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THE TRANSITION TO MARICULTURE: A THEORETICAL POLEMIC AND A CARIBBEAN CASE

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INTRODUCTION

This paper addresses the prospect of mariculture becoming the dominant form of development and human adaptation in coastal marine ecosystems, especially those containing coral reefs.[1] Although the tone of the analysis is generally supportive of the transition to coastal economies based on mariculture, concern is expressed over how this development will occur without causing major social and ecological disruptions. Evidence from around the world demonstrates that the transition to mariculture can cause fundamental alterations of the human and natural resources in coastal marine ecosystems, while it also provides badly needed economic and food benefits (Bailey 1985, 1988; Meltzoff and LiPuma 1985, 1986; Pollnac 1990). Mariculture has been termed the "blue revolution" (Bailey 1985; Miller 1985; Rubino and Stoffle 1990) because it has such great potential for both beneficial and adverse impacts.

This analysis describes several social and ecological factors that should be considered in the design and implementation of mariculture projects, including both potential adverse and positive outcomes of the transition to mariculture. These factors are illustrated with case study data from USAID social and economic assessments of Smithsonian Institution mariculture pilot projects in the Caribbean islands of Antigua and the Dominican Republic (Rubino et al. 1985; Rubino and Stoffle 1989, 1990; Stoffle 1986; Stoffle, Rubino and Rasch 1988) and from two recent social and environmental studies of one Dominican Republic mariculture project site (Stoffle, Halmo and Stoffle 1991; Stoffle et al. 1990). Despite culturally sensitive management by Smithsonian personnel, including the participation of local people in the early stages of the project, the pilot effort was terminated.

Project termination was due to interacting social, cultural, technical, political and environmental factors (Stoffle, Halmo and Stoffle 1991). Nevertheless, termination of the pilot effort does not detract from our assessment that mariculture is a necessary development intervention for the protection of the coral reef and the economic well being of the coastal villagers.

The analysis concludes that the transition to mariculture can produce mutually beneficial developmental change (Gallaher 1968) and minimize adverse environmental impacts if (1) ecosystem-wide social and environmental assessments are conducted before mariculture projects are established, (2) the sovereignty and knowledge of locally affected human populations are recognized and incorporated into the development process, and (3) ecosystem-wide monitoring of key transition variables is established for mariculture pilot projects.

THE TRANSITION TO FOOD CULTURE

It can be argued that the transition to mariculture contains the same inherent potential for positive and negative social and environmental impacts that is associated with the transition to agriculture. As such, it is possible to anticipate potential mariculture impacts, with the goal of maximizing benefits and minimizing social and environmental costs (Pollnac 1990:18). While analogs from agriculture can be used to anticipate problems, it is possible to draw insights from existing mariculture case analyses to assess the utility of agricultural analogs.

At the most general level, mariculture is to fishing and seafood collecting as agriculture is to hunting and gathering. Both transitions involve a food culture system that uses knowledge gained during the pursuit of naturally produced food products. Each transition is preceded by humans experimenting on a small scale with natural processes by capturing wild species and, for varying periods, raising them near to settlements. Each food culture system artificially replicates many aspects of natural food production processes.

The adaptive advantages of food culture practices over capture and collecting practices tend to revolve around issues of supply and access. At the most basic level, the ratio of energy expended versus energy captured is greater under food culture systems. In addition, variability in energy flow is reduced with food culture. These factors alone are sufficient to encourage the incorporation of food culture components into human adaptive strategies.

On the other hand, the transition to food culture often causes humans to reorganize their systems of labor allocation, restructure social stratification systems, reassess fundamental values, and modify land and ocean use practices. The transition can cause a number of unintended consequences such as exhaustion of natural resources used to culture foods, pollution of the environment near food culture areas, modification of the genetic structures of living organisms being cultured as well as of wild organisms due to release of cultivated species, increase in human populations due to increased fertility, and local population growth due to immigration caused by increased carrying capacity of the local natural environment.

Food culture adaptive strategies generally replace natural food capture adaptive strategies, despite adverse human and natural resource impacts. The rare exceptions to this pattern are instructive because they demonstrate that the trend toward food culture is not inevitable. However, unless the coastal marine ecosystem proves to have human or natural factors that will prevent food culture being established, the agricultural transition analog suggests that mariculture eventually will be established despite generating some adverse social and environmental impacts. Worldwide, for example, approximately half of the fish sold for human consumption was produced by mariculture or aquaculture (Nash and Kensler 1990:104). So the question is less should mariculture be established in coastal marine environments than it is when, how, and for whose primary benefit it will be established. Assuming this perspective, research should be directed towards providing data and generating dialogues to address questions of how the transition to mariculture can occur and still achieve human equity, minimal social disruption, and maximum protection of the physical environment.

SOCIAL AND ENVIRONMENTAL ASSESSMENTS OF MARICULTURE

Assuming the premise that mariculture will inevitably replace artisanal fishing as the major economic strategy in coastal environments, development agencies can either plan to reduce adverse human and environmental impacts by conducting social and environmental assessment studies in advance of project implementation or they can risk adverse impacts and project failure by implementing projects based only on technical and economic assessments (Cernea 1985; Kottak 1985). This portion of the paper argues for conducting social and environmental project impact assessments and for considering three key issues when designing these assessments.

