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# Assessment of the Status of the System Developed by the Marine Systems Laboratory of the Smithsonian Institution for Raising the Caribbean King Crab by Mariculture

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## EXECUTIVE SUMMARY

At the request of USAID/Barbados, Dr. Clarence P. Idyll and Dr. John Caperon visited the Smithsonian Institution, Washington, D.C.; Barbados; and Antigua during the period January 3 to 17, 1986 to evaluate the progress of a project to culture the Caribbean spider or king crab, *Mithrax spinissosimus*.

This mariculture project is under the direction of scientists from the Marine Systems Laboratory, of the Smithsonian Institution (MSL/SI).

This crab culture system grew out of research carried out by the MSL/SI on the primary productivity of tropical waters. High production rates of benthic algae were recorded on mats exposed in the water near coral reefs. Searching for ways to convert this high productivity into useful food for man, several species of algae-eating animals were considered for mariculture tests. The Caribbean King was considered to hold the greatest promise.

Trials were conducted in the Turks and Caicos Islands, beginning in 1984, and in the Dominican Republic beginning in 1985. The crab culture project began in Antigua in April, 1985. This is funded by AID/Barbados. The U.S. Peace Corps has supplied four Volunteers, whose task was to have been to receive training from the Smithsonian staff, so that they could train fishermen to raise crabs using the system developed.

We visited the site of the *Mithrax* crab culture operation on January 7 and 8, 1986. This work begun in April, 1985 and had thus been going for approximately eight months at the time of our visit.

Eleven broods of crabs have been started by this operation. The first two, resulting from hatches of the eggs of wild females on May 17 and May 23, 1985, were 235 and 229 days old when we saw them. The two hatches had been combined and are held together in a cage inside the bay, behind a sheltering island. On December 30, 1985, when they were measured last, there were 27 surviving crabs from the two batches. These are survivors from 58 crabs tranferred from the hatching boxes at 80 days of age. On December 30 these crabs were 36 - 66 mm carapace length. These are the biggest crabs raised under culture at this site. A third brood was hatched on July 18, but it was destroyed on September 8 by the predation of other species of crabs that gained access to the culture cage. Eight other broods have been hatched, on various dates from November 11, 1985 to January 4, 1986. These are held each in a separate box close to the reef on the outer edge of the bay.

The algal food for the crabs in being raised on mats or screens set out in the water just inside the reef.

The carapace size data from the May 17 and May 23 broods, with data from the other two sites, were used by MSL/SI to construct a composite growth curve for *Mithrax*. Data to construct this curve exist only for crabs up to about 200 days old in Antigua and about 230 days in the Dominican Republic. The left part of the curve exhibits an increasing slope; this is characteristic of the left limbs of sigmoid (S-shaped) growth curves. The

rest of the crab growth curve is speculative since no size-at-age data are yet available for older crabs.

As the curve is now drawn it indicates that about 400 days (14 months) would be required to grow crabs to about the 4 lb. size (2.7 - 5.3 lb. range), and that about 440 days (14 1/2 months) to grow crabs to approximately the 3 lb. size (2.2 - 3.5 lb. range).

The size of the population of this crab in Antiguan waters appears to be great enough to support a culture activity, but this requires confirmation. It has been asserted that Mithrax crabs are nearly exclusively herbivorous, and that they thrive on a diet of plant material. This has important implications for their culture. But some animal food is consumed, and it may be important nutritionally.

The larval stages of Mithrax appear to be less susceptible to disease and parasites than other crab larvae but it can be taken for granted that this is not entirely so, and not for all stages. It seems likely that whatever diseases and parasites do afflict the species the incidence will be increased when crowding is greater under intense culture.

This crab appears to be uncharacteristically mild-mannered, and this will be a strong advantage to those culturing the species. Some aggressive displays have been observed by the MSL staff in Antigua; whether these will be intensified with larger and more crowded animals is unknown.

Very little experimentation has been carried out testing the effects of variations in environmental parameters on crab growth, and survival and hardiness. It is not possible under the conditions being used in the Antiguan trials to vary temperature and salinity, but such things as frequency of feeding, kinds and amounts of food, current rates, design and construction of cages and screens, density of crabs in the cages, and other parameters which have been shown to have effects with other animals will have to be addressed at some time in order to arrive at the optimal system of spider crab culture.

The Caribbean King Crab Culture Project is not ready for commercial application. Several groups have raised these crabs from the egg through the larval stages and up to adults, some crabs being as large as 200 - 250 mm carapace length. No crabs have yet been raised to market size. It may be that some crabs will be raised to commercial size within a few months but this still will not guarantee profitable commercial culture.

There are four major stages in the development of a profitable mariculture project:

1. The development of a system for raising the animal from a young stage to a saleable size.

2. The testing of this system on a pilot scale, with modifications of the experimental methods to approximate those likely to be used in commercial operations, and to demonstrate that the system is reproduceable.

3. An economic evaluation of the system. If this indicates it could be profitable, Stage 4 can be undertaken; if it is not but looks promising, a return to Stage 2 for further research and development is warranted.

4. Scale-up to full commercialization.

This crab project has not completed Stage 1, since no crabs have ~~not~~ been raised to market size. This phase may be completed within several months, after which the pilot operations should be conducted to determine whether the system is well enough established to raise crabs to market size repeatedly and predictably.

It will be some time before this stage of reasonable assurance will be achieved so that commercial Caribbean king crab farms can be encouraged to start To finish Stage 1 will take a minimum eight to ten months in the Dominican Republic and Antigua. The numbers of commercial sized crabs that will have been raised by then will be small, based on the numbers of small adults surviving so far.

The pilot stage should be allowed to operate through a minimum of two successful broods, each with a significant number of cages, which will require at least two years even if the broods are raised nearly simultaneously. Additional time may be necessary if the economic analysis indicates that the system used and modified in the pilot trials would not be profitable.

An economic analysis made by ~~the~~ another group was examined in terms of the input parameters, and to indicate how any changes in parameter values might alter conclusions.

The input parameters are used to calculate the production of marketable crab products in pounds (yield), the price received for each product class and the cost of production. Yield (lbs. per year) times price ($U.S.) received per pound minus production costs ($U.S. per year) equals annual profits.

Using modified values for costs of inputs, which we regard as realistic, the estimated yearly operating cost is as follows:

| | |
|---|---|
| Fuel | $1,400 |
| Replacement/repair 50%/yr. cages and screens | 4,022 |
| Replacement/repair 20%/yr. boat and motor | 600 |
| Sub-total | 6,022 |
| Contingency at 25% | 1,506 |
| Total Operating Cost | $7,526 |

This figure exceeds the estimated annual income of $7,000 using a 12 month growout figure.

Use of the 16 month growout figure, which is much more consistent with present data, reduces the income to 75% of $7,000 = $5,250. An alternative suggested crab weight with a mid range value of 2.85 pounds may well be possible in 12 months, with essentially the same effect on yield and income, i.e. $7,000 becomes $4,987. If these figures are realistic the fisherman is being asked to invest $8,000 in capital and to increase the risk to his existing boat and motor in the hope that through creativity and hard work he can overcome a $2,500 annual loss, and perhaps one day make a profit (we use the term "profit" for fishermen wages). If he is a capable fisherman he would be far better served to continue to fish, or to start a fishery to exploit the natural crab population. Although we have addressed only the one fisherman case as most relevant to the Antiguan site, essentialy the same changes in the balance sheet are indicated for the commercial enterprise case, i.e. 25% reduction in yield and 20% increase in operating costs.

This review indicates that with present technology this system would not be profitable. This does not necessarily mean that crab mariculture will never be profitable. Since a proven technology has not yet been developed an economic analysis is premature. It does mean that technological progress alone will not be enough to make the project viable. Economic improvements are also necessary.

There are two alternatives for RDO/C action and possible follow on activity that should be considered: (1) orderly close of activities in Antigua, with continued close monitoring of progress at other sites, and (2) continued support for research and development on the crab mariculture project in Antigua.

The first alternative should receive serious consideration. The present MSL/SI system has not been shown to be technically feasible nor does it appear to be economically viable at this time.

The second option involves continuing crab mariculture research and development at Antigua. In that case the recommendation is that a team of the highest calibre be secured to continue after MSL/SI leaves, and that they be directed not only to test the present MSL/SI system, but to develop a fundamental understanding of Mithrax crab mariculture. Thus, new team should not only test the proposed system, but simultaneously conduct the sort of experiments that will tell how growth and survival rates are affected by feeding rates, cage stocking rates, temperature, cage incubation depth, etc.

This work will require two years and funding at about $500,000. If the project is highly successful it will demonstrate the technical feasibility of the mariculture system and provide the hard data necessary for an economic assessment. If the later indicates profitability, then the techniques are ready for commercialization (note that we are saying that at best we are two years away from where MSL/SI thinks we are now). If the project is moderately successful, the participants will be able to argue convincingly on the basis of hard evidence and partial success that no more than one or two more years of work are required before commercialization is possible. If it is only modestly successful it should be terminated after the two years.

## INTRODUCTION

At the request of USAID/Barbados, Dr. Clarence P. Idyll and Dr. John Caperon visited the Smithsonian Institution, Washington, D.C.; Barbados; and Antigua during the period January 3 to 17, 1986 to evaluate the progress of a project to culture the Caribbean spider or king crab, Mithrax spinissosimus.

This mariculture project is under the direction of scientists from the Marine Systems Laboratory, of the Smithsonian Institution (MSL/SI). Crabs are hatched from eggs released by wild females held in cages with small meshed screens. These cages are anchored in the sea, in protected shallow waters. The eggs hatch as zoea larvae. A second zoeal stage is followed by a megalops larval stage, after which the crab assumes a bottom-dwelling juvenile crab stage. From hatching to the first crab stage takes about 120 - 148 hours, depending largely on temperature. As soon as possible after hatching the female is removed from the cage and the cage is then left undisturbed for 60 to 100 days. The juvenile crabs are not fed during this time, and subsist on the algae growing on the cage, stored nutrients, or possible plankton and detritus in the water. At this point approximately 100 small crabs are transferred to floating grow-out cages. They are fed by inserting screens which have previously been exposed in the water adjacent to a coral reef, where they accumulate a dense algal turf of mixed species. The crabs feed on this algae, which is continually renewed by replacing the screens. The aim is to produce 35 to 50 adult crabs of approximately 1 - 1.6 kg. (2.2 - 3.5 lbs.) weight, in about 400 days.

This crab culture system grew out of research carried out by the MSL/SI on the primary productivity of tropical waters. High production rates of benthic algae were recorded on mats exposed in the water near coral reefs; this high productivity was experienced despite the low levels of nutrients which are characteristic of mid-latitude waters. Searching for ways to convert this high productivity into useful food for man, several species of algae-eating animals were considered for mariculture tests. The Mithrax was considered to hold the greatest promise.

As a consequence trials were conducted in the Turks and Caicos Islands, beginning in 1984, with encouraging results (although no market size animals were raised). A second project was launched on the north shore of the Dominican Republic beginning in 1985. It has not been carried out long enough to have produced animals of commercial size. The third crab culture project began in Antigua in April, 1985. This was funded by AID/Barbados (and managed from the AID office in Washington). The U.S. Peace Corps, under an agreement with MSL/SI AID, and the Government of Antigua, has supplied four Volunteers, whose task was to have been to receive training from the Smithsonian staff, so that they could train fishermen to raise crabs using the system developed.

We were asked to "provide RDO/C with an assessment of the status of the present Smithsonian activity in Antigua and recommend a plan of action for possible RDO/C financed follow-on activities", and to suggest activities that might be pursued by AID/Barbados in support of there follow-on actions.

