# Queen Conch Mariculture and Restoration in the Archipiélago de Los Roques: Preliminary Results

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ABSTRACT

Preliminary results of the queen conch *(Strombus gigas)* project being conducted at the Dos Mosquises Marine Station, Archipiélago de Los Roques, Venezuela, are presented and discussed. Special emphasis is given to those aspects related to larvaculture and juvenile growth in captivity and in nature. Of the 63 cultures in 1981, 10 were successfully raised through metamorphosis yielding a total of 4900 juveniles. Of the 60 hatches raised so far in 1982, none have been successful. The average growth rate of juvenile conch in tanks ranged from 0.21 cm/month in an asbest-cement tank with a density of 50 ind/$m^2$ for 360 days to 0.42 cm/month in a plastic tank with density of 25 ind/$m^2$ for 360 days. Under condition of relatively low conch density, monthly growth rates were considerably higher during the first 3 months following metamorphosis. Growth rates appeared to be inversely related to density. Growth rates in nature estimated from tagged conch varied from 0.5-0.9 cm/month.

The eventual goal of this project is to protect and restore conch population at Los Roques. The juveniles cultured in 1981 were seeded in overfished areas. Other conservation measures being implemented are discussed.

The queen conch, *Strombus gigas*, is a large marine snail distributed in most of the shallow waters of the Caribbean. Its biology, fishery and possibilities for culture have been the subject of many studies (Adams, 1970; Alcolado, 1976; Berg, 1976; Blakesley, 1977; Brownell, 1977; Brownell and Berg, 1978; Brownell and Stevely, 1981; Brownell et al., 1977; D'Asaro, 1965; Hesse and Hesse 1977; Iversen, 1976; Little, 1965; Randall 1964; Stevely, 1979). The species supports important commercial fisheries in most islands in the Caribbean and it is a significant source of protein in the region. The conch is about 100% usable; it can yield up to 1 kg of meat (with about 75% of its dry weight constituted by protein) in about 2.5 years from birth, its viscera are used to produce high quality fertilizer, and its shell is sold as a souvenier and/or utilized as a source of $Ca\ Co_3$. Although the conch resource still holds commercial importance, it has been overexploited in many regions and measures are now being taken to protect and restore local populations.

In Venezuela, *S. gigas* is fished exclusively in the Archipiélago de los Roques and Las Aves, areas where the conch is still abundant. In other regions in coastal Venezuela such as Morrocoy, Gulf of Cariaco, and Margarita the species has been practically eliminated by overfishing.

In 1975, studies were made of the biology and mariculture of the conch (Brownell, 1977) at the Dos Mosquises Marine Station, Los Roques. In 1980 a major effort followed up Brownell's initiative. The objective of this 3-year project is to intensively study the biology, ecology and fishery of *S. gigas*, to develop simple larvaculture systems and to determine optimum conditions (substrate type, density) for juvenile growth. These efforts are geared toward the restoration of the depleted conch population at Los Roques. This paper presents the preliminary results of this project, especially aspects related to the culture of larvae and juvenile conch and discusses measures being implemented to protect the conch there.

## MATERIALS AND METHODS

### Rearing Procedures

Research conducted at the Dos Mosquises Marine Station on rearing procedures were basically those of Brownell (1977), with modifications. Briefly the procedure is: eggs are hatched in 35-*l* and 100-*l* plexiglass aquaria placed above rearing tanks and/or in small square chambers lined with nylon net of a mesh size 500 $\mu$ fastened to the side of the tank. After hatching veligers are suctioned directly into the rearing tank or allowed to actively or passively pass through the nylon net to the tank.

Several types of rearing tanks were utilized for the larva cultures: 1000-*l* fiberglass cylinder-shaped tanks (h=1.0 m, d=1.0 m), 3000-*l* fiberglass tanks, U-shaped in cross section (length=5.0 m, maximum width=1.0 m), 800-*l* cup-shaped fiberglass tanks (maximum d=1.40 m) and 500-*l* square-shaped asbest-cement tanks (0.8 m to the side). Rearing tanks placed in illuminated areas receive direct sunlight during the late afternoon hours.

Veligers are raised with enriched natural cultures of phytoplankton prepared as indicated by Brownell (1977). In 1981 veligers were fed every 2 days with a volume of dense phytoplankton equivalent to 10% of the volume of water in the rearing tanks. In 1982 some hatches were fed every 2 days and others every 4 days. The last 20 hatches were fed only when the routine daily analysis of veliger guts under the microscope revealed that a good proportion of them were empty.

