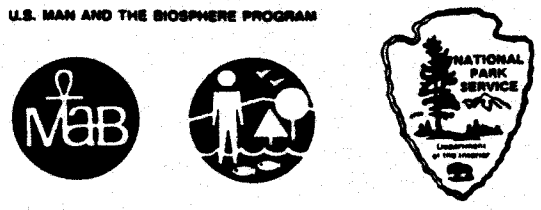
# VIRGIN ISLANDS RESOURCE MANAGEMENT COOPERATIVE

**BIOSPHERE RESERVE**
**RESEARCH REPORT NO.10**

## ASSESSMENT OF FISH AND SHELLFISH STOCKS PRODUCED IN THE BIOSPHERE RESERVE


Arthur E. Dammann
Island Resources Foundation
St. Thomas, U.S. Virgin Islands



**Virgin Islands National Park**

**October, 1986**

# ASSESSMENT OF FISH AND SHELLFISH STOCKS PRODUCED IN THE BIOSPHERE RESERVE

BIOSPHERE RESERVE

RESEARCH

REPORT NO. 10

ARTHUR E. DAMMANN
ISLAND RESOURCES FOUNDATION
ST. THOMAS, U.S. VIRGIN ISLANDS

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

AND

VIRGIN ISLANDS RESOURCE MANAGEMENT COOPERATIVE
VIRGIN ISLANDS NATIONAL PARK
P.O. BOX 7789, ST. THOMAS
U.S. VIRGIN ISLANDS 00801

LOCAL CONTRACTING AGENT
ISLAND RESOURCES FOUNDATION
RED HOOK BOX 33, ST. THOMAS
U.S. VIRGIN ISLANDS 00802
(NPS CONTRACT NO. CX-0001-3-0048)

Abstract

REPORT NO. 10
Subtask 2.3

ASSESSMENT OF FISH AND SHELLFISH
STOCKS PRODUCED IN THE BIOSPHERE RESERVE

At the present time there are no data and no methodologies that are suitable for assessing the production from fishery stocks in such a small and arbitrarily defined geographic area as that of the Biosphere Reserve. For management purposes it is recommended that the Biosphere Reserve utilize the data and management measures which are produced and recommended by the Caribbean Fishery Management Council for the geological platform of Puerto Rico and the northern Virgin Islands.

The entire platform contains stocks which are probably as discrete as any marine stocks can be. Until their relationship to the pan-Caribbean species, of which they are members, can be quantified they should be managed as distinct populations but not as populations confined to politically defined areas within the naturally isolated platform.

The very complex nature of tropical coral reef, grassbed, mangrove ecosystems and the small-scale fisheries which depend upon them, pose many problems for managers. The number of species entering the landings, the difficulty of obtaining statistical data from the scattered points of landing and the lack of middlemen and processors in the fishery make the use of usual mathematical techniques suspect for such fisheries.

Moreover, in contrast to more highly capitalized commercial fisheries of other regions, the socio-cultural aspects of island fisheries become of relatively greater importance than the purely economic aspects. Fishery development projects in these tropical island shelf environments have a notably high rate of failure. Some of the factors which contribute to the failures are (1) the inability of political and economic developers to accept the low productivity and fragility of the fishery stocks on the platforms (2) the imposition of highly capitalized and mechanized fishing efforts on the system and (3) a misunderstanding of the actual role that small-scale fisheries play in the lives and well-being of indigenous people.

TABLE OF CONTENTS



List of Figures



List of Tables

# FOREWORD

Virgin Islands National Park was designated as an International Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in June, 1976. However, the formal dedication did not take place until May, 1983. The standardized, single-page description of the area which was issued by UNESCO under the Man and the Biosphere Program, MAB Project 8, in 1976 is entirely inadequate for the purpose of meeting Biosphere Reserve Objectives.

The purpose of the present (VIRMC I) project was to provide more detailed descriptions of the Reserve's physical and biological features as well as certain aspects of human use, such as fishing and boating. Inherent in the concept of the Reserve is the belief that it is intimately related to the nearby British Virgin Islands and that it should also fit within a future multi-site Lesser Antillean Biosphere Reserve.

The following reports are included in the VIRMC I Research Series Reports.

The West Indies Laboratory (Fairleigh Dickinson University) prepared the reports for "Ecological Community Type Maps and Biological Community Descriptions for Buck Island Reef National Monument and Proposed Marine Park Sites in the British Virgin Islands," "Trends in Recreational Boating in the British Virgin Islands, A Preliminary Assessment of Impact from Human Activities on Anchorages and Development of a Monitoring Program for Safe Anchorages," "Geographic Range and Research Plan for Monitoring White Band Disease," and "Marine Ecosystems of the Lesser Antilles - Identification of Representative Sites."

The Division of Fish and Wildlife (Department of Conservation and Cultural Affairs, Government of the U.S. Virgin Islands) prepared, "Map of Fishery Habitats Within the Virgin Islands Biosphere Reserve," "Fisheries Habitat of the Virgin Islands Region of Ecological Importance to the Fishery Resources of the Virgin Islands Biosphere Reserve," "Utilization of the Virgin Islands Biosphere Reserve by Artisanal Fishermen," and "Long-Term Monitoring of Fisheries in the Virgin Islands Biosphere Reserve."

The Caribbean Research Institute (College of the Virgin Islands) prepared, "Marine Community Descriptions and Maps of Bays Within the Virgin Islands National Park/Biosphere Reserve," and "Collection of Common Organisms Within the Virgin Islands National Park/Biosphere Reserve."

The Island Resources Foundation prepared, "Assessment of Fish and Shellfish Stocks Produced in the Virgin Islands Biosphere Reserve," "Socioeconomic and Cultural Role of Fishing and Shellfishing in the Virgin Islands Biosphere Reserve Area," "Characterization of Lesser Antillean Regional Fisheries," as well as the Synopsis and Executive Summary.

Field work for the project was carried out during the period December, 1983, through October, 1984. Copies of the individual reports can be obtained from: The Virgin Islands National Park, Red Hook Headquarters, P.O. Box 7789, St. Thomas, Charlotte Amalie, VI 00801.

# 1. INTRODUCTION

## 1.1 Background for marine fish stock assessment.

The estimation of marine fishery stock parameters is an extremely difficult undertaking. There is a large and rapidly increasing volume of literature that attests to this fact. Although the basic principles are set forth in every college text on ichthyology and fisheries, a better understanding can be had from such works as those of J.A. Gulland, 1969, 1971, 1976, 1978, 1979, 1982, 1983; G.A. Rounsefell, 1975, and many other fisheries scientists. Much of the statistical methodology presented by them was developed for use in the single-species fisheries of temperate and/or cold waters.

The general kinds of data that have been used to estimate stock size and its utilization on a sustained basis are both biological and fisheries derived (see Figure 1). Examples of the biological data types are; (1) basic productivity in terms of carbon fixation and its transfer through the trophic levels, (2) length-weight frequencies of individual species, and (3) age, growth and mortality rates. The most widely used information from fisheries is catch per unit of effort. Effort has been measured in such units as time, number of boats, gear, and fishermen and the catch by numbers, weights or species composition.