# ITINERARY

| | | |
|---|---|---|
| January 3, 1986 | - | At Marine Systems Laboratory of the Smithsonian Institution, Washington, D.C., talked with Dr. Walter Adey, Director of the Laboratory, and Dr. Maree Hatziolos Manager of the Project for USAID, Washington. |
| January 5, 1986 | - | Travelled to Bridgetown, Barbados |
| January 6, 1986 | - | Met with Mr. Michael Huffman and Dr. Cecilia Karch, AID |
| January 7, 1986 | - | Travelled to St. Johns, Antigua with Mr. Huffman, Dr. Karch and Mr. David Crowley, Peace Corps, Barbados. Met by Mrs. B. Lake, Peace Corps, Antigua. Attended a meeting with Robin Yearwood, Minister of Agriculture; Ernest Benjamin, Permanent Secretary of Agriculture; Francis Henry, Director of Fisheries; Redford Arrendale, Senior Fishery Officer; Mr. Huffman; Dr. Karch; Mr. Crowley; and Mrs. Lake. Visited the Project site on Nonsuch Bay, observing the cages and screens and the working facilities. Talked to the Smithsonian staff, Vincent Ruark and Mitchell Craig, and to the Peace Corps Volunteers, Jim Vega, Maureen McBrine, Michael O'Donnell, and Carl Downes. |
| January 8, 1986 | - | In St. Johns talked as a group with the Peace Corps officials and Volunteers and the Smithsonian staff, and separately with the PCV and Smithsonian staff. Visited Mr. DuBose, the U.S. Charge d'Affaire. Travelled to Barbados. |
| January 9, 1986 | - | AID Office |
| January 10, 1986 | - | Report writing |
| January 11, 1986 | - | Report writing |
| January 13, 1986 | - | Briefing at AID Office with: Mr. James Holtaway, DIR, Mr. Don Soules, A/PRM, Mr. Peter Orr, C/PD&M, Ms. Kim Finan, C/PDD, Ms. Cecilia Karch, SS, Mr. William Baucom, ARDO, Mr. Stephen Szadek, D/ARDO, and Mr. Stan Heishman, RCO |
| January 14, 1986 | - | Report writing |
| January 15, 1986 | - | Report writing |

| | | |
|---|---|---|
| January 16, 1986 | - | Briefing on report with: Mr. Don Soules, A/PRM; Mr. Peter Orr, C/PD&M; Ms. Cecilia Karch, SS; Mr. Stephen Szadek, D/ARDD; Mr. David Crowley, Peace Corps; and Mr. Gerrit Argento, PSO |
| January 17, 1986 | - | Report amendments |
| January 18, 1986 | - | Caperon travelled to the United States<br>Idyll travelled to the United States |

## CHALLENGES FACED BY CRAB CULTURISTS

Attempts to raise crabs by culture face a series of difficulties common to all mariculture systems; these problems are harder in many ways for crustacean culture, and the complexity is enough greater in crab culture that no profitable commercial crab mariculture system exists in the world, as far as we know.

In contrast to land farming, aquatic farming is a small operation over most of the world; only in Asia does it make much impact on food supply. The reasons for this is related to a significant degree to lack of experience by most people with water farming. The agriculturalist takes as a matter of course the vast store of theoretical and practical information accumulated over centuries, which he has absorbed through his own experience and through the information supplied by agriculture research institutions and extension agent systems. With a small number of exceptions, aquaculture starts with a small knowledge base and little experience by the farmer or by any information/extension source he may have.

The low success rate of most kinds of mariculture result, first, from the farmer having to work in water -- an environment far less familiar and congenial than land. His problems are then often compounded by difficulties in getting feed that will satisfy the nutritional requirements of his animals and provide good growth and survival rates; by shortages of adequate seed (eggs or young animals), which must often be obtained from wild stocks and not from captive and manipulative brood stocks; by sudden and often crippling losses of crops by disease, predators, oxygen shortages, temperature changes; by long times between crops (often many months or even some years) which reduces his income and raises his costs.

Of the many kinds of aquatic animals for which farming has been attempted, crustaceans have posed some of the greatest difficulties and have shown fewest successes. This is related to the long and complicated, larval life histories of many crustaceans, the fragility of these larvae, the difficulty of raising or preparing appropriate feeds which will produce optimum growth survival, the losses caused by the agressive nature of may crustaceans and the associated cannibalism. Some species of marine and "freshwater" shrimps have been raised successfully; no lobsters have yet been cultured and few other crustaceans.

As mentioned above, there exists no known profitable commercial farming system for crabs despite trials in Asia and perhaps elswhere, and several successful experiments in raising crabs (including *Mithrax spinosissimus*) through the larval and juvenile stages.

Thus, if the *Mithrax* culture works commercially, it will be a world first. And if the project does work it will require a disciplined and critical scientific approach. To accomplish this, some of the personnel working on the project will have to be well trained and experienced in mariculture generally and in crustacean culture in particular.

## CRAB CULTURE AT THE ANTIGUA SITE

We visited the site of the *Mithrax* crab culture operation run by the Marine Systems Laboratory of the Smithsonian Institution (MSL) with the assistance of the U.S. Peace Corps, on January 7 and 8, 1986. We were accompanied by Mr. Michael Huffman and Dr. Cecilia Karch of AID/Barbados and by Mr. David Crowley of Peace Corps/Barbados. In the course of the visit we talked at some length with the two MSL biologists and with the four Peace Corps Volunteer being trained by them. We also talked with officials of the Antiguan Government, with the local Director of the Peace Corps, Mrs. E. Lake, and with the U.S. Charge d'Affairs, Mr. DuBose.

### Crab Culture Operations

The work at Antigua is the third crab research and development complex under MSL operation. It was begun in April, 1985 and has thus been working for approximately eight months. An arrangement was made under which Smithsonian staff would train Peace Corps Volunteers in crab culture techniques so that they could transfer the technology to local fishermen as a profit-making activity.

In Antigua the crab culture operation is conducted from a vessel anchored in Nonsuch Bay on the Atlantic side of the island. Cage and screen building are done on the boat and a barge alongside, and the placement of cage and screens and their handling during the culture period is by a skiff operating from the boat/barge complex; there is no shore base.

Eleven broods of crabs have been started by this operation. The first two, resulting from hatches of the eggs of wild females on May 17 and May 23, 1985; were 235 and 229 days old when we saw them. The two hatches had been combined and are held together in a cage inside the bay, behind a sheltering island. On December 30, 1985, when they were measured last, there were 27 surviving crabs from the two batches. These are survivors from 58 crabs tranferred from the hatching boxes at 80 days of age. On December 30 these crabs were about 36 - 66 mm carapace length. These are the biggest crabs raised under culture at this site.

A third brood was hatched on July 18, but it was destroyed on September 8 by the predation of other species of crabs that gained access to the culture cage.

Eight other broods have been hatched, on various dates from November 11, 1985 to January 4, 1986. These are held each in a separate box close to the reef on the outer edge of the bay. No measurements have been made on these crabs since it is believed best not to disturb them until they are about 60 - 100 days old, to avoid the danger of allowing predators into the cages during the examination and to avoid possible injury and increase mortality from handling.

The algal food for the crabs in being raised on mats or screens set out in the water just inside the reef. When we were there there were about 150 of these screens in various stages of algal growth. Some were lying flat on the surface of the water and other were tethered vertically, to test the efficiency of each method.

Two cages held wild crabs captured as brood stock: 13 in one and 10 in the other.

The MSL staff at Antigua is led by Vincent Ruark who has a BS in Geology. He worked for a short time as a curator at the Smithsonian. He has had no experience in aquaculture prior to the Antigua operation. Mitch Craig has a BS in Biology, received in 1984. He has had no previous experience in mariculture.

The MSL staff supervise the operation. In addition to taking part in the carpentry and other labor involved in the operation, they make a certain number of biological observations, including the following:

1. Estimates have been made of the meat yield for two male crabs. These were wild crabs of commercial but unspecified size. The estimates were made by weighing the crabs alive, killing and cooking them; extracting the meat in a way similar to that employed by commercial blue crab pickers in Florida (with whom where Mr. Ruark worked briefly) and weighing the meat. The yields obtained were 20% and 24% meat to total live crab weight.

2. Measurements have been made of carapace length, claw length, and total weight all wild crabs brought in by fishermen and others.

3. Measurements have been made of carapace length of cultured crabs:

   a. <u>Crabs Hatched on May 17, 1985</u>

      i. At 80 days of age: average carapace length = 15.11 mm.; range 7.4 to 22.5 mm.; number in sample = 17 average growth rate = 0.19 mm/day

      ii. At 103 days of age: average carapace length = 21.2 mm.; range 17.3 - 34.1 mm; number in sample = 34 average growth rate = 0.21 mm/day

   b. <u>Crabs Hatched on May 23, 1985</u>

      i. At 80 days of age: average carapace length = 14.95 mm; range 11.6 - 18.3 mm; number in sample = 18 average daily growth rate = 0.19 mm/day.

      ii. At 100 days of age: average carapace length = 19.6 mm.; range 14.3 - 26.1 mm; number in sample = 28 average growth rate = 0.196 mm/day

c. Crabs Hatched May 17 and May 23, Combined

i. At 131 days of age (for May 17 brood): average carapace length = 29.53 mm; range 19.88 - 38.9 mm; number in sample (all the survivors) = 42
average growth rate* = 0.22 mm/day

ii. At 160 days of age: average carapace length = 39.6 mm; range 28.5 - 53.2 mm; number in sample (all the survivors) = 36
average growth rate = 0.248 mm/day

iii. At 198 days of age: average carapace length = 52.24 mm; range 35.75 - 65.7 mm; number in sample (survivors) = 27
average growth rate = 0.264 mm/day

The 27 crabs measured at the 198th day were survivors of approximately 2,000 megalops larvae in each of the two batches; survival from megalops to 198 days was thus 0.06%. From the 42 animals alive after 131 days there were 27 survivors after 198 days -- a survival rate of about 65% in 67 days. A linear projection based on three data points are clearly very untrustworthy statistically, but these are the best survival data available to us; they predict zero survival at about 315 days. It should be emphasized that this does not mean that there will in fact be no surviving crabs at 315 days, but that the trend should be a matter of concern.

These carapace size data, with data from the other two sites, were used to construct a composite growth curve for Mithrax. This curve is Fig. 1 in a summary provided by Dr. Adey on January 3, 1985 and attached to this report.

Data to construct this curve exist only for crabs up to about 200 days old in Antigua, and about 230 days in the Dominican Republic. The left part of the curve exhibits an increasing slope; this is characteristic of the left limbs of sigmoid (S-shaped) growth curves. The rest of the crab growth curve is speculative since no size-at-age data are yet available for older crabs. As drawn it departs only a little from a straight line beginning about 150 days until nearly the 500th day of the crab's life, when it shows a slight decrease in slope, or flattening. Many growth curves flatten more quickly than this, reflecting the tendency that animals exhibit slower rates of growth after maturity, until at the oldest ages the curve is nearly flat, showing little or no growth.

As the curve is now drawn it indicates that about 400 days (13 months) would be required to grow crabs to the 4 lb. size (2.7 - 5.3 lb. range), and that about 440 days (14 1/2 months) to grow crabs to the 3 lb. size (2.2 - 3.5 lb. range).

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* These average growth rates are all calculated from day one.

Natural Food of the Crabs

It has been asserted that these crabs are nearly exclusively herbivorous, and that they thrive on a diet of plant material. This has important implications for their culture, since plant food is normally much cheaper than animal food, and especially if the crabs can grow rapidly and attain satisfactory market sizes on the algae produced on the mats set out for this purpose. On the other hand, if the crabs do eat animal food, and in particular if they require some animal protein for optimal growth and survival, as a large number of cultured animals do to get certain essential amino acids, the achievement of optimum growth may require supplemental feeding with food of animal origin. Information bearing on this point has been obtained by observations of the MSL staff at Antigua. First, they have noted, as have biologists at the other two crab cultures sites, that there is a population of small animals in the algal mats -- crustaceans, worms and other small creatures -- and that the grazing crabs undoubtedly consume some of these. As a consequence some of animal protein may be consumed, and it may be important nutritionally. In addition, the MSL scientists in Antigua have several times seen the crabs consume sea urchins. They bite off the spines of the urchin one by one, and appear to manipulate them with their mouthparts. They have been observed to crush the tests of the urchins with their large chelae and consume the soft bodies. In the cages small crabs have been observed on several occasions to consume their companions. Only dead crabs have been eaten, and it is not known whether these were killed by other crabs. Thus aggression and attack may not be involved. Young crabs have refused to eat dead fish offered to them. The evidence is still unclear to what extent these crabs consume or need animal food.

Optimum Feeding Rates

The crabs are fed after 80 - 100 days by putting them into grow out cages into which screens are placed, on which algae has been grown by exposure in the water. The screens are changed at intervals to provide additional food to replace that grazed off the screen.

There are no experimental data on which to judge how much algal (or the best kind of algae) is needed for the crabs at any stage. It is certain that the amount changes upward with age and may be that the kind of food changes as well, judging from experience with many other animals. The amount and quantity of food are two of the most critical variables in determining optimum growth and it is likely certain that the growth rates could be increased if information were available on these points. Further experimentation is needed urgently.

