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See also CRAB CULTURE: WEST INDIAN RED SPIDER CRAB; MUD CRAB CULTURE.

## CRAB CULTURE: WEST INDIAN RED SPIDER CRAB


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### OUTLINE



The West Indian red spider crab, *Mithrax spinosissimus*, is a large majid crab that inhabits coral reefs and rocky outcrops of the tropical western Atlantic Ocean. Its known distribution is from the Carolinas on the east coast of the United States, through the Bahamas and the islands of the eastern Caribbean Sea, and along the continental shelf of Latin America as far south as Venezuela (1,2). It occurs from shallow waters to depths of 180 m (600 ft), and it commonly inhabits manmade canals cut in oolitic limestone, such as the Florida Keys in the United States (3,4). As with most members of the family Majidae, *M. spinosissimus* remain in hiding during the day and venture several meters (yards) from their refuge 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 female. Size frequency distributions for male and female *M. spinosissimus* captured in fish traps indicated a mean size of 133.4 mm (5.3 in.) carapace length (CL) for males and 122.8 mm (4.8 in.) for females (5). Females usually average 50% less in weight than males.

Despite its large size, this crab is taken only occasionally by fisherman, for either home consumption or local marketing. Because of their paucity and sporadic distribution, a commercial fishery for the spider crab has never developed (an exception being in Panama, where they are locally abundant along the walls of the Panama Canal) (6).

Interest in the mariculture potential for the West Indian red spider crab, *M. spinosissimus*, began in the late

1970s at a small marine laboratory on the remote island of Dos Mosquises in the Los Roques Archipelago off the coast of Venezuela. The scientists at the Fundación Scientifica de Los Roques were pioneering the mariculture of several tropical marine species that compose the most valuable fisheries resources of the Caribbean region, among them the queen conch and the spiny lobster. Although the West Indian red spider crab was not fished commercially, its large size, delicious taste, and popularity in local fishing markets attracted attention as a potential mariculture candidate. The researchers at Los Roques reported their preliminary results, including larval development and growth of early juveniles, in the Proceedings of the World Aquaculture Society in 1977 (7).

In 1983, the Marine Systems Laboratory of the Smithsonian Institution began research to develop a full life cycle mariculture system for *M. spinosissimus*, one that emphasized low-technology methods appropriate for developing countries. Their technology was based on a cage culture system, in which crabs were fed a diet of algal turfs that were grown on screens placed in the open sea. Turf algae, characterized by blue-green, filamentous red algae, and benthic diatoms colonized floating screens and produced as much as 30 g (1 oz) dry weight of algal food per day (8). After being allowed a few weeks for the algae to grow, the screens were moved to floating growout cages that housed the crabs. Algal turf mariculture of *Mithrax* crabs was initiated on Grand Turk (in the Turks and Caicos Islands), in the Dominican Republic, and on the island of Antigua, with the intention of transferring the algal turf/cage culture system as appropriate technology to island fishers.

Despite the substantial resources dedicated to the project, positive results were not forthcoming. In retrospect, the concept of rearing *M. spinosissimus* exclusively on algal turf was fundamentally flawed. The flaws can be summarized as follows:

(i) The production of algal turf on floating screens in tropical, oligotrophic (nutrient-poor) waters was greatly overestimated, particularly because inorganic sediments, which comprised more than 25% of the deposition on the screens, were not excluded from the organic weight measurements. The amount of vegetable matter provided from the algal turf screens was insufficient to sustain the biomass of crabs housed in the floating cages.

(ii) *Mithrax* crabs are not docile, obligatory herbivores, as the investigators purported, but rather they are omnivorous, cannibalistic, and highly aggressive crustaceans.

(iii) *Mithrax* crabs undergo a terminal molt at puberty, after which no additional growth occurs. The marketable size of crabs, 1 kg (2.2 lb), based on an economic analysis from the Smithsonian study (9), would be achieved by only a small fraction of crabs that were the progeny of wild-caught broodstock. Only through a selective breeding program, over several generations of crabs, would a significant proportion of the population reach one kilogram prior to terminal molt.

