, the tissue samples were rinsed overnight in freshwater. The samples were then dehydrated in a series of graded ethanols (one change of 60% ethanol and two changes of 70% ethanol for two hours each) and loaded into an automatic tissue processor (Shandon Hypercenter XP, Shandon Scientific Ltd., Pittsburgh, PA) for dehydration, clearing, and paraffin infiltration. Tissues were embedded in Paraplast Plus (Fisher Scientific, Pittsburgh, PA) and sectioned at 4 μm with a rotary microtome. Two serial sections from each tissue sample were mounted on glass slides, allowed to dry overnight, and stained with hematoxylin 1 and eosin Y (Richard Allen Inc., Richland, MI). All laboratory procedures followed approved standard operating procedures developed under the Good Laboratory Practices guidelines (EPA and FDA guidelines).

A detailed histological inspection of each sample was made to assess the stage of gonadal maturity and the percentage of gametogenic tissue. Each animal was given a score from 1 to 8 to quantify gonadal maturity (Table 2). This index was derived from a maturity scale developed by Egan (1985). Because of the small number of animals collected, gonadal maturity scores from 1 to 5 were combined to group animals that would be capable of spawning or had recently spawned (Table 2). Scores from 6 to 8 were combined to group animals that would not spawn again in a season or were not capable of spawning (Table 2). In addition, the percentage of gametogenic tissue present (i.e., the percentage of ovarian or testicular tissue occupying the available space of the section) was visually estimated by using the following index: <25%, 25–50%, 51–75%, and >75%. For statistical analyses, this index was reduced to two categories: <50% and >50%.

Statistical analyses

We evaluated differences in reproductive behavior (mating and spawning) between resident nearshore and translocated nearshore conch for each season by using Fisher's exact test because it is not sensitive to small sample sizes (Zar, 1996). We also examined differences in gonadal condition (i.e., gonadal maturity and the percentage of gametogenic tissue) between resident nearshore and resident offshore conch for each season by using Fisher's exact test. Males and females were analyzed separately. In order to assess the effectiveness of the translocations to the offshore region, we used Fisher's exact test to compare the gonadal condition of translocated nearshore conch with the gonadal condition of resident nearshore conch in summer and in fall. Again, the sexes were analyzed separately. All tests were run on SPSS 9.0 (SPSS Inc., Chicago, IL) for Windows. Results were considered significant if $P<0.05$.

Table 3

Percentage of mating (the number of males and females mating divided by the total number of conch observed during that season) and spawning (the number of females spawning divided by the total number of females observed during that season) in nearshore conch and offshore conch by season (adapted from McCarthy et al., 2002). Numbers in parentheses represent the number of observations; *P* represents the probabilities from Fisher's exact test of differences in reproductive behavior between resident nearshore and translocated nearshore conch. The asterisk (*) indicates that the test was statistically significant. N/A indicates that statistical analyses were not conducted because no mating or spawning was observed among either resident nearshore or translocated nearshore animals.

	Offshore conch	Nearshore conch		
	Resident	Resident	Translocated	*P*
Mating				
Spring	5.3 (95)	0.0 (37)	0.0 (19)	N/A
Summer	2.4 (467)	0.0 (106)	0.0 (81)	N/A
Fall	0.9 (232)	0.0 (20)	0.0 (51)	N/A
Spawning				
Spring	46.2 (39)	0.0 (6)	0.0 (10)	N/A
Summer	16.8 (191)	0.0 (34)	12.2 (41)	0.041*
Fall	5.2 (97)	0.0 (9)	18.5 (27)	0.214

Results

Reproductive behavior: mating

Approximately 84% of the tagged resident nearshore conch, 69% of the tagged translocated nearshore conch, and 88% of the tagged resident offshore conch were observed at least once during monitoring. Resident nearshore conch and translocated nearshore conch were not observed mating during any of the field surveys; conversely, resident offshore conch were observed mating throughout the study (Table 3). The mating frequency of resident offshore conch was highest during the spring (5.3%) and decreased during subsequent seasons to 0.9% in the fall (Table 3). All observed mating occurred between resident offshore animals.