Disease and Parasites

It is believed that this species is nearly or entirely free of disease and parasites. It is true that the larval stages appear to be less susceptible to attack by these afflictions than other crab larvae; this was reported by Brownell, Provenzano and Martinez in their 1977 account of raising this species in Venezuela. But it can be taken for granted that this is not

entirely so, and not for all stages. It seems likely that whatever diseases and parasites do afflict the species the incidence will be increased when crowding is greater under intense culture. Heavy losses are always a threat under such circumstances. Research is needed.

Aggression and Cannibalism

This crab appears to be uncharacteristically mild-mannered, and this will be a strong advantage to those culturing the species. For some other crustaceans the tendency of individuals -- especially males -- to attack and injure or kill others in a tank or pond causes enough losses that the culture system is complicated and raised in cost by having to isolate individuals. Some aggressive displays are reputed to have been observed by the MSL staff in Antigua; whether these will be intensified with larger and more crowded animals is unknown.

No instances have been seen at Antigua of killing and eating of Mithrax crabs by other Mithrax crabs, although it is uncertain how the dead crabs observed being eaten were killed. More experience is needed especially with large crabs and with those under the crowded conditions that come with intensive culture.

Availability of Breeding Stock

Mithrax crabs are apparently not abundant anywhere, and concern has been raised whether enough crabs exist to supply sufficient gravid females for a culture operation. The size of the population of this crab in Antiguan waters appears to be greater than in the other places where culture projects have been attempted by the Marine Systems Laboratory, although the evidence for this is small, and mostly anecdotal. We were told by the Minister of Agriculture, who is a part-time fisherman, that he never (or rarely) fails to catch one or more Mithrax in his fish and lobster traps, and that other fishermen have the same experience. They regard these crabs as useless, however, and either discard them and or kill them and leave them in the traps as bait. As a consequence, after a few abortive trials by the staff to get gravid females by diving, it proved easy to obtain them from fishermen for a small fee, and later for nothing. A shortage of brood animals may therefore not be a problem in Antigua even at a commercial level of culture operation. It is asserted that female crabs can be held in captivity and will continue to bear eggs for some time, and will copulate and bear fertile eggs. It is not certain that these females produced eggs as a consequence of copulation in captivity; this point needs checking.

It should noted that if a fishery is developed, either because the crabs become a market item with success of a culture industry, or because a fishery is promoted by the Antiguan Government, fishing pressure may reduce the number of females below desirable levels in terms of supplies of eggs for the culture industry. This would only be the case if a commercial crab fishery caught more crabs than are captured incidentally. But it seems certain that if a successful crab culture operation and market is established, at least a small fishery being encouraged to start.

Feeding Procedures

It is important that crabs are not killed or lost and that predators or parasites are not introduced during changes of the algal mats for feeding. This requires a careful inspection of the mats under difficult skiff condition, and this will affect the labor requirements and cost. Under commercial conditions there will be a strong temptation only to exchange new screens for old as quickly as possible, with potentially disasterous results.

Environmental Observations

No data have been taken in Antigua on water temperatures, salinities, water current strength, or other environmental or biological variables. Records of this kind would be useful, even though some of the parameters (e.g., salinity) do not vary much. Under certain conditions, including long hot summer days, sheltered waters, relatively calm waters, low tidal amplitude (i.e. conditions that undoubtedly exist at times at the Antigua site), a strong shallow thermocline can develop. Thus crabs in culture will be grown under temperature conditions that they do not naturally experience. Both because unusually elevated temperature may pose a threat to crab survival and became a positive growth rate may result from increase temperature this variable is particularly important. If in some future culture operations crab larvae are raised onshore where water characteristics can be varied, sometimes with advantage to the culturist in terms of growth and survival of the crabs and the algal mats, it would be useful to know what the environmental parameters had been in earlier experiments.

It is not possible under the conditions being used in the Antiguan trials to vary temperature and salinity -- two parameters known to have profound effects on growth rates and well-being of animals. But such things as frequency of feeding, kinds and amounts of food, current rates, design and construction of cages and screens, density of crabs in the cages, and other parameters which have been shown to have effects with other animals could be tested. Many or all of them will have to be addressed at some time in order to arrive at the optimal system of spider crab culture. As far as we could determine, the only variable being observed in Antigua was the growth characteristics of the algae: rough estimates of the amounts on screens set flat on the water surface compared to those set vertically in the water. We did not see any results of these tests.

## SUMMARY STATUS OF CRAB CULTURE PROJECT

The Caribbean King Crab Culture Project is not ready for commercial application. Several groups have raised these crabs from the egg through the larval stages and up to adults, some crabs being as large as 200 - 250 mm carapace length. No crabs have yet been raised to market size. It seems certain that some crabs will be raised to commercial size, within a few months, but this still will not guarantee profitable commercial culture.

There are four major stages in the development of a profitable mariculture project:

1. The development of a system for raising the animal from a young stage to a marketable size.

2. The testing of this system on a pilot scale, with modifications of the experimental methods to approximate those likely to be used in commercial operations, and to demonstrate that the system is reproduceable.

3. An economic evaluation of the system. If this indicates it could be profitable, Stage 4 can be undertaken; if it is not but looks promising, a return to Stage 2 for further research and development is warranted.

4. Scale-up to full commercialization.

The crab project has not completed Stage 1, since no crabs have been raised to market size. This phase may be completed within several months, after which the pilot operations should be conducted to determine whether the system is well enough established to raise crabs to market size repeatedly and predictably. In the course of the pilot work modifications to procedures will undoubtedly be applied to increase the efficiency and profitability of the system. It is only at this stage that it should be said that there exists a technology with enough technical backing to make an economic analysis. If this analysis is favorable fishermen or others can be encouraged to try it for profit. If the economic analysis suggests that the system would not be profitable, but there is evidence that it can be made so, the pilot procedures should be modified to demonstrate this.

It will be some time before this stage of reasonable assurance will be achieved so that commercial Caribbean king crab farms can be encouraged to start To finish Stage 1 will take a minimum eight to ten months in the Dominican Republic and Antigua. The numbers of commercial sized crabs that will have been raised by then will be small, based on the numbers of small adults surviving so far.

The pilot stage should be allowed to operate through a minimum of two successful broods, each with a significant number of cages, which will require at least two years even if the broods are raised nearly simultaneously. More time than this would be preferable to allow for modifications and improvements

in the system. Additional time may be necessary if the economic analysis indicates that the system used and modified in the pilot trials would not be profitable.

We feel that the probability that a system which AID, any Government, or any other responsible agency should accept as ready for commercial application could be developed within two years is no greater than about 20%. Similarly, we feel that the chance that it could be developed in five years, given the likelihood of complications that cannot be anticipated (slower than expected growth rates, higher than expected mortality rates from undernutrition, predators, disease or many other factors), is perhaps 50%. And it must be accepted that there is a chance that a profitable business cannot ever be developed using this technology, for many reasons, both biological and social/economic.

It seems clear that improvements in the economics of the Caribbean nations will be limited if we restrict our consideration only to those projects that seem certain to succeed. Some risks must be taken. The quality of the meat from the Mithrax crab is high; there is every indication that a very good market for it [illegible] exists and; there are many suitable sites for its production in the Caribbean. Therefore, the second alternative discussed above should be given serious consideration.

## ASSESSMENT OF THE TRAVERSE GROUP'S PRELIMINARY FEASIBILITY STUDY

The economic analysis by the Traverse Group Inc. (TGI), given the necessary input parameters, is essentially routine and we assume completely correct. We have neither the time nor facilities to assume otherwise. We have, however, give careful consideration of all of the input parameters and attempt to indicate how any changes in parameter values might alter conclusions.

The input parameters are used to calculate the production of marketable crab products in pounds (yield), the price received for each product class and the cost of production. Yield (lbs. per year) times price ($U.S.) received per pound minus production costs ($U.S. per year) equals annual profits. The parameters will be listed below.

### Yield Parameters

1. Numbers of market size crabs produced per cage.

2. Market size crab weight.

3. Amount of crab product per market size crab.

   a. Crab meat product
   b. Crab section product

4. Number of days required to bring crabs to market size.

### Price Parameters

1. Meat (a commercial consumer product).

2. Sections (a commercial consumer product).

3. Whole crabs (the product form that concerns the individual fisherman).

### Cost of Production Parameters

1. Cage construction and replacement costs.

2. Algal mat screen construction and replacement costs.

3. Time and other costs to service cages.

4. Labor costs.

5. Number of days to grow algal mats.

6. Number of days required to bring crabs to market size (same as yield parameter #4).

7. Number of 100 day old juveniles per brood.

Crabs Produced Per Cage

The number of adult crabs per cage used in the TGI report is 35. This is a very high density for care, feeding and health considerations. It may be argued that they live in caves and holes in nature at these densities, but no data are presented to support such an assertion, and even if true this is only during the inactive daytime period. At night they leave such refuge and range to feed. Constant enclosure at these densities may well not be possible - at least not without depression of survival and growth rate. In the absence of any data the [illegible] estimate is accepted with serious reservation. (See the last paragraph on page 11).

Market Size Crab Weight

Market size crab [illegible] given as 4 pounds. This figure is accepted.

A[illegible]

The figure used in this report is 25%. Other documents available to us (Adey, December 1985) quote 30 to 35%. The lower figure is compatible with yields obtained from some other crustaceans and with yields determined by the NSL [illegible] at Antigua. Without more information about how the higher number was obtained, the 25% figure is retained.

Number of Days to Bring Crabs to Market Size

The figure used in the TGI study is between 360 and 540 days. The best estimate from Smithsonian projections is 430 days, and this figure is a large extrapolation from the present growth data, with almost no predicted slow down in growth rate. Animal populations characteristically exhibit a decrease in growth rate as more of their resources are given to reproduction instead of growth; growth rate eventually falls to zero or nearly zero. With Mithrax we have no data on the second part of the growth curve. The 480 day figure is very nearly the most optimistic projection possible with the limited data available. Clearly we must use nothing less than this 16 month (480 days) figure or abandon the four pounds at maturity weight figure. The 480 day value is accepted for the present, but note that it is very optimistic.

Meat Price

The price used is $12 per pound. This number is accepted as the best guess available, but it's realization depends on effective marketing.

Section Price

The price used is $6 per pound, and is accepted as reasonable.

Whole Crab Price

The price used is $2.50 per pound. The U.S. National Marine Fisheries Service are now encouraging the expansion of a new fishery for a spider crab in California waters which caught 56,000 lbs. in 1984. One of the authors of

the present assessment has caught and eaten many of these crabs over a period of several years. They are excellent and very similar in structure and appeal to Mithrax. They presently have a market price of about $1.25 per pound (whole crab), less than any other west coast crab species. Still, with effective marketing $2.50 may be realistic. One point that must be stressed is that once a market price is established the mariculture activity will be in direct competition with a fishery. Any economic assessment which does not include the fishery can be misleading. Since the fishery does not exist at present in Antigua one must use something like lobster prices which are about $[illegible] (U.S.). We accept the $2.5[illegible] price as realistic.

Cage Construction and Replacement Costs

The cost of 20 growout cages with 4 juvenile cages and 800 screens ( a complete gear [illegible] for one fisherman) is given in the TGI report as $6,478. Using the [illegible] own detailed cost figures [illegible] calculate $5,781; we cannot find the source of this discrepancy. Using our own costing we estimate cage costs at $150 compared to TGI's $[illegible], [illegible] at $125 compared to TGI's $107 and screen costs per 50 units at $[illegible] compared to TGI's $174, for a total cost of $6,944. We think this is a minimum figure for the present state of the technology. This higher figure comes from use of more realistic labor time estimates, [illegible] some items, and correcting an important apparent omission of material.

In addition to initial cost of equipment one must estimate the likely life of the equipment since this [illegible] operating costs. A 5 year life for screens and cages was used by the TGI. Present evidence indicates that 6 months is more appropriate for screens and 2 to 3 years is more appropriate for cages. We use an overall life of 2 years for this gear which is constantly exposed to the hazzards and wear of the marine environment.