Agencies charged with funding development efforts have realized significant achievements by incorporating social science into development planning (Cernea 1988; Pillsbury 1986). The World Bank, for example, recently formulated operational policies and procedures for assessing the socioeconomic and environmental effects of projects (World Bank 1990), most notably those that entail involuntary resettlement (Cernea 1988). Kottak's (1990:723) analysis of 68 World Bank rural development projects documented that attention to sociocultural factors pays off economically and that failure to do so often results in project failure. Fishery project managers too have begun to recognize the value of social and environmental assessments (Pollnac 1985; Talhelm and Libby 1987; Stoffle, Jensen, and Rasch 1987; Vanderpool 1987). Some researchers have even recommended specific guidelines for the assessment of mariculture projects (Siddall, Atchue and Murray 1985:43-49). These guidelines should be evaluated and modified where necessary by considering broader impact assessment models (Branch et al. 1984).

Study timing becomes the question once it is agreed that social and environmental assessments should be conducted. Partridge (1984:21-27) argues that baseline sociocultural studies should be conducted in the planning and design stages of development projects; a period that is often referred to as the "scoping phase" of the impact assessment process. Perhaps the strongest argument for conducting impact assessment during the scoping phase is that it can be used as a means of involving the "locally affected population," a term that will be discussed in detail later. Recent studies (Branch et al. 1984:5-9; Brown, Geertsen, and Krannich 1989:583; Cernea 1985:7-9; Rydant 1984:4) provide three rationales for early assessment: (1) social impacts begin when an area becomes designated as a potential location for a project, (2) initial consultation between the proposers of a project and local government representatives should reflect the actual distribution of the locally affected population, and (3) a locally affected population should be involved in the identification of key issues to be analyzed in a social impact assessment.

Brokensha and Riley (1989:352) point out that, for any fisheries development or resource management intervention, "[W]hat is needed is an understanding, first, of what local fishermen do." Eliciting information on local knowledge systems and resource management practices is an effective way to actively involve local people in the research process (Brokensha et al. 1980; McNeely and Pitt 1985).

There are extensive arguments for including social and environmental assessments with the technical and economic assessments of a proposed mariculture project, but it is beyond the scope of this analysis to present all of these arguments. There are, however, three key assessment issues that need to be considered when agencies are making this decision: (1) who is the *locally affected population*, (2) what ecosystem dynamics are involved, and (3) what is the *scale* of the project.

LOCALLY AFFECTED POPULATION "Locally affected population" is a term used to refer to people who live or work near the location of a proposed project. Social scientists who conduct social impact assessment generally agree that a locally affected population is a key analytical unit because these people potentially experience the most direct benefits and costs from a project. Studies suggest that a locally affected population can be influenced by (1) the type of project, (2) ethnic, racial, and gender groups with social or cultural ties to the project area and (3) the geo-political region within which a project is proposed. Ideally, all of these factors will be considered when identifying a locally affected population.

The Social Impact Assessment Program at the Institute for Social Research, University of Michigan has developed a new method for scientifically mapping the locally affected population associated with a project proposal (Stoffle et al. 1991). Research related to this topic suggests that the operational definition of a locally affected population should be inclusive because it defines the most sensitive of all the social impact assessment study areas and generally defines the political units of consultation between a locally affected population and the proposers of a project. Our studies suggest considering five criteria when seeking a definition of the locally affected population: (1) project awareness, (2) directness of impacts, (3) significance of impacts, (4) numbers of impacts, and (5) duration of impacts. Stoffle et al. (1991) should be consulted for a detailed discussion of these assessment criteria. Both positive and negative impacts should be considered for each of these criteria.

There are people who live outside the locally affected population who can be affected by a development project. These will be people who have social or cultural ties to the project area. Direct economic ties to the area may exist for people such as migrant laborers, traders, and transporters. Cultural or historic ties to the area may exist for people whose relatives or ethnic group members once resided in the area and, therefore, define it as an ethnic homeland containing sites of religious or historic significance. The assessment of impacts on these types of people is important and generally is included in regional, state, national, and international level studies.

INVOLVED ECOSYSTEM ECOLOGY The frame of analysis for the environmental assessment needs to be sufficiently inclusive to understand the whole ecosystem that will interact with the mariculture project. The ecosystem concept has evolved over anthropology's history as a scientific discipline (Moran 1984, 1990). Despite its limitations and the criticisms it has received, the concept of ecosystem is an important frame of analysis for contemporary development and resource management issues (Moran 1990; Rappaport 1990; Lees and Bates 1990). In fact, the current concerns over the human dimensions of global change provide a major challenge for social scientists to develop and apply ecosystem models that have policy relevance for solving practical problems (Moran 1990:25-27).

"Ecosystem" is generally defined as the "structural and functional interrelationships among living organisms and the physical environment within which they exist" (Moran 1990:3). The concept allows for a more holistic, level-specific analysis of complex human-environment interactions, including such factors as historical change and the ways in which humans actively manipulate and transform the environment over time and space. The limits of generalization in terms of level of analysis should, however, be taken into consideration.

Ideally, ecological research should proceed within a framework of "progressive contextualization" (Vayda 1983). Such a staged approach to research ultimately leads to a human ecology of a community, an area, or region that incorporates not only the adaptation of local human populations to their physical environment, but also to surrounding human communities and the political and economic forces that impinge upon them. It is in this context that all human populations are embedded (Partridge 1989).

