Status of Conch Mariculture as a Management Tool in the Grenadines

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RESUMEN

Durante los últimos cuatro años, se ha desarrollado un amplio interés en técnicas que mejoren el manejo de los recursos de *Strombus gigas* en el Caribe. Gran parte de este interés se ha enfocado hacia las técnicas en maricultura, especialmente en la obtención y crianza de larvas. Veligers de *S. gigas* han sido obtenidas en los laboratorios de la Fundación Científica Los Roques, en Venezuela, pero intentos subsecuentes para repetir este trabajo en otros sitios, han fallado. Mientras tanto, el mercado internacional para los productos de *S. gigas* se encuentra en expansión, y existe el peligro creciente de sobre explotación de muchos stocks. En las Granadinas, el incremento de las exportaciones de productos pesqueros a Martinica, ha intensificado la presión pesquera sobre los stocks locales de *S. gigas* durante los últimos dos años.

Projectos para el desarrollo del cultivo de *S. gigas* han sido recomendados como una base para industrias locales, operaciones comerciales en gran escala y como medio para rehabilitar poblaciones naturales que han experimentado sobrepesca. Sin embargo las factibilidades de estas recomendaciones no han sido aun establecidas, e información básica sobre los requerimientos para el mantenimiento de las larvas y juveniles en *S. gigas*, es necesaria antes de evaluar adecuadamente las posibles aplicaciones.

Investigación en cultivos de *Strombus* en las Granadinas, esta orientada hacia los estadós larvales y postlarvales. Se han desarrollado sistemas experimentales simples y efectivos para el mantenimiento de las larvas. Veligers de *S. gigas* han sido criados utilizando una gran variedad de algas como alimento, incluyendo concentrados congelados de *Tetraselmis* sp., homogenizados de algas de la zona intermareal, y fitoplancton cultivado en agua de mar enriquecida. Partículas alimenticias menores de 53 μm en tamaño, producen crecimiento rápido durante los primeros 16-20 dias de vida larval. Diferentes tipos de alimento determinan el crecimiento subsecuente, en alqunos casos se produce un retardo o detención de la metamorfosis

Personal local en Carriacou ha sido entrenado en las tecnicas requeridas para la alunentación básica y estudios de crecimiento de juveniles de *Strombus* mantenidos en cautiverio. Se han iniciado experimentos para evaluar la potencialidad de varios substratos en la crianza extensiva de juveniles de *Strombus*. Los animales bajo estudio se mantienen en simples encierros baja agua, y las tasas de crecimiento serán comparadas con las de un a población natural de control. Utilizando técnicas que pueden ser aplicadas a nivel artesanal, los moradores cooperan con consejeros externos en el desarrollo de las estrategias para una mejor administración del recurso de *Strombus*.

Existe una gran necesidad de un enfoque cooperativo para la investigación dirigida hacia la administración y cultivo de *Strombus*. Instituciones con equipos sofisticados y personal experimentado puede ser de gran ayuda a los proyectos de campo, los cuales a su vez ofrecen oportunidades para el estudio directo y la manipulación de las poblaciones. Ademas, proyectos de campo pueden y deben ser enfocados hacia el desarrollo de los recursos humanos locales para asegurar asi, por períodos largos la viabilidad de los programas administrativos.

Para los inicios de 1981, se ha planificado una conferencia con el fin de fomentar tal coloboración y para definir los problemas críticos comunes, y los enfoques para su solución, así como el papel que podrían desarrollar individuos e instituciones dedicadas a la administración de los recursos de *Strombus* la el Caribe.

INTRODUCTION

A number of reviews and technical reports have been published in recent years concerning the status of queen conch (*Strombus gigas*) stocks in the Caribbean region (Adams, 1970; Hesse, 1975; Brownell, Berg and Haines, 1976; Blakesley, 1977; Brownell, 1978; Stevely and Warner, 1978). All of these have expressed concern for the future of conch stocks, and have concluded that overexploitation is a probable result of present use patterns. In the Grenadine Islands, export of fisheries products to Guadeloupe and Martinique has mushroomed in the last 2 years, and this lucrative export market has further intensified fishing pressure on local conch resources.