In 1984, the Harbor Branch Oceanographic Institution initiated a research program to evaluate the potential for *Mithrax* crab mariculture, which was to include the algal turf/cage culture system as well as alternative methods (10). The information presented below is a synthesis of the results from various studies.

## REPRODUCTIVE BIOLOGY AND LARVICULTURE

Sex and maturity among female *M. spinosissimus* can be distinguished by the shape of the abdominal apron; in males it is thin and narrow, while in mature females it is broad and full enough to cover the egg mass. The apron of immature females is intermediate in width. Spider crabs undergo a terminal molt at puberty, after which no further growth occurs (11). The molt to mature female form occurs by about 75 mm (3 in.) CL. 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, to be fertilized by stored sperm in the spermatheca. However, successive spawns from females kept in the laboratory produce smaller broods, and larval mortality is higher than from spawns collected from the field.

Fecundity estimates vary widely from "tens of thousands" (7) to much higher (up to 100,000) (12,13). Creswell et al. (6) reported $18,826 \pm 3,304$ ova/female, or $59.5 \pm 8.8$ ova/g (~1700/oz) body weight. The ova are approximately 1 mm (0.04 in.) in diameter and weigh 1 mg (0.00004 oz). Newly fertilized eggs are deposited on the pleopods and are bright orange in color, but the gross appearance of the egg mass changes as the embryos develop. As the yolk is absorbed, yolk pigments accumulate in the embryo's integument and eyes, turning the egg mass bright red after the first week, then burgundy, and finally tan to grey when hatching is imminent, 21 to 25 days after fertilization. Orange eggs on four crabs hatched after a period of 18 days (mean value). The average hatching period of red eggs on eight crabs was 9.5 days. (14).

*M. spinosissimus* has an abbreviated and essentially lecithotrophic larval cycle, the egg's yolky reserves providing all the necessary nutrition required for full development of the larva to first crab stage (15,16). Hatching usually occurs at night and continues for several hours. The larvae are released by a fanning motion of the pleopods of the crab, accompanied by vigorous jerking of the abdomen. Larvae usually hatch as swimming *first zoeae* and display positive phototaxis immediately after hatching. First zoeae molt to *second zoeae* within 10 to 12 hours after hatching. Provenzano and Brownell (15) and others have also described a non-swimming prezoela stage. This stage is, however, probably an aberrant occurrence associated with stress on the females or on the developing larvae. The zoeae undergo two molts within 36–48 hours, before metamorphosing to the megalopa (post-larval stage), when they first begin to feed. After three to four days, the megalopa molts to the first crab stage, six to eight days after hatch (Fig. 1) (6,7).

Larvae have been reared intensively in shore-based hatcheries and extensively in cages floating at sea. Brownell and Provenzano (7) reared larvae in 400–600 L

