Coral Reef Management Areas: Prospects And Problems

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ABSTRACT

Present knowledge of natural and social forces which govern sustainability and fishery production of coral reef ecosystems is reviewed for purposes of identifying assessment priorities in support of resource management policies. An attempt is made to present issues from both biological and sociological perspectives. Characteristics of tropical reef fisheries and fishery ecosystems, marine fishery reserves or protected areas, management approaches and experience, management models, and relevant socioeconomic conditions are analyzed; options for assessment are discussed. It is suggested that there are no universal models for tropical reef fishery ecosystem health. While ecological processes will slowly be discovered, managers need to act immediately to enhance production and sustain it over the long term; prevention of destructive practices is essential and an obvious first step. Establishment and maintenance of protected areas is ultimately dependent on sociocultural forces. Sustainability of fishery resources depends upon the existence of reserves but the optimal way to arrange this is dependent on the social and ecological setting; the best strategy is to set aside some fraction of the ecosystem. Routine station monitoring, within and without reserves, could provide a useful picture of stock status and trends; patterns in catch and effort can probably be most accurately pictured by monitoring individual fishermen's catch and effort within gear and bottom type defined strata in the fishery.

INTRODUCTION

This paper reviews present knowledge of natural and social forces which govern sustainability and fishery production of coral reef ecosystems. The purpose of the discussion is to identify monitoring and research priorities for the support of resource management policies. The premise is that management must be done in an atmosphere of uncertainty, i.e., that ecological processes operating on reef ecosystems are only partially understood and are likely to remain so for an indefinite period of time. However, management of coral reef ecosystems is needed now to check massive worldwide degradation, to preserve genetic diversity, and to maintain or enhance fishery productivity. Bradbury and Reichelt (1981:21) articulated much the same thing in recommending a "holding strategy" which implies making management decisions, "... in somewhat of a theoretical vacuum." While they explored the issue of available theory being sufficient to guide managers, this paper attempts to identify standardized, simple, and inexpensive fishery data gathering practices which may help managers make informed decisions in the existing diversity of socioeconomic settings. This discussion is focused upon inshore areas which are characterized by reef corals but it is recognized that sea grass, lagoon flat, and mangrove creek communities are functionally linked (Parrish, 1982).

The recent review by Hatcher *et al.* (1989) of inshore tropical ecosystems research summarizes a considerable body of literature dealing with ecology and management of coral reef areas. The authors indicate that present knowledge does not provide much of immediate practical value. They conclude their section on fundamental research with the assertion that, "... many ecological models do not work on coral reef systems, and few of those which do form a basis for management; a separate class of management models is required" (1989:350). Appeldoorn and Lindeman (1985:513) express perhaps a more positive sentiment that ecological knowledge, while far from complete, offers at least some direction and, "... in the long run, promises a more rational basis for fishery assessment and management." In another review focused upon coral reef fish communities, Sale (1991:596) concludes that, "On all spatial scales up to the biogeographic scale, reef fish occupy a spatially patchy environment." This well known spatio-temporal patchiness in fish community structure is apparently determined by a host of poorly understood biological and physical processes. Sale (1991) suggests that understanding these processes and patterns of coral reef fish distribution will be of direct benefit to managers. We agree that understanding ecosystem response to management is necessary. Yet thorough understanding of ecological processes may not be essential to maintain coral reef fisheries and preserve biological diversity. In this paper we discuss issues of coral reef fishery ecosystem management from biological and social perspectives.

TROPICAL REEF FISHERIES

Millions of people depend on viable reef fishery ecosystems. A potential annual production estimate of nine million metric tons from "...coralline areas in depths less than 30 m..." has appeared in the literature (Munro and Williams, 1985:546). On the basis of reported 1987 total landings of 92.7 million mt (FAO, 1989), this amounts to a significant contribution to total world living aquatic resource production. Literature on the effect of fishing and aspects of fishery production has been reviewed by Russ (1991). A number of studies report annual fishery production on a per area basis. Munro and Williams

(1985), Acosta and Recksiek (1989), Marshall (1980), Russ (1991), and Gobert (1990) tabulated annual production (or yield) estimates from several studies for various reef fisheries and gears. The reported range is from near zero (e.g., 0.3 mt km-2 yr-1 in the Tigak Islands, Bismarck Archipelago; Wright and Richards 1985) to 44 mt km-2 yr-1 (the maximum among several village fishing areas at American Samoa; Wass 1982:74). Catch per unit of effort (CPUE) does not appear to have been as widely estimated as annual yield. That is probably due in part to the wide choice of effort units. Acosta and Recksiek (1989; Table 5) summarized results from several reports. For example, from their own study of a Philippine night spear fishery at Cape Bolinao, northwest Luzon, mean CPUE was 1.33 kg man-hr-1, a figure of the same order of magnitude as other Indo-Pacific spear fisheries. From a study which relied upon considerable interaction with local fishermen, White and Savina (1987) at Apo Island, Philippines, derived an overall estimate for a year (Table 4, p. 73) of 1.47 kg man-hr-1 for "reef" fish. While characterizing CPUE for heavily exploited artisanal tropical reef fisheries as a whole is probably impossible, magnitudes in the neighborhood of 0.1 kg man-hr-1 to 2 kg man-hr-1 appear typical.

Primarily during this century, coral reef habitats have been degraded by various human activities including overfishing, destructive harvesting practices, siltation, pollution, excessive collection and mining of reef material, solid waste disposal, anchor damage, and tourist contact (e.g., Chesher, 1985; Gomez, 1982/1983; Kenchington and Alcala, 1989; Lemay and Chansang, 1989; McLain, 1990; McManus, 1988; Parrish, 1982; Pauly, 1989). Even heretofore remote areas are now visited by itinerant fishermen who use blasting to obtain rapid harvests (White and Palaganas, 1991). The integrity of coral reefs is dependent upon a host of anthropogenic forces - intellectual, economic, historic, demographic, and political. These forces may be throughly international in character. Salvat (1981) attributed the pattern of overexploitation to the breakdown of subsistence systems and substitution of cash economies as a result of the appearance of westerners in the tropical Pacific. Gomez (1982/1983) implicates demand for coral products by developed countries in destructive coral harvests of lesser developed countries' reefs. Munro and Smith (1983) link explosive population growth and inequitable distribution of wealth and land with excessive pressure on living reef resources. Russ (1991:631) notes that stabilization of human population growth is requisite for successful management. Parrish (1982) discusses patterns, causes, and dynamics of overfishing and the effects of overfishing; he also provides comparisons and contrasts between tropical and temperate fisheries.