## 1.2 Special case of tropical shallow water fisheries.

The problems of marine fish stock assessment are multiplied many times in shallow tropical seas. This is so mainly because of the large number of species involved in the fishery and the complex inter-relationships of the coral reef - grassbed - mangrove shoreline ecosystems of which they are part

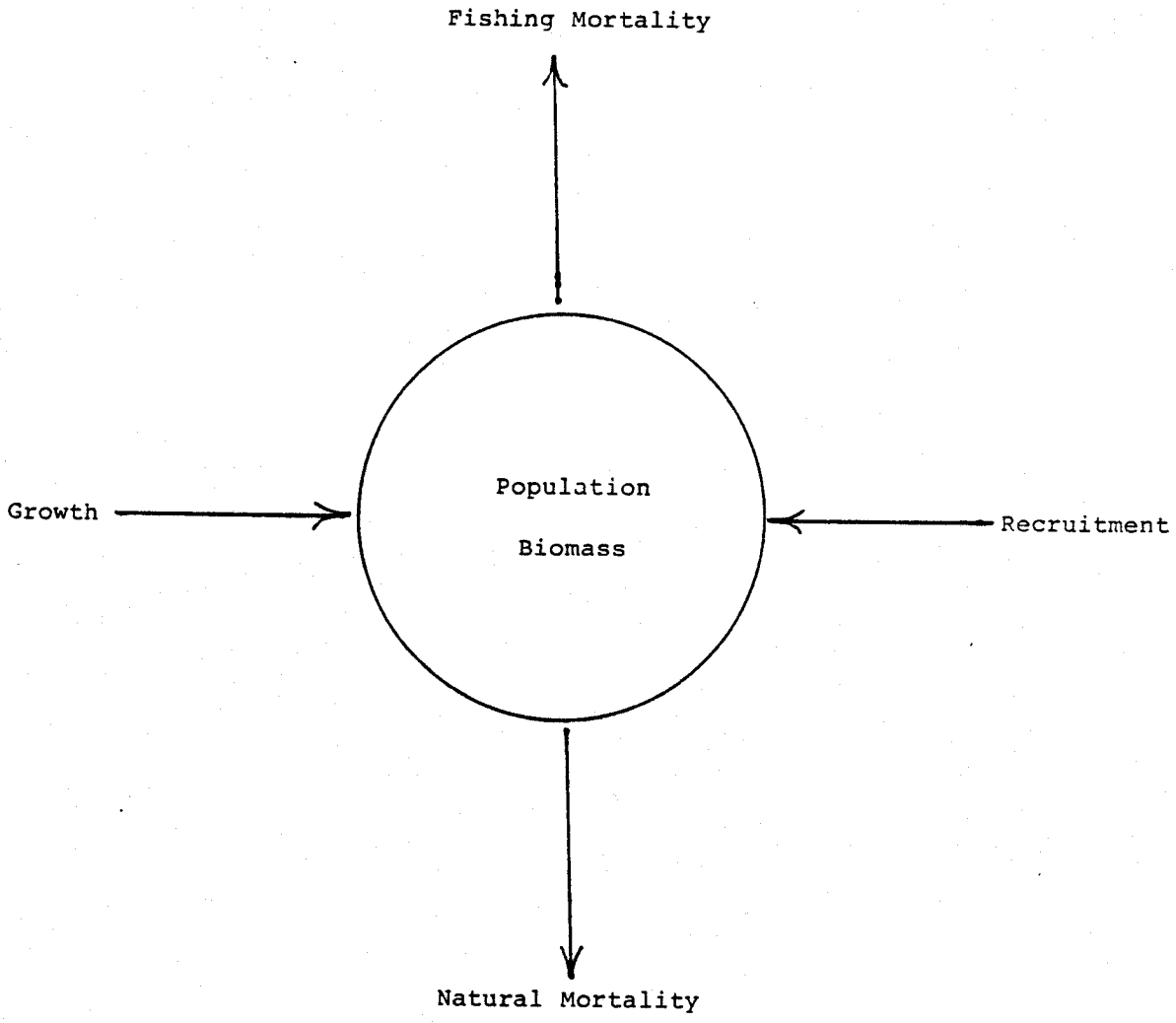



Figure 1 Fundamental Model of Fish Stock Population Dynamics. From M. P. Sissenwine, 1981

In recent years as exploitation of the world's total fish stocks has accelerated, the tropical stocks have become important resources for the countries which have them. Consequently, greatly increased attention is being paid to the assessment and management of these stocks. For an introduction to the special problems and the techniques being developed to solve them, the reader is referred to three publications which deal with all aspects of shallow-water, tropical, reef-fish fisheries. In chronological order they are: Saila, S.B. and P.M. Roedel, 1979, Stock Assessment for Tropical Small-Scale Fisheries; Pauly, D. and G.I. Murphy, 1982, Theory and Management of Tropical Fisheries; and Munro, J.L., 1983, Caribbean Coral Reef Fishery Resources.

The individual papers that make up these publications are listed by author in the reference section. However, Saila, et al., report on an international workshop and divide the presented papers into "perspective" and "experience" sections, both of which address the problems of fishery stock assessment and management in "Lesser Developed Countries" with the title including the identification and delineation of species and stocks, the measurement of stock abundance, the determination of the effects of fishing in multi-species fisheries, the collection of biological and economic information necessary for wise management, and the analysis and interpretation of the data to permit formulation of management measures for tropical fisheries around the world and including the Caribbean region. Munro says that his volume is a second edition of "The Biology, Ecology, Exploitation and Management of Caribbean Reef Fishes: Scientific Report of the ODA/UWI Fisheries Ecology Research Project 1969-1973: University of the West Indies, Jamaica." The original papers on the biology, ecology and bionomics of the various fish and crustacean families in the harvest are included as well as an epilogue on, "The

Progress in Coral Reef Fisheries Research, 1973-1982." This last chapter includes technical and scientific advances with much recent information on mathematical models and the utilization of reproduction and recruitment, age and growth, and mortality rates for many fish and crustacean families in stock assessment and estimation of potential harvests from coral reef areas.

### 1.3 Utilization of data produced by the VIRMC program.

The data produced by the VIRMC program offer the chance to eventually utilize still other methods of assessment. There will be, by direct observation, fish counts by species and estimated individual sizes for each mapped habitat type. It should become possible to quantify the standing stock per unit area of each habitat type and, by extrapolation, the entire area of the Biosphere Reserve as well as the whole geological platform (Ogden, 1982). Sustained yield estimates from this approach will be possible at some time in the future but continued monitoring will verify results and indicate changes in structure. Fish populations fluctuate, and perhaps independently of the perturbations in their habitat (Steele and Henderson, 1984), so that monitoring is essential. Until such time as direct fish counts can be used as a stock assessment tool, more traditional methods must be employed.