There are other factors that affect the fisherman's operating costs: fuel consumption, replacement/repair of boat, motor and boat gear, and a contingency factor. Although very difficult to estimate because it depends very much on particulars of the site (as yet unchosen), the fuel consumption estimate of 1 gallon per day seems low by at least a factor of 2. We use 2 gallons. A contingency factor of 10% is most unrealistic for an activity that is conducted at an off-shore site exposed to theft, vandalism, misadventure and weather extremes. Even the 25% figure that we use is considered conservative and easily defended. A 10-year life for boat and motor is used by TGI. Since the analysis assumes no capital outlay for boat and motor, the crab culturists are assumed to be taking on second hand equipment. A 5 year life must be considered generous. This gives us yearly operating cost of:

| | |
|---|---|
| Fuel | $1,400 |
| Replacement/repair 50%/yr. cages and screens | 4,022 |
| Replacement/repair 20%/yr. boat and motor | 600 |
| Sub-total | 6,022 |
| Contingency at 25% | 1,506 |
| Total Operating Cost | $7,526 |

This figure exceeds the estimated annual income of $7,000 using the 12 month growout figure.

Use of the 16 month growout figure which is much more consistent with present data, reduces the income to 75% of $7,000 = $5,250. An alternative suggested crab weight with a mid range value of 2.85 pounds may well be possible in 12 months with essentially the same effect on yield and income, i.e. $7,000 becomes $4,987.

If these figures [illegible] the fisherman is being asked to invest $6,000 in capital and increase the risk to his existing boat and motor in the hope that through creativity and hard work he can overcome a $2,500 annual loss, and perhaps one day make a profit (we use the TGI term "profit" for fishermen wages). If he is a capable fisherman - and if he is in the business under present conditions [illegible] - he is better served to continue to fish, or to [illegible] the natural crab population.

Although we have principally addressed only the one fisherman case as most relevant to the Antiguan situation, [illegible] the same changes are in the balance sheet are indicated for the commercial enterprise case, i.e. 25% reduction in yield and 20% increase in operating costs.

In order to succeed a project must be technologically feasible and profitable. A review of the Preliminary Economic Feasibility Study of Mithrax (Caribbean King Crab) Mariculture report indicates that with present technology it would not be profitable. This does not necessarily mean that crab mariculture will never be profitable. Since a proven technology has not yet been developed an economic analysis is premature. It does mean that technological progress alone will not be enough to make the project viable. Economic improvements are also necessary.

## RECOMMENDED PLAN OF ACTION

### 1. Definition of Problem

We have been asked to make an assessment of the MSL/SI crab mariculture project in Antigua, and on the basis of this assessment to make recommendations on how best to proceed with the project. We were also asked to provide assistance and documents useful in acquiring the services needed for continuing activity.

### 2. Recommended RDO/C Long-term Goal for Crab Mariculture in Antigua, and Possible Follow-on Activity

There are two alternatives that should be considered: (1) orderly close of activities in Antigua, with continued close monitoring of progress at other sites, and (2) continued support for research and development on the crab mariculture project in Antigua.

The first alternative should receive serious consideration. The present MSL/SI system has not been shown to be technically feasible nor does it appear to be economically viable at this time. Existing AID funding to MSL/SI for continued work in the Dominican Republic and to private interest at Carriacou can be considered adequate to carry the project to success or failure. If these efforts are successful, then little or no time will be lost in establishing a commercial enterprise in Antigua. One disadvantage to this plan of action is that it does not provide additional resources to crab mariculture activities. Additional support to carry on the same sort of effort in Antigua is not warranted. However, additional technical effort to provide a better scientific understanding of crab mariculture could substantially increase the chances of success.

The second option involves continuing crab mariculture research and development at Antigua. But continuning present efforts without change in direction would not accomplish anything significantly different in Antigua. Only site-specific results are likely to flow from such an effort. The recommendation is that a new team of the highest calibre be secured to continue, and that they be directed not only to test the present MSL/SI system, but to develop a fundamental understanding of Mithrax crab mariculture. The new team should not only test the proposed system, but simultaneously conduct the sort of experiments that will tell how growth and survival rates are affected by feeding rates, cage stocking rates, temperature, cage incubation depth, etc. These results will be essential to long-term success in this enterprise. Better data are required on the rate of turf (algal) growth on screens, the specifics on major species eaten and rejected, and the way temperature, water motion and insolation affect algal growth rate. There are other matters that must be addressed but these comments are sufficient to give the character of the study that is recommended.

This work will require two years and funding at about $500,000. If the project is highly successful it will demonstrate the technical feasibility of the mariculture system and provide the hard data necessary for an economic assessment. If the later indicates profitability, then the

techniques are ready for commercialization (note that we are saying that at best we are two years away from where MSL/SI thinks we are now). If the project is moderately successful, the participants will be able to argue convincingly on the basis of hard evidence and partial success that no more than one or two more years of work are required before commercialization is possible. If it is only modestly successful it should be terminated after the two years. But even then it will leave a legacy of documents and publications that will be importantly useful to mariculturalists generally, and all participants, scientists, technicians, local government and RDO/C will be able to view with still pride their participation in the project.

3. Predicted Status of the Present MSL/SI Activities in Antigua by June 1986

Our greatest hope and surely that of the MSL/SI is that they will have 10 to 20 market size crabs that have been reared from eggs at the site, so that the follow-on work can be done, at least partly with second generation material. This will be a significant achievement and cannot help but raise our hopes for success. But even if it comes about this does not alter our recommendation that serious consideration be given to the suggested follow-on activity. Minimally there should be a 20 cage, 800 screen, 4 hatch box system on site for use by the new team. There will have been ample time to fully indoctrinate and train the new grantee staff in the MSL/SI system, and time to establish the good rapport that will make the continuing effort of both MSL/SI and the new grantee much easier and more effective.

4. Recommended Future Role for MSL/SI

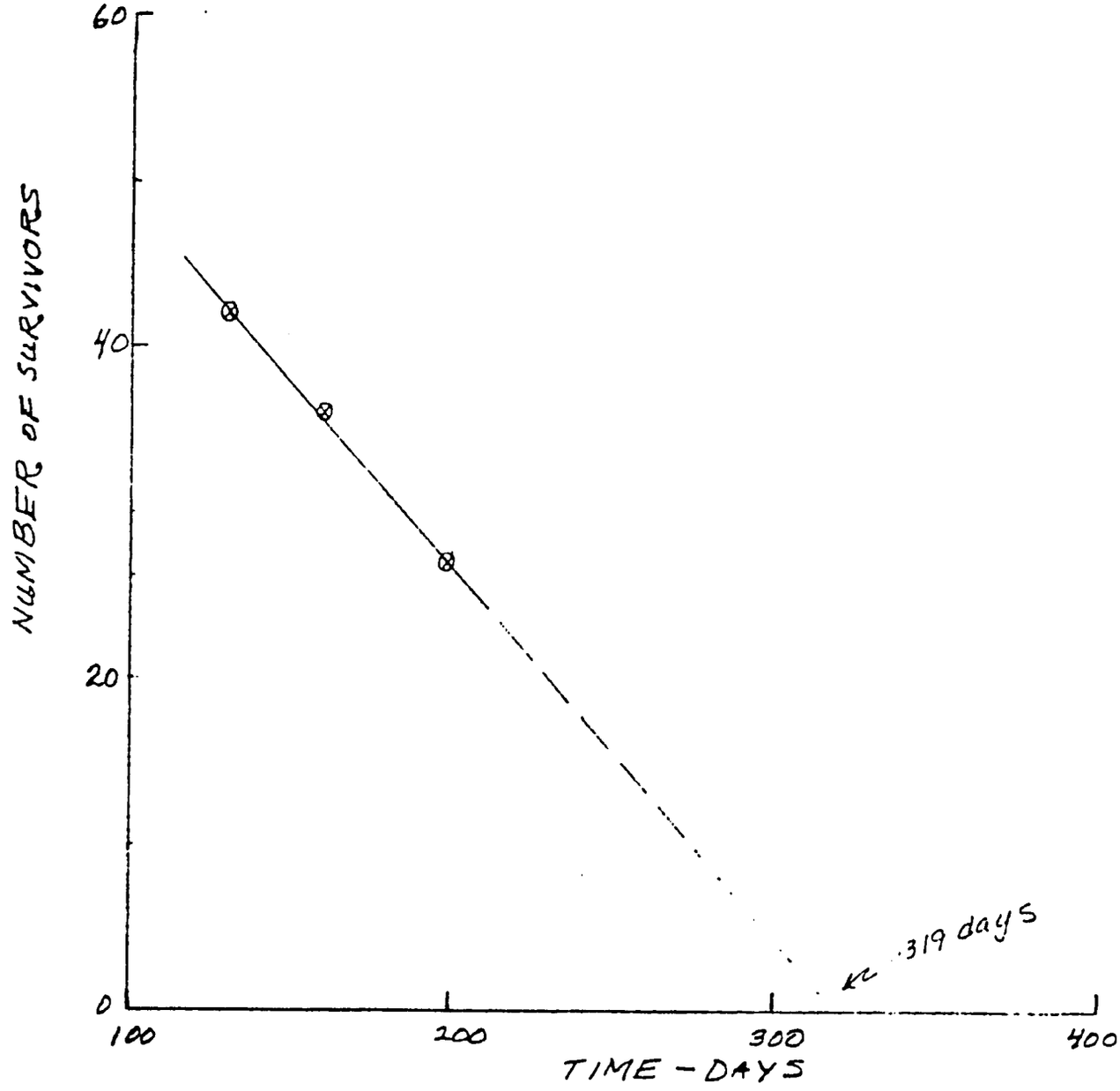
This is already spelled out in the MSL/SI request for additional funding under Grant No. LAC-0605-G-SS-3070, "Completion of Caribbean King Crab model for Antigua" dated December 1985, which seems completely satisfactory. No further comment is offered.

5. Recommended Future Role for the Peace Corps

Such a recommendation is really the responsibility of the Peace Corps and RDO/C and it depends on the nature of the mission that each has in the foreign sector, details of which we do not have. What must be said is that the Peace Corps group associated with this project is very talented and able to be of great help in the overall project objectives. It is understood that they are planning to propose a related crab mariculture or fisheries project that is more consistent with their mission. Every effort should be made to accommodate their needs at the very earliest date.

6. Recommended Future Role for AID/Washington

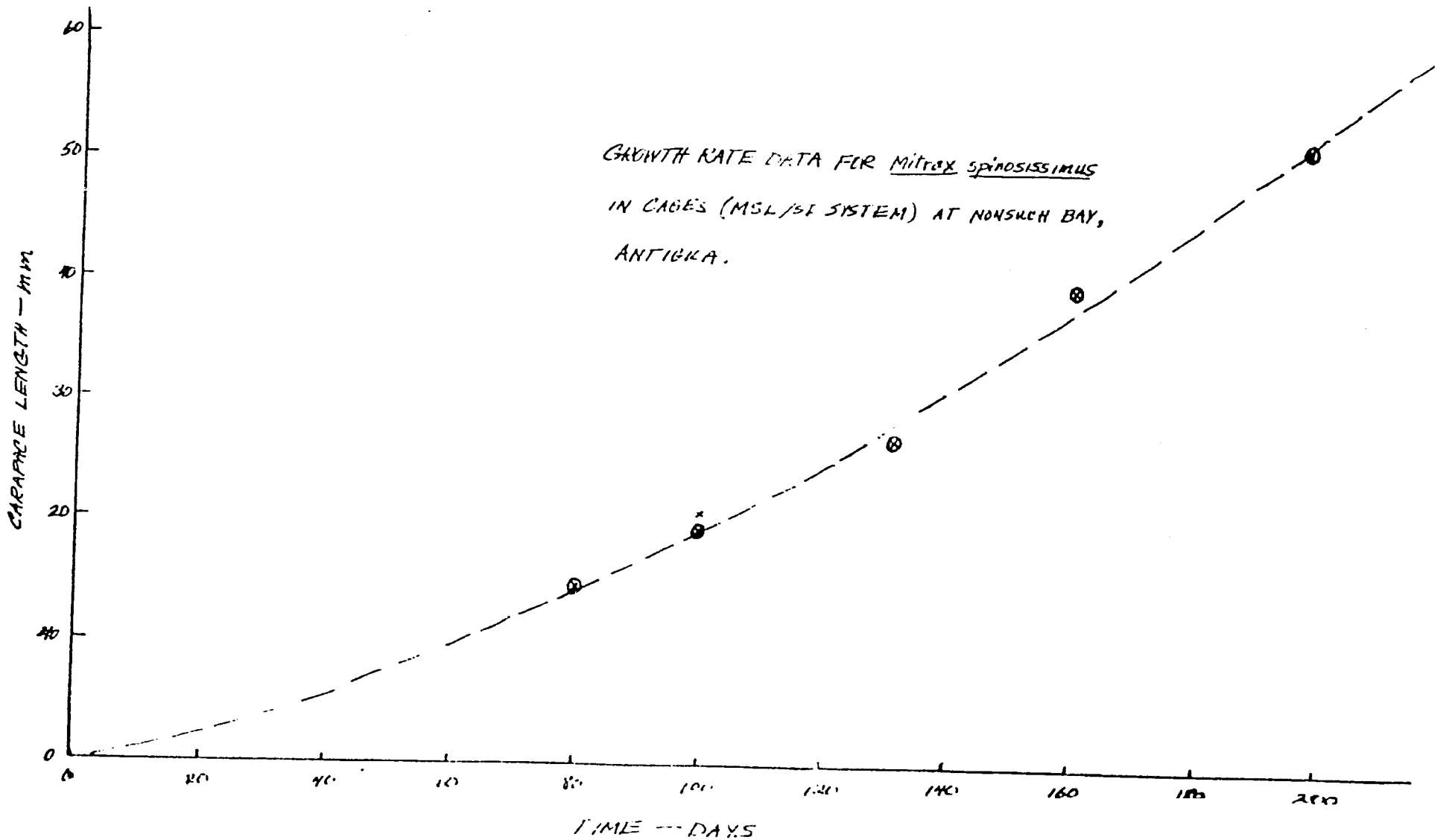
Remarks on this are really outside our competance or concern, with one exception. Every effort should be made to take advantage of AID Science and Technology Office in Washington to assess proposals and review progress reports on behalf of RDO/C.