ASPECTS OF PROTECTED AREA MANAGEMENT

Most, if not all, protected area management schemes call for prevention of destructive practices (Foster and Lemay, 1989; Kenchington and Hudson, 1984;

Lemay and Chansang, 1989; Salm and Clark, 1989; White, 1990; White and Palaganas, 1991). The most obvious problems in the harvesting sector are blast fishing, collecting or fishing with toxicants, and mechanically breaking corals while fishing (described by Parrish, 1982) or gleaning. Common sense dictates that any activity which destroys coral reef habitat should be stopped. Common sense also would dictate that the social disciplines need to be called upon to help provide solutions because the problems are fundamentally non-technical (Hardin, 1968). It is appreciated that the dilemma of widespread environmental destruction is a human problem. Controlling obviously destructive practices in the so-called (Pauly, 1989) developing countries is probably the most important but difficult priority in fishery management for many coral reef areas, especially in light of explosive population growth and burgeoning landlessness. Actually, what one person might regard as benign, another may think destructive. Some consider certain kinds of commonly used artisanal fishing gear wasteful and destructive, e.g., fish traps (pots) and trammelnets. The appropriateness of certain types of traditional fishing gear is a different consideration than the use of dynamite or cyanide.

MANAGEMENT ALTERNATIVES AND TRADITIONAL USE

Much of the recent literature on coastal resource management of tropical reef areas states or implies that conservation and management should be approached on a case-by-case basis (e.g., White, 1990; Lemay and Chansang, 1989; Foster and Lemay, 1989; Salm and Clark, 1989; Kenchington and Hudson, 1984). There is no handbook of management methods which may be universally applied. Many individuals are involved in proposing, implementing, researching, and fine tuning coral reef area management regimes for a host of complex arrangements variously referred to as marine wilderness, parks, sanctuaries, reserves, fishery management areas, etc. (Anon., 1990; Bohnsack, 1989; Castaneda and Miclat, 1981; Foster and Lemay, 1989; Lemay and Chansang, 1989; Kenchington and Hudson, 1984; NOAA, 1990; Salm and Clark, 1989; White, 1990). Approaches vary across a spectrum. At one extreme perhaps is that taken by the Great Barrier Reef Marine Park Authority where a single public agency is charged with managing and monitoring a vast region zoned for multiple uses (Craik, 1989; Cocks, 1984; Kelleher, 1990). Other approaches try to take into account social and cultural aspects of traditional users of the resource.

This socioculturally sensitive view was expressed by Nietschmann (1984) in his paper on indigenous island peoples where he suggested that the most rational resource management strategies would be those which most carefully considered the complex cultural interactions between the islanders and their reef resource base. For life scientists involved with studying these systems and contributing to the management process, the implication is that management policy must be site specific, i.e., tuned to the social setting in the area. Cordell (1989a) makes a strong argument for this approach in a book he edited which reviews traditional sea tenure systems in many areas around the world. It should be emphasized that there are precedents for apparently successful fisheries management of coral reef ecosystems that predate the western influence in the Indo-Pacific; coral reef fisheries supported island peoples for centuries using complicated rules and social pressures (Johannes, 1978, 1981, 1984). Falanruw (1984) describes the subsistence fishery on Yap prior to arrival by Europeans. There, a population eight times that found in the late twentieth century was sustained by a diversified, carefully managed fishery. McGoodwin (1990) reviews some rather limited, anecdotal evidence which suggests that some modern fishing peoples employ self-regulatory measures for conservation purposes.

One must, however, be careful in assessing interpretations of the resource consciousness of "indigenous" peoples (Pollnac and Poggie, 1991; McGoodwin 1990). For example, Cordell (1989a), an anthropologist who has been conducting research related to traditional use rights for many years, notes that little ecological data have been collected to support the proposition that traditional concepts of sea tenure promote biological conservation. Further, Johannes and MacFarlane (1989) clearly demonstrate that there can be significant differences between customary marine tenure systems with respect to their potential role in marine resource management. In the two systems they evaluated, one could play a minor role while the other would impede management efforts. Finally, the archeology of the Pacific provides extensive evidence of negative impacts of prehistoric peoples on the flora and fauna of their environment (e.g., Dye and Steadman, 1990; Kirch, 1984, 1985; Cassels, 1984). This is a very unpopular viewpoint which is bound to raise the ire of the few remaining proponents of back-to-the-noble-savage-for-management, but evidence more than suggests that this cautious viewpoint should be considered (e.g., Pollnac and Poggie, 1991; McGoodwin, 1990; Cordell ,1989b; McCay and Acheson, 1987).

A good example of local involvement in management is provided by Apo Island near Dumaguete, Negros, Philippines. Apo, a 72-ha island, is managed as a fishing area where local people are heavily involved in surveillance and in enforcing gear and area restrictions around the island; technical support is provided by Silliman University (White, 1990). It must be emphasized, however, that involvement of fishing community members in marine conservation projects is not a simple matter. In their discussion of a community based marine resource management project for San Salvador Island, the Philippines, Christie *et al.* (1990) note that conflicts developed between residents adhering to traditional ways and those adopting the new, conservation oriented methods. Involving community members in management of coral reef conservation areas is related to a growing body of research and literature which is frequently referred to as popular participation in fishery development (BOBP, 1990; Pollnac, 1987a).

Recently, many social scientists have begun to refer to the use of popular participation in resource management as "co-management." With respect to co-management of capture fisheries, Pinkerton (1989) points out some of the advantages of co-management such as promotion of conservation and enhancement of fish stocks, improvement of the quality of data necessary for management (discussed in a later section), development of more equitable allocation techniques, promotion of community economic development, and reduction of conflict between different user groups as well as between users and the government. Co-management can also lead to decentralization of decision making, which is necessary when diversity characterizes a resource needing management, as does the diversity of resources and types of exploitation associated with coral reefs. It also helps when the resources are spread over a large area and government personnel with expertise for management are in short supply, as in many developing countries. The papers in Pinkerton (1989) address many of the factors contributing to the success and failure of fishery co-management systems. For purposes of this paper, however, it must be stressed that the sociocultural context plays an important role in the relative success (or appropriateness) of co-management systems.

Some researchers (e.g., McKay, 1980; Berkes, 1986; Jentoft, 1988) have suggested that fishermen's cooperatives can be effectively involved in the actual management and/or co-management process. Jentoft (1988), basing his arguments on an excellent review of the literature as well as his own research experience argues that fishermen involvement in development and implementation of management regulations will increase their legitimacy. He points out that this type of involvement is likely to result in management regulations more appropriately adapted to fishermen's perceived problems.1 This type of legitimacy is likely to lead to fishermen's acceptance and adherence to the regulations. The importance of this type of legitimacy is exemplified by Pollnac and Littlefield (1983) who report that perception of fisheries management rules as "bad" or "unfair" resulted in falsification of data and rule breaking behavior among New England fishermen in the late 1970s and early 1980s - responses which make management difficult if not impossible.

