Mariculture of the Caribbean King Crab, *Mithrax spinosissimus* (Lamarck), in the Caribbean Region: Progress and Constraints

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ABSTRACT

El centollo caribeño, *Mitrax spinosissimus*, (La Marck, 1918), es el cangrejo de los "majidos" de mayor tamaño que habita los arrecifes de corales en el Atla antico occidental tropical. Por su gran tamaño, de comportamiento no agresivo y por ser omnívoro, además, por ser un producto con aceptabilidad en el mercado, éste ha despertado gran interés como una especie con potencial para la maricultura. Se comenzaron varias investigaciones al igual que se desarrollaron varios proyectos pilotos en la República Dominicana, Turks y Caicos, Antigua, Grenada y Florida. Este escrito considera los recientes adelantos en el desarrollo de un sistema integrado de maricultura para la crianza del Mitrax spinosissimus. Se examina el sistema de cultivo diseñado al igual que el sistema de alimentación de las larvas en cultivo. En la actualidad, el desarrollo comercial de este organismo ha encontrado tropiezos, debido al crecimiento pobre y baja supervivencia de los cangrejos juveniles criados en jaulas flotantes. Se describe los métodos actualmente utilizados para el crecimiento de los cangrejos en jaulas.

INTRODUCTION

The Caribbean king crab, *Mithrax spinossisimus* (Lamarck), is the largest crab inhabiting the Caribbean, with a carapace length (CL) up to 180 mm and weighing more than three kilograms (Rathbun, 1925). This species occurs throughout the Caribbean to the Florida Keys, the Bahamas, and rarely north to the Carolinas, where it inhabits holes, ledges, or coral outcrops from shallow water to depths of 100 fathoms (Williams, 1965). In the Florida Keys it is common near shore in canals cut through oolitic limestone (Bohnsack, 1976). The Caribbean king crab, as most members of the Family Majidae, remain in hiding during the day and venture several meters from their ledge at night to browse on benthic algae and associated epifauna.

The sexes are dimorphic; the males reach a greater size overall, and their chelae attain massive proportions compared to those of the females. Size frequency distributions for male and female *Mithrax spinosissimus* captured in fish traps indicated a mean size of 133.4 mm CL for males and 122.8 mm for females (Munro, 1983). Mature females usually average 50 percent less in weight than males.

Despite its large size, this crab is taken only occasionally by fishermen, for either home consumption or local marketing. It is not fished in large numbers commercially due to a lack of organized markets and because natural stocks are often sparse. Off Pedro Bank, Jamaica, catches averaged only 27 crabs/1,000 trap nights (Munro, 1983). However, the Caribbean king crab holds promise as a species for commercial mariculture.

Brownell *et al.* (1977) first reported the potential for the mariculture of *M. spinosissimus*, concluding that the ease of laboratory spawning, the short larval period, the apparent lack of aggressive or cannibalistic behavior, and the herbivorous food habits made it amenable for commercial mariculture. Seafood wholesalers in the United States have quoted F.O.B. $4.00/lb for *Mithrax* meat (Bernard and Bernard, 1985). Another crab imported to the United States, *Centolla* from Chile, fetched $6.75—14.00 for merus meat (Rubino *et al.*, 1985). Recent interest in the development of commercial mariculture technology for the Caribbean king crab has been stimulated by data such as these. This paper summarizes progress to date in the development of an integrated mariculture system for rearing this crab.

STATUS OF *MITHRAX* MARICULTURE

Research and development for *Mithrax* mariculture is being conducted at several sites throughout Florida and the Caribbean. In February 1983 the Marine Systems Laboratory (MSL) of the Smithsonian Institution began research to develop a full life cycle mariculture system for *Mithrax spinossisimus* which emphasized low-technology methods appropriate to developing countries. Their technology was based on a cage culture system in which crabs were fed a diet of algal turfs which were grown on screens placed in the open sea. Turf algae, characterized by blue-green and filamentous red algae and benthic diatoms, colonized the floating screens deployed in back-reef areas over sandy bottoms. Algal turf production was reported to reach or exceed 30 grams/day (dry weight) (Adey and Steneck, 1984). After being allowed a few weeks for the algae to grow, the screens were moved to floating grow-out cages which held the crabs.