## 2. PRESENT STATUS OF KNOWLEDGE REGARDING VIRGIN ISLANDS STOCKS.

### 2.1 Definition of stocks.

Nearly all the species involved in the fisheries of the Virgin Islands and Puerto Rico have pan-Caribbean distributions. A great many of them also range throughout the Bahamas and as far north as Bermuda. Virtually no subspecies or races have been described by taxonomists. To the biologist this genetic integrity at the species level implies considerable gene exchange over time. In other words, if the populations of each insular platform were

absolutely or nearly perfectly isolated from one another, genetic divergence would be obvious, as it is in the terrestrial biotas of the islands. These biotas show a great deal of endemism. They have, in fact, been described and used as natural laboratories in the study of evolutionary processes brought about by geographic isolation (MacArthur and Wilson, 1967).

However, recent and ongoing studies of the blood serum proteins of various Caribbean aquatic species indicate that some isolation does exist. Samples from various parts of the range of these species show consistent differences (Menzies, et al., 1976). Other recent studies (Molinari, et al., 1980) of ocean currents in the Caribbean Sea show clear mechanisms that would allow marine planktonic larvae to maintain their relative position to a particular insular shelf. Thus it has become clear that each insular platform recruits new individuals both from within and outside its own system. The problem remains of determining, in each case, how much recruitment from each source is occurring. This is also discussed by Goodwin (1985) in "Characterization of Lesser Antillean Regional Fisheries."

The Caribbean Fishery Management Council in preparing fishery management plans for spiny lobster, shallow-water reef fish, and an ecosystem-type plan for all the resources of the geological platform, determined that the organisms of the shelf can, and should, be treated as distinct stocks for purposes of management. This viewpoint will prevail until new data indicate differently.

It is difficult if not impossible from a biological or fisheries standpoint to treat the organisms of the Biosphere Reserve as distinct stocks. There are no natural boundaries for the area, and political boundaries are arbitrary and meaningless from a biological standpoint. Many animals actively move in and out of the area on daily and/or seasonal bases.

## 2.2 Existing estimates of productivity: coralline shelves.

A number of estimates of sustainable yield have been made for fisheries in coral reefs and the adjacent shallows such as are found in the area of the Biosphere Reserve. These estimates have been made both from fisheries data (of poor quality and short term for the Virgin Islands as a whole, and non-existent for the Biosphere Reserve) and basic productivity in terms of carbon fixation. The latter method involves many assumptions about trophic level efficiency but forms the basis of most ecosystem, or biomass models.

These estimates on fisheries potential range from less than 1 ton/$km^2$ to 15-20 tons/$km^2$. The lowest estimates come from badly overexploited areas with little living coral reef, and the highest come from areas with a high percentage of living reef. Table 1 indicates that many estimates range from about 3 tons/$km^2$ to 5 tons/$km^2$ for average shelves in good condition. Munro (1983) concludes from the published information that 4-6 tons/$km^2$ are attainable from coralline shelves from the shoreline to the 200m isobath. Marshall (1979) compiled Table 1 and commented on it as follows:

> More important than the catch per se are the insights such information may give regarding yield potential. Munro (1978a), using a surplus yield model based on extrapolations in which the number of canoes in the fishery differed from areas to area, gives a figure of 4.1 tons/$km^2$/yr as the maximum to be expected in managing present fishery practices off the south coast of Jamaica. In the report of the FAO/IOP Workshop on the Fishery Resources of the Western Indian Ocean, sites are calculated against trap fishing intensity to suggest a potential harvest of 5 tons/$km^2$/yr. Though the latter appraisal is based on sketchy

TABLE 1

Estimates of potential fisheries yield of coral reefs and adjacent shallow water environments.

| | |
|---|---|
| Munro (1978)<br>South of Jamaica | 4.1 tons/$km^2$/yr-surplus yield model from concurrent trap fishing intensities with some recognition of seine and gill net catches; i.e., demersal plus neritic pelagic fishes taken |
| FAO (1978)<br>Western India Ocean | 5 tons/$km^2$/yr-extrapolating from trap catch data, different areas |
| Stevenson and Marshall (1973)<br>Worldwide | 4.7 tons/$km^2$/yr-highest yield; presumably diverse gear and for both demersal and neritic pelagic finfish |
| Gulland (1971)<br>Caribbean | 2.5 tons/$km^2$/yr for Bahamas, 4 tons for Caribbean-presumably involves diverse gear; about 80% neritic pelagic, the balance demersal |
| Bayliss-Smith (Unpublished)<br>Pacific | 4.4 tons/$km^2$/yr-maximum yield from and reef-bordered islands |

From Marshall, N., 1979

information, the two approaches reinforce each other. They about equal the maximum yields Stevenson and Marshall (1974) had noted in reviewing the literature; they are roughly in accord with Gulland's (1971) maxima, calculated from the tabulations presented, of 2.4 tons/$km^2$/yr and 4 tons for the Bahamas and Caribbean shelf areas, respectively; and they are similar to the maximum reported by Bayliss-Smith in a comparison of four atolls and reef-bordered islands with Lakeba, Fiji, yielding about 4.4 tons/$km^2$/yr (unpublished ms.).

The canoe fishery analyzed by Munro was largely a trap effort, but other gear, including seines and gill nets, were involved in the fishery, and he referred to the potential as including demersal plus pelagic neritic fishes. The FAO projection was for traps only. The maxima mentioned by Stevenson and Marshall and Bayliss-Smith presumably included all fishes, and Gulland referred both to demersal and to a component of pelagic neritic amounting to about 80% of the total. Apparently these projections generally do not include living resources other than fishes. One should add the potential in lobsters, shellfish, beche-de-mer, turtles, etc., plus miscellaneous gleanings from off the reef, which Hill (1978) notes, in a study on American Samoa, can be both high and relatively noncompetitive with other production.

## 2.3 Productivity estimates for the Puerto Rican and Virgin Islands geological platforms.

The Caribbean Fishery Management Council using a production estimate of 73 lbs/a/yr (33 kg/ha/yr) made by Juhl in 1973 prepared Table 2 for use in the Fishery Management Plan, Regulatory Impact Review and Environmental Impact Statement for the Shallow-water Reeffish Fishery of Puerto Rico and

TABLE 2*

MSY ESTIMATE FOR SHALLOW-WATER REEFFISH IN PUERTO RICO AND U.S. VIRGIN ISLANDS, USING THE BIOMASS APPROACH (Gulland, 1969)**

| Factors | Puerto Rico | U.S.V.I. | All Area |
|---|---|---|---|
| Shelf Area (Ha.) | 553,779 | 196,650 | 750,429 |
| Kg/ha/yr | a/ 33 | a/ 33 | a/ 33 |
| Biomass (Thd. Kg.) 1/ | 18,275 | 6,490 | 24,765 |
| Natural Mortality | 0.5 | 0.5 | 0.5 |
| Fishing Mortality | 0.5 | 0.5 | 0.5 |
| Biomass adjusted for mortality (Thd. Kg.) | 4,569 | 1,622 | 6,191 |
| % Finfish | b/ 76 | b/ 80 | - - |
| Total Finfish (Thd. Kg.) | 3,472 | 1,298 | 4,770 |
| %Shallow-Water | b/ 70 | b/ 80 | - - |
| Total Shallow-Water (Thd. Kg.) | 2,431 | 1,038 | 3,469 |
| MSY (Million pounds) | c/ 5.4 | c/ 2.3 | c/ 7.7 |

1/ Fish and shellfish only
a/ 33 kg/ha/yr is Council's conversion of 73 lbs./ha/yr (Juhl, 1973)
b/ According to 1982 landings
c/ Conversion of kilograms into pounds (1 kg. = 2.2 lbs.)
** This is meant to imply only that the method was taken from Gulland.
* From Caribbean Fishery Management Council documents.

the U.S. Virgin Islands. The biomass estimate of 33 kg/ha/yr includes both fin fish and shell fish.