Survival in cage culture of the crab

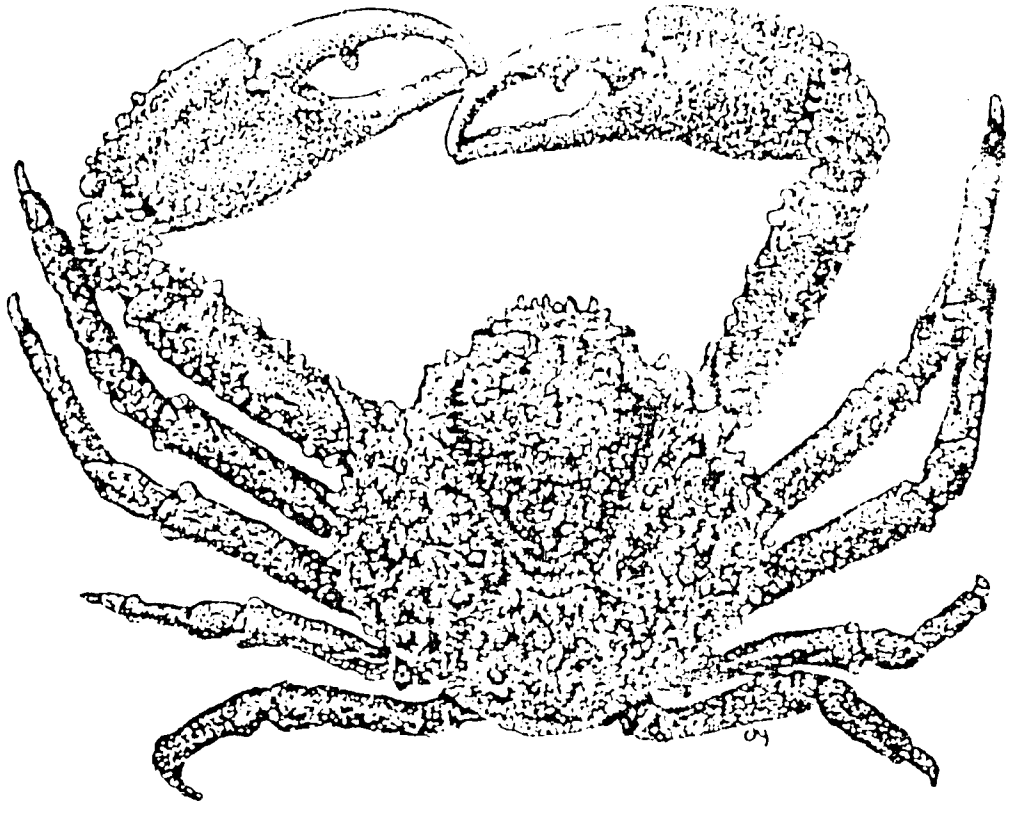
Mithrax spinosissimus (MSL/SI system)

at Nonsuch Bay, Antigua.


GROWTH RATE DATA FOR Mitrax spinosissimus
IN CAGES (MSL/SI SYSTEM) AT NONSUCH BAY,
ANTIGUA.
CARAPACE LENGTH — MM
TIME — DAYS
0
20
40
60
80
100
120
140
160
180
200

ATTACHMENT #1

# MARICULTURE OF THE CARIBBEAN KING CRAB
# (MITHRAX SPINOSISSIMUS)



Marine Systems Laboratory
Smithsonian Institution
Washington, D.C.

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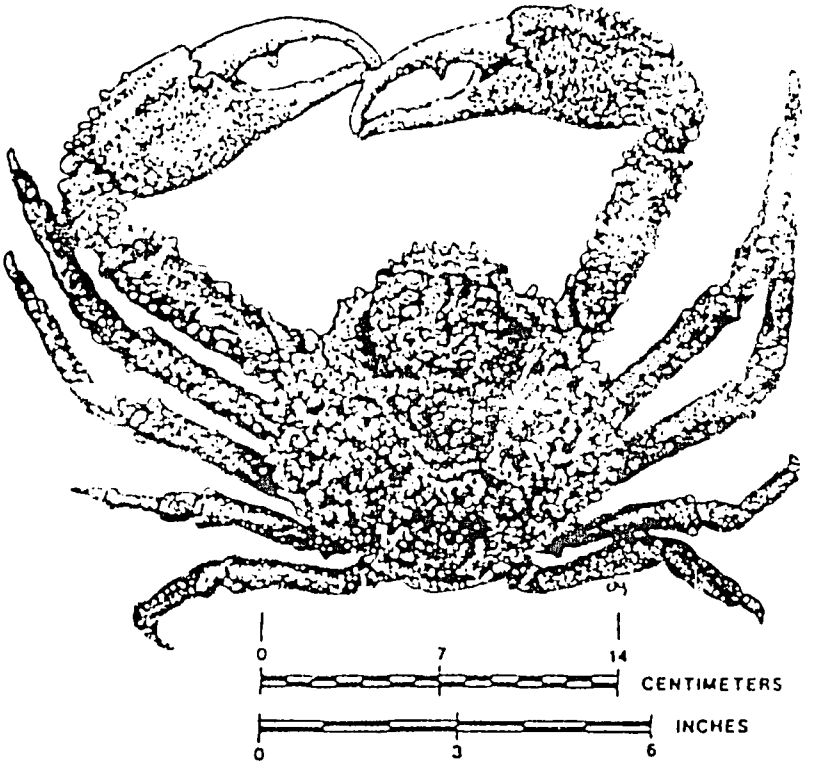
## WHAT IS MARICULTURE ?

Mariculture is the propogation and husbandry of marin animals or plants for human use. Mariculture techniques have bee used for many centuries in various parts of the world. In recen years, increasing worldwide demand for seafood and increasin technological innovations have led to greater interest i commercial aquaculture and a substantial increase in production Annual worldwide output of aquaculture products now exceeds million metric tons, nearly 10% of world fishery output.

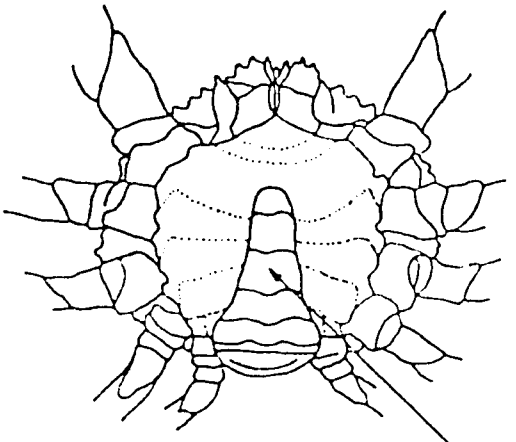
It is now known that the extraordinarily high productivit of tropical reefs is mostly derived from many species of smal marine plants known as turf algae. Researchers at the Marin Systems Laboratory (MSL) have developed methods for inexpensivel cultivating these algal turfs on artificial surfaces at sea. Whe harvested, many uses of this plant material are possible. The MSL has pioneered the use of algal turfs in large quantities fo animal fodder. Funding provided by the Agency for International Development is now being used to teach fishermen techniques for the cultivation of algal turfs to be used as fodder for the Caribbean King Crab. Similar in size and taste to the Alaskan King Crab, its high market value makes it a good alternative for the North American restuarant trade, as the Alaskan King Crab fishery is now in decline.

Mithrax spinosissimus

"Caribbean King Crab"

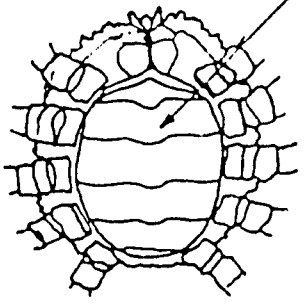


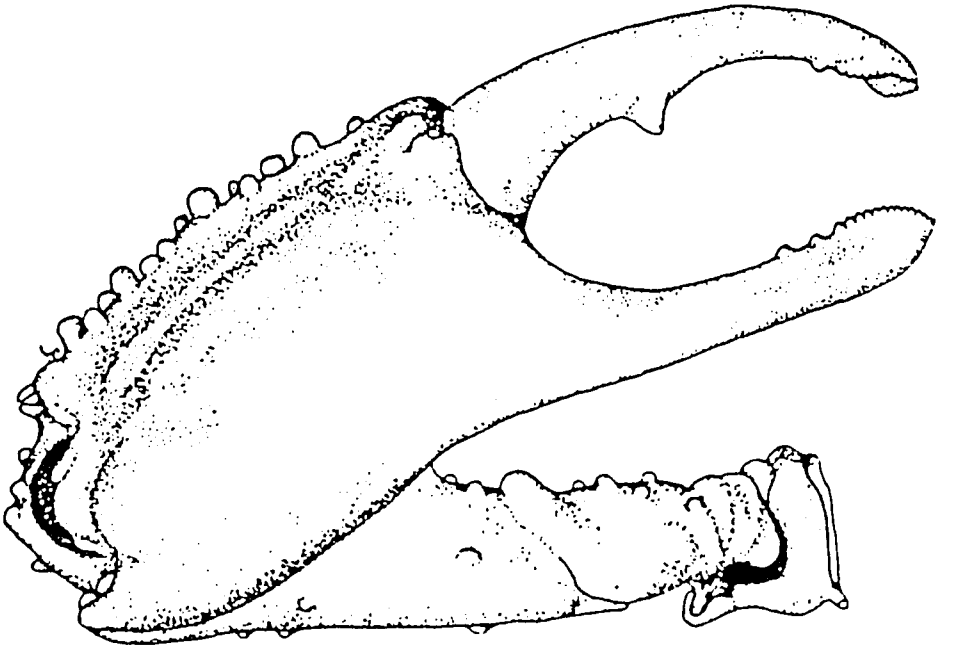

MALE



telson

FEMALE





Male claw - note finely serrated tips adapted for feeding on algal turfs

# LIFE CYCLE OF THE CARIBBEAN KING CRAB

The scientific name of the Caribbean King Crab is Mithrax spinosissimus. It inhabits mostly deeper coral reefs, and other surfaces with caves and crevices, in the Caribbean and Bahamas. When the Caribbean King Crab first hatches, it is 1 mm long. Before it is big enough to be brought to market it must grow for 12 - 15 months, to over 100 mm in shell length. It could, however be processed for canning at as early as 300 days old.

A newly hatched crab is called a zoea. It does not look like a crab at all, nor does it act like one. It swims about freely in the ocean, spending its first two to three days near the surface. Crabs grow by molting ( shedding of the shell with the growth of a larger replacement). The zoea molts twice while it is swimming freely, then begins to sink to the bottom. On the bottom it molts two more times, and only then does it look and act like a crab. It is still only 1-2 mm across the body.

The crab feeds on small marine plants, and also decorates itself with these plants, so as to camouflage itself from other animals. The crabs continue to grow by molting every 12 -20 days for the first 100 days of its life. After that, molting is less frequent (30 - 100 days between molts), but the crab grows at a faster rate.