Reproductive behavior: spawning

Neither resident nearshore females nor translocated nearshore females were observed spawning during the spring (Table 3). However, by summer, translocated nearshore females had attained the capacity to spawn and had a significantly higher spawning frequency than resident nearshore females (12.2% vs. 0.0%, respectively) (Table 3). During the fall, spawning frequency of translocated nearshore females peaked at 18.5%, whereas resident nearshore females had still not exhibited any spawning behavior (Table 3). However, this difference was not statistically significant because of the small number of resident nearshore conch observed (Table 3). Looking at individual performance instead of spawning frequency, seven (or about 14%) of the approximately 50 nearshore females translocated offshore were observed spawning at least once during the study period.

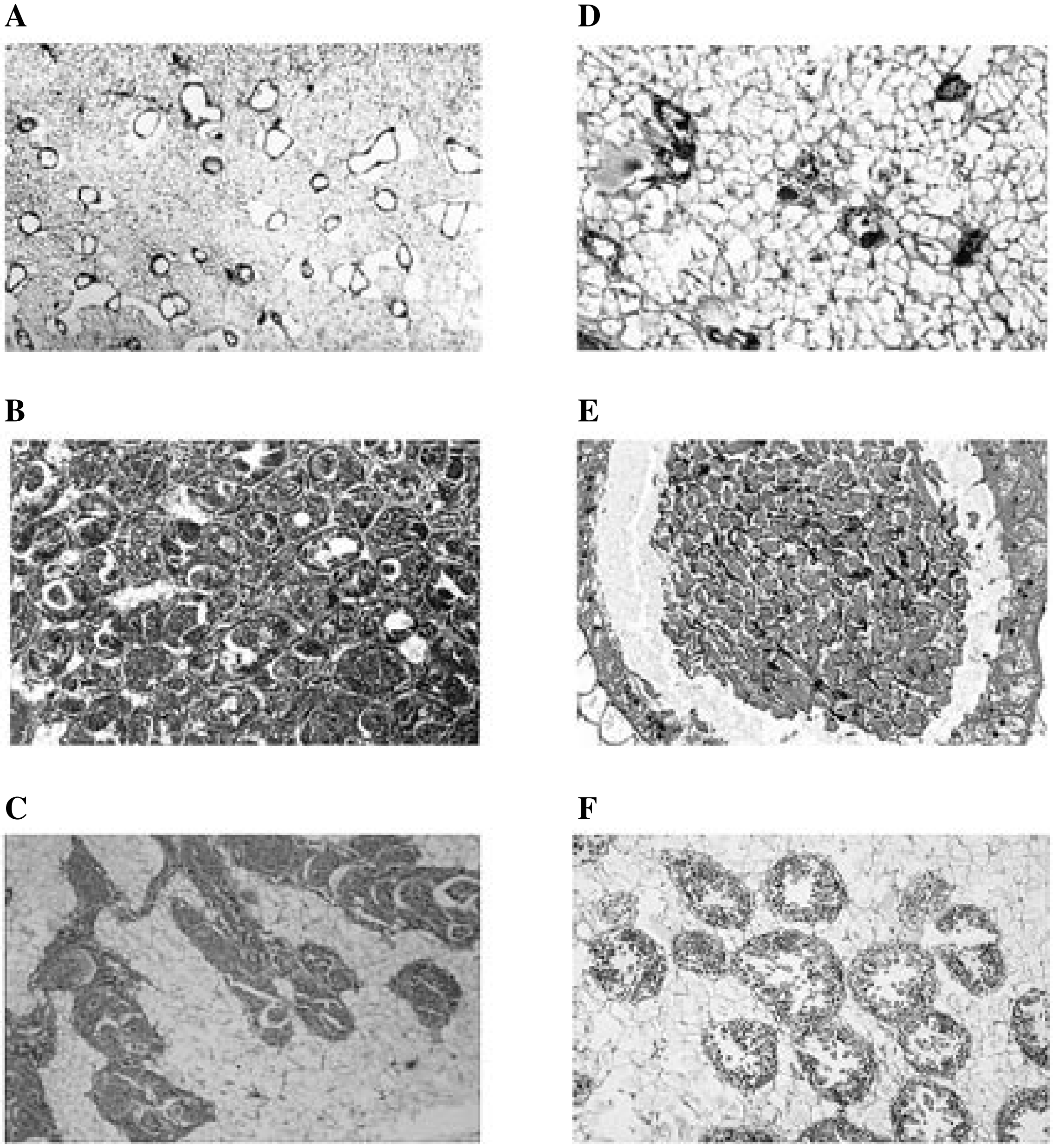

Figure 2