In 1981 half of the water in rearing tanks was replaced twice a day with fresh sea water. In 1982, the same amount of water was replaced every 2 days; however artificial aeration was applied 6 h a day (5:00-11:00 P M).

Temperature, salinity and pH were measured daily. Temperature ranged from 26°C-29°C in January to 28.5–30.0°C in August. Salinity ranged from 36-39°/₀₀, and pH from 8.05-8.7 ($\bar{x}$=8.43, SD=0.23).

### Juvenile growth

Metamorphosis generally takes place in 18-21 days. Recently metamorphosed juveniles are left in the rearing tanks until they reach an average size of 10 mm in shell length (2 months from hatching) and then transferred to growing tanks where they are kept for 1 year (6 cm shell length) then they are released into the environment. Several types of tanks were utilized for juvenile growth: 200-*l* plastic tanks, U-shaped in cross section, 2,000-*l* circular-shaped cement tanks, and 500-*l* square cement tanks.

An experiment was conducted to compare growth rate of two densities of juvenile conch in plastic tanks with treatments of sand and no sand as substrate. The sand was intensively washed once a week to eliminate waste products and the accumulated detritus. In another experiment we compared growth rates in tanks of different densities of juvenile conch collected in the field.

Juveniles in tanks are weekly fed by introducing rocks and/or conch shells with a dense cover of filamentous green algae, generally of the genera *Enteromorpha, Chaetomorpha* and *Cladophora.*

Simultaneously we estimated the growth rate of 350 tagged juvenile conch in the field by measuring the shell length of each every month. Conch were tagged by fastening a small numbered plastic tag with fine nylon cord in two very small holes drilled into on the dorsal surface of the shell.

Table 1. Results of the growth experiments of juvenile conch in captivity and in nature at the Dos Mosquises Marine Station, Archipielago De Los Roques, Venezuela

| Tank type | Substrate | Tank Capacity (lt) | No. | Density Ind/m2 | Density Ind/l | Initial length (cm) $\bar{x}$ | Initial length (cm) SD | Final length (cm) $\bar{x}$ | Final length (cm) SD | Duration in days | Growth Rate (cm/month) | Mortality Ind/month | Mortality Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plastic | None | 150.0 | 21 | 25 | (0.12) | 0.74 | 0.09 | 7.23 | 0.38 | 480 | 0.38 | 0.12 | (10) |
| Plastic | Sand | 150.0 | 21 | 25 | (0.12) | 0.60 | 0.10 | 7.63 | 0.61 | 480 | 0.42 | 0.40 | (30) |
| Plastic | None | 150.0 | 82 | 109 | (0.54) | 0.22 | 0.04 | 4.31 | 0.71 | 480 | 0.27 | 0.50 | (10) |
| Plastic | Sand | 150.0 | 82 | 109 | (0.54) | 0.21 | 0.04 | 4.38 | 0.53 | 480 | 0.27 | 1.00 | (20) |
| Asb.-Cem. | Sand | 2.000.0 | 90 | 58.3 | (0.09) | 3.55 | 0.86 | 6.58 | 0.98 | 360 | 0.21 | 2.33 | (31) |
| Asb.-Cem. | None | 500.0 | 12* | 17.0 | (0.024) | 8.63 | 0.99 | 10.70 | 1.52 | 180 | 0.35 | - | |
| Asb.-Cem. | None | 500.0 | 24* | 31.0 | (0.048) | 8.26 | 1.31 | 9.84 | 0.97 | 180 | 0.26 | - | |
| Asb.-Cem. | None | 500.0 | 42* | 54.0 | (0.084) | 8.54 | 0.93 | 9.41 | 0.83 | 180 | 0.14 | - | |
| Field | Thalassia bed | | 100 | 0.37 | 2.33 | 9.9 | 0.22 | 23.8 | 0.70 | 480 | 0.9 | 0.50 | (8) |
| | " | " | 130 | " | " | 5.8 | 0.20 | 23.5 | 0.28 | 330 | 0.7 | 1.00 | (8) |
| | " | " | 120 | " | " | 8.10 | 0.17 | 11.53 | 0.18 | 180 | 0.57 | 0.32 | (1.6) |

* Conch collected in the field.