Jentoft (1988) argues that fishermen's cooperatives provide an excellent vehicle for this type of fishermen involvement in management and reviews several examples of both successes and failures. His review of potential problems in the use of cooperatives is especially important because it makes the point that the involvement of fishermen does not guarantee successful management, that perceptions of "unfairness" and conflicts can develop between fishermen within and between cooperatives. The level of success of the cooperative as a functioning organization influences its effectiveness as an entity to be involved in management.[2]

This final point is important because one frequently finds inaccurate statistics concerning the level of cooperative development in developing countries. There are many reasons for these inaccuracies (cf. Pollnac, 1987b), but it should be sufficient to note that one of us (Pollnac) has spent many months in developing countries, bouncing over back roads in search of "on-paper" cooperatives only to find an empty building, rumors of "managers" who ran off with the funds, or nothing at all. Hence, before deciding to use fishermen's cooperatives as the basis for coral reef management area co-management schemes it will be essential to go beyond government reports concerning the existence of the organizations and determine their present levels of effectiveness as well as whether or not they are structured so as to be able to take on the added effort and responsibility of co-management. Numerous factors influence the relative success and failure of fishermen's cooperatives (cf. Poggie *et al.*, 1988; Pollnac, 1988c; Pollnac *et al.* ,1991), and these factors should be evaluated at an early stage of planning their involvement in management efforts. This may seem obvious, but the authors are aware of fisheries development projects based on non-existant, "on-paper" fishermen's cooperatives.

Hence, the strategy for effective management of coral reef conservation areas will vary widely. This should be expected considering the variety of levels of economic development, cultures, priorities, and governments among modern nations. When wealthy societies like the United States or Australia develop the will to conserve their natural resources, they possess the wealth, social arrangements, and central authority to legislate and enforce regulations. Others are not so fortunate and their hopes must often rest with either ineffective management or some of the locally based strategies discussed above.

TROPICAL REEF FISHERY MANAGEMENT AREAS

If clearly destructive practices can be halted by some social rearrangement, the next question revolves around how one manipulates the ecosystem to achieve some particular end. In a biological context this means adjusting the system for certain perceived optima, e.g., biomass, production, diversity, aesthetics, etc. These "adjustments" are accomplished by regulation of fishing, i.e., closed seasons and areas, size limits, protected sexes or stages, gear restrictions (beyond the limitation of obviously destructive methods), quotas, environmental enhancements (stocking and artificial habitats), and limited access (summarized in part by Munro and Williams, 1985). Munro and Williams (1985) and Parrish (1982) discuss the dynamics of exploited tropical reef fish populations and the unique fishery assessment problems in support of management. Gulland (1982:287), in a paper on tropical fishery management (not just reef ecosystems) asserts that, "Little management ... has been done in tropical waters for compelling reasons - the available mathematical models of the dynamics of fish populations are not immediately applicable to tropical situations; the basic information to apply any model is generally sparse; there are few scientists to carry out the necessary studies, and often there is not the administrative structure to implement and enforce the detailed restrictive measures typical of fishery management ..."

Certainly the same mix of social ills which drives destructive exploitation prevents resource assessment and enforcement of regulations. A perusal of the management oriented literature cited previously will convince the reader that social problems must be confronted before attempting to assess or repair a damaged fishery. This paper addresses these problems by identifying and justifying assessment priorities which are least dependent upon costly technical infrastructures. The hope here is to help build appropriate technology for fishery assessment and management in those settings where there is enough wealth and commitment to afford the minimum.

Management on an area-by-area-basis according to the socioeconomic realities of the setting is probably more practical in coral reef systems than other marine ecosystems because the communities of juvenile and adult reef fishes are relatively site attached (Parrish, 1982; Hartsuijker and Nicholson, 1981); tagging studies have confirmed the pattern for larger individuals (Randall 1961, 1963; Bardach, 1958). Traditional "resource management" by the Indo-Pacific islanders seems to have been considerably site-specific (Johannes, 1978, 1981, 1984; Falanruw, 1984). The prospect of having different management policies on adjacent reefs, atolls, islands, multiple use zones, etc. is certainly realistic. As long as there is a supply of new recruits from somewhere,

management may be able to adjust to unique social demands of the situation. Note that when recruitment habitats, e.g., nursery areas like sea grass flats or mangroves, are disconnected in space from the fishing grounds, the former also must be considered part of the management area.

Perhaps being able to predict system responses may be the most important element in the process of developing political support for a management strategy. Predicting an increase in future yields and how long it will take to achieve them would add credibility to any management policy. White's (1989) case history of management successes (Apo Island) and failure (Sumilon Island) in Philippine Visayan fishery management areas indicate that prediction of future changes in yield is a practical prospect.

FISHERY RESERVES OR SANCTUARIES

Like other marine fishery ecosystems, reefs are open ended in that spawning events are more or less disconnected in space and time from recruitment events. Recruitment is defined here as the transition from pelagic larva to demersal, resident juvenile (e.g., Victor, 1983). The fundamental management problem is ensuring and then protecting a supply of new recruits to resupply losses due to fishing and natural mortality. There is evidence that recruitment rates are the principal determinant of reef fish population dynamics (Victor 1983, 1986a, 1986b; Doherty, 1987; (see reviews by Hatcher *et al.*, 1989; Russ, 1991; Richards and Lindeman, 1987). Thus common sense demands a seed source somewhere; and that necessitates the existence of an area where fish can survive long enough to reproduce. Regardless of how a reef fishery is regulated, there is at times considerable justification for establishing a core sanctuary or wilderness area as a mechanism for maintaining sustainability of reef fisheries (Bohnsack, 1989). A recent National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum (NOAA, 1990:1 Abstract) presents compelling arguments that marine fishery reserves where no extractive uses (fishing) are permitted, will "... benefit reef fisheries by protecting critical spawning stock biomass, intra-specific genetic diversity, population age structure, recruitment supply, and ecosystem balance while maintaining reef fish fisheries." The basis of the authors' report is that fishing mortality results in, "... fewer adults, less total egg output, and reduced average spawning age" (NOAA, 1990:2). This results in increased probability of recruitment failure and "... evolutionary responses (e.g., smaller size at age) due to genetic changes" (NOAA, 1990:2). The report also proposes socioeconomic benefits. The authors suggest that the marine fishery reserve concept, like that of existing wilderness on land, is acceptable to the public (of wealthier societies like that of the United States and Australia) and that enforcement and data collection needs are simplified.

The concept of a fishery reserve as an important management strategy is accepted in several quarters. Salm (1984) and Salm and Clark (1989) have described a reserve system where a central "sanctuary" is surrounded by a controlled area. This concept has been applied to island fishery management projects in the Philippine Visayas as mentioned previously (White, 1989). Multiple use zones as implemented in the Great Barrier Reef Marine Park (Kelleher, 1990; Cocks, 1984) could be considered a variation of the idea. Of course, the big questions are how large and where the reserves must be to adequately supply competent larvae; Hatcher *et al.* (1989) review the issues of size and scale. An unknown proportion of the spawner biomass will wander out on feeding or breeding migrations (e.g., groupers). Quantifying recruitment and emigration processes, either in general or with reference to particular systems will take decades. In this uncertain atmosphere, the authors of the NOAA (1990) report have made an educated guess and have specified 20% of the total continental shelf fishing ground as being sufficient to achieve goals of a reserve.