In the area of the Biosphere Reserve, the shellfish harvest is represented by spiny lobster, conch and whelk. The same organization used the virgin stock biomass approach to prepare the following excerpt from the Environmental Impact Statement/Fishery Management Plan and Regulatory Impact Review for the Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands. The MSY was estimated by using the virgin stock biomass method described by Gulland which calculates that the MSY of an unexploited stock is taken when that stock is fished to approximately one-half the total stock. (Adequate data for other methods of calculation do not yet exist in this fishery).

> To estimate the virgin stock biomass, shelf areas around Puerto Rico and the U.S. Virgin Islands were divided into 15 zones. Estimates of the probable effective habitat in each zone were made based on geologic, photographic, bathymetric, and ecologic information. Virgin biomass for each zone was estimated from observed lobster densities and effective habitat area in the Virgin Islands. From this baseline information, the virgin biomass for each of the three larger areas, Puerto Rico, St. Thomas-St. John, and St. Croix was calculated. All of this shelf area with suitable habitat is not easily fishable because of sea conditions, currents, depth, bottom topography, and distance from port as these relate to the boats and gear presently in use.
>
> The estimates of MSY for each area were then calculated by multiplying one half the virgin stock biomass by an appropriate estimate of fishing,

mortality (.5 instantaneous rate, .39 annual rate). The resulting estimates for spiny lobster are given below:

| Area | MSY ESTIMATE (live weight) |
|---|---|
| Puerto Rico | 610,000 lbs/yr |
| St. Thomas-St. John | 116,900 lbs/yr |
| St. Croix | 102,400 lbs/yr |
| Total Management Area | 829,300 lbs/yr |

The above total is rounded to 830,000 lbs/yr which is the estimated MSY.

All the recent local studies and derived data for spiny lobster populations are presented by the Caribbean Fishery Management Council in the plan for the spiny lobsters of Puerto Rico and the U.S. Virgin Islands. However, the British Virgin Islands have also adopted the provisions of the U.S. FMP.

Caddy (1981) recommended that this same method be used in the British Virgin Islands in order to safely develop a fisheries program for their waters. Since the British Virgin Islands share the same geological platform with the northern American Virgin Islands and Puerto Rico, along with the presumably same fish stocks, this would have the advantage of making the data from all three political entities comparable.

The following abstracts are for fishery management plans which are presently in effect in U.S. Caribbean waters.

Abstract of the existing plan for spiny lobster.

Harvest Restrictions

The Virgin Islands has previously regulated lobster harvest on the basis of a 3.0-inch minimum CL, while Puerto Rico has had no minimum size limitation. Small lobsters in Puerto Rican landings have increased at the average rate of two percent per year over the past decade. The average size of lobsters in Puerto Rico has declined from a 4.0-inch

CL in 1957 to a 3.68-inch CL in 1979. During this same period, the percentage of lobsters landed having a CL of less than 3.5 inches increased from 19.6% to 40.7%. The fastest rate of growth in spiny lobsters occurs between a 1.6- and 3.5-inch CL. Sexual maturity is attained by most females between a 3.0- and 3.5-inch CL. A minimum size limit of 3.5 inches is established to take advantage of this period of rapid growth and to achieve sustained reproduction of the population. This minimum size restriction should reverse the trend of declining average size of lobsters and subsequently increase total yield from the fishery. Lobsters with a CL of less than 3.5 inches can be retained in traps as attractants.

The relationship of the minimum CL (3.5 inches) to reported landings or values will be analyzed when these landings or values deviate significantly from expected landings or values specified in the FMP. If the results of this analysis indicated that the 3.5 inch minimum CL does not provide sustained recruitment into the fishery or anticipated changes in income, the Secretary of Commerce, after consultation with the Council, and an opportunity for public comment has been afforded, can adjust the minimum CL in units of 1/4 inch by regulatory amendment.

The regulations prohibit the retention of berried spiny lobsters and require that such lobsters be immediately returned to the water unharmed unless they are used as attractants in traps. Stripping lobsters of their eggs is prohibited. These measures are designed to aid recruitment by providing additional protection to spawning stock.

There are no time, area, or effort limitations in these regulations.

## Permits and Markings

Vessels in the lobster fishery are required to possess either a permit issued by the governments of Puerto Rico or the Virgin Islands or by the Regional Director, Southeast Region, National Marine Fisheries Service (NMFS).

All vessels are required to display their official number along with the color code issued with their permit. Also, traps or pots and affixed buoys have to be identified with the vessel's color code and permit number. These markings will help resolve gear-ownership conflicts between fishermen, aid law enforcement, and assist in the acquisition of data on the fishermen's mobility and fishing effort.

## Gear Restrictions

The regulations require all traps or pots used for harvesting spiny lobsters to contain on any vertical side, or on the top, an opening no smaller than the diameter of the entrance to the trap. The opening may be covered either with degradable netting or with some other material fastened to the traps with degradable fiber or wire. These openings will allow the escapement of lobsters from lost or abandoned traps.

The use of explosives, poisons, chemicals, spears, hooks and similar devices is prohibited for the taking of spiny lobsters. These restrictions are intended to minimize injury and mortality of sublegal-size lobsters and to prevent damage to coral reef habitat.

## Statistical Reporting

Information is needed for effective management of the spiny lobster fishery. In the past, Puerto Rico collected landing statistics on a voluntary basis, while the Virgin Islands has a mandatory collection system. The FMP requires mandatory reporting of catch and effort information through the improvement of these systems. Therefore, NMFS is developing a mandatory reporting system that utilizes sampling methods whenever a sample will provide adequate information. The Center Director, Southeast Fisheries Center, NMFS, will determine the number of individuals selected, the reporting interval, and the duration of reporting, based on the data required for specific management needs.

Because this system has not been completely developed and forms not yet prepared, the regulations reserve Subsection 645.5, which provides for the collection of statistical data. It is anticipated that the mandatory reporting system will be proposed as soon as sampling procedures and reporting forms are developed and approved. The forms will be submitted to the Office of Management and Budget for clearance under Section 3507 of the Paperwork Reduction Act, Pub, L. 96-551. Until such time, current methods of data collection will be used.