Photomicrographs of the gonadal condition of resident nearshore, resident offshore, and translocated nearshore queen conch (*Strombus gigas*). (**A**) Resident nearshore female during spring, no tissue and <25% gametogenic tissue. (**B**) Resident offshore female during spring, ripe and >75% gametogenic tissue. (**C**) Translocated nearshore female during summer, late development and 25–50% gametogenic tissue. (**D**) Resident nearshore male during spring, early development and <25% gametogenic tissue. (**E**) Resident offshore male during spring, ripe and >75% gametogenic tissue. (**F**) Translocated nearshore male during summer, ripe and 25–50% gametogenic tissue.

Resident offshore females were observed spawning throughout the study (Table 3). Their spawning frequency peaked during the spring at 46.2% and decreased during subsequent seasons to 5.2% in the fall (Table 3).

Histology: females

Histological examinations revealed that the gonadal condition of resident nearshore and resident offshore female

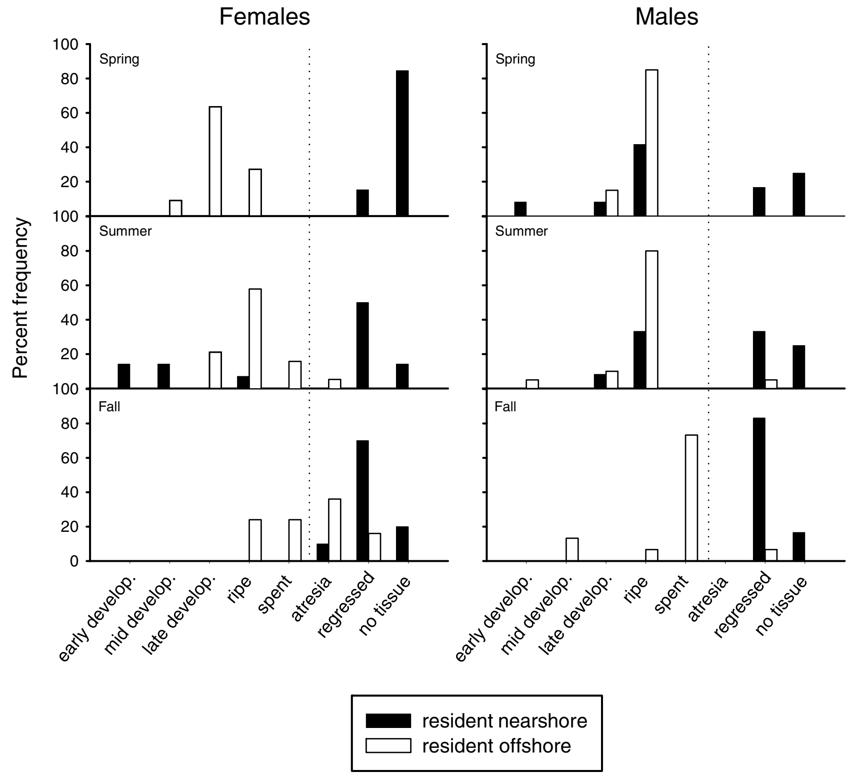

Figure 3

Gonadal maturity of resident nearshore and resident offshore queen conch (*Strombus gigas*) by sex and season. The dotted line separates the categories that were combined for statistical analyses.