For the past 4 years, Environmental Research Projects, at the request of the Government of Grenada, has provided research and advisory services for the development of a management strategy for Grenada's conch and spiny lobster resources. This work has been supported by the Canadian International Development Agency, and more recently by the Rockefeller Brothers Fund and the World Wildlife Fund-U.S. Faced with the unsatisfactory choice of either accepting overexploitation as inevitable or attempting to enforce restrictive legislation, increasing attention is being directed toward mariculture as a possible third alternative. Much of the current interest in mariculture has stemmed from the work of Berg (1976) and Brownell (1977) who demonstrated the feasibility of rearing conch larvae through metamorphosis under laboratory conditions. Conch mariculture (in the broad sense of human manipulation of *any* part of the animal's life cycle) has been suggested as a possible basis for cottage industry at the artisanal level, for large-scale commercial operations, and for rehabilitation of over-fished wild stocks. The feasibility of these suggestions has not been established, however, and several attempts to duplicate Brownell's work have not been successful. The need for research directed toward the problem of rearing conch larvae under artificial conditions has led to the involvement of a variety of institutions, including the National Marine Fisheries Service, the University of Miami, the Osborn Laboratory of Marine Science, Foundation PRIDE in the Turks and Caicos Islands, and Environmental Research Projects in the Grenadine Islands.

Our work in the Grenadines has been directed toward the need for basic information on culture systems for conch larvae and juveniles. A primary purpose of the ERP conch project is to develop techniques which can be applied by local people on a scale appropriate to local conditions. The objectives of the 1980 project were: (1) to develop a simple experimental system for field research on the maintenance requirements of conch larvae through metamorphosis, including means for predator control; (2) to identify food organisms suitable for the maintenance of conch larvae; (3) to define minimal quantities of foodstuffs required for veliger maintenance; (4) to identify one or more indicators of the 'health' of a culture system, and to provide the baselines for judging the effects of various culture systems; and (5) to compare the growth of juvenile conch in simple underwater enclosures with the growth of free conch on natural substrates.

MATERIALS AND METHODS

Egg masses for veliger experiments were collected on breeding grounds close to Carriacou in depths ranging from 15 to 20 m. Most egg masses were incomplete at

the time of collection (that is, were taken before the gravid female had completed the laying process). Egg masses were transported in a polyethylene container to a temporary laboratory on Carriacou, and were transferred to a glass aquarium containing 20 l seawater filtered through a 90 μm nylon mesh filter. Two or 3 days after collection, several strands were carefully unravelled from the egg mass, the adherent sand grains removed, and the number of eggs per unit strand length was determined. Additional segments of strands were then removed from the egg masses in lengths sufficient to provide 600 larvae in the 30 l experimental tanks. A highly consistent density of eggs within the strand and a hatch rate close to 100% made this a convenient procedure for regulating initial concentrations of larvae in the experimental system. Measured strand segments were suspended on stainless steel mesh trays in separate 30 l aquaria filled with fresh seawater which had been pumped through a 10 μm filter (commercial cellulose cartridge filters, Whatman "Gamma-12," were used interchangeably with a "balloon" filter made by fastening a bag of 10 μm nylon mesh to a polyethylene tube with vinyl tape).

At the onset of hatching, each aquarium was connected by means of a siphon to an overhead supply tank filled with 10 μm filtered seawater. Distal ends of the siphons were fitted with hypodermic needles to meter the flow of fresh seawater at a daily rate equal to at least one-third the aquaria volume. An overflow siphon with its intake close to the bottom of the tank was provided in each aquarium to maintain a constant water level. Each overhead supply tank was aerated continuously.