## Abstract of the existing plan for reef fish

The following action is to adopt and implement a fishery management plan for the shallow-water reef fish fishery within the area of authority of the Caribbean Fishery Management Council around Puerto Rico and the Virgin Islands. The objectives of the plan are to: 1) obtain the necessary data for management and monitoring; 2) stop the

declining trends (i.e., decrease in landings and catch per unit of effort [CPUE]) in the resource; 3) reduce conflicts among harvesters of the resource; 4) promote compatible, if not uniform, management of the pan-Caribbean species in the unit, and 5) help to solve the ciguatera problem.

The following measures are intended to accomplish the objectives: 1) establish 1-1/4" minimum mesh size for fish traps; 2) require a self-destruct panel and/or self-destruct door fastening in fish traps; 3) require owner identification and marking of gear and boats; 4) prohibit the hauling or tampering of another person's traps without owner's written permission; 5) prohibit the use of poisons, drugs, other chemicals, and explosives for fishing; 6) establish a minimum size for high-value species like yellowtail snapper and Nassau grouper; 7) establish a closed season for Nassau grouper; 9) recommend to the Government of Puerto Rico to close a section of the island of Culebra and the islands of Mona and Monito, to all fishing on an experimental basis to assess the "closed areas" as a management strategy; 10) recommend that pertinent authorities cooperate with the National Park Service (NPS) in the U.S. Virgin Islands in establishing fishery research projects to assess stocks inside and outside the NPS system; 11) recommend to the local governments to prohibit taking haul or beach seines onto the beach; 12) recommend to the pertinent authorities to fund and support research to help solve the vexing and dangerous problem of ciguatera and; 13) to recommend the local governments to adopt and implement the management measures proposed in this FMP within their fishery jurisdiction in order to manage the species through their entire range.

Wood et al. (1983) surveyed conch populations in the American Virgin Islands. They estimate an MSY of 364,000 lbs. annually for the shelf area around St. Thomas and St.

John (162,925 ha). Boulon (1985), includes conch, whelk and spiny lobster counts along with fin fish in selected habitat types of the Biosphere Reserve. Randall (1964) studied whelk on the south shore of St. John within the area of the Biosphere Reserve and this represents all the published material on local whelk populations. It is not feasible to extrapolate data from any of these studies into a productivity estimate for the Biosphere Reserve.

However, all these data are presently being incorporated into an "ecosystem type" fishery management plan and model for the Puerto Rican and Virgin Islands geological platform by the Caribbean Fishery Management Council. The government of the British Virgin Islands is actively involved in the preparation of this plan so that the fish stocks which are common to this naturally defined area can come under compatible management and development regimes. It seems, as previously indicated, unreasonable to artificially isolate the area of the Biosphere Reserve from this larger naturally discrete region.

Given the fact that there are insufficient fisheries data for the area of the Biosphere Reserve to employ standard fisheries statistical methods, other methods of estimating productivity for the area should be considered.

It is technically possible to calculate the marine area of the Biosphere Reserve, make an adjustment for the fact that virtually all of it lies within very shallow water, multiply by some productivity estimate such as 33 kg/ha/yr or 5 tons/$mi_2$ and arrive at a productivity number or MSY for the Biosphere Reserve. This, in reality, is such a meaningless exercise that one hesitates to commit such a number to the printed page. Such numbers become detached from their original context and are then used in future calculations, thus compounding the uncertainties and errors, which were involved in their origin.

It is probably best, for the present, to use the data from Boulon (1985) which give some indication that many

juvenile fin fish species as well as the juveniles of spiny lobster and conch are most numerous in very shallow, protected, near-shore habitats such as mangrove shoreline.

He says, "The average size of fish per species in this habitat gives the greatest evidence for the theory that the mangrove habitat is a nursery habitat. Except for species unique to this habitat, all species present had an average size less than the average size per species for all habitats". He counted twenty-five species of commercially important fish and says; "Many of these were very abundant and can thus be considered species for which this habitat is significant as a nursery or juvenile development area." Slightly further offshore, in deeper water, larger individuals were found. According to Boulon the Lower Fore-reef habitat..."forms the seaward border to most reef systems where they drop off into deeper water...the number of pelagic species observed was higher than in any other habitat...also supports a large number of lobsters...of the forty species...32 species had an average size per species, larger than or equal to the total average size for all habitats. This would suggest that this habitat supports mature reproductive individuals with a few juveniles and sub-adults. Further supporting this hypothesis is the number of species found here with larger individuals than in any other habitat." A good bit of evidence suggests that pelagic eggs are released in these deeper offshore waters and that the resulting larvae return, or are returned, to the inshore nursery areas. However, there is virtually no quantification of such a process.

## 3. MANAGEMENT RECOMMENDATIONS

At the present time it would seem prudent to incorporate management concepts and measures that are either in effect or in preparation for the rest of the geological platform into those for the Biosphere Reserve. Unless it can be demonstrated that such measures are inappropriate for the

fisheries of the Biosphere Reserve, this would have several advantages.

First it would attempt holistic management of naturally occurring fishery stocks throughout their range. Second, it would simplify and economize management for the user groups as well as the agencies responsible for carrying out management regimes. Third, it would provide a common, or comparable, data base between the various management agencies. Since all the agencies are attempting to monitor, utilize and manage the same stocks this will eventually prove to be an enormous advantage in quantifying the successes and failures of the management regime.

Therefore, it is recommended that the measures in the Fisheries Management Plans (see the previous abstracts for two plans) which are prepared by the Caribbean Fishery Management Council be incorporated as nearly as possible into the management scheme for the Biosphere Reserve. Moreover, it should be recognized that management is a dynamic, continuing process which must change as biological stocks and fishing for them change and that this is only accomplished by continuing a carefully planned monitoring regime.