## RESULTS

### Culture

Between October 1980 and December 1981, 63 hatches were raised: 43 were in cup-shaped tanks, 4 in cement tanks, 4 in 1-m high fiberglass tanks and 12 in 5-m long fiberglass tanks. Of the 43 hatches in cup-shaped tanks, only 5 were successfully raised through metamorphosis, of which 2 yielded about 1000 juveniles each, and 3 about 400 each, totaling about 3200 juveniles. Initial larval densities in these tanks ranged from 250-400 veligers/*l*. Metamorphosis occurred in 18-21 days and it was observed that in 8-10 days the veligers were well developed with six lobes. Of the remaining 38 hatches, 6 failed in 1-4 days, 17 in 10-12 days and 8 in 18-21 days. The other 7 failed outside these critical periods.

All the 12 hatches in the 5-m long fiberglass tanks failed in 10-12 days with overnight massive mortality of the veligers. Of the four hatches in the 500-*l* cement tanks, two were raised through metamorphosis and yielded about 500 conch each. Initial larval densities in these tanks ranged between 150-300-veligers/*l*. Metamorphosis occurred in 18-21 days. Of the four hatches in the 1-m high cylinder fiberglass tanks, three were successfully raised, of which one yielded 500 juveniles, and the other two about 100 juveniles each. Initial larval densities in tanks ranged from 300-500/*l*. Metamorphosis occurred in 19-21 days. In total, about 4900 juveniles were obtained in 1981.

From May to September 1982, 60 hatches were raised, 40 were in cup-shaped fiberglass tanks and 20 in 1-m high cylinder-shaped fiberglass tanks. None of these hatches were raised through metamorphosis. Of the 40 hatches in cup-shaped tanks, 22 failed in 1-4 days, 6 in 10-12 days, 2 in 16 days and 10 in 18-20 days. Of the 20 hatches in cylinder shaped tanks, 2 failed in 1-4 days, 7 in 10-12 days and 11 in 18-20 days. Initial veliger density in all tanks ranged from 100-400/*l*.

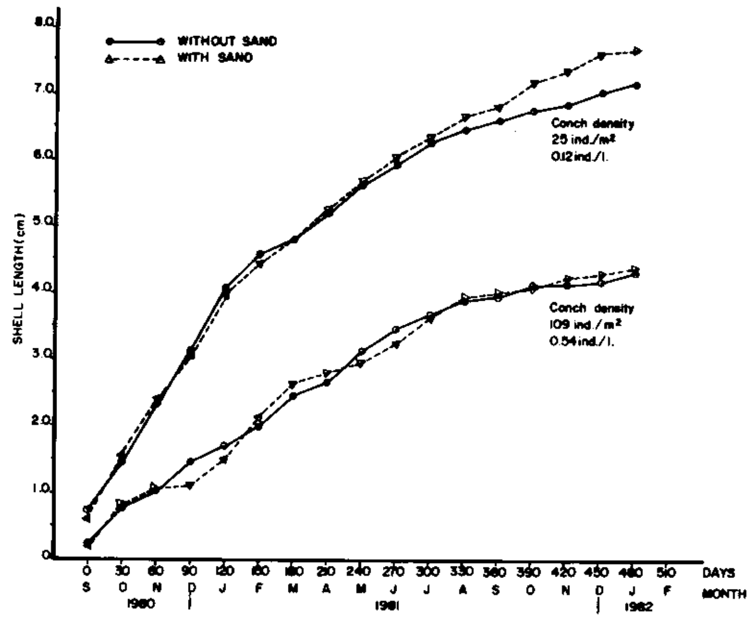


Figure 1. Comparison of size-age relationships of two densities of juvenile conch *(S. gigas)* in 200 *l* plastic tanks with sand and no sand as substrate. The regression equations are: density of 25 ind/m² in sand, $y = 1.77 + 0.04\,x$; no sand, $y = 1.95 + 0.013X$; density of 109 ind/m² in sand, $y = 0.67 + 0.009\,x$; no sand $y = 0.61 \pm 0.009\,x$.