PRESENT KNOWLEDGE OF TROPICAL REEF FISHERY ECOSYSTEMS

In addition to not being able to quantify the direct biological effects of reserve areas on adjacent fished stocks, there are few baselines of the complete fish fauna in coral reef areas under more-or-less natural conditions where variability at various spatial and temporal scales is quantified. Comprehensive reviews, from an ecological perspective, by Sale (1991) and Russ (1991) summarize current ideas on, respectively, coral reef fish community dynamics and coral reef fisheries. Certainly the most complete picture of reef fish communities has been developed from studies of the Great Barrier Reef (Sale, 1991). Several papers have contributed to our concept of coral reef fish communities. Williams and Hatcher (1983) used explosives to quantify community characteristics on the windward reef slope with respect to number of individuals, weight, and species indices between inshore, mid-shelf, and outer shelf reefs. They were able to quantify changes in "trophic categories" and "guilds" across the 130 km transect; algal grazer biomass was markedly less represented inshore and cesionid planktivores were dominant at mid-shelf reefs. Using visual census, Russ (1984b, 1984c) quantified species distribution and numerical abundance for herbivorous grazers (Acanthuridae, Scaridae, and Siganidae) across the same shelf gradient (as Williams and Hatcher, 1983). Grouping fishes into families, he included classifications for different shelf area reefs ("locations") and "zones" (e.g., reef slope, reef crest, etc.). The most variability was attributable to different zones within reefs; when different zones were compared, one at a time, across the shelf, then significant cross-shelf differences were

apparent. Russ concluded that both studies (1984b and 1984c) "... demonstrated that herbivorous fishes occur in assemblages which are characteristic of several major zones... The similarity in the patterns of zonation of herbivorous fishes on replicate reefs ... suggests that these patterns are likely to be maintained through time" (Russ, 1984c:42). The implication of these studies is that standing stocks of certain families, feeding guilds, or trophic groups may persist and be measurable through time; thus monitoring assemblages at well-defined zones should mirror severity of perturbations, like fishing, to the system.

SYSTEM RESPONSE TO MANAGEMENT OR EXPLOITATION

From a few areas where management policies have been implemented, there is evidence that regulation of fishing influences size distribution or stock size. For island reserves in the Philippine Visayas, White (1986, 1988, 1990) and Russ (1985) have documented management effects. Using visual census in controlled areas, they have shown higher fish abundance and species richness as well as higher abundances of those species which were known to be targets of fishermen. These workers quantified differences (between times or between areas) in abundance and species richness among certain groups, usually families and functional groups (e.g., planktivores and piscivores). Using visual census methods, Bohnsack (1982) identified differences in predator abundance between

Looe Key, Florida, where spear fishing was permitted, and protected reefs in the Key Largo National Marine Sanctuary. After Looe Key was added to the National Marine Sanctuary system, abundance of fish predators increased (Bohnsack, 1983; NOAA, 1990). Beinssen (1989), at Boult Reef, Great Barrier Reef, clearly demonstrated and quantified decreases in abundance of large predator species after a closed area was opened to fishing. Carter (1990) has shown changes in size distribution in Nassau grouper aggregations between "pristine" and fished areas in Belize. Certainly, for any defined area, monitoring yield and CPUE for the same gears over time will indicate trends. Alcala (1988) showed this for Sumilon Island during the years that management existed on the island (White, 1989).

The greatest body of system response (to fishing) data has been accumulated from studies of the Great Barrier Reef. Craik (1989) has completed a summary of research where a concise critique of recent studies has been provided; the research has tended to focus on the larger piscivorous serranids. For some of these, species specific cross-shelf distributions have been demonstrated and areas of abundance have been identified. For the most abundant species, coral trout, Plectropomus leopardus, densities on fished and unfished reefs have been estimated; fished reefs have been shown to harbor less and smaller individuals.

Roberts and Polunin (1991) review the effectiveness of marine reserves in managing reef fisheries; they provide accounts of reserve experience to date (Table 1, fish size, and Table 2, abundance). These authors note that (p. 82) "... abundances and average sizes of many larger carnivorous fishes increase within protected areas." They point out that real evidence for enhancement of fishing beyond the borders of reserves is rare and worthy of further of further study. The same authors (Roberts and Polunin In Press) in an analysis of reserve effects in the northern Red Sea note that changes in abundance, size, and biomas were far from clear.

ECOLOGICAL MODELS FOR PRACTICAL MANAGEMENT

It is a virtual certainty that there will be significant functional differences between areas managed for maximum production, as in nations harboring artisanal coral reef fisheries, and, for example, sport fishing quality. The latter again is epitomized by nations like the United States and Australia. Munro and Smith (1983:128) discuss the theory of transition, with increased effort, from a fishery dominated by predatory fishes to "... herbivorous, omnivorous or planktivorous species." Assuming that the fishery were structured to land as much biomass as possible with minimal effort (probably the typical case; Munro and Smith, 1983), the biomass of higher trophic levels would be replaced by lower levels. Parrish (1982) also has discussed effects of exploitation from a functional point of view; he suggests that removal of large piscivores would tend to increase stock biomass of their prey. Studies mentioned in the previous paragraph support this supposition but quantifying this successional phenomenon remains for the future. Russ (1991) notes that there is little evidence for an increase in abundance or biomass of prey species when predators are removed. In discussing this issue he reminds us that (p. 624), "... current ideas on what determines abundance suggest that larval supply (recruitment) is more likely to be the ultimate control on abundance of populations ..."

There exist some numerical models which may be applied to emulating trophic interactions and fishery yield in coral reef ecosystems. Polovina's (1984:9) ECOPATH model, applied to the Northwest Hawaiian Islands, has been used to demonstrate that harvesting only the highest trophic levels ("tunas, sharks, and jacks,") would result in relatively low (fishery) yields; removing all "top predators" results in a substantial increase in yield (e.g., from 0.1 mt km-2 yr-1 to 6 mt km-2 yr-1). Parrish (1975) has described a trophic interaction model, applied to fishes, which was designed as a tool to study ecosystem performance. Numerical simulation of fishing is a promising

prospect for predicting ecosystem response (Munro, 1987). However data sets to validate such models and a wide choice of designs, especially simple ones, are not available.