Algal turf mariculture of *Mithrax* crabs was initiated on Grand Turk, Turks and Caicos, and additional sites were established on South Caicos, Buen Hombre and Azua-Puerto Viejo, Dominican Republic and Antigua. A new private mariculture site has been established on Grand Turk by West Indies Mariculture, Inc., operated by former MSL staff. The latter group has changed the function of previous mariculture sites in the Turks and Caicos from research to pilot-scale commercial operation (Stoffle, 1986). The two groups in the Dominican Republic are continuing their efforts supported by the Dominican Republic government, the Smithsonian Institution, and the United States Agency for International Development (USAID). At the Buen Hombre site a low-technology protocol involving the floating cage/algal turf technology will be continued, implemented by local fishermen. The Azua-Puerto Viejo group has focused on shore based hatchery technology and algae production. Smithsonian-MSL's role in crab culture in Antigua has been transferred to the Harbor Branch Oceanographic Institution (HBOI). Through support by USAID, HBOI is constructing a land-based hatchery and pilot scale grow-out facility. Staff scientists at HBOI and the Florida Institute of Technology in Vero Beach, Florida are conducting basic research on all aspects of *Mithrax* biology for field testing in Antigua.

West Indies Sea Farms, Ltd., established on the island of Carriacou, has adopted a commercial scale model for *Mithrax* mariculture utilizing the Smithsonian-MSL algal turf technology. To date, 16,000 crabs are in various stages of grow-out at this site, and several modifications of the original Smithsonian-MSL methodology have been made (Bartel, pers. comm.).

The Association for the Development of Aquaculture in Martinique has begun to investigate cage culture of *Mithrax* utilizing algal turfs and collected *Sargassum* sp. The Association Franco-Caribe has started a small-scale research project in Guadeloupe.

BIOLOGY AND CULTURE

Although little is known about the reproductive biology of *M. spinosissimus*, Hartnoll (1965) reports that most species of spider crabs undergo a terminal molt at puberty, after which no further growth occurs. Copulation can take place any time after the final molt; a soft-shelled condition is not required. Females are able to produce successive egg masses for extended periods fertilized by stored sperm in the spermathecae. In Jamaica, berried females have been found during every month of the year with no obvious maxima, suggesting that spawning is continuous following the terminal moult (Munro, 1983). Newly fertilized eggs, 1 mm in diameter and orange in color, are deposited on the pleopods where they develop for about three weeks before hatching (Creswell, pers. obs.). As embryogenesis proceeds and yolky reserves are consumed, the color of the egg mass gradually changes from orange to bright red, burgundy, brown, and finally beige just prior to hatch.

Fecundity estimates vary widely from 30,000—50,000 (Adey, 1985), 17,000—70,000 (Bernard and Bernard, 1985), "tens of thousands" (Brownell *et al.*, 1977) and 5,000—8,000 (Idyll and Caperon, 1986). Weight-specific fecundity determined gravimetrically from excised pleopods for six females averaged 18,826 ± 3,304 ova/female (range = 9,744—28,649 ova) with fecundity increasing with body weight (Creswell *et al.*, unpbl. data). Successive broods occur at six week intervals for captive females, but the larval viability may decline. Aborted broods, and the tendency of the female to eat developing eggs, occurs with increasing frequency during the successive broods of captive females.

M. spinosissimus has an abbreviated and essentially lecithotrophic larval cycle, a favorable characteristic for culture (Provenzano and Brownell, 1977). Larvae emerge from the egg capsule as free-swimming zoeae usually during the evening. Several researchers have reported that larvae hatch as non-swimming prezoeae, resting two hours on the bottom before molting. Our data indicate that the prezoea hatch is an anomalous condition which results in high mortality (Provenzano, pers. comm.). Zoeae undergo two molts within 36—48 hours after hatch. The larvae then remain as megalopae for 3—4 days before reaching the first crab stage, 5—6 days after hatch (Brownell *et al.*, 1977). Larvae have been reared intensively in shore-based hatcheries and extensively in cages floating at sea. Brownell *et al.*, (1977) reared larvae in 400—600 l tanks supplied with filtered (360 um mesh) seawater and mixed cultures of phytoplankton (10^4 cells/ml). They reported significant mortalities during the molt from second zoea to megalopae, with higher survival during the molt to first crab. However, from an initial hatch of "tens of thousands" only 200—500 (2—5%) reached crab stage. Diets of phytoplankton and *Artemia nauplii* (10/ml) did not increase survival over non-fed controls. Small "kreisel" tanks used by Smithsonian investigators in Grand Turk, Turks and Caicos, and Antigua yielded less than 4% survival through juvenile crab stage (Porter *et al.*, 1984). Addition of *Dunalliela tertiolecta* (104 cells/ml) significantly enhanced survival to the first crab stage over unfed controls.

