Who Will Control the Blue Revolution? Economic and Social Feasibility of Caribbean Crab Mariculture

Article *in* Human Organization · December 1990

DOI: 10.17730/humo.49.4.r1201168042n1t68

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Human Organization, Vol. 49, No. 4, 1990

0018-7259/90/040386-09$1.40/1

Who Will Control the Blue Revolution? Economic and Social Feasibility of Caribbean Crab Mariculture

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New mariculture technologies that use "appropriate" technology or rely on the natural productivity of the oceans to supply feed sources for seafood farming in coastal waters are being developed. These technologies may be feasible for small-scale commercial mariculture projects implemented by fishermen-farmers in developing countries. This article presents research data regarding the economic and social feasibility of the adoption of a new mariculture technology by artisanal fishermen in two small fishing villages in Antigua and the Dominican Republic in the Caribbean. The technology involves growing algae on offshore screens and feeding it to Caribbean spider crabs (*Mithrax spinosissimus*) raised in offshore cages. The research indicates that the adoption of crab mariculture by fishing crews is feasible because they have requisite values, skills, corporate resources, market relationships, and territorial rights. However, fishing crews may lack start-up capital and may require visible evidence of technological feasibility before adoption. If fishermen make a commitment to mariculture, their new activity may conflict with other relationships in their villages and they may catch fewer subsistence fish for local and urban markets.

Key words: aquaculture, fishermen, technology transfer

NEW SEAFOOD FARMING TECHNOLOGY combined with Third World development initiatives may herald the dawn of a "blue revolution," a term used by Miller (1985) to describe the Smithsonian Institution research on new methods of seafood farming based on the natural productivity of the oceans, and by Bailey (1985) to describe technological innovations for Third World fisheries. Like its predecessor, the green revolution, the blue revolution employs new technologies in the production of new food species, thus reducing hunger and increasing economic self-sufficiency. Also like the green revolution, the blue revolution has the potential to cause social and cultural changes.

The blue revolution in this article refers to seafood farming or mariculture in coastal waters using "appropriate technologies," low cost or locally available materials and practices familiar to artisanal fishermen, or the natural productivity of the oceans to supply feed sources. The combination of appropriate technology and low operating costs may make these technologies feasible for small-scale commercial mariculture projects implemented by fishermen-farmers in developing countries.

Investors, businesses, governments, artisanal fishermen, and international aid agencies recognize the development potential of blue revolution technologies: food for local and tourist consumption, jobs, exports, and foreign exchange earnings. Mariculture could also supplement or replace fishermen's income lost by declining catches due to overfishing.

Who will implement, control, and derive the major benefit from blue revolution technologies? Local fishermen, national governments, international corporations, or joint ventures between local and foreign businessmen are all possible adopters. Artisanal fishermen currently utilize the reefs, bays, and coastal waters where the new mariculture projects will be located. The fishermen will either be moved aside by the new projects, participate as hired labor in seafood companies, or adopt the new technology themselves.

One of the most publicized blue revolution technologies in the Caribbean during the 1980s was developed by the Smithsonian Institution. The technology involves growing algae on offshore screens and feeding it to Caribbean spider crabs (*Mithrax spinosissimus*) raised in offshore cages. The commercial potential of a *Mithrax* mariculture appeared to be promising for several reasons if the technology could be successfully developed. *Mithrax* crabs might command very high market

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prices because they look and taste like high value king crab species. In addition, using algae as the crab's primary feed source might avoid the need for expensive commercially prepared feeds.

The United States Agency for International Development (AID) invested several million dollars in three crab mariculture research efforts. One was conducted by the Smithsonian in the Turks and Caicos, Antigua, and the Dominican Republic; a second by the Harbor Branch Foundation in Antigua and Florida; and a third by a private company in Grenada. Private companies have also started crab pilot projects in Turks and Caicos and the Dominican Republic, and crab research has been undertaken in Martinique.

Local artisanal fishermen living near the sites of these public and private sector projects participated in, have been directly affected by, or may be affected by these crab projects. The potential for fishermen to adopt the crab mariculture technology was one of the primary justifications for AID funding these research efforts (Adey 1983, Stoffle 1986).

This article presents research data regarding the economic and social feasibility of Caribbean artisanal fishermen adoption of crab mariculture. The research focuses on two Caribbean countries and two small fishing villages near the Smithsonian crab project sites, Willikies in Antigua and Buen Hombre in the Dominican Republic. (See Figures 1 and 2.)

The research indicates that the adoption of crab mariculture by fishing crews may be feasible because they have requisite values, skills, corporate resources, territorial rights, and market relationships. However, the research cautions that the fishing crews may lack start-up capital and may require visible evidence of technological and economic feasibility before adoption. If fishermen make a commitment to mariculture, their new activity may conflict with other relationships in their village and they may catch fewer subsistence fish for local and urban markets.