In early experiments, 2- to 3-day old veligers tended to accumulate near the bottom of the aquaria, and were thus exposed to settled debris and waste materials. Veligers were subsequently found to be positively phototropic, and the sides of the tanks were fitted with black-painted light shields to more faithfully simulate a normal illumination regime.

Three types of algal food were used in this study: (1) A frozen concentrate of *Tetraselmis* sp., obtained from axenic culture, which provided about 7×10^7 cells/ml; (2) A refrigerated homogenate prepared by chopping 100 ml wet-packed *Cladophora* sp. in an equal volume of seawater using a household blender, then grinding the resulting mixture in a Potter-Elvejhem-type tissue grinder; (3) A refrigerated algal polyculture prepared as follows: 30 l seawater were filtered through a 90 μm nylon mesh into a 30 l aquarium, and enriched as indicated in Table 1 to produce a modified f-l medium (Guillard and Ryther, 1962). 30 l fresh seawater were filtered through 90 μm nylon mesh, then again through 10 μm mesh. The material retained by the 10 μ filter was used to innoculate the medium described above. Constant aeration and illumination (20 w "Cool White" fluorescent lamp at 15 cm) were provided. After 10 days the culture was harvested by siphoning 1/2 the volume through a 53 μm mesh filter, then through a 10 μm mesh, rinsing the smaller mesh into a small flask, and centrifuging the resulting material to obtain a final volume of about 20 ml. Fresh 10 μm filtered seawater and nutrients were added to the culture tank to replace the withdrawn volume, and the harvest procedure repeated at 4-5 day intervals. The second crop was first filtered through 90 μm mesh, while the third and subsequent crops were filtered through 202 μm mesh to provide larger food particles as the veligers grew.

Addition of algal foods was begun in experimental tanks one day after hatching. Additions were made once daily (except that animals receiving algal polyculture

Table 1. Nutrient substances added to 40 l filtered seawater for algal cultures

$NaNO_3$	6.0 g
NaH_2PO_4	400 mg
$FeCl_3 \cdot 6H_2O$	252 mg
Na_2SiO_3	1.8 g
EDTA	344 mg
$MnSO_4$	12.4 mg
$ZnCl_2$	840 µg
$CoCl_2$	800 µg
$CuCl_2$	539 µg
Thiamine HCl	8 mg
Tris(hydroxymethyl)-aminomethane	20.0 g

concentrate were not fed on days 4, 6, and 9 after hatching). *Tetraselmis* concentrate was added in 2 ml increments to give concentrations of approximately 7,000 cells in the experimental tanks. *Cladophora* homogenate was added in 20 ml volumes, since total chlorophyll determined by the SCOR / UNESCO procedure (Strickland and Parsons, 1972) indicated that the latter homogenate contained roughly 0.1 the chlorophyll present in the *Tetraselmis* concentrate. Algal polyculture concentrates were added to experimental tanks in 2 ml volumes which gave concentrations of about 1,600 cells / ml in the experimental tanks.

Siphonal length measurements were made with the aid of an ocular micrometer. The pH was monitored daily to 0.01 unit using an Orion model 399A meter. Temperature was measured with a YSI model 43 thermistor monitor. Prior to use, glass aquaria were scrubbed with household scouring powder, rinsed thoroughly with tap water, treated with commercial bleach (5.25% sodium hypochlorite) for 15 min, rinsed again, and allowed to dry in the sun to reduce any residual chlorine. Erythromycin (Mardel Laboratories "Maracin") was used in early experiments at a manufacturer's recommended concentration (6.0 - 6.7 mg/l), but had no demonstrable benefits and was subsequently discontinued.

Underwater pens for comparative growth studies were constructed from T-shaped concrete blocks (Fig. 1). These are arranged to enclose a 2.4 m x 2.4 m surface on beds of *Thalassia* sp. or coarse coral sand at a depth of 3 - 4 m. Twenty juvenile *S. gigas* (siphonal length range = 10 cm - 18 cm) were placed in each enclosure. Each animal was measured and tagged by means of numbered plastic label tape (Dymo Industries) tied around the spires with nylon seine twine prior to penning. Some enclosures are "enriched" by the introduction of plastic flour sacking which has been suspended in midwater close to the pens until an algal film has formed on the sacking surface.