Our preliminary studies using "kreisel" tanks confirmed previous reports of high mortality at molt from zoea to megalopa. The propensity of the larvae to attach to screens covering stand pipe drains led to an alternative larviculture system utilizing screens (500 um) floating in shallow watertables (10 cm deep). Results indicate that over 90% of the zoea larvae successfully molt to megalopae using this design, with 30—50% survival through first crab stage without feeding (Figure 1; Tunberg and Creswell, unpubl. data). Megalopae cling to the screen or swim short distances before reattaching suggesting that the presence of a substrate is a requisite for successful molting. A mixed diet of cultured benthic diatoms, *Enteromorpha* sp., *Ulva* sp. and *Gracilaria* spp. are provided after 50% of the megalopae have molted to first crab.

An alternative approach for rearing crab larvae utilizes a "hatch box" which is floated in a protected lagoon (Adey, 1985). The cage is anchored in the water for three weeks to accumulate algal turf on the 500 um mesh. Females with well developed eggs are placed in the cage just prior to egg hatch. The female is removed after hatching, and two or three algal turf screens are placed in the cage to provide forage for the juvenile crabs. After 20—30 days, screens are replaced at four day intervals. The boxes are not harvested for 100 days to prevent handling mortalities. Survival is low in the floating boxes, averaging 0.06% after 131 days (Idyll and Caperon, 1986). Introduction of predators inhabiting algal turf screens has been implicated as a major cause of mortality in these hatching cages.

In Grenada, survival during the first 100 days has been improved by increasing the volume of hatch boxes, periodic flushing of debris from each box and introduction of screens after the first week post-metamorphosis (Bartel, pers. comm.). After 30—40 days the juvenile crabs (5 mm CL) are transferred to intermediate cages (2 mm mesh). Growth of juvenile crabs as reported from several studies suggests that a reasonable size for 100 day old crabs is 20 mm CL (Figure 2).

GROW OUT TO HARVEST

The Smithsonian-MSL protocol for grow-out of crabs to marketable size(150 mm CL, 1.2—2.5 kg) utilizes wood framed floating cages (6'x3'x3', 1/2" mesh) supplied with algal turf screens. Juvenile crabs are stocked in floating grow-out cages at 100 crabs/cage, and supplied with algal turf screens conditioned at-sea for 20—30 days. Screens are changed-out every three days during the first 200 days, and thereafter the screens are exchanged daily (Adey, 1985). West Indian Sea Farms, Ltd. in Grenada is growing crabs in cages with some modifications of the Smithsonian-MSL methodology.

Alternative methods for grow out of spider crabs is being investigated by the Harbor Branch Oceanographic Institute in Antigua. Land-based raceways are used for intensive culture of crabs fed combinations of cultured fresh macroalgae, minced fish and artificial feeds. Feeding rates, food conversion efficiencies, and growth and survival of crabs on a variety of diets are being determined (Winfree and Weinstein, this volume). Techniques for rearing crabs in submerged cages, as well as methods to provide a variety of diets are being evaluated.