Examples of Blue Revolution Technologies

Several mariculture research and development projects may become commercial ventures in the Caribbean during the next

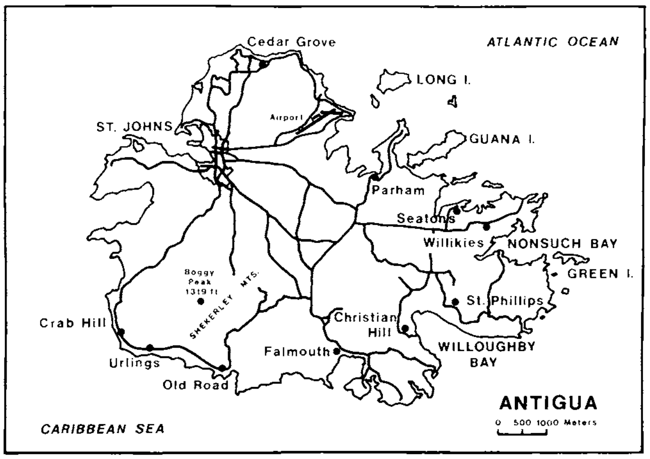

FIGURE 1 ANTIGUA

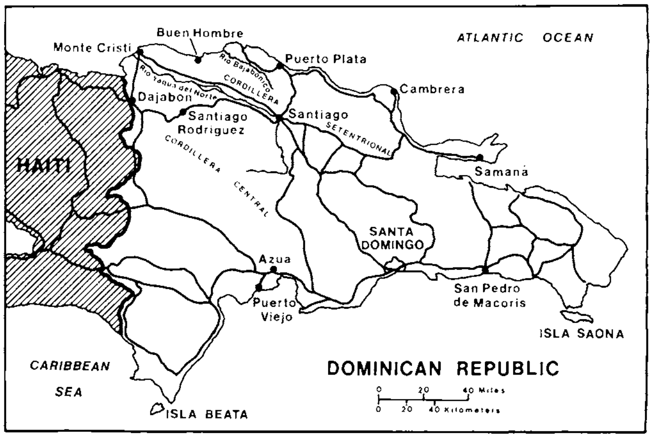

FIGURE 2 DOMINICAN REPUBLIC

few years. The Caribbean has been chosen as a place to test new technologies because the subtropical environment of the region's bays, lagoons, and reefs provides excellent conditions for seafood farming. Technologies under development include mariculture in or on cages, rafts, and other floating devices and on the seabed.

Cage culture species include finfish, lobsters, spider crabs, shellfish, and seaweeds. The Association for the Development of Aquaculture in Martinique (ADAM) and the French Institute of Research for the Exploitation of the Sea (IFREMER) are pioneering low cost cage culture production of the European sea bass (*Dicentrarchus labrax*), snapper (*Lutjanus* spp.), redfish (*Scianenops ocellatus*), tilapia, and other finfish (Marion 1986a). ADAM's program includes fishermen training and demonstration projects. In Antigua, Harbor Branch Foundation developed a method of recruiting juvenile spiny lobsters from the wild on screens in reef areas and then raising the lobsters in cages to market size (Winfree et al. 1988). Cage culture techniques designed for salmon in cold water regions and for yellowtail (*Serolia quineradiata*) in Japan are being applied to warm water species such as mahi mahi (*Coryphaena*) (National Research Council 1988).

Raft culture of mangrove oysters is conducted in Cuba (National Research Council 1988) and has been tested on a pilot scale in Jamaica. A variety of floating devices such as plastic screens and ropes are used to culture species of algae and seaweed for use in a variety of preparations. The seaweed *Gracilaria* is cultivated in bays in St. Lucia on nylon ropes held together by bamboo rafts (Rakocy and Hargreaves 1986). The seaweed is used in "sea moss," a Caribbean beverage.

Mithrax mariculture has combined algae and crab culture. As techniques for *Mithrax* mariculture are still at the research or commercial pilot stage, a variety of technical approaches are being used. The Smithsonian Institution's Marine Systems Laboratory (MSL) pioneered *Mithrax* mariculture technology with projects in the Turks and Caicos, the Dominican Republic, and Antigua from 1983–1986. MSL cultivated crabs in underwater cages. Gravid females (initially obtained from the wild) are placed in wood frame cages (1 m by 0.5 m by 0.5 m) covered with a fine plastic mesh. After the hatch of 5,000 to 80,000 eggs, the female is removed and the cage is left undisturbed for 50 or more days. MSL reported that 100 to 1,000 juveniles from each hatch survive to 100 days old, a number sufficient to stock two m^3 growout cages to a density of 50 crabs per cage. The crabs reach harvest size of two kg after one to two years of growth. Survival rates of growout cage crabs following stocking were reported to be 50% (Adey 1985).