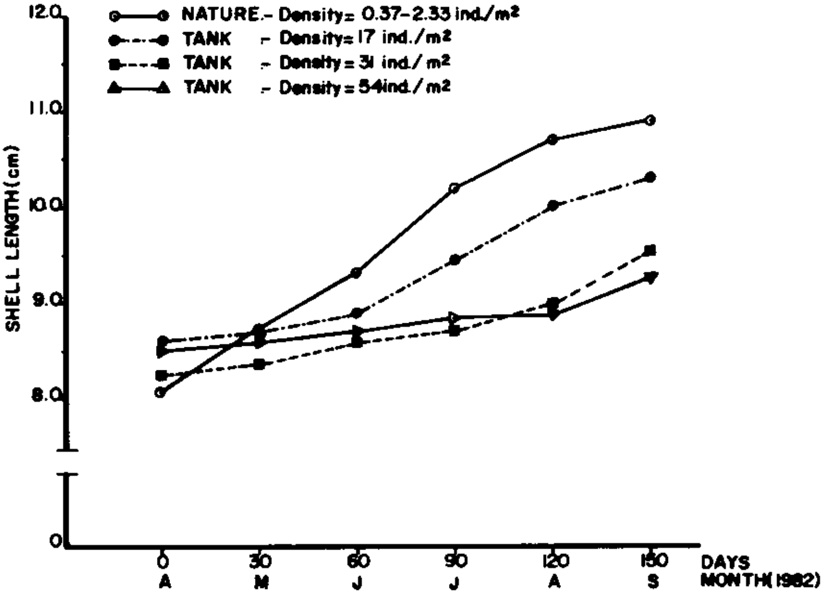


Figure 2. Comparison of size-age relationships of juvenile conch *(S. gigas)* collected in the field and placed in tanks at three different densities, and of conch tagged and left in their natural environment. Regression equations are: density of 17 ind/m$^2$, y = 8.86 + 0.08 x; 31 ind/m$^2$, y = 8.15 + 0.008 x; 59 ind/m$^2$, y = 8.48 + 0.004 x; conch in nature, y = 8.20 + 0.019x.

## Juvenile growth

The preliminary growth data and other relevant information are given in Table 1. The size-age relationships obtained from the different growth experiments are illustrated in Figures 1, 2 and 3. Overall, the average monthly growth rate of juvenile conch in captivity varied from 0.21-cm/month in an asbest-cement tank with a density of 50 ind/m$^2$ (0.23 ind/*l*) for 360 days to 0.42 cm/month in a plastic tank with sand as the substrate with a density of 25 ind/m$^2$ (0.12 ind/*l*) for 360 days. Generally the average growth rate of juvenile conch in tanks was higher (2-3 times) during the first 2-3 months, than during the remaining time (Figs. 1,2,3). This was particularly pronounced in tanks with relatively low conch densities.

Results show that the presence or absence of sand as substrate has no significant effect on the growth rate of juvenile conch at either low or high density (Fig. 1). However overall mortality was about double (20%) in tanks with sand (Table 1). Note that mortality of juvenile conch in an asbest-cement tank with sand was on the order of 30%. (Table 1). The average monthly growth rate in tanks with low conch density (25 ind/m$^2$, 0.12 ind/*l*) was considerably higher than that of conch at a high density (109 ind/m$^2$, 0.54 ind/*l*) (Fig. 1). This was particularly pronounced during the first 3 months when growth rates at low conch density reached values as high as 0.8 cm/month.

The comparison of size-age relationships of three different densities of conch collected in the field with an initial average shell length of 8.5 cm and placed in tanks for a period of 150 days and 120 conch of comparable initial size, tagged and left in its habitat is shown in Figure 3. The growth rate in the field was significantly higher than in tanks. However tank densities were much higher than natural densities. In tanks, the growth rate of juvenile conch was inversely related to their density (Table 1).

The size age relationships of two groups of conch tagged in the field with different initial shell length (Fig. 3, Table 1) show that the monthly growth rate in the field was considerably higher than any of the growth rates estimated in captivity. Also that the growth rate was quite consistent with age, only declining when conch reached a size of approximately 20-22 cm in shell length.