The growth of conch in these enclosures is to be compared during 1981 with the growth of several wild populations of similar age. Additional comparisons are to be made with juvenile conch contained in naturally enclosed seawater ponds which receive substantial organic input from nearby mangroves.

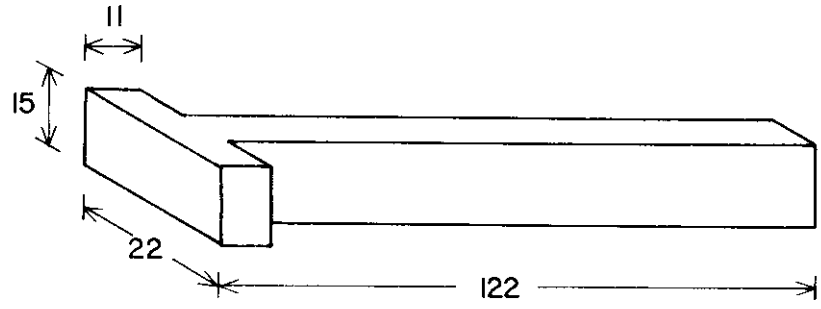

Figure 1. Concrete blocks used to construct underwater pens for juvenile conch (Dimensions in meters).

RESULTS

The experimental culture system described above was adequate for routine rearing of conch veligers. A total of four batches (600 veligers per batch) was raised on *Tetraselmis* concentrate, five batches on *Cladophora* homogenate, and two batches on concentrated algal polyculture. Temperature in the experimental system ranged from 27.1 to 29.8°C.

Larval density in the individual tanks was critical, and batches which exceeded 20 veligers/l "crashed" before day 9 after hatching. Heavy mortality in other batches was not found to coincide with age or behavior of the larvae, but in all cases was correlated with a drop in pH below 8.30 (pH of incoming water was 8.35-8.37). In the final series of experiments in which larvae were transferred to fresh tanks when pH approached 8.30, mortality was greatly reduced.

With a single exception, predatory or parasitic organisms were not a problem in the system described. The exception occured when tanks containing larvae received fresh coarsely chopped *Cladophora* without prior refrigeration or fine-grinding. Within 2 days these tanks were heavily infested with ciliates and nematodes, and after 4 days no live larvae remained.

Larvae fed on concentrated algal polyculture exhibited the most rapid growth, and were the only animals to metamorphose. Veligers which received *Tetraselmis* or *Cladophora* homogenate grew rapidly until day 20, and survived at least through day 30, but did not metamorphose. Larvae fed on *Cladophora* homogenates were slightly larger at all ages than were larvae which received concentrated *Tetraselmis*. The quantities of *Tetraselmis* and *Cladophora* specified above are close to minimal, as growth and survival were greatly reduced in batches which received smaller rations. Siphonal length of veligers raised on the test foods is plotted as a function of age in Figure 2. Data presented by Brownell (1977) and D'Asaro (1965) are included for comparison.

DISCUSSION

A great deal of time and concern in this project was directed toward the problem of water quality. The key features of the system we found most effective are: filtration of water in rearing tanks to 10 μm; refrigerating, freezing, or fine-grinding foodstuffs (this appears to substantially reduce the problem of introducing parasites