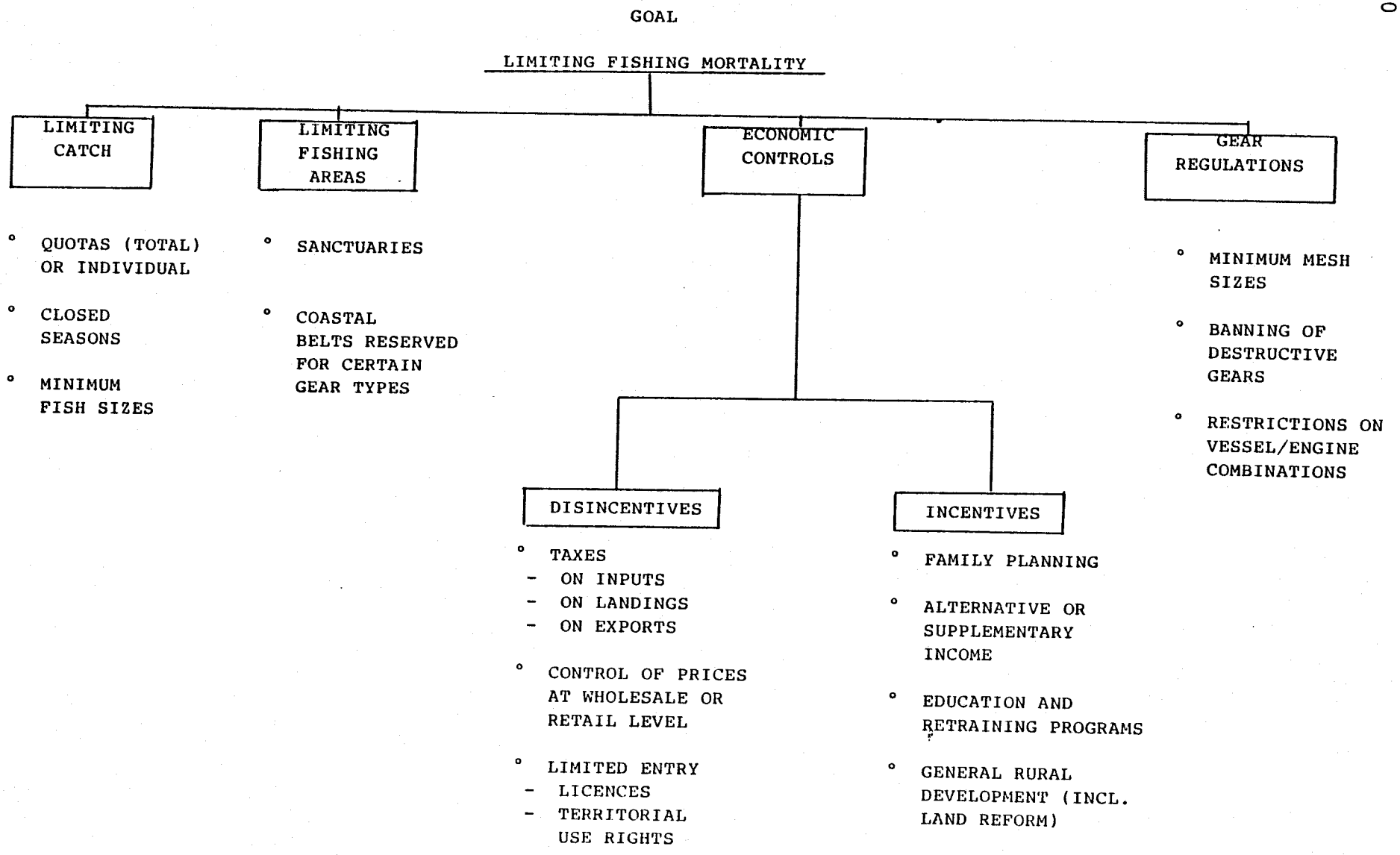
These FMP's from the Council incorporate monitoring procedures, and the governments of Puerto Rico, U.S. Virgin Islands and the British Virgin Islands have so far, by letters from the governors and legislative actions, adopted them for use in territorial waters as well as in waters of national extended jurisdiction. As the work of the Caribbean Fishery Management Council proceeds new data and new management measures will be included.

There is little possibility that the managers of the Biosphere Reserve could amass and support the same kind and amount of technical fisheries expertise represented by the Caribbean Fishery Management Council. In any event, it would seem inappropriate to attempt any such duplication of effort. It would be appropriate and welcomed by the Council

to have a technical and/or policy making representative from the National Park Service attend Council meetings and working group sessions.

Figure 2 illustrates the concepts that managers could consider when attempting to limit fishing mortality. It should also be remembered that natural mortality rates are influenced by environmental factors and that in addition to man-made changes, such events as hurricanes and volcanism play large roles. If sea levels are presently rising and continue to do so for the next hundred years, one can expect many changes in present shoreline and shallow water features.

FIGURE 2. OPTIONS FOR LIMITING FISHING MORTALITY




From Munro and Smith 1983

REFERENCES

Adams, P.B. 1980. Life history patterns of marine fishes and their consequences for fisheries management. Fish. Bull. 78(1):1-12.

Barans, C. 1982. Methods for assessing reef stocks. In Huntsman, G.R., W.R. Nicholson & W.W.Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 105-123.

_____ and S.A. Bortone. 1983. The visual assessment of fish populations in the southeastern United States; 1982 Workshop. So. Car. Sea Grant Consor. Tech. Rept. 1. 52 pp.

Beets, J. & L. Lewand. 1985. Collection of common organisms within the Virgin Islands National Park/Biosphere Reserve. Caribbean Research Institute, College of the Virgin Islands. VIRMC I Research Series, Report No. 3. U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 44 pp.

_____ & E. S. Zullo. 1985. Long-term monitoring of fisheries in the Virgin Islands Biosphere Reserve. Caribbean Research Institute, College of the Virgin Islands. VIRMC I Research Series, Report No. 13, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 118 pp.

_____, L. Lewand & E. S. Zullo. 1985. Marine community descriptions and maps of bays within the Virgin Islands National Park/Biosphere Reserve. Caribbean Research Institute, College of the Virgin Islands. VIRMC I Research Series, Report No. 2, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC.

Bohnsack, J.A. & S.P. Bannerot. 1983. A random point census technique for visually assessing coral reef fishes. In Barans, C.A. and S.A. Bortone (Eds.), The visual assessment of fish populations in the south-eastern United States, 1982 Workshop. So. Car.Sea Grant Consor. Tech. Rept. 1. pp. 14-17.

Boulon, R.H., Jr. 1985a. Map of fishery habitats within the Virgin Islands Biosphere Reserve. Div. of Fish and Wildlife, DCCA, Govt. of the U.S. Virgin Islands. VIRMC I Research Series, Report No. 8, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 53 pp.

_____. 1985b. Fisheries habitat of the Virgin Islands region of ecological importance to the fishery resources of the Virgin Islands Biosphere Reserve. VIRMC I Research Series, Report No. 9, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 19 pp.

_____ & I.E. Clavijo. 1985. Utilization of the Virgin Islands Biosphere Reserve by artisanal fisheries. Div. of Fish and Wildlife, DCCA, Govt. of the U.S. Virgin Islands. VIRMC I Research Series, Report No. 11, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 33 pp.

Brother, E.B. 1979. Age and growth studies in tropical fishes. In Saila, S.B. & P.M. Roedel (Eds.) Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston,RI. pp. 119-136.

Caddy, J.F. 1981. Estimates of fisheries potential for the British Virgin Islands together with some comments on biological factors relevent to the marketing of fish in the Lesser Antilles. FAO Fish. Dept. B.V.I/79/001. 13 pp. (mimeo).

_____ & S. Garcia. 1983. Production modelling without long data series. FAO Fish. Rep. 278 (Suppl.). pp. 309-313.

Caribbean Fishery Management Council. 1981. Environmental impact statement, fishery management plan and regulatory impact review for the spiny lobster fishery of Puerto Rico and the U.S. Virgin Islands. NOAA-NMFS-CFMC. 64 pp.