conch were markedly different at the beginning of the study (Fig. 2, A and B). There were significant differences in gonadal maturity between resident offshore and resident nearshore female conch during the spring, summer, and fall (Table 4). During the spring, the gonads of most resident offshore females were categorized as being in late development; by summer most were ripe and by fall most were either spent, in atresia, or regressed (Fig. 3). In contrast, the gonads of most resident nearshore females contained no germ cells during the spring (Fig. 3). By summer, the gonads of some resident nearshore females were found to be in the early stages of development, but most females were still incapable of spawning, and by fall, all the resident nearshore females sampled were incapable of spawning (Fig. 3). There were also significant differences in the percentage of gametogenic tissue between resident offshore and resident nearshore females during the spring, summer, and fall (Table 4). The gonads of most resident offshore females contained >75% gametogenic tissue throughout the study period, whereas those of most resident nearshore females had <25% (Fig. 4).

The gonadal condition of translocated nearshore females (Fig. 2C) improved when compared with the gonadal condition of resident nearshore females (Fig. 2A). There were significant differences in gonadal maturity between translocated nearshore and resident nearshore females during both the summer and fall (Table 5). There was

Table 4

Probabilities from Fisher's exact test of differences in gonadal maturity and the percentage of gametogenic tissue between resident nearshore and resident offshore conch by sex and season. *n* represents the total number of observations. Asterisks (*) indicate that the test was statistically significant.

	Females		Males	
	n	*P*	*n*	*P*
Gonadal maturity				
Spring	35	<0.001*	32	0.004*
Summer	33	<0.001*	32	0.002*
Fall	35	0.006*	21	<0.001*
% gametogenic tissue				
Spring	35	<0.001*	32	<0.001*
Summer	33	<0.001*	32	<0.001*
Fall	35	0.002*	21	<0.001*

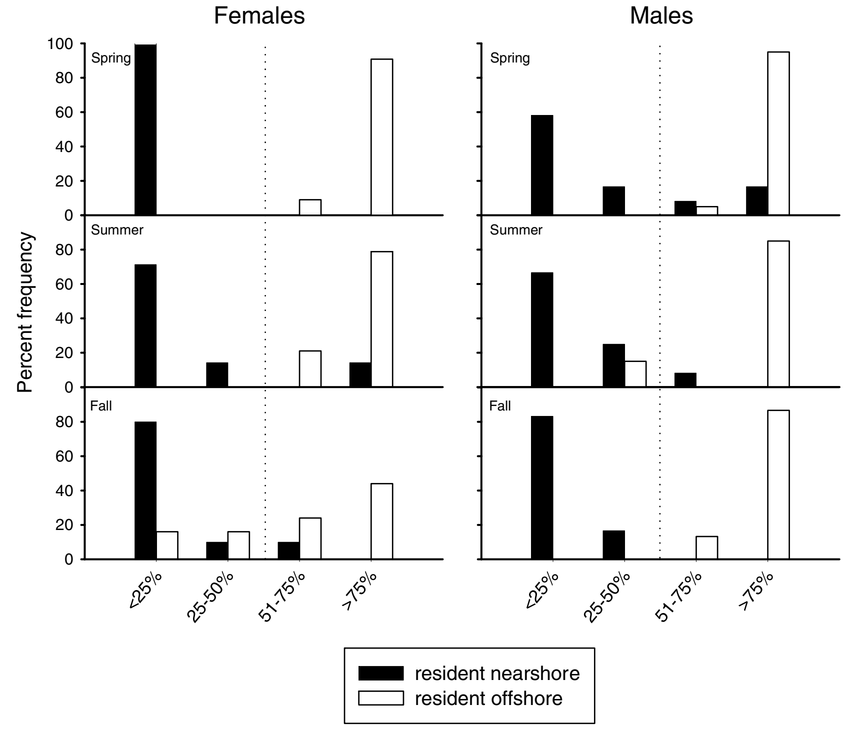

Figure 4

The percentage of gametogenic tissue of resident nearshore and resident offshore queen conch (*Strombus gigas*) by sex and season. The dotted line separates the categories that were combined for statistical analyses.