Algae, the crab's primary food source in the MSL method, is cultivated on plastic mesh screens suspended from lines floated on the landward side of a coral reef. The reef wave action and nutrients provide conditions conducive for algae growth on the screens. During the crab's growout stage, algae-covered plastic mesh screens are fitted into the cages. The screens are replaced every three days as the crabs consume the algae.

Crab culture using algae as a food source is labor intensive: screens must be periodically rotated from cages to algae growth areas and screens and cages must be scraped and well-maintained. A 20 cage operation requires 800 screens in the water or in cages. MSL and others estimate that a 20 cage operation will require five man hours per day of labor.

Variations of the MSL method have been tested. On land, hatchery production of juvenile crabs has been demonstrated in Florida (Winfree et al. 1988) and Martinique (Marion 1986b). In addition, other projects are experimenting with prepared commercial feeds in addition to or as a replacement for algae because algae alone may not provide a nutritionally complete diet for the crabs.

Economic and Social Feasibility Studies of Crab Mariculture: Research Questions and Methodology

The authors conducted intensive field studies in mid-1985 in Antigua and the Dominican Republic and followed *Mithrax* mariculture developments during 1986–1989. AID initiated economic and social soundness analyses of potential fishermen adoption of crab mariculture at two Smithsonian MSL crab mariculture research sites in 1985. At the time, MSL's research was approaching its third year of AID funding and six research or pilot projects were planned or under way. The original MSL research was conducted on Grand Turk and South Caicos Islands. Willikies in Antigua and Buen Hombre in the Dominican Republic were relatively new research sites selected by MSL on the basis of scientific criteria for algae and crab culture.

The economic and social soundness analyses were funded and conducted separately. This permitted independent assessment of the two sites. Each study team collected its own data, although some data were shared while in the field during site visits in July and August 1985 (the amount of time in the field was dictated by research budget constraints). The authors arrived at similar conclusions concerning fishermen adoption of crab mariculture (Rubino et al. 1985, Stoffle 1986).

The economic study included a financial analysis of large and small scale crab operations, a review of crab market potential, and an analysis of the economic constraints and incentives associated with fishermen production in the two countries. Estimates of small scale project net revenues were compared to field data estimates of current fishermen income. To gather the production, cost, market, and income data, over 200 interviews were conducted in both countries with fishermen, middlemen, hoteliers, businessmen, operators of processing and export companies, government officials, and MSL staff.

The social feasibility study collected data using ethnographic methods, especially key informant interviews and participant observation. Primary documents like fishermen's records were used when available. In Antigua more than 100 interviews were conducted with fishermen, fish marketers, local village residents, and government officials. One three-man crew in Willikies was interviewed in depth and their fishing and marketing activities were observed over a three-week period. Almost 200 interviews were conducted in the Dominican Republic especially in Buen Hombre, and an interview schedule was administered to all 45 members of the Buen Hombre Fishermen's Association.

Since 1986 three nonprofit institutions and several small corporations have worked with *Mithrax* projects. The authors followed the developments of these groups and companies by interviewing the project principals and others who had visited project sites and by making site visits to a few of the projects during 1986–1989.

In addition to their research questions, the authors brought to their work a series of questions derived from previous scientific studies of mariculture, aquaculture, and fisheries technology adoption in developing countries, especially in the Caribbean and Latin America. These studies suggest the importance of the following issues: territoriality (Acheson 1972, 1975); fit with existing social structures (Epple 1977); use of and impact on local market relationships (Acheson 1981; Epple 1977; Forman and Riegelhaupt 1970; Pollnac 1981, 1982; Kottak 1983); relationship to occupational multiplicity (Comitas 1973); theft of fish pots (Berleant-Shiller 1984, Thompson 1945); the contribution of subsistence activities (Burpee et al. 1986, Mintz 1956, Smith 1977); adequacy of risk capital (Christensen 1977); competition between artisanal fishermen and larger fishing operations (Berleant-Shiller 1981, Faris 1977); and individual versus cooperative adoption and the allocation of the benefits from new technology (Epple 1977; McCay 1980; Peterson 1982; Poggie 1980a, 1980b; Poggie and Gersuny 1974; Pollnac and Carmo 1980). Previous studies generally conclude that seafood farming projects are more likely to achieve their goals if the local community is involved in project design and implementation, the technology is "appropriate," and local people directly benefit from the technology.

Site Specific Characteristics

The physical, economic, and social characteristics of the two sites differed, but the structure and function of fishing crews, the multiple occupations of fishermen, the types of fish caught, and the seafood distribution patterns were similar in many ways for both villages. The Smithsonian projects were sited in offshore waters of bays protected by coral reefs near the two fishing villages.

Because Antigua is a small island, fishermen of Willikies and other fishing communities live and work close to their markets: the public fish market in the city of St. John's, tourist hotels, and international exporters. Most fishing crews operate eight meter boats with 40 horsepower outboard motors and sails. Fishing is conducted up to several miles offshore by means of fish pots, long lines, and diving. The village of Willikies, an active fishing center, appears to have participated in the general economic growth of Antigua. Fishermen live in wood frame or cinderblock homes and possess electric appliances. Some own motorbikes and automobiles.