For our purposes, the "coastal ecosystem" is defined here as a bounded spatial area, defined by community members or the "ecological population" (Rappaport 1990:51). Thus, like Rappaport (1968), we have defined the boundaries of the ecosystem using the concept of territoriality (cf. Moran 1990:22). The coastal ecosystem is composed of both marine and terrestrial units or components termed "ecozones" (Stoffle et al. 1990). Within these ecozone units are still smaller units termed "microzones." In other words, the analysis takes into consideration the "patchiness" of the environment and associated heterogeneity (Moran 1990:23). While it is recognized that each of these units are usually defined as individually bounded, functioning ecosystems (e.g., coral reef ecosystems) in a biological sense, mariculture impact data suggests that both terrestrial and marine ecozones are impacted, directly or indirectly, by development interventions. Consequently, social and environmental assessment studies should include analysis of both ecozones. Human activities influence changes in each ecozone and are in turn shaped by physical and biological changes in each. It is our contention that the human ecology of coastal communities is incompletely understood by analyzing activities in a single ecozone, such as the marine nearshore waters (Stoffle et al. 1990; Stoffle, Halmo and Stoffle 1991).

Ecological research demonstrates that marine and terrestrial ecozones are closely linked by biophysical processes. Human activities often alter these biophysical processes in both ecozones (Mosher 1986:244; Burbridge, Norgaard and Hartshorn 1988:5-7). In coastal marine ecosystems, human alteration of terrestrial ecozones frequently has negative consequences for marine ecozones (DuBois, Berry and Ford 1985). Deforestation of upland areas, for example, can result in increased surface runoff, sheet and gully erosion of hillslope soils and, ultimately, siltation of coral reefs through river systems. Such effects are well documented in coastal areas of Africa (Dubois, Berry and Ford 1985), Asia, and Latin America (Sidall, Atchue and Murray 1985). Consequently, linkages exist in patterns of land use practices and potential adverse effects on coastal marine ecosystems as a whole, as well as one or more of their components, both in biophysical and human terms.

As an example, the construction of mariculture projects often involves the conversion of salt flats or the clearing of mangroves for culturing ponds (Bailey 1988:35; Siddall, Atchue and Murray 1985). Mangroves function as natural buffers against wave action, nurseries for numerous varieties of fish and shellfish, and provide local people with resources. Conversion of mangroves to mariculture ponds can alter the biophysical functions of marine and terrestrial ecozones (Bailey 1988:35; Sidall, Atchue and Murray 1985:3; Burbridge, Norgaard and Hartshorn 1988:6-7), which in turn affect local economies.

SCALE OF PROJECT A major issue for international mariculture development planning has to do with the scale of investment and intervention. The concept of scale has several meanings, notably the scale of society or the number and intensity of human relations as defined by Wilson and Wilson (1968:25). For present purposes, scale refers to the "size" of the project. In this sense, project scale can include (1) the amount of space the project occupies, (2) the level of technology employed, (3) the number of workers or employees involved in the enterprise, and (4) the amount of money the project generates.

Mariculture can be developed on a large-scale, industrial basis with benefits accruing largely to the nation-state in terms of foreign exchange and export commodities. Mariculture also can be developed with the goal of providing coastal populations with new technology for increasing food consumption and generating cash income through small-scale mariculture projects (Molnar and Duncan 1989:29). The scale of the venture will influence the kinds of environmental, sociocultural, and economic impacts that will occur (Rubino and Stoffle 1989, 1990:389-393).

The issue of scale relates to another important issue, that of environmental protection. Size and scale of interventions will largely dictate the scale of environmental alterations necessitated by the mariculture project. Differential impacts on project beneficiaries and non-project populations potentially can exacerbate environmental exploitation. For example, large numbers of small-scale fishermen and fish farmers have been displaced by large-scale fish culture operations worldwide, thus forcing the former out of business. These displaced fishermen and fish farmers often choose alternative means of livelihood that have negative environmental consequences, such as charcoal making, which can result in increased deforestation in upland and mangrove ecozones.

Finally, Clark (1987) demonstrates the importance of different temporal and spatial scales for assessing the interactions of climate, ecosystems, and societies. He suggests that forecasting social, ecological, and climatic changes requires an integrated model that includes interactive data provided for micro and macro levels of analysis. Historical studies of selected aspects of the model and of selected local situations should help test hypotheses regarding the long-term, large-scale social or ecological processes on the vulnerability of systems to various forms of climatic variability (Clark 1987:369). One such case might be the impact of shrimp mariculture along the Pacific coast of Ecuador.

Many of the social, economic, and environmental impacts of both small and large scale aquaculture enterprises on various marine and terrestrial environments and activities have been summarized by Pollnac (1990). His discussion illustrates how development of such operations can adversely affect a variety of productive ecozones in coastal environments that, in turn, cause negative economic impacts and social conflicts among a variety of producers. These complex interrelationships need to be recognized and documented throughout the project cycle (Molnar and Duncan 1989:34-35) so that adequate mitigation measures can be developed.

THE CASE OF CRAB MARICULTURE IN BUEN HOMBRE, DOMINICAN REPUBLIC

The Marine Systems Laboratory of the Smithsonian Institution developed a new technology that involved cultivating algae on screens suspended in nearshore waters inside inner coral reefs (Adey 1983; Adey and Farrier 1989). Cultivated algae was then fed to *Mithrax* crabs (Caribbean king or spider crab). This method of mariculture occurred in the nearshore waters of the coral reef ecozone, and so it neither involved mangrove acquisition nor clearing. The mariculture was designed to be an appropriate technology so it could be adopted by small scale producers throughout the world. With USAID support, the technology was to be tried in various Caribbean pilot projects and then transferred to the Third World as an ecologically sound, sustainable source of subsistence and market seafood. Caribbean pilot sites included the Turks and Caicos, Antigua, Grenada, and the small village of Buen Hombre located on the north coast of the Dominican Republic.