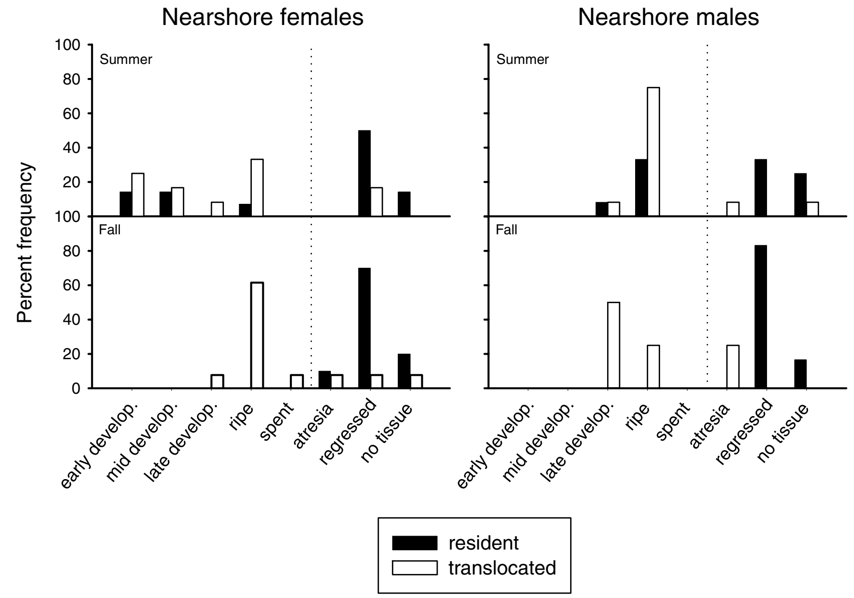

Figure 5

Gonadal maturity of resident nearshore and translocated nearshore queen conch (*Strombus gigas*) by sex and season. The dotted line separates the categories that were combined for statistical analyses.

a higher percentage of translocated nearshore females in some stage of gonadal development than resident nearshore females during the summer; in fact, about 30% of the translocated females were ripe (Fig. 5). By fall, the differences were even more extreme; over 60% of the translocated nearshore females were ripe, whereas all of the resident nearshore females were incapable of reproducing (Fig. 5). Although there was a significant difference in gonadal maturity between translocated nearshore and resident nearshore females during the summer, there was no significant difference in the percentage of gametogenic tissue (Table 5 and Fig. 6). However, by fall, there were significant differences in the percentage of gametogenic tissue between translocated nearshore and resident nearshore females (Table 5). Most translocated nearshore females had developed >75% of the gonad, whereas most resident nearshore females still had <25% gametogenic tissue (Fig. 6).

Histology: males

There were marked differences in gonadal condition of resident nearshore and resident offshore male conch (Fig. 2, D and E). There were significant differences in gonadal maturity between resident offshore and resident nearshore male conch during the spring, summer, and fall (Table 4). During the spring and summer, the gonads of most resident offshore males were categorized as ripe; by fall most were spent (Fig. 3). In contrast, at least half of the resident nearshore males were not capable of spawning during the spring and summer, although some were in the early stages of testicular development and some were even ripe (Fig. 3). However, all the sampled resident nearshore males were incapable of spawning by fall and none were identified as spent (Fig. 3). Histological examinations also revealed significant differences in the percentage of gametogenic tissue between resident offshore and resident nearshore males during the spring, summer,