Buen Hombre is a remote fishing village of about 855 people located on the north coast of the Dominican Republic. In terms of housing and material possessions, this is a poor village relative to other villages in the country and the Caribbean. Potable water is hauled over nearby mountains by truck or donkey, houses are of wood and mud construction, there is no electricity, and the dirt roads are periodically impassable. But, from the standpoint of diet, health, community stability, and public safety, the people of Buen Hombre appear to have a higher quality of life than other poor areas observed in the country. Many foods, including meats and fish, are produced by the villagers themselves. The ten fishing crews that operate out of the village possess eight boats (four to seven m) with sails and four motors in various states of repair. Most fishing at the time of the study was either nearshore or reef fishing using lines, nets, and diving. Fishermen are connected to markets by two middlemen who visit the village once a week with a truck and by several middlemen with motorscooter transport.

Fisherman Adopter Groups

In both countries studied, local fishermen can be placed into three categories: subsistence, mixed, and large vessel commercial. Each of these categories is defined in terms of a combination of factors: equipment used, structure of the production unit, time committed to fishing, and primary goals. Mixed fishermen conducted their fishing as members of two to four man crews who work together on a regular basis and fish up to five times per week, weather permitting. They are oriented toward both subsistence fishing and the commercial market. Mixed fishermen are distinguished from large vessel (over ten m) fishermen based out of a deep water port who fish solely for the commercial market and from subsistence or part-time fishermen who eat or trade all that they catch. In Antigua, 43% of the island's fishermen were of the mixed type, 43% subsistence, and 14% commercial (Simon 1983). Willikies included mixed and subsistence type fishermen. The members of Buen Hombre's Fishermen's Association belonged to mixed fishing crews.

The research data presented below in this article suggest that crab mariculture adoption by fishermen is most likely to occur amongst the mixed fishermen who reside in a village overlooking a bay where *Mithrax* cages could be tended. While individual subsistence fishermen have many of the skills, values, knowledge, and interests required for successful adoption, tending crab cages and screens on their own without assistance would likely be impossible. Crab culture by large vessel fishermen (vessel owners or skippers) would be similar to mariculture by any other business group with access to capital or bank financing that does not live and fish in proximity to the mariculture site. Commercial fishing enterprises may not be pursuing crab mariculture because the technology is unproven. Research data examining potential mixed fishermen adoption of crab mariculture include a financial analysis of crab mariculture, a comparison of current fishing income with potential crab mariculture income, social and cultural variables, and significant constraints to mixed fishermen adoption.

Financial Analysis

A preliminary financial analysis of two likely scales of crab mariculture was conducted to determine if adoption might be financially viable (reported in detail in Rubino et al. 1985). A 20 growout cage operation that could be implemented by a mixed fishing crew and a 1,000 growout cage project large enough to support a commercial processing plant were examined. Other scales are possible, but the large and small scale models provide indicators with which to evaluate financial feasibility. The determination of profitability in a "financial" analysis is from the accounting perspective of the private sector business. Gittinger (1982) provides project analysis methods and definitions.

The analysis was based on average production figures reported by MSL researchers (including four lb or 1.8 kg harvest size after one year of growth, stocking of sixty 60 to 100 day old juvenile crabs per two m^3 growout cage, and survival after one year of 50 crabs per cage for a commercial operation, 35 in wood cages for a fisherman operation in Antigua, and 25 in bamboo cages for a fisherman operation in the Dominican Republic); likely market prices for *Mithrax*; production costs gathered at both sites; and availability of start-up capital or loans (20 cage operation obtains loan for all of start-up costs, 1,000 cage operation obtains loan for 60% of capital costs). All monetary figures were expressed in 1985 United States dollars.

Given these assumptions, the financial analysis shows that both large and small scale *Mithrax* mariculture may be financially viable. Financial and production indicators for a 20 cage operation in Antigua were: capital costs $6,500, yearly operating costs $4,000 (including capital debt repayment), production per year 2,800 lbs (6,200 kg) of whole crab, sale price whole live $2.50 per lb ($5.50 per kg), net yearly revenues $3,000, breakeven price per pound $1.42, payback period on capital two years, and project internal rate of return 46% (without financing assumption). (Internal rate of return is a measure of the rate of return on capital invested in a project.) Returns for a 20 cage operation in the Dominican Republic, where costs and prices were lower, were similar.

Indicators for a 1,000 cage operation with a processing plant in Antigua were: capital costs $600,000; yearly operating costs $415,000 (including capital debt repayment); production per year 200,000 lbs (90,700 kg) of whole crab, 75% of crab processed into meat, 25% into sections; sale price meat $12.00 per lb ($26.46 per kg); sale price sections $6.00 per lb ($13.25 per kg); net yearly revenues $184,000; project internal rate of return 23% (without financing assumption); and payback period on capital three years. Returns for a 1,000 cage operation in the Dominican Republic, where costs and prices are lower, were similar.