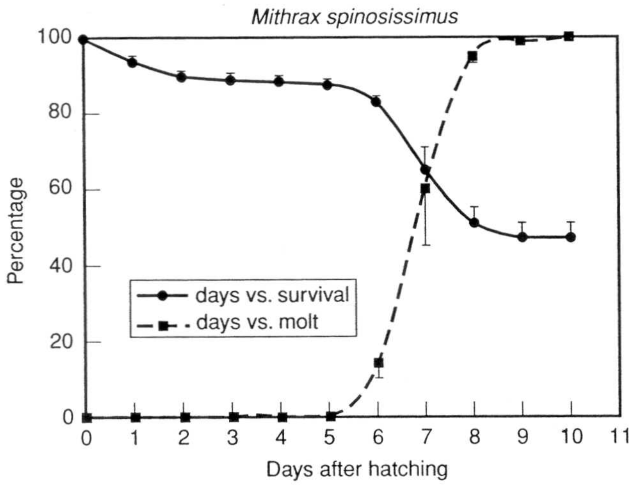


**Figure 1.** Survival rates of *M. spinosissimus* using the shallow tray system.

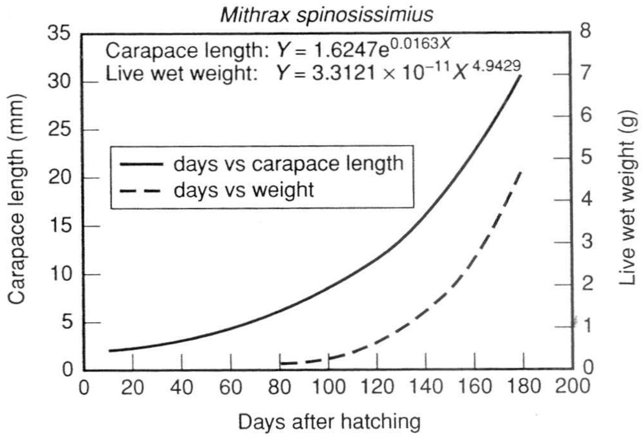


**Figure 2.** Growth rate of *M. spinosissimus* during first 180 days after hatching.

(105–158 gal) tanks supplied with mixed cultures of phytoplankton. They reported significant mortalities during the molt from second zoeae to megalopae, with higher survival during the molt to first crab (total survival to first crab was 2–5%). The Smithsonian Institution, in Turks and Caicos and in Antigua, B.W.I., attempting to raise crab larvae in small "kreisel" tanks, reported similar discouraging results (<4% survival). The authors experienced similar high mortalities at molt from zoea to megalopa when using fiberglass tanks with upwelling currents (i.e., cone-bottomed kreisel tanks). An alternative larviculture system, utilizing screen-bottomed [500 μm ($0.04 \times 10^{-3}$ in.)] trays floating in shallow water tables, resulted in survival rates exceeding 85% during molt from zoea to megalopa and approximately 50% to first crab stage (Fig. 1), indicating that the presence of substrate may be critical for successful completion of the molt to postlarvae. By utilizing the shallow tray system, zoea can be stocked at densities of 25,000/m$^2$ (10.8 ft$^2$), with survival exceeding 70% to first crab stage (10).

## EARLY GROWTH

The 2nd and 3rd crab stages occur at around 15–20 days and 25–30 days after hatching, respectively. The water temperature during the studies described above was ca. 27–28 °C (81–83 °F). Molting frequency is dependent upon temperature (17–20), so it is likely that the intermolt period would decrease at higher temperatures [30 °C (86 °F)] and that more rapid growth would result.

Studies by Tunberg and Creswell (21) on early development (up to stage 12 crabs) showed that the intermolt period increases with stage (except between stages five and six). Stage two lasted for about 10 days; stage eleven lasted for about 20 days. Figure 2 shows the growth rate (carapace length and live wet weight) during the first 180 days after hatching. The growth rate (carapace length) at molt varies between approximately 22 and 40%, and the corresponding mean weight (live wet weight) increase varies between 90 and 135%.

Abdominal length and width measurements indicate that it should be possible, by visual observations, to distinguish between the sexes at a carapace length of approximately 12–15 mm (0.48–0.6 in.), that is, at an age of about 120–140 days.

During a long-term study (180 days) (21), only about 20% of the crabs survived throughout the period.

## NUTRITION

Although the larvae of *M. spinosissimus* are facultative lecithotrophs, growth and survival were enhanced when feeding was initiated five to eight days after hatching (14). Benthic diatoms, as well as various types of macroalgae (e.g., *Enteromorpha*, *Gracilaria*, *Ulva*) and seagrasses (e.g., *Thalassia*), are provided as food for megalopae and early crab stages.

Winfree and Weinstein (22) reported that juvenile and adult *M. spinosissimus* are omnivorous and opportunistic feeders upon turf algae and seaweeds (24 species tested), marine fish and invertebrates (23 species tested), fresh beef (heart), pork (liver), chicken (muscle) and dry prepared feeds (12 varieties tested). Small juveniles [≤17 g (0.6 oz)] consume primarily macroalgae (78% of diet) when offered both algae and meat on a free-choice basis. Larger crabs are truly omnivorous and exhibit a strong tendency to supplement their macroalgal diet with meat, the relative proportions of algae and meat chosen being reversed. Crabs will consume a range of commercially available dry feeds, including homarid lobster and penaeid shrimp feeds, tropical fish flakes, and guinea pig pellets. Whether feeding on fresh or dried diets, the daily ration for *Mithrax* crabs is approximately 2.7% (dry feed to live body weight) (10).