Female crabs become sexually mature at about the 300th day from hatch. After they reach this age, and mate, they will produce a new set of eggs every 6 to 8 weeks. A female crab with eggs is termed gravid. She carries the eggs beneath her under her abdomen. Depending on her size she may carry 5000 to 80,000 eggs. It takes 4 - 6 weeks for the eggs to mature and hatch.

A male crab grows to a larger size than female crabs. A sexually mature male crab is identified by its massive foreclaws called chelipeds. These chelipeds may contain 1/2 lb. or more of meat. While the crabs are not cannabalistic and get along well in crowded quarters, some limited fighting does occur, most likely over females.

The primary defense of the Caribbean King Crab is to hold tightly to the bottom in its holes. As a result, the leg muscles are well developed and a large amount of meat occurs in the legs and body/leg joints. A typical 4 lb. (1.8kg) crab has 1 1/2 (.75 kg) of meat. The meat is sweet tasting, similar to lobster, and not as stringy as most crab meat.

From a marketing standpoint, the Caribbean King Crab is comparable to the Alaskan King crab, and likely to command a similar price and use. Most important, it can be hatched from eggs, is easily reared in captivity, and its food can be inexpensively grown.

## HATCHERY

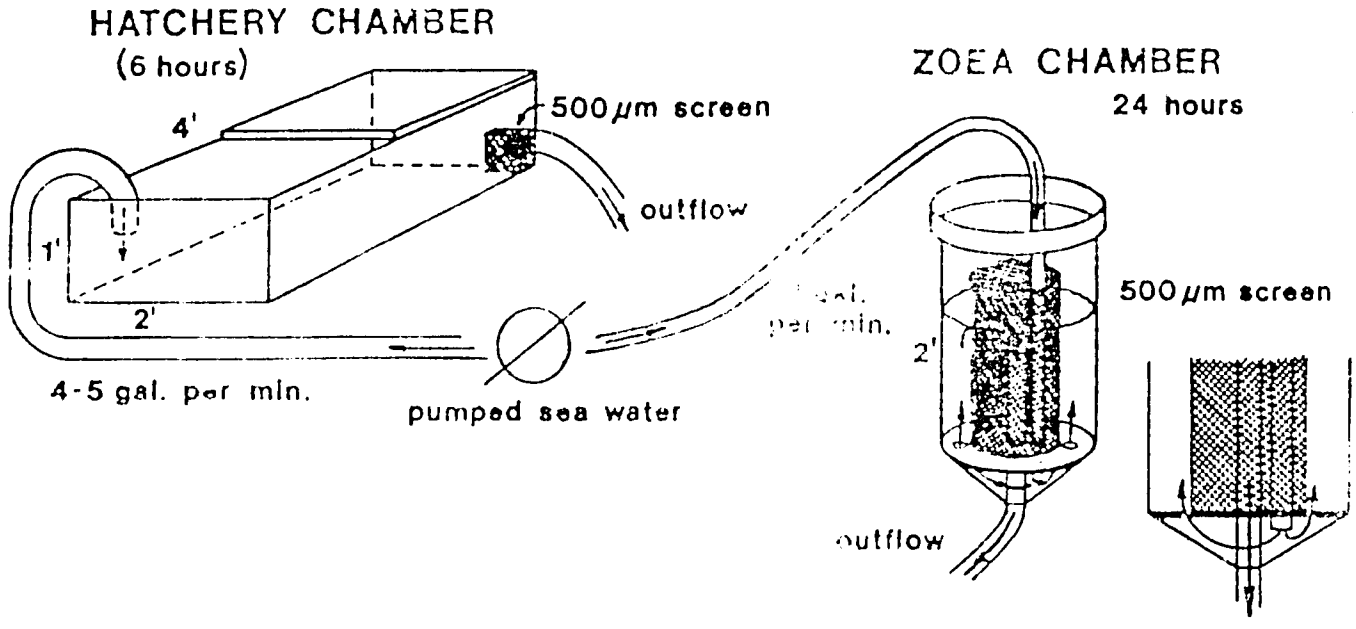
Caribbean King crab eggs can be obtained by capturing gravid females in the wild (using SCUBA or lobster traps) or by fertilization when male and female crabs are kept in captivity. Most mature females captured are carrying eggs. Just before the female is to release her eggs, she is placed in a hatchery box. Water for such a box should be pumped from any non-polluted, reasonably open and silt free sea water source at a flow rate of 2 - 5 gallons per minute. Each gravid female will produce 1000-8000 viable young every few months.

The hatchery chamber is designed so that the young can be easily removed after hatching. One end of the box is covered and therefore darker. The other half of the box is uncovered and the first young (known as zoea, 1mm in length) swim rapidly toward the lighted end of the box. Within [illegible] 6 hours after hatching is complete (it can take several hours for a female to release all her young) the larvae are siphoned out of the hatchery box using a clear garden hose and placed in a larval rearing chamber. Here, the young are kept up in the water by a constant water flow through the chamber which enters at the bottom to create an upwelling current. During the first 24 -36 hours after hatching, the zoea molt several times. Following these moltings, the young become crab-like (megalops) approximately 60 hours later ( or 120 hour after hatch) and metamorphose to young crabs and settle on the chamber screens.

An alternate to pumping water into tanks on land is at-sea rearing. In this method, a gravid female is placed and kept in the juvenile cage (described on the following page) until she releases her eggs. The female crab is then removed and the larval crabs allowed to grow undisturbed for 60 days. This method is simpler, but the crab survival is significantly less.

# HATCHERY

## 0-5 days

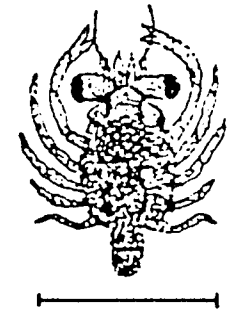



ZOEA

700 μm

36-48 hours

MEGALOPS



1mm

60-72 hours

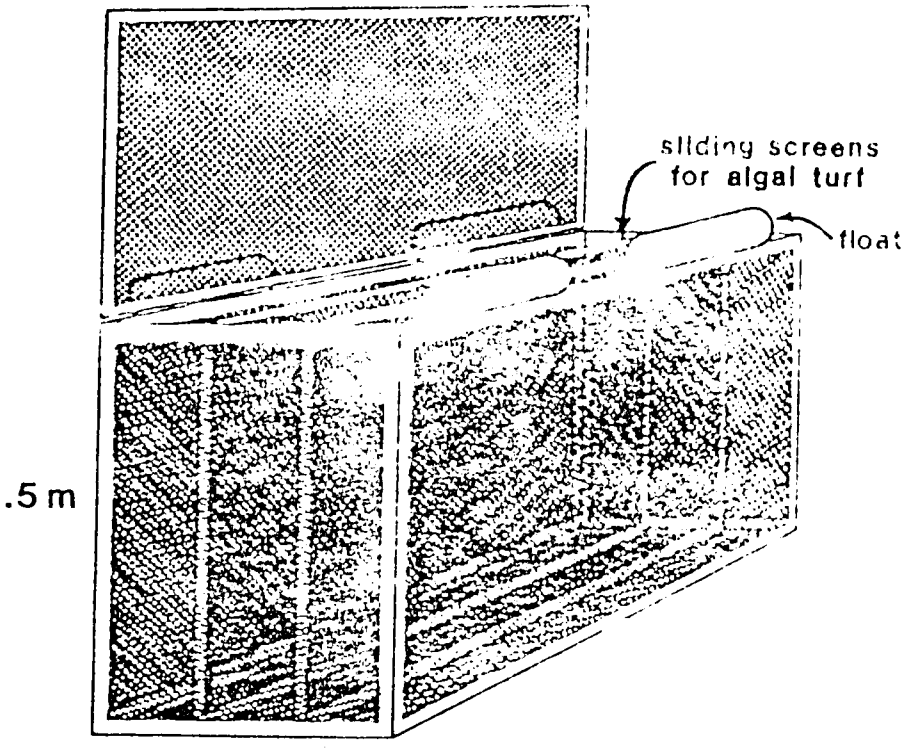
## GROWOUT TO 100 DAYS

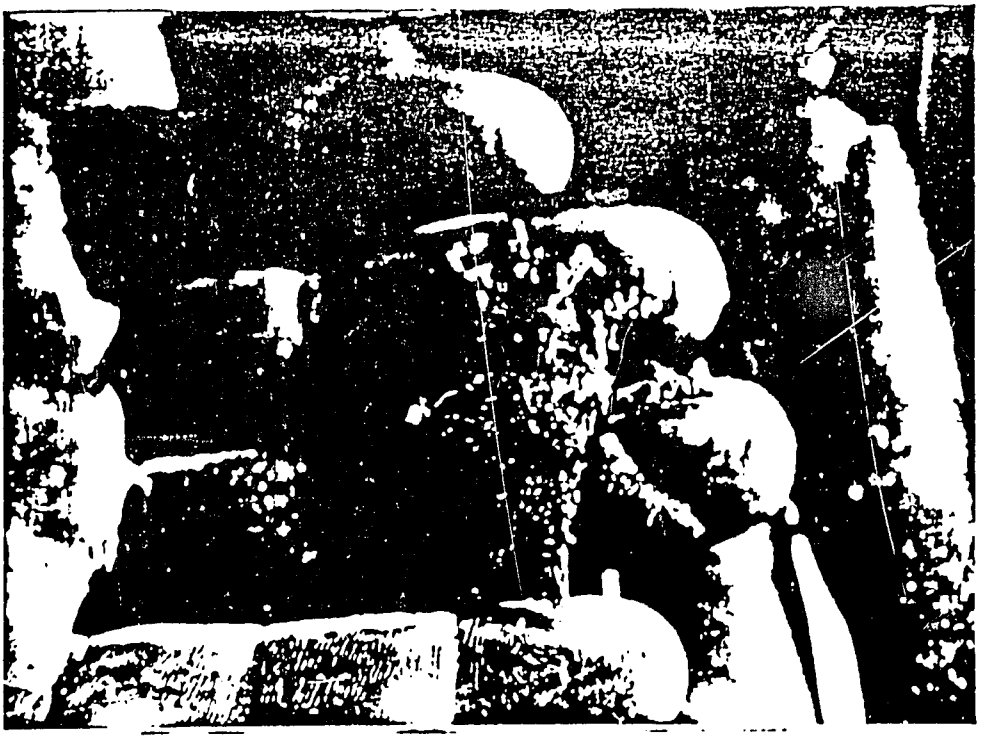
Within a few hours after metamorphosis of the megalops to crabs (5 days), the larval rearing chamber screens upon which the crabs have settled should be pulled out and lightly shaken in a five gallon bucket of seawater until all of the crabs have been removed. The crabs can then be transferred to a juvenile crab grow out cage that is anchored so as to be suspended in the water column 9 - 10 feet (3 meters) beneath the water surface. Rough, turbulent water should be avoided as the young crabs may be forced into the screen and trapped there before they are strong enough to withstand the wave action. The cage should be placed in an area of moderate wave action (1 foot deep) and some current flow (0.05 - 0.5 knots) as well as being in an area of shallow water (less than 5 m depth) with a white sandy bottom. These cages can be left undisturbed for 40 - 60 days.

The juvenile crab grow-out cage is a simple, fiberglassed wood frame box covered by fine mesh (0.5mm) screen. It should be placed in the water 10 days before use to allow for a an algal film to develop. After 60 days, the crabs need more algae than can be grown in the cage. Screens constructed and placed in the water on the same date as the hatching of the brood should be ready to place into the cage at the 60th day of crab growth. The algae has grown on these screens is known as algal turf. The cage design depicted here has slots for two screens. They may remain in the cage for ten days. At that point the cage must be pulled next to a boat so as to exchange the removable screens with fresh screens. As the old screens are pulled out, the young crabs that remain should be gently brushed off, back into the cage. This screen changing and crab feeding scheme should be maintained for 40 days (4 screen changes) at which point the 100 day old crabs may be placed in a larger adult crab cage.

# YOUNG CRAB "GROW OUT"

5 – 100 days



## FINAL GROW OUT TO MARKET

After 100 days, the young crab bodies are 15 mm in diameter and it is possible to handle them individually. From this point on growth rate is dependent upon the amount of algal food supplied. Adequate feeding is of greatest importance. This can be accomplished by designing the rafts in such a way that the algae consumed can be continuously replenished. Therefore, the crab grow out raft is fitted with plastic algal screens that can slide in and out, so that the algae can be grown outside the raft. For example, a raft holding 15 screens, each 1.5 square meters, can fully support about 200 young crabs to a weight of about 1/4 kg (about 200 days old).