The product form, the marketing structure, and the target market will affect the price of *Mithrax* produced in the Caribbean. Each species of crab has different types and qualities of meat, each of which bring different prices ranging from a few dollars to over $30.00 per pound of meat. Prices captured by *Mithrax* producers of at least $12.00 per pound ($26.00 per kg) for picked meat or $4.00 per pound ($8.67 per kg) for live crab may be necessary for mariculture profitability.

The financial viability of mariculture usually depends upon two key variables: sale price and product yield (which in turn depends on survival and growth rates and stocking density). Sensitivity analyses show that relatively small changes in yield and market price could make *Mithrax* mariculture either very profitable or a financial failure. Therefore, marketing to obtain high sale prices, careful management to increase crab yields, and cost efficient cage designs may create the conditions for profitable *Mithrax* operations. However, the operations will have little margin for lower crab survival rates (than those used in the assumptions) or losses due to natural disasters, theft, poor management, or unproductive labor, if the expected sales prices and MSL projected yields are not obtained. A review of the MSL research and Rubino et al.'s (1985) financial analysis reinforced the conclusions of the sensitivity analysis and suggested that the MSL yields might be difficult to achieve and that high operating costs due to storms and theft might make crab mariculture unprofitable (Idyll and Caperon 1986).

A comparison of fishermen net cash income from fishing with potential net income from crab mariculture provides another indicator of economic feasibility. Net income from a 20 cage operation operated five man-hours per day for 365 days per year (1,825 hours per year) was estimated to be $3,000 per year in Antigua. Current net income estimated from field data per mixed crew fisherman realized by fishing 150 days per year 12 hours per fishing day (1,800 hours per year) from small boats was $2,430 to $4,207 per year. In Buen Hombre, net income from crab farming was estimated to be $1,800 compared to net fishing income per crew member at $1,000 to $1,700 per year (from fisherman association records). Net cash income from fishing and potential net income from crab mariculture per hour of effort were therefore roughly equivalent. The comparison points out that the fishermen may not abandon a known source of income for a new activity unless they can include it in some combination of their current activities and unless subsidies or other incentives are made available for crab mariculture.

As in any production or financial analysis, the results depend upon the assumptions used. The financial analysis was based on production numbers from research projects, not commercial operations. Therefore, the analysis provided only a general indication of the costs and revenues from *Mithrax* mariculture and the critical production of economic variables that affect profitability. Financial statistics or feasibility analyses from the fledgling commercial operations in the Dominican Republic and Grand Turk are proprietary and were unavailable to the authors.

Social Characteristics of Mixed Fishing Crews Supporting Crab Mariculture Adoption

Current economic activities and social and cultural variables indicate many factors supportive of mixed fishing crews adoption of crab mariculture.

SKILLS. Fishermen have many of the values, skills, understandings, and experience required for the adoption of the mariculture technology. Fishermen are already farmers engaged in vegetable and crop production during non-fishing days. They also routinely hold and feed captured spiny lobsters in wooden and wire cages.

CORPORATE STRUCTURE. Fishing crews have corporate resources and responsibilities, mechanisms for replacing members, trust among members, and legitimacy in their villages.

INTEREST. Fishermen at both sites conveyed a positive attitude toward the idea of crab mariculture and proposed the fishing crew as a unit of adoption.

OCCUPATIONAL MULTIPLICITY. The mixed fishing crew members are involved in a wide range of subsistence, cash, and barter activities designed to assure the maintenance of themselves, family, and friends (described in detail in Stoffle 1986). The term "occupational multiplicity" describes the web of subsistence and economic activities that constitutes the adaptive strategy of a person (Comitas 1973). The term aptly describes the activities of many fishermen in Antigua and the Dominican Republic.

Mixed fishermen crews are not likely to fish more than 150–180 days per year because small boats limit mobility in rough weather. During non-fishing days, they repair equipment, farm vegetables, drive taxis, or engage in other trades. Fishermen could fit crab mariculture into their current fishing and multiple activities. If they adopt crab mariculture, the fishermen may eliminate some adaptive tactics or adjust their levels of commitment to certain activities. The time required to tend 20 cages may replace an existing activity. Another possibility is that the number of crew members may expand to accommodate an increased number of crew activities. Current part time or replacement crew members may become full time crew members with responsibility for crab cage supervision. This is what occurred at the MSL Buen Hombre project in 1986–1988. Members of fishing crews hired by MSL to work on the crab pilot project continued their fishing crew activities. The entire fishing crew added crab farming to their daily routine and part time fishermen were added to the crew.

The fishermen's crew, extended family, and village will likely support fishermen mariculture efforts by providing additional and replacement labor and protection against theft.