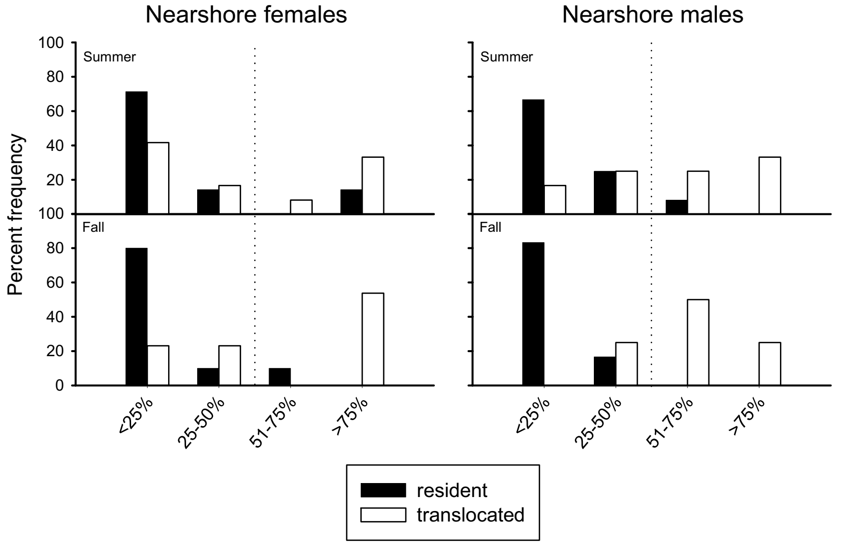

Figure 6

The percentage of gametogenic tissue of resident nearshore and translocated nearshore queen conch (*Strombus gigas*) by sex and season. The dotted line separates the categories that were combined for statistical analyses.

and fall (Table 4). Most resident offshore males had >75% gametogenic tissue throughout the study period, whereas most resident nearshore males had <25% (Fig. 4).

The gonadal condition of translocated nearshore males (Fig. 2F) improved in relation to the gonadal condition of resident nearshore males (Fig. 2D). There were significant differences in gonadal maturity between translocated nearshore and resident nearshore males during both the summer and fall (Table 5). Almost 80% of the translocated nearshore males were ripe during the summer, whereas about half of the resident nearshore males were incapable of reproducing (Fig. 5). By fall, most translocated nearshore males were still capable of reproduction, whereas none of the resident nearshore males were (Fig. 5). There were also significant differences in the percentage of gametogenic tissue between resident nearshore and translocated nearshore males during the summer and fall (Table 5). During the summer, the gonads of most of the resident nearshore males contained <25% gametogenic tissue, whereas translocated nearshore males were divided equally among the four gametogenic tissue categories (Fig. 6). During the fall, the gonads of most of the resident nearshore males still had <25% gametogenic tissue; however, most translocated nearshore males had developed >50% of the gonad (Fig. 6).

Table 5

Probabilities from Fisher's exact test of differences in gonadal maturity and the percentage of gametogenic tissue between resident nearshore and translocated nearshore conch by sex and season. *n* represents the total number of observations. Asterisks (*) indicate that the test was statistically significant.

	Females		Males	
	n	*P*	*n*	*P*
Gonadal maturity				
Summer	26	0.019*	24	0.045*
Fall	23	<0.001*	10	0.033*
% gametogenic tissue				
Summer	26	0.130	24	0.014*
Fall	23	0.038*	10	0.033*

Discussion

In the nearshore region of the Florida Keys, adult queen conch had severe deficiencies in reproductive behavior and gonadal development. Histological examinations of resident nearshore conch revealed that most were incapable of reproducing, whereas resident offshore conch exhibited a normal reproductive cycle (as described by Egan, 1985, and Stoner et al., 1992). Furthermore, our results suggest that female conch may be more sensitive to the negative effects of nearshore conditions than male conch. For example, during the spring and summer, some resident nearshore males were ripe (although their reproductive output would have been severely reduced because of a low percentage of gametogenic tissue), whereas the gonads of most resident nearshore females contained no germ cells. The latter condition may have been due to the fact that egg production is more costly bioenergetically than sperm production (Ricklefs, 1990).