After 150 days in this cage (250 days from hatching), the crabs are 1/2 kg in weight. Some could be marketed at this point while leaving the rest to continue to grow to a larger market size of 1 - 2 lbs. Depending on the availability of hatchings, it may be desirable to use only the largest crabs for continued growth while harvesting the females for canning or other small crab marketing.

The final 150 days (400 days from hatch) of grow-out to 2 kg or more entails a similar algal screen change scheme. Each crab will need about 1/3 meter of screen/day of algae. Therefore, to insure adequate territory and ample food for the crabs, the number of crabs per this type of raft should be reduced to 50. It should be noted that although this part of the process is relatively labor intensive, the screens can be changed quickly. The crabs soon learn the process and leave the screens for the bottom of the cage when screen pulling is initiated.



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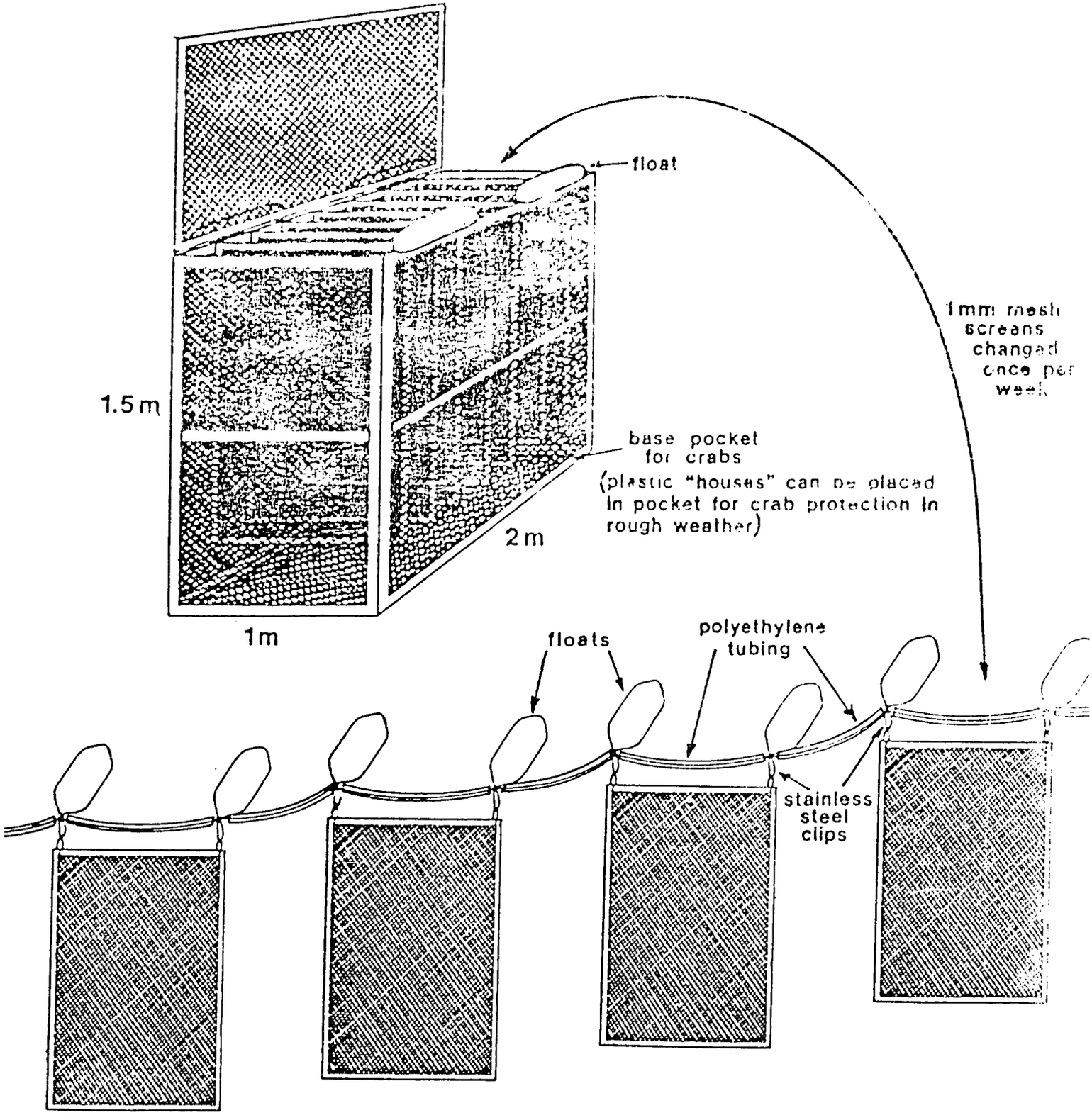
# ADULT CRAB "GROW OUT"

100 – 400 days



## PRODUCTION OF ALGAL TURFS FOR FEED

For a maximum harvest of algal turfs (approximately 15 - 25 g/m2/day) several conditions have to be met: (1) moderate wave action (a large lagoon or reef flat situation is required); (2) maximum light with minimum ultraviolet radiation (met by submerging screen below water surface); (3) a shallow, bright sandy bottom to maximize reflected light; (4) light and wave resistant plastic screens of 1 to 3 mm mesh; and (5) harvest (manually or by animals) once every 7 to 12 days.

When starting up new screens, they should be scraped manually once per week for 6 weeks. They are then ready to be used for crab feeding. When the algal screens are constantly fed to the crabs and set out for regrowth, the crabs tend to eat the more desirable, small turf algae and ignore the overgrowing larger algae. Maximum growth of the most desirable turf algae is achieved by keeping a regular harvest interval of 7 - 12 days which prevents the larger, less productive algae from developing.

Although many patterns of feeding/algal screen management are possible, one effective method is to have three sets of screens for each raft, one set being used for feed inside the raft, while the other two are regrowing outside. The sets are exchanged every 3rd day. The entire process of changing, scraping and resetting screens for a single adult raft requires about 1 hour for 1 person, depending on the exact situation. Crab growth rate is probably on the order of 10 - 35 % higher by this method. The cost and availability of labor relative to materials and construction costs of rafts will determine these relationships in each case.

Using the methods discussed in this pamphlet, an algal production rate of 100 - 200 g (wet weight) per square meter of screen per day can be achieved. This will become about 10 - 20 grams of adult crab. Thus a mature crab of 2 kg will require about 15 kg of algae (wet weight) or about 100 days adult growth on 1/3 square meter screen. As the adult crabs eat roughly 60 grams of algae per day, a 1.5 meter square screen can feed 3 - 4 crabs. Algal losses in cleaning, inefficient feeding, etc. probably means that 200 - 300 days in the adult cage is closer to the real picture. In any case, these rough numbers can be used to make calculations for varying situations.

## GEOGRAPHICAL SITUATIONS FOR CRAB PRODUCTION

Although almost any situation in open, non-polluted or sediment rich tropical sea water provides the potential for crab mariculture, certain conditions are optimal. For example, a broad back reef flat of 1-2m depth with constant wave surge and wave driven currents, used for algal growth, backed by a protected lagoon, with moderate currents, for crab growth, is ideal. Minimum labor and fuel cost for transport of feed algae to the crabs is thus attained.

As long as growth over the first 100 days, when the young crabs are still relatively fragile, is carried out in quiet but not stagnant localities, much of the remainder of the King Crab growth process can be carried out under moderately rough conditions of partially protected shelves or lagoons. However, the cage, algal screens and anchoring systems must be strengthened and generally protected against chafe. Liberal use of garden hose to protect polypropylene line is essential. Also, to prevent molting crabs from being damaged or killed in rough weather, the addition of plastic houses at the base of the grow out cage has proven quite successful.

PROJECTED COSTS (for a 1000 crabs per year operation)

| Materials | Costs (U.S.$) |
|---|---|
| 1 Hatching and zoeal chamber plus pump and hose | 600 |
| 5 juvenile cages | 100 |
| 15 adult grow out cages | 750 |
| screens, line and floats needed to service the above cages | 2190 |
| Total | $3640 |

These costs apply to the single fisherman operation having the basic requirements for working in the Caribbean : a small b with outboard motor, a shore base and a marketing source. Becau local costs and mode of operation vary widely, these data must be loosely applied to the local situation.

## MARKETING

*Mithrax spinosissimus*, the Caribbean King crab, can be handled and marketed much the same as the spiny lobster. In live shipping to local markets, or delivery to freezing plants, more care needs to be taken with the crab than the lobster as it is more subject to early death due to sun exposure in an open boat or to leg loss resulting from rough handling. However, since the animal is being farmed it should be easier to avoid these conditions. Flash freezing for distant markets and air-freighting is quite suitable for this product.

THIS PROJECT AND PAMPHLET FUNDED BY:

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

PEACE CORPS

EARTHWATCH

ATTACHMENT #2

# Summary of Caribbean King Crab (*Mithrax spinosissimus*) mariculture development

December, 1985

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## Introduction

A large amount of quantitative data on the mariculture production of algal turfs and the herbivore crab Mithrax spinosissimus bas been assembled during the period mid 1983 thru 1985. The early work emphasizing algal (feed) production (as herbivore feed), is in manuscript form, mostly in review, as attached. The attached crab paper is the first in a series of three - the remainder will be completed within six months.

During the next six months the remaining data will also be collated into several additional publications, primarily on Mithrax spinosissimus but also on Cittarium pica and several parrot fish. This summary primarily deals with Mithrax spinosissimus mariculture and is taken as means from the most recent data available from the Dominican Republic and Antigua field sites as of December 31, 1985.

As proposed to and funded by the Agency for International Development, the mariculture techniques developed in this project were specifically directed towards minimum technology and minimum cost as might potentially be carried out by itinerant Caribbean fishermen.



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Breeding Stock

Wild populations of Mithrax spinosissimus vary widely in abundance on Caribbean shores. In some areas breeding stock can be easily obtained with a few SCUBA dives or with fish traps. In other areas they are difficult to find. In every area we have worked in (Mayaguana, Grand Turk, northwest Dominican Republic and Antigua) within six months, a more than adequate breeding population was obtained. Each adult female releases 5000 to 100,000 eggs, depending upon female size, roughly every six weeks, and although we have not worked with mariculture-produced adult females, we have no reason to think that the breed stock cannot be domestic as well as wild. Stock improvement by breeding is very likely a future possibility.

Well-fed adult female Mithrax sp. will produce two or more crops of eggs every 4 to 8 weeks after being placed in a breeding cage. 6-8 females kept with several males under good conditions will more or less continuously produce eggs at the same rate at least for a period of 8-10 months and probably for several years. While hatchling mortalities are relatively high using "in-situ" methods, a breeding stock is easily maintained. In our experience, for the independent fisherman model, more hatchlings will generally be available than are needed for adult production. Subsequently released into the wild, un-used hatchlings will probably improve wild stocks.

Hatchling and juvenile development

Initially developed as a simple laboratory technique using pumped sea water in kriesal tanks, *Mithrax sp.* hatching at our field sites is now carried out "in situ" in small "hatch" boxes (see Porter et al). This technique can easily be handled by fishermen - the crucial elements are to seal the cages properly to avoid introduction of predators and to avoid heavy seas during the first 60 days of development.

An average-size female crab produces 30,000-50,000 eggs, and several days prior to releasing (as determined visually by egg color) she is placed in the hatchling cage which has previously been anchored in the water for about three weeks. Monitored daily, the female is removed when hatching is complete and after about 24 hours the zooea are distributed among several cages depending upon hatch density. Newer hatch boxes have slots for two to three algal screens (as well as the growth on the cage walls) and after 20-30 days, these screens are changed every three to four days. Typically three to five hatch boxes bearing 100 crabs each will be found at 100 days. Numbers can vary widely depending largely on: 1) the age and condition of the female; 2) the care taken to isolate predators from the hatch and juvenile cages; 3) care taken in handling while feeding; 4) the rate and quality of algal feeding and 5) the quality of water motion (neither stagnant nor rough seas). At 100 days, juvenile crabs average about 2cm lengthwise across the carapace and are more or less easily handled. In general, it seems apparent that more frequent handling increases mortality. Standard mariculture will

probably show improved survivorship rates over our heavily handled animals.