_____. 1983. FMP for the fishery resources of the Puerto Rican and Virgin Islands geological platforms. NOAA-NMFS-CFMC. 81 pp.

_____. 1984. Fishery management plan, regulatory impact review, and environmental impact statement for the shallow-water reeffish fishery of Puerto Rico and the U.S. Virgin Islands. NOAA-NMFS-CFMC. 67 pp.

Colin, P.L. 1982. Aspects of the spawning of Western Atlantic reef fishes. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 69-78.

Dammann, A.E. 1969. Study of the fishery potential of the Virgin Islands. Carib. Res. Inst., V.I.E.R.S. Contrib. No. 1. 204 pp.

Davis, M., E. Gladfelter, H. Lund, & M. Anderson. 1985. Geographic range and research plan for monitoring white band disease. West Indies Laboratory. VIRMC I Research Series, Report No. 6, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 12 pp.

Gladfelter, E.H., M. Anderson, H. Lund & M. Davis. 1985. Marine ecosystems of the Lesser Antilles - identification by representative sites. West Indies Laboratory. VIRMC I Research Series, Report No. 7, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 39 pp.

Gladfelter, W.B. & E.H. Gladfelter. 1978. Fish community structures as a function of habitat structure on West Indian patch reefs. Rev. Biol. Trop. 26 (Suppl.1):65-84.

Goodwin, M.H. 1985. Characterization of Lesser Antillean regional fisheries. Island Resources Foundation. VIRMC I Research Series, Report No. 14, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 48 pp. 45 pp.

Gulland, J.A. 1965. Manual of methods for fish stock assessment, Part 1; fish population analysis. FAO Fish. Tech. Paper 40, Rev.1. 154 pp.

_____, (Ed.). 1971. The fish resources of the oceans. Fishing News (Books) Ltd., London. 255 pp.

_____. 1974. The management of marine fisheries. Univ. of Wash. Press, Seattle, WA. 198 pp.

_____. 1978. Fishery management: new strategies for new conditions. Trans. Amer. Fish. Soc.

_____. 1979. Stock assessment in tropical fisheries: past and present practices in developing countries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island,Kingston, RI. pp. 27-34.

_____. 1982. The management of tropical multi-species fisheries. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 287-298.

_____. 1983. Stock assessment: why? FAO Fish. Circ. No. 759. 18 pp.

Hartsuijker, L. 1982. A re-assessment of the stocks of reef fish on Pedro Bank. Minist. of Agric.,Kingston, Jamaica.

Hobson, E.S., Jr. 1982. The structure of fish communities on warm-temperate and tropical reefs. In Huntsman, G.R., W.R. Nicholson and W.W. Fox, Jr. (Eds.), The biological bases for reef fisheries management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 160-166.

Hongskul, V. 1979. Report on studies of multispecies systems in fisheries. In Saila, S.B. & P.M. Roedel, Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp.173-182.

Huntsman, G. R., W.R. Nicholson & W.W. Fox, Jr. (Eds.). 1982. The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. 216 pp.

James, M. K. & K. P. Stark. 1982. Application of the three bays ecosystem model to fisheries management. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc.9, Int.Cent. for Liv. Aqua. Res.Manage., Manila. pp. 99-121.

Juhl, R. 1971. Status and potential of the fishery in the Caribbean. Proc. Gulf Carib. Fish. Inst. 23:175-183.

_____. 1973. Fishery resources of the Caribbean and their potential. In C.O. Chichester & H.D. Grahm, Microbial safety of fishery products, Acad. Press, NY., London.

Kirkwood, G.P. 1982. Simple models for multispecies fisheries. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries. ICLARM Conf.Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 83-98.

Koester, S.K. 1985. Socioeconomic and cultural role of fishing and shellfishing in the Virgin Islands Biosphere Reserve. Island Resources Foundation. VIRMC I Research Series, Report No. 12, U.S. Virgin Islands National Park/Biosphere Reserve Program, USDOI/NPS/VIRMC. 23 pp.

Lagler, K.F. 1979. Predictive stock and catch assessment for decision-making in the management of tropical small-scale fisheries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 70-73.

Larkin, P.A. 1982. Directions for future research in tropical multispecies fisheries. In Pauly, D. & G.I. Murphy, (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 309-328.

_____ & W. Gazey. 1982. Applications of ecological simulation models to management of tropical multi-species fisheries. In Pauly, D. & G.I. Murphy, (Eds.), Theory and management of tropical multispecies fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 123-140.

MacArthur, R.H. and E.O. Wilson. 1976. The Theory of island biogeography. Princ. Univ. Press, NJ. 203 pp.

Majkowski, J. 1982. Usefulness and applicability of sensitivity analysis in a multispecies of approach to fisheries management. In Pauly, D. & G.I. Murphy, (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent.for Liv. Aqua. Res. Manage., Manila. pp. 149-165.

Marshall, N. 1979. Fishery yields of coral reefs and adjacent shallow-water enviornements. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar.Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 103-109.

_____. 1982. Revised comments on the fisheries potential of coral reefs and adjacent shallows. Univ. of Rhode Island. Manuscript.

Martin, G.G. & J.J. Polovina. 1982. A comparative study of fish yields from various tropical ecosystems. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 255-289.

McFarland, W.N. 1982. Recruitment patterns in tropical reef fishes. In Huntsman, G.R., W.R. Nicholson and W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 83-91.

Menzies, R.A. & J.M. Kerrigan. 1978. Implications of spiny lobster recruitment patterns in the Caribbean -- a biochemical genetic approach. Proc. Gulf Carib. Fish. Inst. 31:164-178.

Molinari, R.L., D.K. Atwood, C. Duckett, M. Spillane & I. Brooks. 1980. Surface currents in the Caribbean Sea as deduced from satellite tracked drifting buoys. Proc. Gulf Carib. Fish. Inst. 32:106-113.

Munro, J.L. 1977. Actual and potential fish production from the coralline shelves of the Caribbean Sea. FAO Fish. Rep. 200:301-321.

_____. 1979. Stock assessment models: applicability and utility in tropical small-scale fisheries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res Dev., Univ. of Rhode Island, Kingston, RI. pp. 35.47.

_____. 1982. Estimation of biological and fishery parameters in coral reef fisheries. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries, ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 71-82.

_____. 1982. Some advances and developments in coral reef fisheries research: 1973 - 1982. Proc. Gulf Carib. Fish. Inst. 35:161-178.

_____. 1983. A cost-effective data aquisition system for assessment and management of tropical multi-species, multi-gear fisheries. Fishbyte (June). Metro Manila. pp. 7-12.

_____, Ed. 1983. Biological and ecological characteristics of Caribbean reef fishes. In Caribbean coral reef fishery resources. Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 223-231.

_____, Ed. 1983. Assessment of the potential productivity of Jamaican fisheries. In Caribbean coral reef fishery resources. Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 232-248.