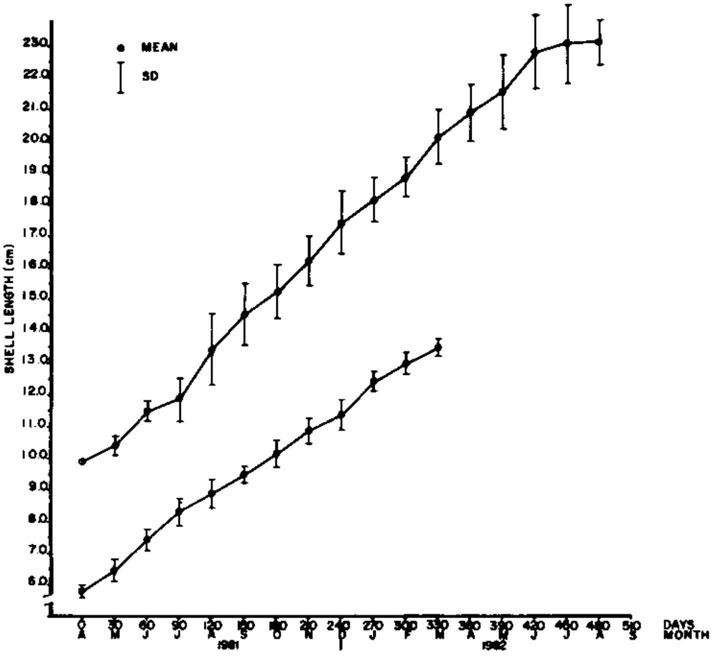


Figure 3. Size-age relationships of two groups of juvenile conch of different initial shell length tagged and left in their natural environment. Regression equation are: conch of mean initial length 5.8, $y = 5.95 + 0.023\ x$; conch of mean initial length 9.9, $y = 9.83 + 0.03\ x$.

## DISCUSSION

The attempts to culture conch in the laboratory produced mixed results. In spite of the many failures, we believe we had partial success, at least in 1981. Of the 63 hatches raised in 1981, 10 were successful, yielding a total of 4900 juveniles. To our knowledge no comparable yearly production has been obtained before. Although Brownell (1977) did raise 10 cultures of *S. gigas* through metamorphosis at Los Roques, he did not report the total number of juveniles produced. We believe the production in 1981 could have been higher if it were not for the fact that the spawning season was cut short due to an abnormal early water temperature drop; no egg masses were found after 15 October. In 1980 egg masses were found through 15 December.

So far in 1982 none of the hatches (60) had been successfully raised through metamorphosis. However, 21 of those (with veliger densities of up to 400/*l*) were raised to the 18-20 day period, when total mortality of the apparently healthy veligers took place in a period of 2-3 days.

We have no clear idea or reasons for the successes of 1981 or the failures in 1981 and 1982. However we wish to comment on this, based on our observations over 2 years. No measurable change in the physico-chemical parameters in the rearing tanks (temperature salinity, pH) was associated with successful hatches. And although we do not have trustworthy data on oxygen levels the fact that the water in rearing tanks was frequently changed and/or artificially aerated assures to us that oxygen deficiency was not a problem.

Although we experimented with several types of rearing tanks, our data are still insufficient to make any solid conclusion on the ideal type of rearing tank to use. However it appears that the cup-shaped, cylinder-shaped fiberglass and asbest-cement tanks are appropriate for larvaculture. Shallow tanks such as the 5 m long, (40 cm deep fiberglass tank) seem unsuitable for veliger growth.

A major problem encountered in the cultures was the presence of a tremendous abundance of predators, especially copepods. This was particularly true in 1982; most of advanced-stage veligers observed under the microscope had a small copepod on it, presumably eating it. These copepods could be filtered out with very fine mesh at the expense of excluding potential phytoplankters for veliger growth. Although we did follow Brownell's (1977) recommendation of using a filter mesh size of 120 $\mu$ to exclude most predators and the phytoplankters as food of advanced stage veligers, the problem was not lessened. Another critical problem was the very high incidence of protozooans especially, *Vorticella*. Most advanced larval stages were observed with several of these sesile-ciliates attached.

We do believe that for one reason or another there are times of the year when there is a higher probability of success. All successful hatches in 1981 and those that reached the advanced stage in 1982 occurred in August and September, and coincided with times of very high tides. Possibly the composition of the phytoplankton at these times of the year is more suitable for veliger growth. In fact, the apparently fortuitously occurrence of successful hatches could be explained by the cyclical abundance of plankton in nature. Thus our lack of real control of the type and density of the phytoplankton supplied as food is perhaps our most limiting problem.

A study to determine temporal variations in phytoplankton composition and abundance in the area of Dos Mosquises will be conducted in 1983.