Mating and spawning do not occur among resident nearshore conch presumably because of their retarded gonadal development; however, the translocation of nearshore conch to the offshore region mitigated the deleterious effects that the nearshore environment had on their gonadal development. The reproductive tissues of translocated nearshore conch began to develop during the summer after the conch had spent about three months offshore. Most translocated female conch were in the early stages of gonadal development, whereas most translocated male conch were ripe. We believe this difference in gonadal development is due to the fact that the starting gonadal condition of nearshore females was worse than the starting condition of male conch. By fall, after six months offshore, most translocated females had become ripe. In addition, the percentage of gametogenic tissue in the gonads of both sexes increased through the summer and fall.

In conjunction with the improvement in gonadal condition, nearshore females translocated to the offshore region were observed spawning during the summer and fall; however, no mating was observed among nearshore conch translocated offshore. Resident offshore conch also had low mating frequencies (<6%). Similarly low mating frequencies have been reported in the Virgin Islands (Randall, 1964) and the Bahamas (Stoner et al., 1992). We suspect that the lack of observations of nearshore conch mating in the offshore region may have been an artifact of the low probability of encountering that activity due to the small number of nearshore conch translocated offshore. Nevertheless, we believe mating must have occurred because translocated nearshore conch were observed spawning. However, it is unknown if queen conch are capable of laying unfertilized egg masses.

The beginning of reproductive activity in queen conch is linked to the start of spring, when water temperatures begin rising (Randall, 1964; Stoner et al., 1992; Weil and Laughlin, 1984). This same seasonal pattern was observed in our study with resident offshore conch. They exhibited the highest mating and spawning frequencies during the spring and reproductive behavior decreased during the ensuing seasons. However, compared with the spawning pattern of resident offshore conch, peak spawning in translocated nearshore conch was delayed; peak spawning occurred during the fall. Nevertheless, there was evidence to suggest that the timing of reproductive behavior of both resident offshore and translocated nearshore conch might eventually become similar. Our results indicated that it takes at least three months after translocation for the negative effects of the nearshore environment to be mitigated and for gonadal maturation to occur. The out-of-phase spawning may have been prevented if the translocations had occurred earlier in the year (e.g., January, instead of March).

Identifying the causative factor or factors that inhibit the reproductive viability of nearshore queen conch requires further study. However, the juxtaposition of the nearshore conch aggregations with human population centers suggests that anthropogenic changes to the nearshore region may be partially responsible. Decreased reproductive output caused by anthropogenic contaminants has been observed in several marine invertebrates, including dogwinkles (*Nucella lapillus*) (Bryan et al., 1987; Gibbs and Bryan, 1986), scallops (Gould et al., 1988), sea urchins (Krause, 1994; Thompson et al., 1989), and shrimps and crabs (Wilson-Ormond et al., 1994). For example, chronic exposure to tributyltin has been shown to sterilize females of several species of mollusks (Matthiessen and Gibbs, 1998), and sublethal levels of copper greatly inhibited gamete production and maturation in scallops (Gould et al., 1988). There have also been numerous reports implicating eutrophication in nearshore habitat degradation in the Florida Keys (Lapointe et al., 1990; Lapointe and Clark, 1992; Szmant and Forrester, 1996); however, very little is known about the effects of increased nutrient levels at the organismal level.

The retarded gonadal condition in nearshore queen conch may also be due to environmental factors such as suboptimal habitat, poor food quality, or temperature extremes associated with shallow water. Research on bivalves has shown that habitat, diet, and food quality directly affect gamete production (Le Pennec et al., 1998; Madrones-Ladja et al., 2002). As they increase in age and size, queen conch undergo ontogenetic migrations from shallow, nearshore sites to deeper-water habitats (Randall, 1964; Sandt and Stoner, 1993; Stoner, 1989; Weil and Laughlin, 1984). It has been hypothesized that as conch grow larger and require more food, they migrate to take advantage of the augmented food supply in more productive offshore habitats (Sandt and Stoner, 1993; Stoner, 1989). However, nearshore queen conch in the Florida Keys are prevented from migrating offshore by Hawk Channel (Glazer and Berg, 1994). Therefore, translocating nearshore conch offshore would, in effect, link these isolated environments.