## AGRESSIVE AND CANNIBALISTIC BEHAVIOR

From postlarvae to large juveniles [approximately 50 mm (2 in.) CL; 50 g (1.7 oz)], *Mithrax* are aggressive and highly cannibalistic, even if well fed. Larger crabs appear to be less vulnerable to cannibalism, probably because of their thicker, more protective shells, except immediately following the molt. Evidence suggests that the severity of "cannibalistic" confrontations can be mitigated by providing the crabs adequate space and protective cover, although it is unlikely that manipulating these factors alone will totally eliminate this behavior.

Most crustacea become aggressive and/or cannibalistic when crowded beyond a certain density. This crowding factor, or density index (DI), may be expressed numerically as the ratio of the area of available habitat to the area of crustacea housed there (measured as the sum of the squares of the carapace lengths of those animals). The smaller the DI, the more crowded the animal, until a critical density index (CDI) is reached and aggression begins. Ryther (10) reported that cannibalistic encounters were observed far more frequently in females and that whereas the CDI was 50 to 60 for males [8 crabs/$m^2$ (0.8 $ft^2$) for 5 mm (0.2 in.) CL], it was 90 to 100 for females. These data suggest that elimination of females from the population at the earliest time possible [approximately 15 mm (0.6 in.) CL] would both increase survival and provide maximum system capacity for growout. Providing protective cover and/or complex, three-dimensional habitats, particularly during the early juvenile stage, may improve survival by reducing cannibalistic encounters. Unprotected open area systems, such as cages, raceways, or ponds and simple, two-dimensional structures afford little protection against aggressive behavior and are inappropriate for large-scale production of *Mithrax* crabs.

## ENVIRONMENTAL CONDITIONS

*Mithrax* crabs tolerate a rather narrow range of environmental parameters, a fact that has practical implications for commercial production, particularly for site and stock selection (10). Survival of juvenile and adult crabs in captivity is directly proportional to salinity and temperature. Although crabs easily adapt to hypersaline conditions (40 ppt), stress becomes evident at 25 ppt and complete mortality occurs at 20 ppt. The optimal temperature range for culture occurs at 28–29 °C (83–84 °F), with poor growth at temperatures below this range and poor survival at temperatures above. Below 25 °C (77 °F), crabs are inactive, consume little feed, and are seldom agressive towards each other. At temperatures exceeding 30 °C (86 °F), lethargy, anorexia (despite active feeding), and proneness to disease and abnormal shell development occur. *Mithrax* reared in floating cages or coastal ponds may be subject to environmental fluctuations beyond ranges that are minimally required for healthy growth and survival. Terrestrial runoff could depress salinities over short time periods and cause mortality (or added stress leading to disease). Increased production time to marketable size should be expected in areas where water temperatures fall below 25 °C (77 °F) for extended periods, and unacceptably high mortality may occur in locations that experience temperatures above 30 °C (86 °F). This situation may eliminate the potential of production in northern areas, shallow bays, and tropical saltwater ponds, unless specific strains of *Mithrax* are identified that can tolerate these conditions.

## INFECTION AND DISEASE

Ryther et al. (10) reported chronic bacterimia, similar to that described for other crustacea by Tubiash et al. (23), in *Mithrax* crabs cultured in recirculating seawater systems. Early signs include a loss of vigor and reduced feeding activity, which is followed by decreased joint mobility, particularly of the claws (chelipeds). Death occurs without warning, or occasionally preceded by limb loss. Postmortem examination of crabs succumbing to the infection reveals complete atrophy of the musculature and viscera, which are replaced by a spongy white bacterial mass. Application of nitrofurazone (furacin bath) and oxytetracycline (terramycin injections or bath) may be used to treat infections; however, improved water quality and nutrition will likely decrease the incidence of bacterial pathogens.

## GROWTH TO HARVEST

All known species of majid crabs lose the ability to molt, and hence to grow, after they attain a specified point in the life cycle. The maricultural significance of a terminal molt in *Mithrax* depends upon whether the animal is large enough for sale at the time it occurs. Mean size of male crabs in terminal molt collected from Antigua was 125 mm (4.9 in.) CL (10); from other islands (Grenadines, Dominican Republic, Turks and Caicos), it was 131 mm (5.2 in.) CL (24).