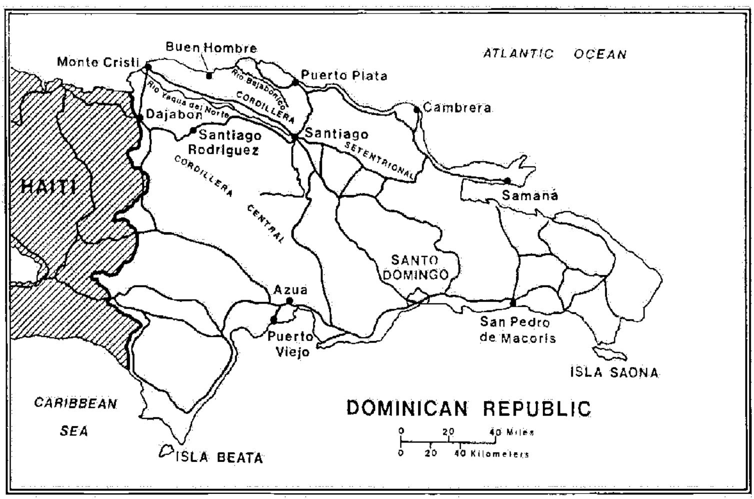

Figure 1. Map of Dominican Republic.

The northern coastal village of Buen Hombre was chosen as one of two pilot project locations in the Dominican Republic for researching and developing the new Smithsonian mariculture technology (see Figure 1). Smithsonian scientists preferred the Buen Hombre site because of environmental factors such as water quality, wave action and the excellent condition of the coral reefs off the arid north coast. The second pilot site was selected for the south coast near the town of Azua, and was to be combined with a hatchery and laboratory. The pilots were implemented to increase host country food production as well as generating additional foreign exchange by growing a seafood commodity for the export market (Rubino et al. 1985; Stoffle 1986).

The community of Buen Hombre had a population of about 900 in 1989, of whom there are approximately 55 adult males who identify themselves as farmers and about 45 adult males who identify themselves as fishermen. Few of the farmers occasionally fish, but all fishermen also farm. Fishermen-farmers in the community of Buen Hombre utilize two marine ecozones: (1) the tidal shore or littoral ecozone, which includes beach, mangrove, and lagoon microzones, and (2) the coral reef ecozone, which includes inner and outer reefs (Stoffle et al. 1990; see Figure 2). The microzones of the tidal shore ecozone are used for multiple purposes, primarily for the harvesting of several varieties of seafood species which nest and feed on the thick seagrass beds. Other resources such as wood for house frames and ornamental plants are gathered from the mangrove. The coral reef ecozone is where most traditional fishing activities take place.

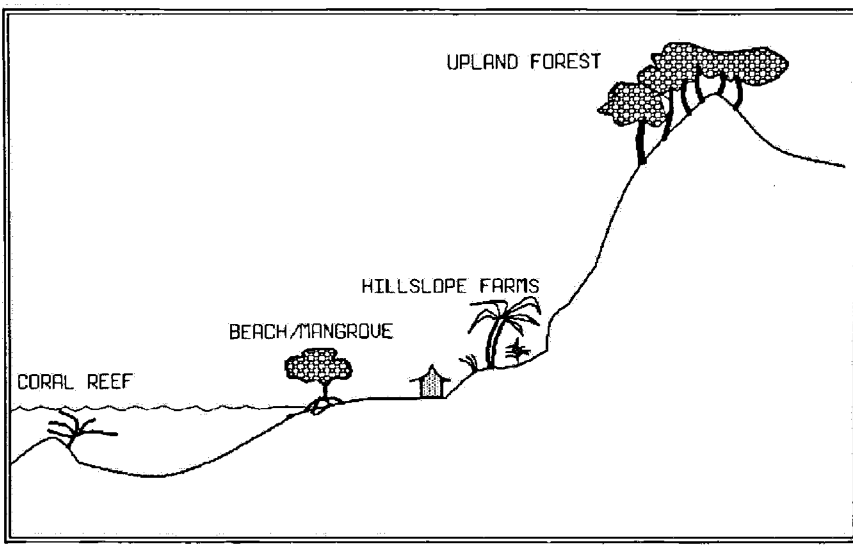

Figure 2. Ecological zones in project area.

Although the use of mangroves is legally prohibited, coastal villagers still use its resources in sustainable ways, occasionally collecting shellfish, decorative and medicinal plants, and occasionally cutting a wood preferred for the construction of roofbeams for houses. Villagers are cognizant of and obey the legal restrictions against killing the manatee and removing large amounts of plants from the mangrove. Local people informally regulate the use of the mangrove by both themselves and outsiders.

THE BUEN HOMBRE PILOT PROJECT In order to involve local people in the mariculture pilot project, ten fishermen representing an equal number of fishing crews comprising approximately 40 fishermen were selected and hired to work on the project. Project fishermen were trained by Smithsonian scientists to operate both the algae and crab culture portions of the technology.

The labor of the mariculture crews was designed to be like that of fishing crews where members share equipment, labor tasks, subsistence fish and income from commercial sales. Mariculture crews adopted the term *fincas del mar* ("farms of the sea") to describe their crab raising operations. Work on the mariculture project fit well into the preexisting sociocultural and economic system, which involved a social security system termed "occupational multiplicity" (Comitas 1973; Stoffle 1986; Stoffle, Halmo and Stoffle 1991).

Most village women had no relationship with the mariculture pilot, but two women did help their spouses tend the algae screens and the crab cages, and one woman prepared meals for the mariculture crews. In Buen Hombre, males are responsible for both fishing and marketing, which is unlike most of the Caribbean where men fish and women market the seafood catch.