Discussions of applying fishery production model ideas derived from single species assessments in temperate systems to amalgamations of tropical reef species have been published (e.g., Kirkwood, 1982; Munro and Thompson, 1983; see Huntsman and Waters, 1987; Bannerot *et al.*, 1987 for discussions of multispecies, snapper/grouper, fishery model applications for the tropics). As in the single species temperate zone case, logical assemblages of fish species typically are considered as a single entity for estimating equilibrium yield as a function of fishing effort (production model). As well as concisely reviewing the subject, Appeldoorn and Lindeman (1985) present a convincing rationale that functionally similar and related species may be collected into "higher taxonomic categories" for purposes of fishery assessment. Their analysis was based upon catch and fishing effort data from an inshore Puerto Rican haemulid trap fishery, for which they estimated maximum sustainable yield (MSY) and other population attributes. The authors point out that such analyses, while rough, are superior to no quantitative assessment whatever, and, that theirs "... served its purpose: supplying an assessment where no prior information existed" (Appeldoorn and Lindeman, 1985:513). Munro (1987:647) summarizes the situation, "All of the (fishery) models have acknowledged deficiencies in the form of assumptions of constant parameters or stock-recruitment relationships, and all are basically intended for single species assessments. As species interactions are still very difficult to quantify, the choice is one of either simply summing the yield curves for single species or empirically regressing catch per unit effort, against effort, for all or parts of exploited communities if applying the existing methodologies to multispecies stocks."

Although they did not focus on inshore fisheries, Polovina and Ralston (1986:759) outline a practical yield assessment strategy based upon a selection of techniques from the (fishery stock assessment) literature "... designed specifically for tropical fisheries resources in situations where catch and effort data are lacking." These authors applied their approach to estimating MSY for the unexploited snapper/grouper assemblage in "deep slope" areas of the Mariana Archipelago; they state that the approach is "... most suitable for resources where prey-predator interactions are negligible" (p. 768). Certainly slavish acceptance of (fishery) model assumptions, e.g., no predator-prey interactions, would doubtless prevent their application in most coral reef areas, yet, an indicator, albeit flawed, is superior to speculation from the beach. The critical matter perhaps is to view quantitative stock estimators as heuristic aids, not concrete foundations for policy.

The art of predicting biological consequences in response to implementing management policy for tropical reef systems is in its infancy. The problem seems especially tenuous when people must figure prominently in the system as major, generalized predators. If the management goal is maximum sustainable exploitation, the questions become how much fish biomass and what disposition among trophic levels with respect to age structure of the component species are desired. One could ask if there exist simple, repeatable, system indicators for guiding the management process which could be universally applied. For instance, would a certain biomass density and proportion of piscivores, planktivores, and herbivores be an indicator of system health for the purpose of optimizing fishery productivity? Or, should simply measured attributes of selected indicator species, e.g., length frequency, density, etc., be used to guide managers?

POTENTIAL FISHERY PRODUCTION

Considering the previously discussed reports of yield from various tropical reef fisheries, it is difficult if not impossible to clearly associate catch and effort with condition of the ecosystem. Marshall (1985) discusses the concept of "Ecosystem Sustainable Yield (ESY)" where expected production depends upon the "physiographic features" of the area, e.g., "extent of the corals, profile of the outer reef slopes, the extent to the lagoon or other adjacent shoal areas, the presence or absence of mangroves along the shore, and the tidal range" (Marshall, 1985:526). To this list one could add the transfer of energy between the coastal ecosystem and the open ocean, e.g., the catch of pelagics which seasonally wander near. Even the catch of planktivores (discussed by Russ, 1991) could be considered an input, albeit indirect, from the sea. Marshall (1985) reconsiders the utility of a morphoedaphic index (Marten and Polovina,

1982) for potential harvest per unit area as a function of reef area, shelf area and "some other factors" (Marshall, 1985:529). He suggests that derivation of such an index is far off. He also notes that "... an area must be fished if we are to gain any insight into this potential and that harvest records, inadequate as they may be, are the one means for judging ESY" (Marshall, 1985:526).

Marshall's (1985) review leaves the reader with the realization that associating measurable system characteristics with potential yield is not easy. His paper reminds one that how the system is exploited is yet another added complexity. Consider that traditional Indo-Pacific fisheries, from gleaning the back reef to fishing the open ocean off the reef crest, target on a mix of species and functional groups; by contrast, sport fishermen in the Florida Keys pursue larger piscivorous carnivores like snappers, groupers, and jacks, leaving behind planktivores, herbivores, and diel migrating carnivores (e.g., haemulids). This implies that the kind of fishery, therefore the socioeconomic setting, must contribute to shaping any predictive index. Other problems seriously confound dealing with potential yield. Annual production is generally considered on a per area basis, usually metric tons per square kilometer year, or "relative production" (sensu Gobert, 1990), as it was previously in this paper. This is generally delimited by some depth, i.e., from the shore seaward until a certain isobath is reached. The choice of this depth must be at least somewhat subjective. There are apparently geometry problems as well. For instance, consider an ideal island shelf as an inverted cone with the apex (the island) just touching the surface. A doubling of the distance along the cone will enlarge the production area by a factor of four and will, therefore, reduce relative yield in inverse proportion. Russ (1991) has commented upon choice of maximum depth. Gobert (1990), who studied production in Martinique and provided comparisons with other reports from Caribbean fisheries, characterized "relative production" of the island's fisheries by dividing the surrounding inshore area into "fishing sectors and depth strata." The choice of stratum was based upon topography and fishing techniques. Relative production among strata ranged over more than an order of magnitude with an average of 1.68 mt km-2yr-1. Gobert's (1990) paper impresses upon the reader that assessments of potential and actual yield are inherently noisy but, nonetheless useful for comparing system production; he asserts that relative production estimates are of use in assessing levels of exploitation in reef fisheries provided that "... estimation methodologies are clearly stated and that a sufficient knowledge of fishing effort and ecological context is available" (p. 181). Note that quantifying stock density on a per area basis is similarly complicated. How to describe, for comparative purposes, stock densities along steep fore reefs is not straightforward.

ASSESSMENT OF MANAGEMENT POLICY

It would seem that the first step in understanding how these ecosystems respond to manipulation would be to conduct controlled experiments (proposed by Parrish, 1982 and strongly recommended by Russ, 1991), e.g., experimental exploitation designed to affect an entire fishery. Beinssen's (1989) study at Boult Reef epitomizes an experimental approach. However, simulating an artisanal fishery typical of a developing country setting as an experimental treatment would be expensive. And, experimental commercial fishing within a functioning reserve would probably not be acceptable to its stewards. The same can be said for fishery management areas; existing users of the area would not appreciate a competing fishery.