Adult Grow Out

Juvenile crabs placed in adult cages similar to that shown in the pamphlet "Mariculture of the Caribbean King Crab" will reach maturity in an additional two or three hundred days depending upon the size and weight desired. Quantity and quality of feed (algal turf) are crucial to growth rates and survivorship. It appears (more experience is needed) that 40 mature crabs can be achieved from a stocking density of 100 juveniles.

Because the quantity and quality of algal turf is so crucial to adult grow out, careful reference should be made to the algal papers. Good flow and wave surge are essential to good production and this can range from 10-25g(dry wgt)/m2/day. The screens should be placed perpendicular to water flow, double attachment points are crucial and a weighted screen base will greatly improve results. It is desirable to gradually increase feeding rates as the adults in a cage increase in size. While a screen change every 3-5 days is acceptable from 100 to 200 days, thereafter the rate should be increased finally reaching every day during the last 50 days. Allowing screens to develop a roughly 10-cm long turf (20-30 days growth) will also improve growth and survivorship of the larger adults.



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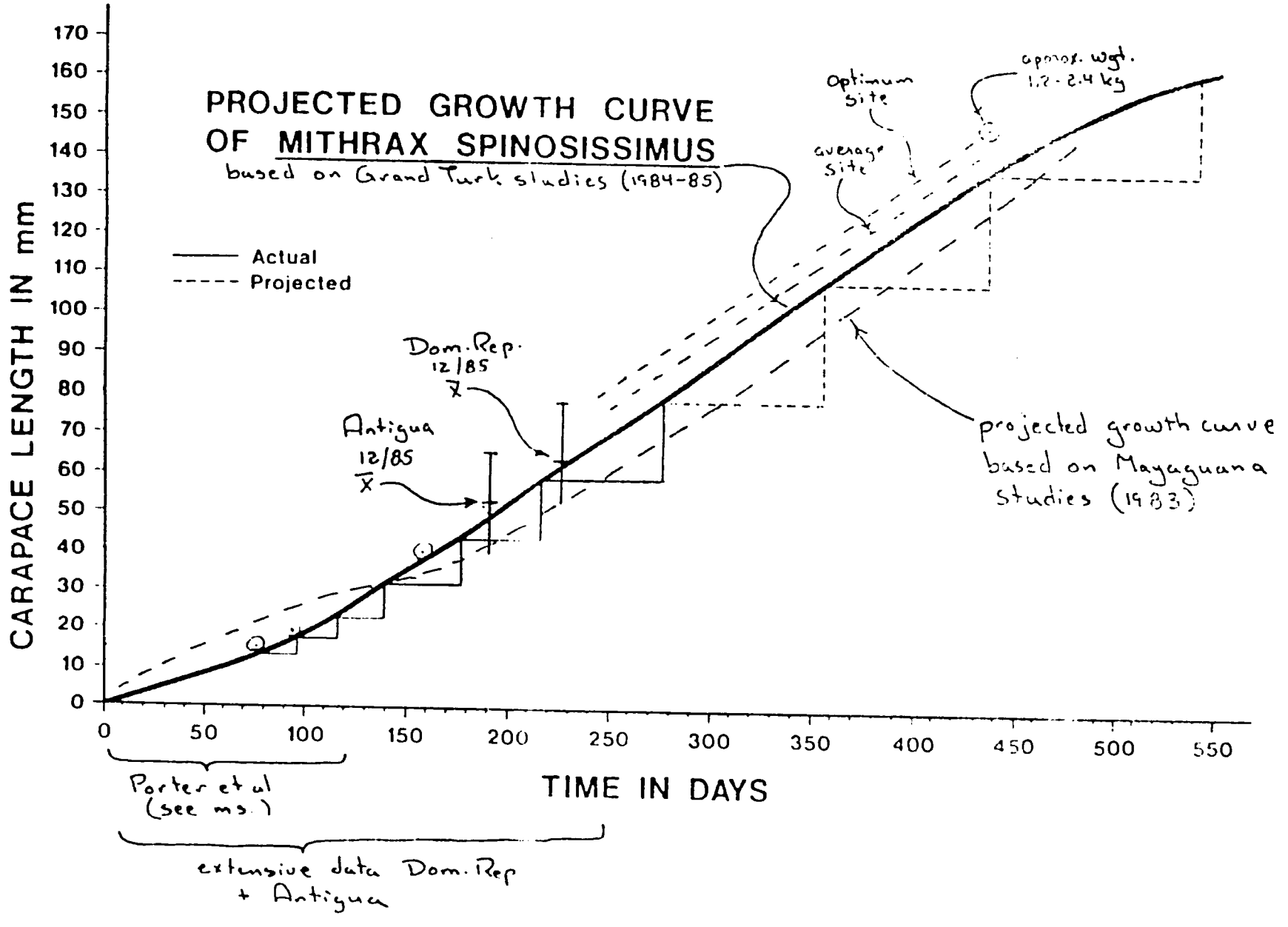
Growth Curves

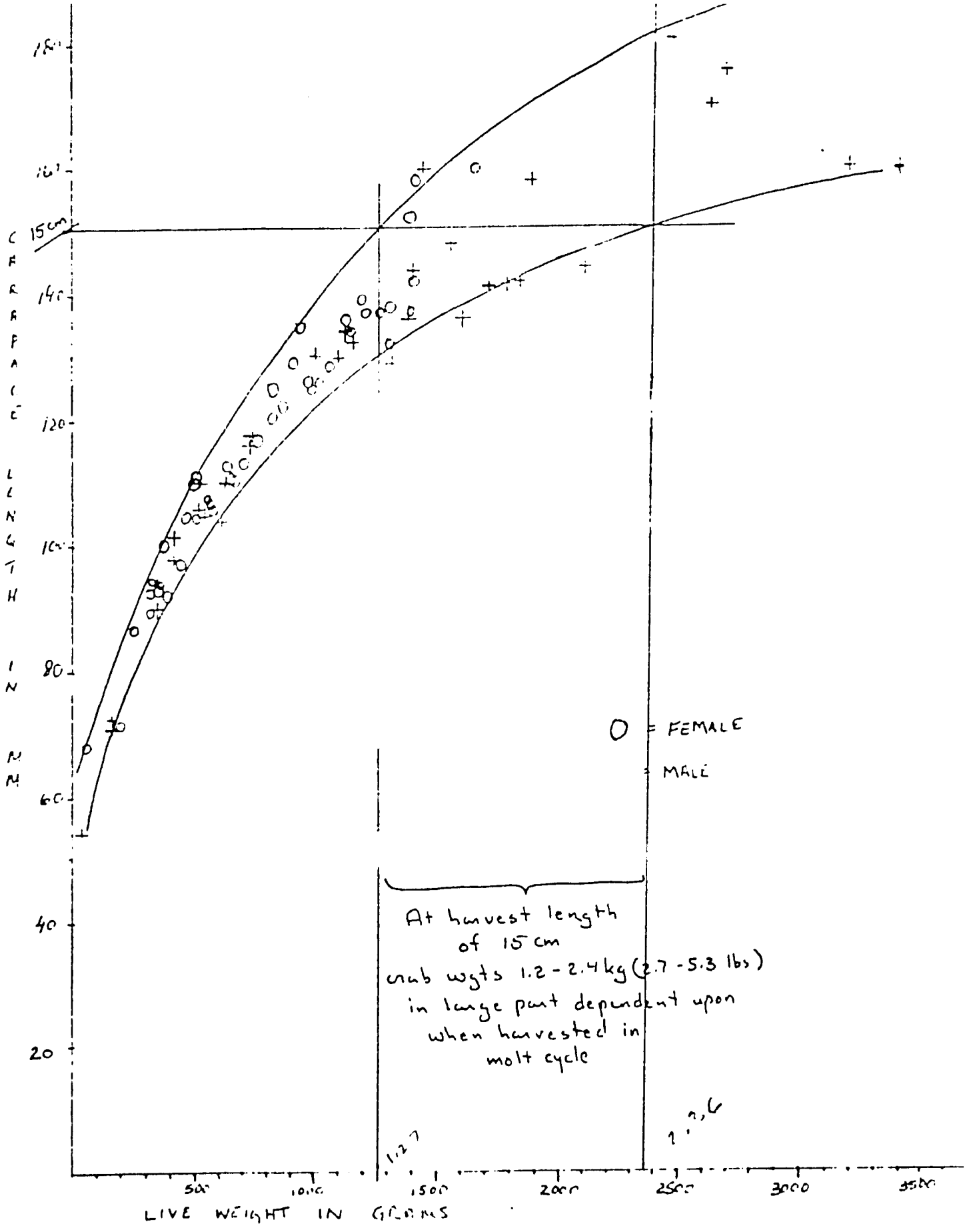
Figure 1 is a composite curve from four sites. While a few crabs were brought to one year at Grand Turk, significant numbers are only now being produced at the Dominican Republic and Antigua. The two oldest crops at the Dominican Republic were lost in a hurricane in late November, 1985. The lost cages broke free and beached: The adult cages that remained did not sustain significant losses indicating that as long as they are properly secured and anchored the adults can take quite heavy weather. Growth rates will probably be significantly improved at an ideal (water flow and wave surge) site such as Cariacou, Grenada (see figure 1).

Note that 15 cm is arbitrarily taken as a harvestable size. The actual harvest weight would range widely over several weeks as a function of exact harvest time within the molt cycle (Figure 2). 15 cm may be too large to be practical and it might well be better to harvest at the previous molt in roughly the 1-1.6 kg (2.2-3.5 lb) range.

Marketing

Based on several shipments from the Dominican Republic and the Turks and Caicos to Florida, the adult crabs remain alive on ice in excellent market condition for at least 10 hours. Recent cooked meat weight studies carried out by International Fisheries have indicated a marketable meat weight of 30-35% of total live weight. Properly cooked, several crab experts have indicated that the meat has the highest market quality.


PROJECTED GROWTH CURVE
OF MITHRAX SPINOSISSIMUS
based on Grand Turk studies (1984-85)
Actual
Projected
CARAPACE LENGTH IN mm
TIME IN DAYS
Optimum site
average site
approx. wgt. 1.2 - 2.4 kg
Dom. Rep. 12/85 $\bar{x}$
Antigua 12/85 $\bar{x}$
projected growth curve based on Mayaguana studies (1983)
Porter et al (see ms.)
extensive data Dom. Rep + Antigua




Length to weight of live Mithrax spinosissimus

Figure 2.

ATTACHMENT #3

The island of Antigua is flat and relatively arid, surrounded by natural harbors and beautiful white sand beaches. It is estimated that approximately 40%-50% of GDP is directly or indirectly related to tourism. Light industry plays a growing but distant second place role in the economy and agriculture follows with a third place position and less growth potential. This is the outcome of a dramatic shift in the economy from sugar plantation monoculture to tourism and light manufacturing which has witnessed a shift in the types of businesses operating in Antigua. The service sector (excluding Government services) now constitutes the largest source of GDP; hotels and restaurants contributed some EC$63 million in 1984 while 23% of employment is in tourist and distributive trade activities.

On the other hand, fishery and livestock production has declined. Despite the substantial implied demand from the hotel and restaurant sector, and a growing resident population, production of beef, mutton and pork fell 5.4% per year, and fish and lobster landings have declined, on average, 10.5% per year since 1980.

In 1981, the year Antigua gained its independence, it achieved a real GDP growth rate of 3.8%. During the world recession years of 1982 and 1983, Antigua achieved real GDP growth rates of 1.7% and 3.3% respectively. Meanwhile the other countries of the Eastern Caribbean were suffering negative growth rates. The estimated real growth rate in 1984 was between 4.5 and 5.0%, and in 1985 it is expected to exceed 6.0%. Between 1983 and 1984 tourist arrivals increased by 30% and initial figures for 1985 indicate a further 16% increase. With a population growth rate of only 1.3% per year, Antiguans have been able to enjoy a fairly steady increase in standard of living. The per capita GDP of $1,700 is the highest within the OECS (except Montserrat).

However, Antigua demonstrates a demographic profile which is worrisome. Although population growth has held fairly steady at 1.3% per year, the numbers of persons entering the labor force for the next ten years will be inordinately high due to earlier high fertility factors. It is estimated that some 10,000 persons will be added to the total labor force within the next five years. Contractions in manufacturing, agriculture and fisheries have affected unemployment and both government and the private sector are seeking new avenues for investment. Particular attention is being given to activities in the productive sector which will have important *multiplier effects such* as tourism promotion, manufacturing investment promotion, small enterprise assistance and assistance with the production, processing and marketing of food products, including livestock and fisheries, consumed in the tourist sector.