TERRITORIAL RIGHTS. Fishermen have informal territorial fishing rights to the bays and reefs near their villages. A fishing village or group of fishermen currently "own" and exclude other fishermen from the bays and reef areas they fish. Mariculture projects started by persons who are not fishermen will likely have to work with, make arrangements with, or hire fishermen living and working in the area where an operation is established. Field data and previous research indicate that fishermen may disrupt activities located in their traditional fishing areas or that fishermen may be displaced from fishing by mariculture activities (Bailey 1988; Berleant-Shiller 1984).

MARKET CONNECTIONS. Mixed fishermen have established market connections. Fishermen may be able to sell *Mithrax* through their existing market distribution networks for lobster and first class fish. In Buen Hombre, fishermen sell to middlemen. In Antigua, fishermen make direct sales to hotels and restaurants and sales to middlemen and exporters.

Constraints to Fisherman Adoption

The fishermen at both sites pointed out the major constraints to fisherman adoption of crab culture. They indicated that they would require visible evidence of technical feasibility and market demand, grants or loans for start-up costs, and the assurance of government extension agent assistance, before they would risk the time commitment to crab farming four to five man-hours per day for at least one year and perhaps two years before cash returns are realized. Fishermen are not likely to replace their current activities with a highly risky venture of unproven technology that is not likely to earn them more net income than their current activities. The financial analysis outlined above indicates that net cash income per hour of effort from fishing and potential net income crab mariculture are roughly equivalent.

DEMONSTRATE TECHNOLOGY. *Mithrax* mariculture research and development has been under way for less than a decade. Fishermen have seen no evidence of successful crab mariculture and are understandably reluctant to undertake the risks of developing a new technology. Visible and successful commercial or government demonstration projects may induce fishermen to adopt crab mariculture technology.

CAPITAL NEEDS. Crab mariculture will require fishermen or others willing to make an initial capital outlay and tend crab cages for one to two years before sales of market size crabs can be made. Most mixed fishing crew members lack cash savings and would not be able to venture the risk capital to pay for their own crab mariculture start-up equipment.

Interviews with local commercial bank officials indicated that loans for mariculture are likely to be unavailable to fishermen who typically have no credit history, or assets, or are perceived to be poor credit risks. If bank loans were available, the interest rates (greater than 20%) could be prohibitively expensive. Bank officials also said that *Mithrax* mariculture would have to be proven on a commercial scale before bank loans would be made available to any investor.

TECHNICAL AND INFRASTRUCTURE SUPPORT. Most Caribbean countries lack the infrastructure that may be necessary to support mariculture. Government research, laboratory, extension agent, and training program services; commercial processing and transportation facilities; and availability of qualified seafood farming technicians form the basis of seafood farming industries in other countries.

MARKET DEVELOPMENT. While the market potential of *Mithrax* is high, marketing programs may be required to raise the wholesale prices to levels required for profitable mariculture. Although existing marketing systems will provide the means to distribute small volumes of *Mithrax* in Antigua and the Dominican Republic, processing, refrigeration, and transportation facilities will have to be expanded to market and export the production emanating from numerous projects.

A review of the local and export market potential of *Mithrax* underscored the marketing needs. A local market for *Mithrax* exists in the Dominican Republic where hotels and restaurants do their own processing. Wholesale prices for *centolla*, the local name for *Mithrax*, are low relative to spiny lobster due to the low volume and poor delivered quality caused by lack of ice. Although *Mithrax* is not sold in the Eastern Caribbean due to lack of wild supply, a gourmet food product market could be developed to meet the high demand for seafood by the tourism industry. Sales of *Mithrax* may be limited in Antigua by the hotels' demand for processed seafood. Some hotel managers cited the high labor costs of picking crab meat in hotels. *Mithrax* received a positive initial response from buyers in the United States (Miller 1985) where crab meat prices vary by species from $4.00 to $27.00 per pound wholesale. The high international market prices commanded by the large size king and spider crab species will assist the development of *Mithrax* mariculture.

POTENTIAL IMPACT ON CHANGED FISHERMEN MARKETING RELATIONSHIPS. Crab farming may change the relationship of fishermen and their market outlets. Mariculture may allow fishermen to time and stagger crab production cycles and the sale of crabs to maximize their economic returns. Sales could be timed to coincide with the influx of tourists during the winter months, for example. The ability to decide when to sell crabs may provide fishermen with greater market and price setting power vis-à-vis middlemen and consumers than they currently have with fish and lobsters. Rubino and Stoffle (1986) traced the impacts of crab mariculture on traditional seafood distribution.