The next best approach to experimentation is empirical, essentially monitoring status and trends in standing stock and production. Perhaps the greatest progress in consciously developing efficient monitoring has been initiated by the Great Barrier Reef Marine Park Authority. The institution has adopted a systematic, deliberate approach toward defining monitoring program specifications (Gilmour and Craik, 1985; Craik, 1986; Lassig *et al.* , 1988). Craik (1986) articulates four objectives of the monitoring program; the third of these is "To test the well-being of the biological components and the state of the physical components of the Marine Park" (Craik, 1986:785). However, Lassig et al. (1988:313) note that, "There is a lack of widely accepted and practiced standardized data collection techniques. Even for a single genus of fish (*Plectropomus* sp.) few field workers can agree on the best census methods ..." Craik (1989:73) comments that there is a need "... for standardized information on abundance and distribution at major life history stages of fish of recreational and commercial importance." She suggests priority research should include (among other items) additional studies of catch, effort, age at maturity in fished and unfished areas, together with "... repetition of broad scale surveys of coral trout every 5 years." In a recent United States government document (MMS 1990) synthesizing present knowledge of the south Florida shelf area, Alevizon (1990:236), in a section devoted to reef fish communities, notes that, "None of the methods used to quantify the structure of reef fish communities of Florida reefs have demonstrated an acceptable level of precision or accuracy to suggest that they may be considered reliable estimators of actual or relative abundances of component species." He goes on to suggest that future changes will be difficult to quantify but that past studies are nevertheless valuable provided that their limitations are considered. In any event, accumulating experience in manipulating coral reef fishery ecosystems for various extractive and conservation purposes and experimenting with assessment strategies appear to be the major priorities at this time.

Beyond preventing damage, regulation of fishing is the manager's tool to manipulate the tropical reef fishery ecosystem. Stock dynamics, catch, and

CPUE are the response variables. Experience in how stocks respond to management (or lack of it) has been documented in some areas. While catch and CPUE has been described in places, what level and disposition of catch is desirable is difficult to articulate, and it is functionally linked to the socioeconomic environment.

Management success or failure must be judged when the managed system responds favorably or not. The expectation is that some combination of size/species distribution and, in fishing areas, production is caused to change and stabilize in a desired direction. Whereas the social climate may require differing approaches to management, it is proposed that a universal approach to stock/production assessment in coral reef areas is a practical prospect. It is suggested that standard methods, applied in exactly the same locations, over the long term, i.e., standard monitoring of well-defined stations, would be most fruitful in developing management experience for the long term. To be widely applicable, it is important that these standard methods be minimally dependent upon expensive apparatus or advanced scientific education. Resources to carry out environmental assessments and monitoring are often lacking or scarce in most developing country settings (Marr 1982) so the collection of management data must be as efficient as possible in those cases. It also seems important that the field data be archived in a consistent way so that experience may be readily shared with stewards of other systems. Since fundamental ecological processes are likely to remain poorly understood in the foreseeable future, it is reasonable to adopt an empirical approach and attempt to manage as well as can be expected.

Monitoring requirements among reserves and fishery management areas differ in some respects. Both systems require assessments of standing stock to evaluate status and trends in response to management. In reserves it is also a fundamental concern that the spawners which represent the source of varied genetic material do not swim to other areas where they may get caught. Thus it must be shown that the size/species distribution is stable and, ideally, the flow rate of spawners out of the reserve should be known. Of course, the effectiveness of any reserve as a supply of competent larvae will undoubtedly remain poorly understood or, at best, costly to quantify. In fishing areas, stock status must be quantifiable, as with reserves. But monitoring fishery production (catch) and effort should also be undertaken in order to develop some cause-and-effect information between stock and production. Note that monitoring CPUE provides a relative but independent estimate of stock size.

DISCREET STATION MONITORING

Much has been learned about physical and biological trends operating on reefs by returning after long time intervals to exactly the same spot and recording current status. Dahl and Lamberts (1977) described changes in reef sites in Pago Pago Harbor, American Samoa since a previous survey in 1917. Davis (1982) compared his reef map with one of 1881 at Dry Tortugas, Florida. Shinn (1976) documented coral cover changes at Key Largo, Florida and around the Quatar Penninsula at a scale of a decade; he essentially rephotographed the same sites. Dunstan and Halas (1987) documented reef changes over the same transects, 1974 to 1982, at Key Largo. It is proposed here that the same approach, i.e., station monitoring over time, may be fruitful in assessments of stock and production of the fish communities in reserves and management areas. The fundamental problem is that the signal to noise ratio for most measurements of fishery interest is low. Considering that, for several species at least, spatial variability is so pronounced at several levels (shelf, reefs, zones within reefs; Russ 1984a, 1984b; Williams and Hatcher, 1983), it appears that monitoring events at discrete spots is reasonable. How large to make such sampling stations and how often to visit them, i.e., how to scale stations in space and time to the parameters being measured, are the next questions.

PRIORITY ASSESSMENTS

The other fundamental issue is exactly what standard measurements should be reported and tracked through time. For standing stock, following Parrish (1982), it would appear to be most fruitful to monitor (trophic) functional groups with respect to biomass per unit area. Changes in predator biomass have been clearly demonstrated (NOAA, 1990; Beinssen, 1989; Craik, 1989). One should be able to demonstrate a signal in response to management by considering disposition of biomass by trophic composition (as by White 1988 and Russ 1985 in the Philippine Visayas) or reasonable taxonomic groupings (like Appeldoorn and Lindemann's [1985] haemulids in western Puerto Rico).

We propose that an assessment strategy which accounts for the highest proportion of the total fish biomass is most useful for management. In a given location (sensu Russ, 1984a) one would use a mix or repertoire of methods, some based on visual census and some not. Each transect, stationary sampling station, trap location, etc. would be permanently marked (e.g., Dunstan and Halas, 1987) so that the site could be repeatedly visited. Placing nearby a permanent small boat mooring anchor (Halas, 1985) would serve double duty by permanently marking the site and providing safe attachment for research boats (These moorings can be made quite unobtrusive - only a stainless steel ring protruding from coral rubble; we do not recommend permanent buoys - such items are vulnerable to theft or tampering.). With respect to visual census, Greene and Alevizon (1989) have shown that accuracy may be increased by censusing discrete groups, e.g., surgeon fishes, haemulids. Thus, to save time, it makes sense to rely on the method which appears to provide lowest variance for well defined discrete groups. Note that if one follows Greene and Alevizon (1989), for any station and method, one would have to repeatedly census a transect until all the discrete groups were done, e.g., snappers and grunts first, parrotfishes and surgeonfishes next, etc. It would appear that different visual census techniques could be applied to different discrete groups, each technique dependent upon the target groups' distribution in space and time. The following schedule is proposed: Stationary sampling (Bohnsack and Bannerot, 1986) for herbivores, site attached planktivores, and diel migrators; line transect (e.g., Miller and Hunte, 1987) for cryptic, widely distributed or (at night) nocturnal species; large predator survey (Beinssen, 1989) for reef piscivores. Many variations of visual census technique appear in the literature but a means of assessing wide ranging transients or reef pelagics (e.g., tarpon, *Megalops atlanticus*, or yellow jack, *Caranx bartholomaei*, in the tropical western Atlantic) which are frequently encountered, but at unpredictable moments, by assessment biologists has yet to be considered. These species, which are not site attached nevertheless probably have regular home ranges which could be sampled by some yet-to-be-developed technique; these animals are undoubtedly of great importance to the ecology of the reef fish community.