The pilot project was designed to be turned over to local fishermen when it reached commercial production. Equity for other community members who did not wish to or could not participate in the mariculture pilot would be achieved by having a portion of the profits reinvested in the community, either to start new mariculture operations for other fishermen or to support other community development projects. Through reinvestment, all members of the community would benefit from the mariculture project (Stoffle 1986:118).

MARICULTURE IMPACTS ON ECOZONE USE Survey and focus group interviews were conducted in 1989 and 1990 to measure changes that had occurred during the pilot stage of the mariculture project.[2] Eight of the ten fishermen who worked on the project were interviewed along with a random sample of other fishermen and farmers in the village. The spouses of all men were also interviewed separately.

Change in Fishing Patterns The pilot mariculture project had some impact on the use of both marine and terrestrial ecozones. Thirty-eight percent of the project fishermen interviewed in 1989 reduced the amount of time they spent fishing so that they could concentrate their efforts on growing crabs. Twenty-five percent of these fishermen also changed fishing locations from the inner coral reef to the outer reef and deep water fishing (Stoffle, Halmo and Stoffle 1991). The mariculture project therefore reduced fishing pressure on the inner reef.

Change in Farming Patterns With regard to land-based activities, mariculture stimulated 25% of the project fishermen to take their land out of production by fallowing their fields. Another 25% changed the timing of agricultural tasks in order to allocate time to mariculture (Stoffle, Halmo and Stoffle 1991).

These findings indicate that mariculture can cause changes in land and marine components of coastal ecosystems by stimulating local producers to modify their array of economic activities in the system of occupational multiplicity. All of these changes were perceived by the fishermen and others interviewed to be positive both for the condition of the coral reef system and the fertility of the agricultural fields.

INDIRECT PROJECT IMPACTS ON THE COMMUNITY **The New Road** A seasonally impassable mountain road into the village was improved as part of the mariculture project. The road stimulated increased economic activity in the village of Buen Hombre by improving access to and from the village for seafood market intermediaries, vendors of outside commodities, and the villagers themselves.

The new road also facilitated access to the village by national and foreign tourists. Since the road was improved, there has been a rapid increase in land sales to tourists, who have built a number of large homes on beachfront property in the village.

A parallel but not directly related change during this period was an increase in the number of tourists in the region. Tourism is a rapidly growing industry on the north coast. Foreign tourists vacationing at a resort hotel in a neighboring fishing village have begun to engage in recreational tours of local mangroves and sand keys where they fish, snorkel, tour by boating, and water ski (Stoffle et al. 1990). The growth of these activities eventually may conflict with those of local fishermen and subject the ecozones to increased risk of degradation.

These examples illustrate that the transfer of mariculture technology does not occur in isolation. Often mariculture projects require additional inputs such as roads, buildings and other new equipment. Roads increase travel and population, and buildings require land acquisition and clearing for construction. Social and environmental assessments should account for these additional inputs to the project and their effects on coastal ecosystems and economies as well.

LOCAL SOVEREIGNTY Many nations officially define coastal marine areas as a common property resource, open to all in a given area in terms of access and use (Bailey 1988; McCay 1981; McCay and Acheson 1987). Acheson (1981:281) demonstrates that in many societies fishermen do have culturally recognized but nonlegal ownership of the marine resources. He suggests that local ownership rights reduce uncertainty associated with fishing and are not intended to protect or conserve the fish as much as to reserve the fish for local people. Berleant-Schiller's (1984:815) analysis of lobster divers in Barbuda, West Indies suggests that fishermen restrict outsiders from the coral reefs to conserve the natural resources more than to maximize personal profits. Whatever the intended purpose of local marine resource rights, it is essential to recognize that both local fishermen and the other members of coastal communities perceive marine ecozones as part of their community's territories (Cordell 1989a, 1989b, 1989c; Pollnac 1990).

The people of Buen Hombre perceive the beach, lagoon, mangrove, and the coral reef to be part of their community territory. Community boundaries extend roughly five kilometers in all directions from the main road through the village, so the northern boundary extends out to sea about five kilometers, encompassing both the inner and outer coral reefs and off shore shallow banks.

The mariculture project and its location were established with the permission of the Dominican Republic government, but members of the village were neither contacted for permission to conduct the project nor consulted as to where to locate the project. The Smithsonian research and project boats were anchored between the inner reef and the shore without consultation. The screens and cages were placed without local consultation. Portions of the beach were utilized for the storage of some equipment, but only with the permission of one property owner who was a tourist who had purchased the property from a member of the village. In general these territorial encroachments occurred without becoming a major problem for either the project or the villagers.[3] The process by which the project was located, however, set a precedent that local people perceived as inappropriate.

The encroachment by outsiders into the territory of the community was a common concern expressed by people in the village. Buen Hombre fishermen, for example, expressed concern that commercial fishing fleets from nearby coastal urban centers such as Monte Cristi were depleting the fishery by using illegal net techniques which capture all sizes and varieties of fish. Concern also was expressed over competition with other small-scale fishermen from neighboring coastal villages and with a group of farmers from a distant inland village who received new fishing equipment from a church-sponsored community development project. Fishermen reported in 1989 that the fish catch had reached its lowest point in 20 years and attributed this decline to outside encroachments.

LOCAL KNOWLEDGE AND PARTICIPATION The value of local knowledge and practice tends not to be appreciated by development technicians (Brokensha and Riley 1989). Small-scale fishermen have developed and maintained sophisticated systems of knowledge and management of marine environments and resources (Johannes 1981; Klee 1985; Polunin 1985).