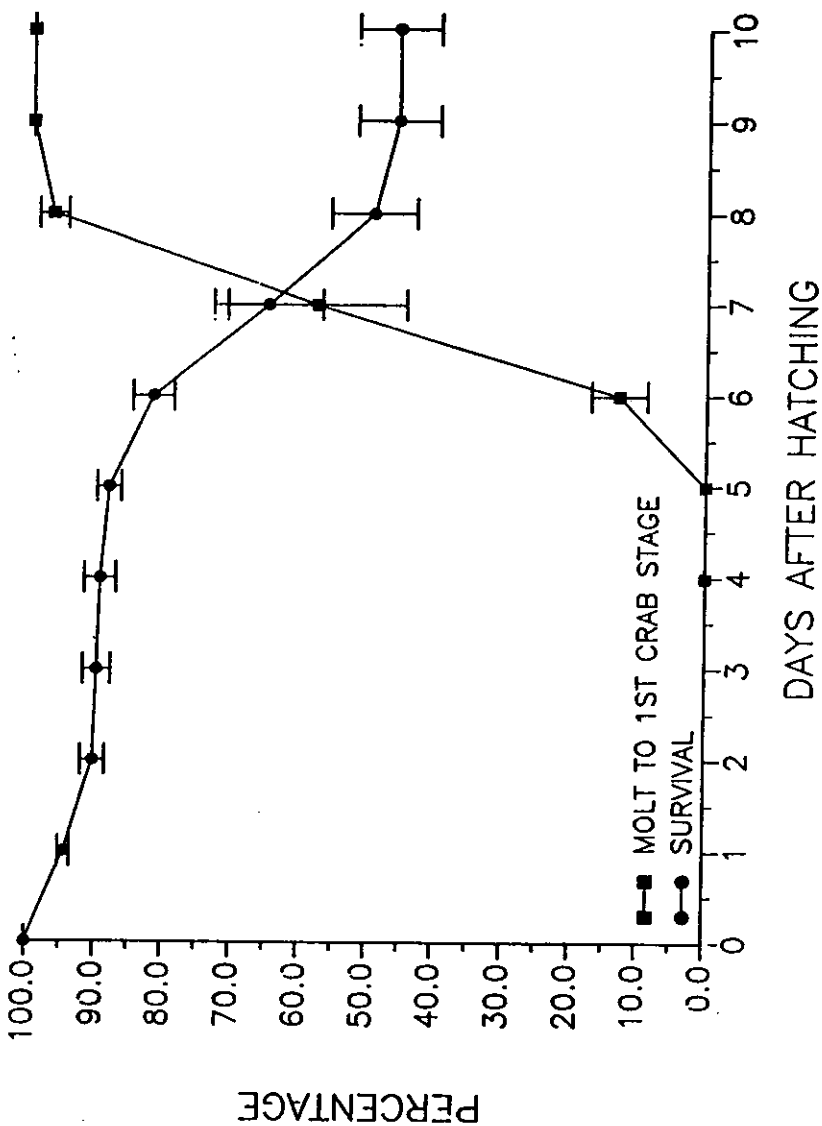

Figure 1. Survival of larval Caribbean king crab (*Mithrax spinosissimus*) through metamorphosis to first crab stage. Metamorphosis to first crab occurs 5–8 days after hatching. Mean survival ± one standard error are given for 50 crab larvae/treatment (stocking density 1.5 crab/cm^2), n=6.