In back reef areas and seagrass meadows, traditional fishing gear which catches live fish has its place in completing a picture of standing stock. Antillean fish trap catch has been shown to be proportional to density in some species (Miller and Hunte, 1987; Recksiek *et al.* , 1991). Traps also may be used to collect fish for mark and recapture; Recksiek *et al.* (1991) used Chao's (1989) estimator of marked fish to estimate, for a dominant parrotfish and a grunt species, population size on an 8-ha reef in southwestern Puerto Rico. In addition it is suggested here that traps fished for short, standardized soak times, at exact stations, provide useful CPUE values for long term monitoring. Other methods which catch fish live certainly have much to offer. Encircling nets based upon Indonesian concepts (Subani and Barus, 1988/1989, Figure 106 and Figure 107) for sampling seagrass meadows and flats to assess densities of nocturnal foragers could generate precise estimates. Note that such seines, fished over constant (circular) areas, could provide reliable estimates of absolute density for size classes fully vulnerable to the gear (see also Jacobsen and Kushlan, 1987; Sogard *et al.*, 1987).

These methods all may be used to develop size frequencies (thus weight frequency if length/weight relationship is envoked). While most visual methods purport to estimate fish per unit area, it would perhaps be best to consider them as providing a kind of CPUE (sights per station or transect) so as to avoid problems of estimating catchability, and, the fundamental dilemma of how to define density when the topography is complicated. Monitoring this CPUE at well defined stations allows one to assess status and trends (for management) without necessitating making absolute density estimates.

In comparison with estimating standing stock in coral reef fisheries, particularly in the clear waters near shore, accurately quantifying production seems difficult. A variety of techniques have been used to estimate catch and effort. The usual approaches are to determine the disposition of the catch through sampling the market and/or obtaining data from fishermen (See Munro and Williams, 1985; Acosta and Recksiek, 1989; Marshall, 1980; White and Savina, 1987; Gobert, 1990). Sampling the market alone does not provide a measure of effort nor does it account for fish used for home consumption and fish sold or given away before entering the distribution chain (Stevenson *et al.*, 1982). At Apo Island, Philippines, White and Savina (1987) partioned marketed catch from that dried and consumed at home. These workers noted that by including non-marketed catch (p. 75), "... the estimate (31.8 t km-2 yr-1) ... for Apo is at the high end of yields reported ..." Acosta and Recksiek (1989:112) proposed that "... for tropical small scale fisheries, CPUE estimates based upon measurements from the fishing grounds, before the catch is diverted to domestic consumption and/or the market, provide useful indicators of stock size and condition on specific fishing grounds." Fishermen's skill varies tremendously and they may have several good reasons why not to be candid with an interviewer. On top of this, weather, seasonal concentrations, market conditions, gears, fishing power of different gears, fishing costs, and socioeconomic conditions are in constant flux. In preparing assessments of catch and effort under different social and environmental conditions, the choice of which variables to record is no easy task. As discussed previously, there is as yet no standard as to what tonnage, let alone its disposition among trophic levels, a healthy fishery ecosystem should or should not be producing.

INVOLVEMENT OF LOCAL POPULATIONS IN ASSESSMENT

We noted above that development and management of protected areas must take into account sociocultural and economic aspects of affected fisheries as well as biological information (also see Fisk, 1992). It is also important to note that obtaining reliable CPUE information from fishermen depends on an adequate assessment of the sociocultural and economic context of their activities. The only reliable source of socioeconomic and cultural information is the fishermen themselves. Hence, it is essential that the protected area assessment system accounts for social and cultural aspects of the occupation of fishing which can impact the collection of data and information.

There are numerous characteristics intrinsic to the occupation of fishing that influence sociocultural characteristics of both the workers and their communities (cf. Pollnac, 1988a).4 These characteristics are influenced by both technological and environmental aspects of marine capture fishing. Of interest here are characteristics which directly or indirectly influence obtaining information from fishermen. We will focus on two categories of behavior that influence information acquisition: 1) availability of fishermen for observation or interview and 2) attitudes of fishermen towards interviews.

AVAILABILITY OF FISHERMEN

In many parts of the world fishery resources are characterized by a fair amount of variability in production. One type of variability is seasonal. Human populations have adapted to seasonal variability through occupational multiplicity (e.g., fishing part of the year and farming the other part) or migration, following the availability of fish. Both of these adaptations frequently result in shifts in residence. This type of movement makes it difficult to determine statistics as basic as total number of fishermen in many countries (cf. Pollnac, 1988b; Lawson and Robinson, 1983). Although the problem is obvious, the solution is not. How is one going to develop cost effective, adequate sampling techniques to generate information of a quality that can be used for management decision making in a region or country characterized by fishermen with shifting residences? It is especially difficult when dealing with countries with limited human and monetary resources.

Another factor which influences availability of fishermen is fishing time. There is a great deal of variability with respect to gear limitations, fish feeding habits, market conditions, etc. Many fishing peoples fish at night or the very early morning hours and land their fish in the early morning. They frequently rest or sleep in the late morning and early afternoon. Hence, their resting hours coincide with the working hours of most government agencies. They either make themselves unavailable or are uncooperative when people try to interview them during their resting times. Fisheries characterized by variable hours or long trips also pose problems in access. In brief, obtaining information from fishermen differs significantly from obtaining information from most other occupational subgroups. One usually cannot interview them while they are working because they are out at sea. The times they are available onshore are frequently unpredictable or inconvenient for resource agency personnel.

Although this problem in access is also obvious, the authors have observed many instances of government fishery officials arriving in fishing communities at inappropriate times, encountering non-fishermen, hangers-on, or uncooperative fishermen and using them as sources for information. They then rush back to their air-conditioned offices, complaining about the quality of information and repeat the same mistake the next time they get requests for data. The question posed by this problem is a little easier to deal with because one only has to determine how to convince fishery officials to adjust their information gathering exercises to appropriate time periods.

FISHERMEN'S ATTITUDES

It was noted above that fishermen are sometimes uncooperative if interviewed during resting or sleeping hours. There are, however, other more general factors which influence fishermen's attitudes towards providing information. Numerous characteristics of the occupation of fishing serve to insulate fishing peoples, both geographically and socially, from the larger societies within which they are located (cf. Pollnac, 1988a). For example, fishermen tend to live along the narrow margin of the sea, and in many parts of the world, especially in developing countries, this results in residential isolation from the larger society. In the case of migratory fishermen, they are frequently viewed as outsiders as they follow their prey through established communities along the coast. Additionally, short term variations in the availability of fish influence the hours and days that fishermen work. Currents, winds, and relative visibility of gear frequently result in nighttime or very early morning fishing activity. These work patterns differ from the more regular hours kept by people in most other occupations; hence, they serve as a factor socially insulating fishermen from non-fishing people.