Lack of appreciation of local knowledge and its incorporation into flexible implementation strategies was a key factor in the demise of the crab mariculture pilot project in Buen Hombre. Post-project social and environmental assessment studies conducted by the authors documented that local fishermen had innovative ideas for (1) improving growout cage design and construction, (2) incorporating multiple varieties of algal feed in crab raising, (3) creating new crab raising structures, and (4) locating the mariculture technology (Stoffle, Halmo and Stoffle 1991).

Fishermen working on the mariculture project suggested that a more efficient method of cage construction would be to insert horizontal screens in the sides of the cage. In this way, baby and juvenile crabs would be more easily able to move and feed on the algae rather than having to cling to vertical screens. Vertical cling feeding increased the risk of mortality due to crabs being shaken free by rough wave action, falling to the bottom of the cage and starving to death. Soft, developing shells and claws would be protected from damage caused by buffeting. To supplement feeding of young crabs, fishermen designed a circular opening at the top of cages through which algae could be hand fed to the crabs.

Project fishermen conceived of a *centolla* (crab) corral, constructed of wooden poles tied together with plastic screen placed around the interior. This corral would serve as a storage pen for market-sized crabs, and its placement near the mangrove would afford protection from severe weather and storms. The mariculture cages would be placed in natural openings of the mangrove.

Through many years of observing wild crab behavior, fishermen knew that crabs feed on a variety of algae types. Four types of algae were identified by local fishermen as being abundant in shallow waters inside the inner reef. They pointed out that three types were soft in texture and ideal feed for baby and juvenile crabs.

Because project fishermen perceived of themselves as eventual owners and operators of the technology, they took active steps to improve the mariculture operation. These innovations made the process more demanding in terms of labor commitment, but the fishermen were positively oriented to adopting the technology, and were willing to devote additional labor time to its operation. Innovations in cage design were partially implemented by the fishermen. During the later stages of the pilot project, however, the ideas and recommendations of project fishermen regarding location of the technology and other improvements were ignored or rejected by Dominican Republic project managers and technical staff.

ADMINISTRATIVE CONFLICT AND PROJECT TERMINATION As the mariculture project approached the threshold of commercialization in the summer of 1986, growing bureaucratic conflicts eventually resulted in the withdrawal of U.S. agencies from the mariculture project. The details of the process by which agency withdrawal took place are more fully discussed elsewhere (Stoffle, Halmo and Stoffle 1991). USAID turned administrative, managerial, and technical control over the project to the Fundacion Natura Dominicana, Inc. (NATURA). Dominican Republic Fishery Department staff were heavily committed to other responsibilities, so personnel were not available to oversee the project. With a supervisory void left in the wake of U.S. agency withdrawal, an agricultural engineer with some knowledge of freshwater aquaculture was assigned as the project supervisor by the Office of the Secretary of Agriculture, in response to a request by NATURA. He was assisted in supervisory tasks by a Peace Corps Volunteer who decided to build a school instead of working on the mariculture project.

Social Discontinuity in Technical Assistance and Supervision The new project supervisors made a series of fatal decisions due to their lack of familiarity with coastal mariculture and rapport with local fishermen. The supervisors stationed themselves on one of the project vessels, which was left anchored near the outer coral reef. Fishermen interviewed in 1990 indicated that the agricultural engineer could not swim and knew little if anything about coastal fishing systems. Consequently, over protests by local project participants, the mariculture technology was moved from its previous location inside the inner reef to the outer reef.

A storm surge hit the north coast of the Dominican Republic in late 1986 and, as predicted by local fishermen, the mariculture technology was destroyed and the crab crop lost due to turbulent waters well offshore in the outer reef. Soon after this event, and following a failed attempt to rebuild the project through credit in the form of loans to project fishermen which could not be repayed in the time allotted, the project was officially terminated (Stoffle, Halmo and Stoffle 1991).

Ironically, the Buen Hombre pilot project was on the verge of commercial success. By mid-summer of 1986, Buen Hombre mariculturalists had successfully raised near market sized crabs and so almost "closed the cycle" of achieving reproduction of crabs in captivity. This was the only Caribbean pilot site where such achievements had been realized.

EVALUATION AND RECOMMENDATIONS Economic feasibility studies of the Caribbean crab mariculture pilot projects indicated that various scales of operation could be adopted by fishermen-farmers. A projected small-scale operation consisting of 20 cages and 1,000 screens would produce an estimated 900-1,300 kilograms of crab per year, resulting in a net income equivalent to US $2,000 for Buen Hombre crab farmers. Income deriving from crab mariculture would be identical to income derived from fishing 150-200 days per year (Rubino and Stoffle 1989:139-140). The small scale project would also have allowed fishermen to continue some of their current traditional fishing activities and other economic commitments (Rubino and Stoffle 1989:141).

No single agency or decision was solely responsible for the termination of the mariculture project. While an uncontrollable, environmental event destroyed the mariculture technology, it was a series of decisions and actions on the part of all agency actors that resulted in an administrative, managerial, and technical atmosphere of conflict and competition. Such an atmosphere initiated the collapse of the project under the weight of bureaucratic conflict and misinformed, unilateral decisions without listening to knowledgeable local participants.

Today, forces that can destroy the Buen Hombre coral reef ecozone have been set into motion. Without intervention, the reef will likely be destroyed due to land and tourism development, overfishing, and population pressures. The social and environmental assessment studies suggest that regional events such as an extended drought, national events such as a stressed economy, and local events such as the rise of tourism can directly or indirectly cause the reef to die. These studies also suggest a plan for reducing the regional, national, and local stresses on the coral reefs by (1) developing an ecologically protective fish production project like mariculture and (2) empowering the local people to help protect and co-manage the local natural resources.