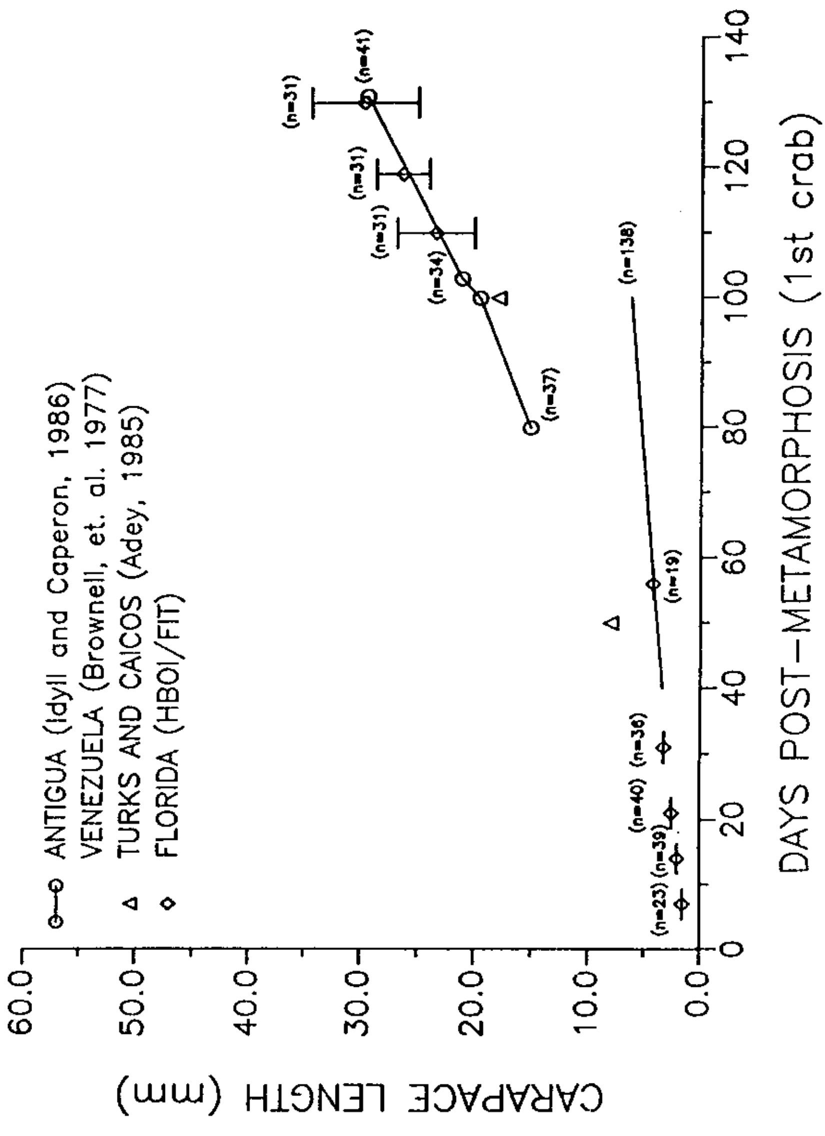

Figure 2. Growth of juvenile Caribbean king crab (*Mithrax spinosissimus*) from metamorphosis to 140 days. Vertical bars indicate standard deviation of samples where several individuals were measured; sample sizes are given.

According to Smithsonian-MSL projections, crabs grown on algal turf screens reach marketable size in 450 days. However, this estimate of growth rate can not be substantiated since no crabs have been reared to harvest. Our preliminary results indicate that relative increase in weight and carapace length during molting are consistent over a wide range of sizes. Measurements of carapace length before and after molting for crabs ranging from 1.9—100.0 mm (n=59) indicated that mean length increase during molts was 26.8 ± 7.2%. The average weight increase for these crabs (2—392 gr) was 122.0 ± 20.6% (Creswell, unpbl. data). Therefore, a 100 day old crab (CL approximately 20 mm) will undergo six molts before reaching a marketable size (150 mm). The duration of intermolt cycles for crabs approaching harvest weight is unknown. The lack of scientific information describing intermolt cycles precludes any reasonable estimate of production, a critical input parameter for economic analysis of crab mariculture.

CONCLUSIONS

The Caribbean king crab, *Mithrax spinosissimus*, has become a popular candidate for mariculture development in the Caribbean region. Its biological characteristics and attractive market potential have stimulated investigations into appropriate technologies for commercial mariculture. Although improvements in rearing the larvae and early juveniles in land-based hatcheries or floating cages at-sea has increased survival during the first 100 days in culture, little experimentation has been undertaken to determine the effects of culture methods, nutrition, or environmental parameters on crab growth and survival to marketable size. To realize the commercial mariculture potential of *Mithrax spinosissimus*, research and development should be directed towards determining:

1. Yield vs. production costs for land-based hatcheries and in situ hatch box production of juvenile spider crabs.
2. Feeding strategies (kinds, quantity of diets and frequency of feeding), and stocking densities for rearing juvenile crabs from metamorphosis to 15 mm CL.
3. Growth and survival of crabs from 100 days to harvestable size supplied algal turf screens vs. cultured live and artificial diets.
4. Cost effectiveness of cage culture vs. land-based intensive culture of spider crabs.

As more scientific information about the behavior, nutritional physiology, and growth of *Mithrax spinosissimus* are applied to developing culture techniques, the feasibility of commercial mariculture enterprises for this crab will become more clearly defined.

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