POTENTIAL ADVERSE SOCIAL IMPACTS. Is fishing activity likely to decrease if fishermen adopt crab mariculture? Will crab culture provide additional cash income that will replace a noncash in-kind economic activity? Will a sufficient quantity of second and third class fish continue to be caught for village food? These are some of the social impact issues raised by the introduction of a new mariculture technology. Fishermen are likely to continue fishing for subsistence and cash needs even if they adopt crab mariculture, but the volumes and types of fish caught may change. If crab production precludes sufficient production of third class fish, it is expected that this portion of the fishermen's or village's market will be curtailed or eliminated and the poor will have to find alternative sources of inexpensive protein.

Pilot and Commercial Mithrax *Projects*

Private, nonprofit organization, and government *Mithrax* projects during 1986–1989 illustrate a range of crab mariculture implementation and fishermen participation scenarios. Information gathered during telephone interviews of project participants supports many of the conclusions of the studies at Willikies and Buen Hombre. In particular, fishermen have not adopted the technology because the technical feasibility has yet to be proven. Significant social and economic changes may have occurred at sites where fishermen were hired to participate in research projects. A social assessment restudy of Buen Hombre in 1989 examined these changes (Stoffle et al. 1990).

The Smithsonian *Mithrax* program during 1983–1986 was supported by AID in part because of the promise of fishermen adoption of the technology (Adey 1983, Stoffle 1986). AID also contracted Harbor Branch Foundation, a nonprofit institution, to conduct *Mithrax* laboratory and growout research in Florida and Antigua during 1986–1987. Only one of five AID supported research sites, the Smithsonian site at Buen Hombre in the Dominican Republic, included fishermen participation.

Fishermen in Buen Hombre were invited to become active participants in the Smithsonian research trials in late 1985 and continued their participation in 1987 and 1988 as responsibility for the project was transferred to three groups: the Government of the Dominican Republic, a nonprofit corporation called Natura, and the Buen Hombre Fishermen's Association. Eight fishermen from four of the ten fishing crews in the village were hired by MSL from late 1985 to May 1986 to tend crab cages and algae screens and to receive crab culture training. Fishermen's Association members demanded to be involved in the selection of the mariculture participants and indicated that one member of each crew should be hired to learn the technology. The participants were hired for four hours a day, five days a week, at 85 pesos per week. In addition, the participants were given use of several boats and motors. Several things occurred:

1. The crab culture participants continued to fish with their fishing crews.
2. The use of boats and motors doubled the means of fishing production in the village. Fishing crews shifted from near shore line and spear gun fishing to pot fishing in deeper waters.
3. In practice, one of the fishermen participants was absent from crab work each day. The other fishermen participants conducted the work of the absent participant, extending the mutual support system of the mixed fishing crew.
4. Fishermen participants introduced innovations to cage and screen design to improve durability and ease of operation.

In late 1986, a Dominican nonprofit group, Natura, took over responsibility for the project with the assistance of the Dominican Ministry of Agriculture. A Dominican agricultural engineer replaced MSL staff as site manager acting in effect as part extension agent, part project technical director. Natura financed crab cages and fish pots for each of the fishermen participants in the crab project. Financing was provided at low interest rates and with a year's grace period to permit cash flow generation from crab operations to materialize while they waited 16 months for their first harvest.

The Buen Hombre mariculture project was on the verge of completing its first production cycle when a series of externally derived events led to its termination in 1987. The agricultural engineer relocated the crab cages from an inner reef to an outer reef site against the recommendation of the local fishermen. Hurricane David extensively damaged the equipment and market size crabs in the cages. After the hurricane, the Dominican government attempted to restart the project by offering loans to the participating fishermen to repair the cages and equipment. In order to pay back the loans, the fishermen increased their fishing effort while continuing to maintain crab cages. However, the fishermen were unable to meet the loan repayment schedule and the government confiscated most of the equipment thereby ending the crab project. A social assessment restudy has documented the primary causes of termination, evaluated the accuracy of the 1985 social soundness analysis, and assessed the impacts of project termination (Stoffle et al. 1990).

Three private companies are undertaking crab mariculture pilot projects. Desarrollo Agronegocios, S.A. (Dansa) established a hatchery and growout site in the Dominican Republic near Azua, and West Indies Mariculture, Ltd. did the same on Grand Turk in 1987. Both projects were started by former MSL staff members. Dansa and West Indies Mariculture both reported successful hatching and growout to market size of *Mithrax* in captivity in mid-1988. Neither venture included fishermen participants, but both groups may hire fishermen to conduct growout activities.

International Fisheries, Inc., based in Jacksonville, Florida, started a *Mithrax* operation in Carriacou, Grenada. They obtained AID grant funds to build a processing factory shell and conducted algae and crab growout trials. MSL staff were active consultants to International Fisheries. Fishermen were to be hired and trained to provide the venture's labor force.