Re-establishment of small-scale mariculture would appear to be an appropriate intervention for economic development and environmental protection reasons. Despite some potential adverse effects, the benefits for long term sustainability of the coastal zone would seem to outweigh any socioeconomic adjustments local fishermen might have to make to accommodate mariculture.

Potential Beneficial Effects The most obvious beneficial effects of mariculture are the production of relatively cheap protein-rich food sources and a high value export seafood commodity for the generation of foreign exchange. A potential environmental benefit of offshore coastal mariculture on a small-scale is that it can serve to relieve pressure on capture fishery resources and thus help to protect fragile environments such as coral reefs. Mariculture could result in a potential increase in total seafood. For local fishermen engaged in crab farming, incomes equivalent to that derived from traditional fishing can be achieved for less labor expenditure. Part-time or apprentice and older, beached fishermen also might have the opportunity to become full-time members of mariculture crews in the production of crabs, thus extending the productive life of fishermen. Improvements in employment opportunities, the means of production (boats and motors), and reduction in outmigration may result from adoption of crab farming (Rubino and Stoffle 1989:142-143). In addition, fishermen may gain greater control over market and price-setting power because crabs do not have to be sold immediately after catch. Fishermen could time production cycles and sales to meet peak market periods such as high tourist seasons as well as high value markets (Rubino and Stoffle 1989:140; 1990:391).

Potential Adverse Effects There are a number of potential adverse effects of mariculture development, regardless of scale. Pollnac (1990) has summarized numerous use conflicts identified by a host of researchers. These use conflicts can span from the coast to the uplands, and involve fishermen and farmers and their families alike. Conversion of habitats, increased social stratification, inequitable benefits, loss of land and resources, and conflict among and between groups are just some of the potential adverse effects of mariculture development.

Adoption of mariculture will potentially cause fishermen to renegotiate social and economic commitments with family, community, and market middlemen (Rubino and Stoffle 1990:393). If involvement in mariculture results in the curtailment of fishing activities by crab farmers, there may be a shortage of fishermen to catch an adequate supply of subsistence and commercial fish. This could negatively affect diet and nutrition of families and the community as a whole. Middlemen, who rely on buying portions of the fish catch, might begin to seek other markets for obtaining fish if mariculture results in a substantial decline in local fish catch. This would jeopardize community marketing connections (Rubino and Stoffle 1989:142).

Finally, crab mariculture production is extremely sensitive to subtle changes in market price and yields, which are related to growth and survival rates. Crab farms suffering low growth and survival rates could fail financially. Consequently, crab farmers will have to rely on trusted market networks to obtain high sales prices, manage operations carefully to ensure increased crab yields, and utilize cost efficient materials for mariculture cages (Rubino and Stoffle 1990:390). Evidence from Buen Hombre suggests that local fishermen have the skills and characteristics necessary to operate sustainable crab farms (Stoffle, Halmo and Stoffle 1991).

Monitoring and Evaluation Whatever the scale, the transition to mariculture should be monitored throughout the life cycle of the project.

Provisions for ongoing evaluation and monitoring of project impacts during each stage of the project cycle should be built into project designs and plans (Pillsbury 1984; Pomeroy 1989:43). Allowance for long-term monitoring well after project completion can generate important insights on the long range effects of projects and the changes they incur (Pollnac 1989).

Natural and social scientists monitor human induced environmental changes such as deforestation and its effects on global climate (Graedel and Crutzen 1989; Postel 1988). Siddall et al. (1985:29) note that Philippine agencies had begun to monitor mangrove areas and fishponds with LANDSAT imagery. Such efforts have come to include the use of increasingly sophisticated remote sensing technology (e.g., Conant 1990; Green and Sussman 1990). Dual goals of this approach are to (1) understand, measure and monitor conditions on both the micro and macrolevel, and (2) mitigate adverse impacts by intervening in the decision process faster with better information to develop strategies to protect the environment.

CONCLUSION

Around the planet, coastal marine ecosystems, especially those containing coral reef ecozones, are undergoing degradation and are faced with potential destruction (Bunkley-Williams and Williams 1990; Langreth 1990; Goreau 1991). Despite being one of the most biologically productive ecosystems in the world, coastal marine ecosystems are fragile. A number of well documented environmental factors, such as climate, water temperature, sedimentation as a result of runoff, and disease, have contributed to the process of degradation. Reef bleaching is the most recent physical sign that the world's coral reefs are being stressed. When coral reefs die only their skeletons remain; this causes the reefs to appear white as if bleached.

Satellite imagery has documented the dramatic occurrence of reef bleaching around the world. Some scientists argue that reef bleaching derives from global warming, and this has been the focus of attention up to now. Social and environmental studies, however, demonstrate that human use and pollution also kill reefs. Protective measures must be implemented to save the world's reefs from total destruction because the reefs are essential to the natural balance of the planet and the well being of millions of fisherfolk who depend on this productive ecozone. One means of protecting reefs is to develop culturally and environmentally sensitive mariculture projects (Goreau 1991). A first step toward this goal is to assess current environmental and sociocultural conditions for the purpose of sound decision making. Two concepts, ecodevelopment (Riddell 1981) and co-management (Pinkerton 1989), form the basis for an approach to mariculture development that is socially and economically sustainable and serves to protect the environment.