The implications of this study are of particular importance to the FWC-Florida Marine Research Institute's ongoing queen conch stock restoration program. Translocating naturally recruiting nearshore conch to offshore areas would be more cost effective than hatchery production of juvenile conch, especially because production costs are eliminated and survival of translocated conch is likely to be much greater than that of hatchery outplants (see Stoner, 1997, for a review of juvenile mortality in stock enhancement efforts). Translocations would also have a more immediate effect on reproductive output than would the release of hatchery-reared conch. A translocation program would focus on moving large juveniles and adults offshore, whereas a hatchery program must release small juveniles (to minimize production costs) that would then have to survive to maturity. Consequently, translocations would quickly alleviate the depensatory mechanisms described by Appeldoorn (1995) that can affect the recovery of queen conch stocks. Finally, translocations provide the added benefit of maintaining the genetic diversity of the population. Hatchery-reared conch are typically derived from a few egg masses and there is a concurrent loss in rare alleles (Allendorf and Ryman, 1987). However, the use of wild conch to enhance the spawning aggregations eliminates this problem.

Queen conch appear to be a prime candidate for rehabilitation by translocation because they meet the criteria associated with successful translocations reported by Griffith et al. (1989). These factors include release within the historical range of the species or into areas of increased habitat quality (or both). Additionally, herbivorous animals stand a greater chance of translocation success than do carnivores or omnivores. Lastly, wild animals translocate more successfully than captive-bred animals. According to these parameters, queen conch are ideally suited for translocations.

However, before a full-scale translocation program can be implemented, there are some theoretical considerations that must be addressed. For example, Stoner and Ray-Culp (2000) reported that conch reproductive behavior reached an asymptotic level near 200 conch/ha.; therefore, it would seem advantageous to enhance reproductive aggregations to that density. However, without high habitat quality, translocations have low success rates regardless of how many animals are released (Griffith et al., 1989). First, we must ascertain if offshore habitats can support the added number of conch or if the translocated or native animals (or both) will simply disperse after release because of density-dependent factors (e.g., intraspecific competition for limited resources). Conch grazing has been shown to significantly reduce the biomass of seagrass macrodetritus and epiphytes (Stoner, 1989). In addition, the effects of removing nearshore conch from the nearshore environment need to be investigated.

Additionally, if increased recruitment is the ultimate goal of the translocation program, larvae must survive and be retained within the Florida Keys. At this point, it is unknown whether larvae produced from translocated nearshore conch are viable or as viable as the larvae produced by native offshore conch. Furthermore, the relative contribution of local and upstream sources to recruitment is unknown. Stoner et al. (1996, 1997) suggested that most of the queen conch larvae entering the Florida Keys come from upstream sources. If this is indeed the case, then local translocations will not be as effective as an international or regional management strategy. However, mechanisms for larval retention in the Florida Keys have been described by Lee and Williams (1999), who suggested that the periodic formation of gyres in the lower Keys may facilitate the retention and recruitment of locally produced larvae. If larvae are retained within the Florida Keys system, any increase in local larval production will increase larval supply and may increase recruitment. Therefore, translocation sites should be located in the lower Keys in order to ensure maximum larval retention and recruitment.

The present study has shown that translocation may be a viable method for rehabilitating queen conch populations in the Florida Keys. We have demonstrated that nearshore conch that were translocated offshore regained some of their reproductive capacity and abilities. Therefore, moving conch from nearshore larval sinks to offshore larval sources may be the key to expediting the recovery of queen conch stocks. Further research (e.g., larval retention studies, studies on the effect of water quality on larval survival, carrying capacity studies) and monitoring will determine the efficacy of this restoration strategy.

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