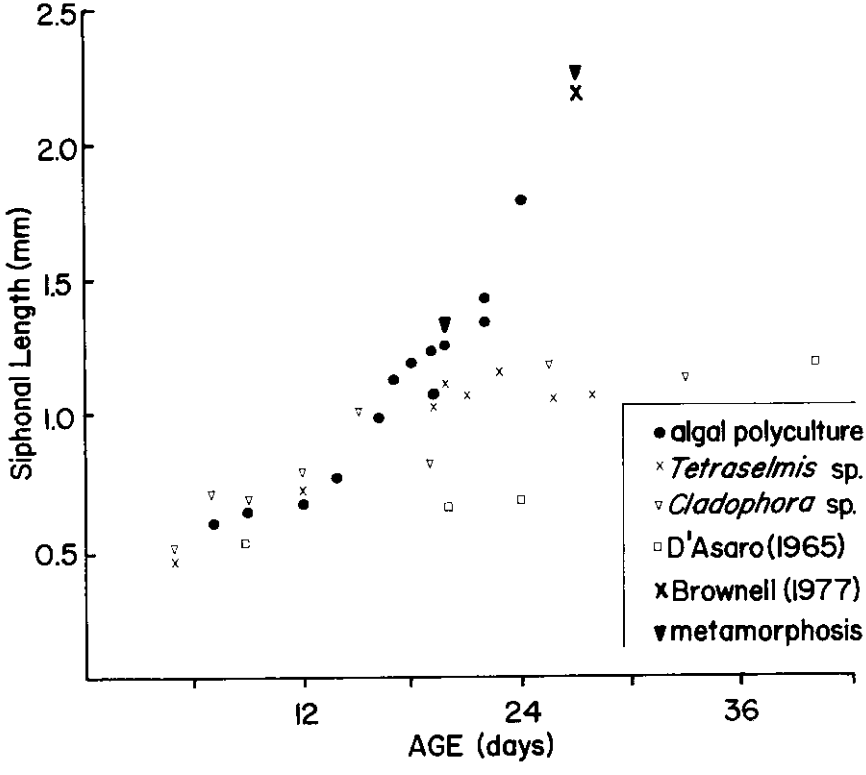

Figure 2. Siphonal length of conch veligers raised on various algal foods vs. age of the veligers.

and predators along with food organisms); and scrupulous cleaning of the rearing tanks prior to use. The pH is a simple and reliable indicator of water quality and when a tank is due for a change.

Results of feeding experiments summarized in Figure 2 indicate that growth and metamorphosis of *S. gigas* veligers are highly dependent upon the quality of available food organisms. D'Asaro (1965) reported that rapid growth was obtained when veligers were fed a combination of 90 μm filtered reef water and *Platymonas tetraselmis* at a concentration of 20,000 cells/ml. This combination was not sufficient for completion of development through metamorphosis, and the "veligers were probably undernourished as early as 38 days." D'Asaro's illustrations reveal that growth at all stages was not as rapid as that obtained with any of the foods tested in the present study, even though much lower concentrations were used in the latter. These observations suggest that the *quantity* of available food organisms may not be as important as the *type* of foods present. Data of Figure 2 also suggest that nutritional requirements change between day 16 and day 20 (the time at which the larvae are close to or on the bottom), and foods which are adequate for growth during the early larval stage may not be satisfactory during the latter stages.

Berg (1976) reported that *S. gigas* veligers collected from the plankton had a mean

siphonal length of 1.24 mm at the time of metamorphosis (within 24 h of collection, exact age unknown). This is the best available estimate of size at metamorphosis under natural conditions. Brownell (1977) found that metamorphosis occured 27 days after hatching, and the post-larvae had a mean siphonal length of 2.2 mm. Data of the present study (20 days to metamorphosis, siphonal length = 1.26 mm) were close to those of Berg, and may be a close approximation of the natural condition. For purposes of future studies, it is suggested that growth rate between day 10 and 16 after hatching may provide an early indication of the suitability of an experimental feeding scheme, and that a rate of 0.1 mm/day is adequate, while 0.04 mm/day is probably too low. It is important to note that Brownell's work and the present study represent the only instances to date in which Caribbean queen conch have been reared from egg through metamorphosis, and in both cases this has been achieved with algal polycultures derived from native plankton. Future work is needed to identify the important elements of these polycultures, and to evaluate the suitability of well-defined combinations of cultured algal species.