"Ecodevelopment" is a concept that refers to planned change projects that both provide revenue and reduce pressures on natural resources. These projects differ from sustainable development which tends to imply maintaining natural resources at current levels and resource conservation which tends to prohibit local use of resources. "Co-management" refers to local people sharing natural resource management functions with government officials charged with natural resource management. Fundamental to the ecodevelopment approach in coastal marine ecosystems is that such ecosystems must be viewed as having both terrestrial and marine components. Economic development that is sustainable requires complex management of human and natural resources. Some degree of environmental protection and management is critical to the sustainablility of seafood culture operations.

INTERDISCIPLINARY ENVIRONMENTAL ASSESSMENT IN COLLABORATION WITH LOCAL PEOPLE The authors are currently involved in an interdisciplinary research project with earth scientists, designed to collect micro and macrolevel baseline data on historic and recent changes in land and marine resource use in the community of Buen Hombre as a foundation for monitoring future changes (Stoffle and Halmo 1991). The research is part of the Consortium for International Earth Science Information Network (CIESIN) initiative funded by the National Aeronautics and Space Administration (NASA) for the purpose of applying state-of-the-art satellite technology to assist in the study of global change issues and the human factors involved in such change processes.

One satellite image used in the CIESIN Dominican Republic project is a recent 20 kilometer by 20 kilometer edge sharpened Landsat image of Buen Hombre and its immediate environs. This natural color image shows in maximum detail the existing land use and infrastructure for the local area covered by village decision making processes. It covers the two terrestrial ecozones near the village in addition to the tidal shore and coral reef ecozones. A second satellite image is a composite Landsat TM (Thematic Mapper) image which provides detailed bathymetry information for a 40 km portion of the coast centered on Buen Hombre. This bathymetry serves a number of functions, including providing accurate water depth information for the coastal ecozone and a chart of the inner and outer coral reefs.

The third image is a Landsat TM change image, covering the same 40 km by 40 km area as the second image, over a five to eight year period. This image graphically indicates the locations and nature of mangrove and reef changes that have occurred during this period of time. This image also illustrates albedo changes in the coral reef such as "bleaching" or "whitening." A marine ecologist from East Carolina University and local expert fishermen have worked with ethnographers to produce inventories of marine species in the coral reef and mangrove ecozones. Depth measurements have been made at over 50 "stations" or pixel locations drawn from the series of 28.5 meter pixels on the Landsat bathymetry image produced by remote sensing scientists. These stations, comprising 21 marine sites, also have been "sea truthed." Interview data collected from fishermen regarding marine ecozone resource use have been used to help identify and map marine areas at risk of overuse and degradation. The process will be replicated in terrestrial ecozones.

Linking remote sensing images with observed land and marine resource use activities will result in the identification of ecosystems and resources at risk. Once identified, human-environment interactions can be monitored and data can be brought to bear on policy-relevant recommendations to host country government resource managers and decision-makers, so that they can begin to formulate informed policies that effectively incorporate concerns for environmental protection and sustainable development alternatives for human communities. The data also will serve to inform community level decision-makers of options regarding the management of their resources. The research will serve to integrate new methods with state-of-the-art technology in formulating operational procedures for monitoring project initiatives.

Combining remote and on-the-ground field methods of monitoring will be applicable to other threatened coastal marine areas around the world. The combination of space technology and on the ground documentation methods for collecting and interpreting data can be an effective way to improve planning and monitoring of coastal area development for host country agencies that have limited funds and staff for consistent field monitoring. Finally, the remote sensing and field data will be of use to international lending agencies currently conducting environmental assessment studies as part of development project planning and implementation.

Contemporary development anthropologists and others have continually recommended that "putting people first" (Cernea 1985) and including them early in the project process by accounting for social and cultural variables serves to enhance project success (Kottak 1985, 1990). Interdisciplinary research involving state-of-the-art methods, technology and collaboration with local people (Arnould 1990) can contribute much needed information for monitoring the development process in general, as well as coastal and mariculture development in particular. Social and environmental assessment studies, incorporated early on in the mariculture project cycle, can effectively inform ecologically sound, sustainable development that benefits human populations, the environments in which they live, and the resources that they use.

FOOTNOTES

1. A portion of the research funds for this study were provided by the University of Michigan's Population-Environment Dynamics Project (PEDP) through the United Nations Fund for Population Activities (UNFPA) and the MacArthur Foundation. Professors Gayl D. Ness and William D. Drake, co-directors of the PEDP, provided both guidance and assistance throughout the research process. Dr. Steven Heeringa, Head of the Sampling Section at the Institute for Social Research, helped develop the research sampling procedures. In the Dominican Republic, Lt. Com. Rafael Negrette Olivares, former Director of the Department of Fishery Resources, provided letters of introduction and support of the research. William and Kathy Bernard helped with local arrangements and shared their insights about fishing and mariculture.

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2. Information about the mariculture site in the village of Buen Hombre in the Dominican Republic was produced by studies conducted in the summers of 1985, 1989, and 1990. These studies used a series of research methods including informal interviews, focus group interviews, survey interviews, oral history interviews with community elders, and participant observation. A total of 284 interviews were conducted with local fishermen, farmers, women, government administrators and project personnel (Stoffle 1986; Stoffle, Halmo and Stoffle 1991; Stoffle et al. 1990).

3. Territorial encroachment problems did occur with the Smithsonian pilot project in Antigua. There the project boats were located over a conch diving area which interfered with seafood harvesting by local fishermen. The landing area for the Smithsonian boats also caused the relocation of a local fisherman. So local sovereignty became more of a problem in Antigua.

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