Conclusions and Recommendations

The blue revolution poses implementation and technology transfer issues similar to those encountered in the green revolution: who will implement and benefit from coastal mariculture technology, how will technology transfer occur, and what are the economic, social, and environmental impacts? Conclusions of the economic and social feasibility studies of *Mithrax* mariculture support much of the preexisting aquaculture, fisheries, and green revolution literature and raise new issues about fishermen adoption and technology transfer applicable to *Mithrax* and other blue revolution projects. While this article focuses on one mariculture technology, the findings concerning the feasibility of fisherman adoption of mariculture and the policy implications for mariculture development can be applied to many other species. The findings become even more pertinent as more and more mariculture technologies suited for coastal waters of developing countries become technically feasible and as the pressures to exploit coastal resources increase.

The authors' findings show that:

1. *Fishing crews are prime units of adoption.* The crews have a corporate structure, territorial rights to mariculture sites, and possess many of the skills required to conduct mariculture.

2. *Widespread adoption of mariculture will depend upon the success of one or more "real life" demonstration production units.* Before large-scale or a series of small-scale commercial ventures are attempted, commercial pilot projects operated by local businessmen and/or fishermen need to be undertaken to refine the technology, gain operational experience, prove the economic feasibility, and market the product. The public and private projects in Antigua, the Dominican Republic, Martinique, Turks and Caicos, and Grenada, may provide the concrete examples of successful *Mithrax* production that fishermen require before adoption of the technology.

3. *Economic incentives and government support may be required for fishermen or small local business adoption of the technology.* Mixed fishermen's lack of capital and local banks unwillingness to loan funds to fishermen for mariculture point up the need for government support programs that nurture the fishermen's initial efforts with financial (credits, loans, or grants) assistance, market development, and extension agent

programs. Government extension agent assistance should be especially available during the first few years of fishermen crew implementation of crab farming. Market development programs will stimulate market demand and may serve to raise crab prices to levels that support the mariculture. Such government credit and extension programs are similar to agricultural and fisheries programs throughout the world.

4. *Fisherman adoption of crab mariculture can have significant impacts on existing social, cultural, and economic structures.* Whether they eliminate some adaptive tactics or adjust levels of commitment, these changes will modify the fishermen's social relationships with members of their family, community, and market distribution networks. The effects of the integration of crab culture into fishermen's current set of fishing and other activities warrant further examination if successful operations are to be established. In particular, if fishermen participation in crab mariculture eliminates third class or subsistence sources of fish, will the mariculture project provide other sources of food or income to compensate for the community's loss? Other impacts to be considered include the following:

a. scale of project and influence on fishing village;
b. impact on crew structure such as expansion of fishing sector employment opportunities by expansion of crew size;
c. impact of new equipment and boats on the ownership and use of the means of fisheries production;
d. market distribution and fishermen, middlemen, and consumer interactions.

5. *Nonfisherman coastal mariculture will involve or affect local fishermen.* Fishermen will be displaced from traditional fishing areas or hired as wage labor by mariculture projects. Based on previous experiences, fisheries and mariculture projects that do not include or address the needs and concerns of local fishermen and their territorial rights are not likely to be successful in terms of financial or social soundness criteria. The success of crab culture by groups other than fishermen such as local or foreign companies may depend upon the involvement and approval of local fishermen.

6. *Other models, in particular, combinations of larger business and fishermen ventures, are possible means of mariculture implementation.* Several factors may force or provide incentives for different business and social groups to be associated in a crab mariculture production, processing, and marketing program. Economic development objectives and fisherman territorial rights and knowledge of local customs, materials, and coastal processes argue for fisherman adoption or participation in crab mariculture. The need for start-up capital, scientific expertise, and market development argue for the participation of companies with mariculture experience and access to capital.

7. *Fishermen should be involved in the technology development and pilot projects conducted by government and private sector groups in order to give both the technology/project and fisherman adoption the best chance of success.* The fishermen's detailed working knowledge of coastal processes and local materials and practices will contribute to effective project design and operation. Fisherman participation will reduce the chances of theft and project subversion because the fishermen have territorial rights to the coastal areas suitable for mariculture. Including the adopter groups in the operation and decision making process from the beginning will reduce the mistakes that have occurred in Caribbean fisheries development projects where fishermen were not fully consulted in advance of project implementation.

8. *Once fishermen are involved in the project, it should proceed in a manner that does not encourage an authority dependency relationship between project initiator/scientists and adopter groups.* This may be accomplished by gradually transferring more and more project decisions from the project initiators to the adopter businessmen and/or fishing group(s). Such an approach will help to eliminate the post-project authority, decision making, and knowledge void that has occurred in development projects.

9. *The inclusion of social, cultural, and economic analysis along with the technical research in the pilot projects will assist implementation of successful and accepted mariculture projects.* Consideration of potential adverse impacts on existing fisherman social and economic structures during project design may allow for the integration of mariculture into existing activities. As new information about production, price, and cost factors becomes available during research or initial adopter projects, the cash flow analyses can be checked to see the effect of the new information on cash flow and financial returns. In addition, social and cultural impacts identified during project implementation can be assessed relative to baseline data about existing and historical, cultural, and economic structures.

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