_____, Ed. 1983. Epilogue: progress in coral reef fisheries research, 1973 - 1982. In Caribbean coral reef fishery resources. Int. Cent. for Liv. Aquatic Res. Manage., Manila. pp. 249-265.

_____, Ed. 1983. Caribbean coral reef fishery resources. ICLARM Stud. and Rev. 7, Int. Cent. for Liv. Aqua. Res. Manage., Manila. 276 pp.

_____ & I.R. Smith. 1983. Management strategies in multispecies complexes in artisanal fisheries. Paper presented at the 36th Annual GCFI Meeting in Trinidad. ICLARM Cont. No. 172. pp. 1-22.

Murphy, G.I. 1982. Recruitment of tropical fishes. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 141-148.

Ogden, J.C. 1982. Fisheries management and the structure of coral reef fish communities. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 147-166.

_____ & E.H. Gladfelter (Eds.). 1983. Coral reefs, seagrass beds and mangroves: their interactions in the coastal zones of the Caribbean. UNESCO: Montevideo. 133 pp.

Olsen, D.A. 1981. Strategems for spiny lobster management in the Caribbean. Manuscript.

Parrish, J.D. 1979. Approaches to some problem areas in tropical small-scale fisheries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 89-102.

Pauly, D. 1979. A new methodology for rapidly acquiring basic information on tropical fish stocks: growth, mortality and stock recruitment relationships. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical and small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 154-172.

_____. 1982. Studying single-species dynamics in tropical multispecies context. In Pauly, D. & G.I. Murphy (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 33-70.

_____ & G. I. Murphy, Eds. 1982. Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. 360 pp.

Pollnac, R.B. 1981. Social and cultural aspects of surveys of small-scale fishermen. In Sutinen, J.G. & R.B. Pollnac (Eds.), Small scale fisheries in Central America: acquiring information for decision making. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI.

Powers, J.E. 1983. Puerto Rico and U.S. Virgin Islands reef resources. In Report of the Southeast Fish. Cent. Stock Assess. Work., August 3 - 6, 1982, Miami, FL. pp. 146-150.

_____. 1983. Report of the Southeast Fisheries Center Stock Assessment Workshop, August 3 - 6, 1982, Miami, FL. 229 pp.

_____ & M.E. Crow. 1982. Modelling Western Atlantic reef fishes. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 185-201.

Randall, H.A. 1964. A study of the growth and other aspects of the biology of the West Indian topshell, Cittarium pica (Linnaeus). Bull. Mar. Sci. Gulf Carib. 14(3):424-443.

Randall, J.E. 1963. An analysis of the fish populations of artificial and natural reefs in the Virgin Islands. Carib. J. Sci. 3(1):1-16.

_____. 1964. Contributions to the biology of the queen conch, Strombus gigas. Bull. Mar. Sci. Gulf Carib. 14:246-295.

Richards, W.J. 1982. Planktonic processes affecting establishment and maintenance of reef fish stocks. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 92-100.

_____. 1982. Recruitment of reef fishes/stock delineation, session summary. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80 pp.101-102.

Rettig, R.B. & J.G. Ginter, (Eds.). 1978. Limited entry as a fishery management tool. A Wash. Sea Grant Pub. distr. by the Univ. of Wash. Press. 463 pp.

Rounsefell, G.A. 1975. Ecology, utilization, and management of marine fisheries. The C.V. Mosby Co., St. Louis, MO. 516 pp.

Saila, S.B. 1979. Some environmental considerations for stock assessment of small-scale fisheries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 60-69.

_____. 1979. A tentative structural modelling approach to some aspects of small-scale fisheries management. In Saila, S.B. & P.M. Roedel (Eds.). Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 183-190.

_____. 1982. Markov models in fish community study - some basic concepts and suggested applications. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 202-210.

_____ & P.M. Roedel (Eds.). 1979. Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. 198 pp.

Sainsbury, K.J. 1982. The ecological basis of tropical fisheries management. In Pauly, D. & G.I. Murphy, (Eds.), Theory and management of tropical fisheries. ICLARM Conf. Proc. 9, Int. Cent. for Liv. Aqua. Res. Manage., Manila. pp. 167-188.

Sale, P.F. 1978. Coexistence of coral reef fishes - a lottery for living space. Envir. Biol. Fish. 3:85-102.

Sissewine, M.P. 1981. An overview of some methods of fish stock assessment. Fisheries. 6(6):31-35.

Smith, C.L. 1982. Patterns of reproduction in coral reef fishes. In Huntsman, G.R., W.R. Nicholson & W.W. Fox, Jr. (Eds.), The biological bases for reef fishery management. NOAA Tech. Memo., NMFS-SEFC-80. pp. 49-66.

Steele, J.H. & E.W. Henderson. 1984. Modeling long-term fluctuations in fish stocks. Science 224:985-987.

Stevenson, D.K. 1979. Use of length-frequency data to estimate growth and mortality rates for species exploited by tropical small-scale fisheries in Puerto Rico and Costa Rica. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston. pp. 137-153.

_____. 1981. A review of the marine resources of the Western Central Atlantic Fisheries Commission (WECAFC) region. FAO Fish. Tech. Pap. 211. 132 pp.

Stoddard, D.R. & R.E. Johannes, (Eds.). 1978. Coral reefs: research methods. UNESCO: Paris. 581 pp.

Sutinen, J.G. & R.B. Pollnac, Eds. 1981. Small scale fisheries in Central America: acquiring information for decision making. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI.

Swingle, W.E., A.E. Dammann & J.A. Yntema. 1979. Survey of the commercial fishery of the Virgin Islands of the United States. Proc. Gulf Carib. Fish. Inst. 22: 110-121.

Sylvester, J.R. & A.E. Dammann. 1972. Pot fishing in the Virgin Islands. Mar. Fish. Rev. 34(9-10): 33-35.

_____ & A.E. Dammann. 1974. Some observations on the deepwater fishery resources of the Virgin Islands. Carib. J. Sci. 14(3-4):103-165.

Thorne, R.E. 1979. The application of hydroacoustics to stock assessment for tropical small-scale fisheries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston RI pp. 110-118.

Virgin Islands. 9th Legislature, Fourth Special Session. Commercial Fishing. As amended by Act 3330, Chap. 10, Title 12. 1972.

Western Central Atlantic Fishery Commission (WECAFC). 1983. National reports and selected papers presented at the third session of the working party on assessment of marine fishery resources. Kingston, Jamaica, 17-21 May 1982. FAO Fish. Rep. 278 Suppl. 313 pp.

Wilimovsky, N.J. 1979. Perspectives of minimal data requirements for aquatic resource management in developing countries. In Saila, S.B. & P.M. Roedel (Eds.), Stock assessment for tropical small-scale fisheries. Int. Cent. Mar. Res. Dev., Univ. of Rhode Island, Kingston, RI. pp. 78-86.

Wood, R.W. & D.A. Olsen. 1983. Application of biological knowledge to the management of the Virgin Islands conch fishery. Proc. Gulf Carib. Fish. Inst. 35: 112-131.