Our results confirm the fact that the well defined critical time periods in conch larvaculture occur at 1-4, 10-12 and 18-21 days. Generally, larval mortality in the 10-12 days was massive occurring in a period of a few hours. D'Asaro (1965) points out that 9-10 day period is critical, when food stored in albumen cells is utilized if inadequate phytoplankton is supplied. The mortality at the 18-21 day period was not of the massive type and occurred over 2-3 days. This mortality was accompanied by high incidence of predators (small crustaceans, echinoid larvae, worms, protozoans). The massive mortality that frequently occurred during the first 4 days cannot be accounted for by any of our observations.

The monthly growth rates of juvenile conch estimated in this study are considerably lower than those obtained by Brownell (1977) at this marine station. He reported monthly growth rates for recently metamorphosed juveniles of up to 0.9 cm for the first 270 days of age (9 months). We obtained monthly growth rates of 0.8 cm/month but only during the first 150 days and at conch densities of 25 ind/m$^2$ of tank area. After 150 days the growth rate was reduced to 0.3 cm/month. Berg (1976) and Ballentine (unpublished data) also report growth rates of 0.8 cm/month for recently metamorphosed juveniles. Iversen and Siddall (unpublished report) report growth rates from 0.7-1.2 cm/month for individuals in suspended net cages and significantly lower values for individuals in tanks. Our generally lower growth rates could be accounted for by the fact that they were estimated under conditions of higher conch density.

Our results also showed that growth rates appear to be inversely related to conch density (Table 1). However, even at very high densities of up 110 conch/m$^2$, the growth rate was not greatly reduced (36% reduction). Based on these results we suggest that conch could be intensively cultured in tanks at densities between 25-50 conch/$m^2$ during the first year when the growth rate may reach 0.8 cm/month, after which they should be transferred to suspended cages or marine pens. The use of sand as a substrate in rearing tanks is not recommended, not because it inhibits growth, but because mortality is significantly increased under this condition.

The monthly growth rate estimated for conch in nature were comparable to those reported by Alcolado (1976) and slightly higher than that given by Iversen and Siddall (unpublished report). They were significantly higher than those found in our experimental tanks, and surprisingly comparable to growth rates reported by Brownell (1977), and Berg (1976), for juvenile conch in captivity. It should be noted that our field data were gathered in a *Thalassia* bed with conch densities of 0.33-2 ind/$m^2$, which are 45-300 times lower than our tanks densities.

Generally, the average monthly growth rate of juvenile conch in the field at Los Roques varied from 0.5-0.9 cm. Thus, if we estimate an average growth rate in nature of 0.6 cm/month it will take 3 years for a recently metamorphosed conch, to reach commercial size of 20 cm in shell length. On the other hand if we consider our average growth rate of 0.4 cm for juvenile conch in captivity, at a density of 25 ind/$m^2$, it will take 5 years to reach a commercial size of 21 cm.

Finally we feel it's appropriate to mention that the main goal of the conch project at Los Roques is to develop simple rearing systems for larvae and juveniles to be operated by trained technicians at Los Roques and/or in other parts of Venezuela. We have tried to avoid complicated systems and equipment as well the rearing of artificial monocultures of phytoplankton. So far we have had mixed to negatives results; that some hatches were quite successful is encouraging to us. Within this framework of research we will continue experimenting with different methods of larvaculture and give special emphasis to feeding. The fact that we have an abundance of egg masses in the vicinity of the marine station facilitates long term research on larval development.

The research efforts at Los Roques are geared not only toward the optimization of simple rearing systems, but toward the restoration of the depleted conch stocks in the eastern portion of the archipiélago (Weil and Laughlin, 1982). The juveniles produced in 1981 were released in overfished areas. Although this number was hardly a significant quantity, the measure has opened up the eyes of the many involved in the policy making and management of the fisheries and national parks of Venezuela. Another important conservation measure that we have implemented is the transplantation of about 2000 egg masses a year from the southwestern areas of the archipiélago, where fishing is prohibited, to the eastern overfished areas. We believe that because the currents in the archipiélago are predominantly from the east, most of the veligers hatched from the egg masses laid in this area are transported outward to deep water to the west of the archipiélago. Finally, our results on conch population dynamics and reproduction are actually being used by the authorities to change fishing regulations. Today the fishing season exactly coincides with the reproductive season (May-November), a measure obviously not biologically sound.

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