Further, due to characteristics of the occupation, fishing communities tend to be characterized by relatively egalitarian workgroups and increased status of women (cf. Pollnac, 1988a) which frequently distinguish the community of fishermen from other occupational subgroups within their society. When fishing people form part of a society that has a strong system of social stratification as in India (Norr, 1972), traditional Japan (Norbeck, 1954, 1968), China (Ward, 1955; Anderson, 1975), and Korea (Brandt, 1971), ocean fishing is frequently organized as the occupation of a low status, caste-like group. Norr and Norr (1974) suggest that this caste-like separation of fishermen functions to insulate the larger society from the potentially threatening egalitarian relationships that are characteristic of fishing peoples.

This social insulation of fishermen tends to influence their attitudes toward outsiders - they tend to distrust them, even more so than other occupational subgroups. A common complaint heard among many workers from agencies that have contact with fishermen is that they are uncooperative and hard to work with. This is probably a result of their distrust of outsiders. The question to be posed here is how does one break through this barrier of distrust to obtain cooperation and reliable information?

Suggestions for information acquisition Several authors have discussed problems in obtaining information from fishermen (eg. Pollnac and Sutinen, 1979; Sutinen and Pollnac, 1980; Stevenson *et al.*, 1982; Fox, 1986; Holthus, 1990) and techniques devised by anthropologists, sociologists, and psychologists can be applied to this problem. These techniques must be built into information acquisition schemes aimed at establishing, monitoring, and evaluating coral reef management areas if one desires decisions based on adequate data. In the Philippines, White and Savina (1987) sucessfully relied upon local people in preparing catch assessments; these authors acknowledge this participation (p. 75): "Much credit goes to the many Apo fishermen and middlemen who were interested ... to record their catches for the year."

Obtaining information, even if it is limited to CPUE and minimal sociocultural and economic data, can be quite costly. Officials sometimes balk at the costs. Sometimes adequate funds are simply not available as in many lesser developed countries. In these cases it will be necessary to rely on low cost, rapid appraisal techniques (cf. Longhurst, 1981; Kumar, 1987; Fox, 1986). Although these techniques may not provide ideal data sets for generating needed information, if properly applied they can at least provide some indicators in situations where decision makers would otherwise be operating with information characterized by wishful thinking, rumor, or outright misinformation. Some have suggested that fishermen's organizations (e.g. cooperatives) can be used to facilitate obtaining information (e.g. Latiff, 1976; Pollnac and Littlefield, 1983; Jentoft, 1986, 1988). These organizations (if effective) could function to improve the two-way communication between scientists and fishermen (cf. Jentoft, 1986) as well as overcome the logistical difficulties of collecting catch and effort statistics from fishermen who are scattered over a large area.

Given the above information, it seems that the most reasonable thing to do is to divide the fishing grounds into manageable areas and stratify these by gear use (as by Gobert, 1990 at Martinique) and to monitor catch and effort from selected individual fishermen and/or fishermen's organizations over time. For each stratum of the fishing grounds, and for each individual fisherman and/or organization, accurately monitoring CPUE of individual targeted species' sizes through time should provide information useful to guide managers. It is proposed that working with trusted, representative individuals and/or organizations who can provide full details is more fruitful than a procedure for sampling the catch of all participants since relative values only are enough to decide what is happening in the fishery. For example, if our experienced fisherman no longer takes Nassau groupers where they were once frequently encountered, then one can be assured that something has changed. Suggestions for development and use of record keeping forms and logs to be used by fishermen and primary buyers to provide CPUE data are discussed in Sutinen and Pollnac (1980) and Stevenson *et al.* (1982). Evaluations of information generated with the use of these techniques can be found in Sutinen and Pollnac (1980).

As noted above, the proposal to rely on individual fishermen and/or organizations to provide CPUE data is realistic only if the persons in charge of assessing the fishery are sophisticated enough to communicate with them as familiar individuals. The assessment biologists must know the sociology, technology, and grounds of the fishery. It is realistic also that any fisherman and/or organization providing data should somehow be compensated for the service. For example, purchasing the privilege to monitor landed catch would seem to be a fair exchange; Acosta and Recksiek (1989) believe that this approach contributed to accuracy in their study. Relying on a cadre of individuals to provide accurate information depends upon sensitivity and subtlety. Failing that, one must rely on the fish market but one has then no idea what is really going on. While providing compensation to help out may appear costly, it seems more cost effective than relying on a full-time market sampler. What is desired for management is an accurate picture of status and trends in size and species distribution for defined strata. It is proposed that an analysis based on individual production obtained from either the individual or a fishermen's organization would produce the most useful information.

CONCLUSIONS

Failing a model for ecosystem health and faced with a complex of social settings, management of coral reef fishery ecosystems is not clear cut. While ecological processes will slowly be discovered, managers need to act immediately to enhance production and sustain it over the long term. Establishment and maintenance of protected areas is dependent on sociocultural as well as biological factors. People will continue to depend upon coral reef ecosystems for food and recreation. Prevention of destructive practices is essential. Sustainability depends upon the existence of reserves, essentially marine wilderness, but the best way to arrange this is unknown; the best guess is to set aside some fraction of the ecosystem - a tough if not unattainable prospect in many developing country settings. Routine station monitoring, within and without reserves, will probably provide a useful picture of stock status and trends, at least functionally. Status and trends in production can probably be most accurately pictured by monitoring individual fishermen's catch and effort within gear and bottom type defined strata in the fishery.

FOOTNOTES

[1] This is extremely important, especially in light of the fact that fishing communities in a particular country and even in a given region of a country sometimes vary widely due to variance in the physical and/or social environment. Poggie and Pollnac (1981) pointed out how differences between a number of New England fishing ports resulted in differential responses to management initiatives and argued that rules should be flexible to account for such differences. Use of cooperatives or other fishermen's organizations can provide this flexibility. Ruddle (1987), in part, attributes the successful use of fishermen's cooperative associations (FCA) in Japan to rules and regulations which, "...limit themselves virtually to a simple statement of basic principles and fundamental rules of behavior [which allow] a wide latitude for interpretation. In general, the rules and regulations permit a flexibility, on a characteristically Japanese case-by-case basis, as suited to the specific requirements of each FCA" (Ruddle, 1987:86).

[2]. While, ideally, fishermen's cooperatives can be used as tools to insure equitable management, one must keep in mind the fact that they can also be used as tools for bureaucratic exploitation of the producers (cf. Hannig, 1988).

[3]. Craik's (1989) text does not have page numbers. The quote is from the seventh page (including the title page).

[4]. Attempts to generalize about behavior of a group of people as diverse as fishermen are destined to be confronted with cases which run counter to the generalizations. Nevertheless, such generalizations are useful since they facilitate preliminary planning which can then be adjusted to deviations from expected situations.

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