The investigations described in this paper are quite preliminary, and are presented as a starting point for more detailed future studies of optimum food type, food concentration, larval density, and feeding regime. The results of this project, however, have formed a focal point for developing local interest in the management of conch resources, and suggest that much of the needed work can be effectively undertaken on a small scale under field conditions. This approach is especially desirable in that it offers opportunities for local training and development of technical capabilities at the artisanal level and in a local context. But the most effective approach to management and mariculture of queen conch involves a collaborative effort. Important questions concerning nutrition, growth, and induction of metamorphosis can only be answered in well-equipped research institutions. A conference is planned for early 1981 to foster this much-needed collaboration between individuals and organizations concerned with conch management, and to define current critical problems, approaches to their solution, and the possible roles of those involved with the use and protection of these important Caribbean marine resources.

ACKNOWLEDGMENTS

This work was carried out by Environmental Research Projects as part of the Eastern Caribbean Natural Area Management Program of the Caribbean Conservation Association, and was funded by the Rockefeller Brothers Fund and the World Wildlife Fund-U.S. to whom we are deeply grateful. The author also wishes to thank K. Hesse and W. Brownell for their consultations, and to express special appreciation to K. Putnam, D. Rector and S. Taylor without whom this work would not have been possible.

LITERATURE CITED

Adams, J.E.
1970. Conch fishing industry of Union Island, Grenadines, West Indies. Trop. Sci. 12: 279-287.

Berg, C.J.
1976. Growth of the queen conch, *Strombus gigas*, with a discussion of the practicality of its mariculture. Mar. Biol. 34: 191-199.

Blakesley, H.L.
1977. A contribution to the fisheries and biology of the queen conch, *Strombus gigas* L., in Belize. Paper presented to American Fish. Soc., 107th Ann. Meeting, Vancouver, B.C., Sept. 15-17, 1977.

Brownell, W.N.
1977. Reproduction, laboratory culture, and growth of *Strombus gigas, S. costatus,* and *S. pugilus* in Los Roques, Venezuela. Bull. Mar. Sci. 27: 668-680.

———
1978. Report on the status of conch fisheries and related research in Belize, Turks and Caicos, Dominican Republic, Antigua, Dominica, St. Lucia, Barbados, Grenada, Trinidad & Tobago, and Venezuela, with notes on three countries not visited (Cuba, Bahamas, and St. Vincent). Report to Inter-regional Project for the Development of Fisheries in the Western Central Atlantic (WECAF), September, 1978.

———, C.J. Berg and K.C. Haines.
1976. Fisheries and aquaculture of the conch, *Strombus gigas,* in the Caribbean. Paper presented to CICAR-II symposium, Progress in Marine Research in the Caribbean and Adjacent Regions, Caracas, Venezuela, July 12-16, 1976.

D'Asaro, C.N.
1965. Organogenesis, development, and metamorphosis in the queen conch, *Strombus gigas,* with notes on the breeding habits. Bull. Mar. Sci. 15: 359-416.

Guillard, R.R.L. and J.H. Ryther.
1962. Studies of marine planktonic diatoms I. *Cyclotella nana* Hustedt, and *Dentonula confervacea* (Cleve) Gran. Can. J. Microbiol. 8: 229-239.

Hesse, R.C.
1975. The conch industry of the Turks and Caicos Islands. Rep. Turks and Caicos Govt. and Fish Dept. 18 pp.

Stevely, J.M. and R.E. Warner.
1978. The biology and utilization of the queen conch, *Strombus gigas* L., in the Florida Keys and throughout its geographic range. Rept., Marine Resource Inventory, Florida Cooperative Extension Service.

Strickland, J.D.H. and T.R. Parsons.
1972. A practical handbook of seawater analysis. Fish. Res. Bd. Canada, Bull. 167.