Growth studies conducted at Harbor Branch Oceanographic Institution (10) indicate that postmolt increase in length of *Mithrax* crabs is relatively constant with age (27%), while weight increase fluctuated from 94 to 136%, with an overall average of 125%. Percentage postmolt weight change decreases as the crab increases in size, while the intermolt period tends to increase with age in a curvilinear fashion, with a greater percentage change during the later molt cycles.

Growth models suggest that male crabs grown to 650 grams (1.4 lb) (the predominant size class reached before terminal molt) would require approximately 20 months in culture (slower-growing female crabs would be discarded as small juveniles). Meat yield averages 20% of total weight (10).

## CURRENT STATUS

Interest in the culture of the West Indian red spider crab, *M. spinosissimus*, has waned since the late 1980s, in large part because of some of the constraints on culture outlined herein. One commercial venture, West Indies Mariculture, Inc. (WIM), operated 1988–1994 on North Caicos, in the Turks and Caicos Islands. The project was managed by alumni from an earlier program on Grand Turk Island conducted by the Smithsonian Institution, and the culture methods employed a hybrid of algal turf screens and those later developed by Harbor Branch Oceanographic Institution. West Indies Mariculture produced softshell *Mithrax* crabs and marketed them directly to restaurants throughout the Turks and Caicos Islands.

Adult crabs were held in floating cages attached to docks in a tidal creek with strong currents. Juvenile crabs were fed algal turf until they reached 25 mm (1 in.) CL; thereafter they received a pelleted ration specifically formulated by WIM. Crabs reached 70–80 mm (2.8–3.1 in.) CL in 7–10 months and were transferred to shedding trays where, after molting, they were iced for transport to buyers.

Research into the mariculture of the West Indian red spider crab continues at the University de Oriente, Venezuela (25), but to the authors' knowledge no commercial operations exist today.

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See also Crab culture; Mud crab culture.

# CRAPPIE CULTURE

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## OUTLINE



Crappie, members of the family Centrarchidae and therefore relations of largemouth bass and various sunfish species, are popular recreational fish in the regions of the United States and Canada in which they are found. No commercial foodfish production of crappies exists, but crappies are cultured for stocking ponds, lakes, and reservoirs. Crappies tend to be so prolific in small ponds that overpopulation and stunting often occur, though the problem seems less severe with white crappies than with black crappies (1). The two species, black crappie (*Pomoxis nigromaculatus*) and white crappie (*P. annularis*), have similar culture requirements and respond similarly to the culture environment.

## DESCRIPTION AND LIFE HISTORY

The black crappie is common in the Canadian provinces of Quebec and Manitoba and is found in the northern and eastern United States and as far south as Florida and Texas. Black crappies are more abundant than white crappies in the northern part of their range. Typically weighing up to about 900 g (2 lb), black crappies as large as 2.3 kg (5 lb) have been collected (Fig. 1).

White crappies can be found from Minnesota eastward, including into southern Ontario, Canada. Their distribution is then southward to the Gulf of Mexico and includes South Carolina along the east coast. White crappies tend to weigh from 450 to 900 g (1 to 2 lb), with some specimens reaching as much as 1800 g (4 lb).

The two crappie species have about the same overall shape. Black crappies tend to have more black pigment on their scales than do white crappies, but pigmentation is not a suitable way to distinguish between the two species.

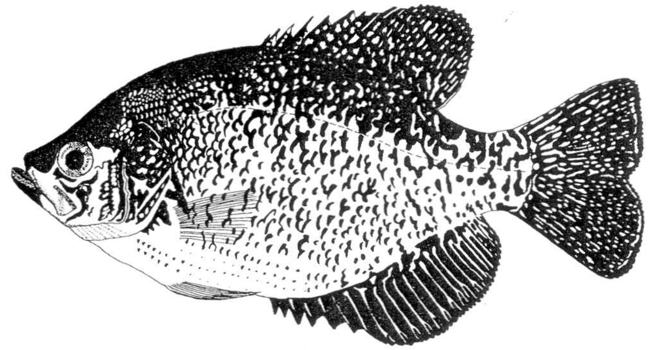

**Figure 1.** Black crappie (*P. nigromaculatus*). Original drawing by Michele McGrady.