FISHERIES STOCK ASSESSMENT
Title XII — Collaborative Research Support Program

TRIENNIAL REVIEW AND CONTINUATION PROPOSAL

May 1988

FSA/CRSP
Management Office
International Programs
College of Agriculture
The University of Maryland
College Park, Maryland 20742

In cooperation with the United States Agency for International Development (Grant No. DAN-4146-G-SS-5071-00) the Fisheries Stock Assessment CRSP involves the following participating institutions:

The University of Maryland--Center for Environmental and Estuarine Studies
The University of Rhode Island--International Center for Marine Resource Development
The University of Washington--Center for Quantitative Sciences
The University of Costa Rica--Centro de Investigación en Ciencias del Mar y Limnología
The University of the Philippines--Marine Science Institute (Diliman)--College of Fisheries (Visayas)

In collaboration with The University of Delaware; The University of Maryland--College of Business and Management; The University of Miami; and The International Center for Living Aquatic Resources Management (ICLARM).

The Fisheries Stock Assessment

Title XII Collaborative Research Support Program

TRIENNIAL REVIEW AND CONTINUATION PROPOSAL

May, 1988

Program Management Office
International Programs
College of Agriculture
The University of Maryland
College Park, MD 20742

Executive Summary

The Fisheries Stock Assessment Title XII Collaborative Research Support Program (CRSP) is a global research program designed to develop new methodologies for stock assessment and management for small-scale multispecies tropical fisheries, funded under a five year grant by USAID/S&T. This document reviews the first three years of CRSP research accomplishments and presents the plans for the final two years of the current grant and a proposal for continuation of CRSP activities in a three year grant extension.

The principal participating institutions include the University of Maryland, the University of Washington, the University of Rhode Island, the University of Costa Rica, and the University of the Philippines. Altogether, there are about 60 researchers from a dozen research institutions in five countries engaged in CRSP activities.

Selected research accomplishments to date include the following:

1) University of Maryland and University of Costa Rica reseachers have a) developed the first stage of a state-of-the-art expert system/decision support system for analyzing fishery data, predicting future harvests, and providing advice to fisheries managers on optimal management strategies of fish stocks, and b) made substantial progress in extending standard fishery models to give advice to managers even when fishery data and information are limited.

2) University of Washington and University of Costa Rica researchers have a) applied new and innovative statistical methods to the problem of stock assessment sampling in artisanal fisheries, b) developed a new theoretical framework for length-based stock assessment analyses, c) demonstrated that some tropical fish can be aged by microscopic examination of selected hard structures of fish, and d) demonstrated new techniques for using hydroacoustics for fish detection in shallow waters.

3) University of Rhode Island and University of the Philippines researchers have a) developed a new empirical multispecies model for analyzing observed changes in the catch ratio of similar species and for predicting the stability and changes in multispecies fish assemblages, b) developed new multivariate techniques for analyzing fish community structure, and c) initiated unique, extensive long-term coral reef ecological, fish recruitment and reproduction, and fishing impact field studies.

Initially planned as a $1 million per year research program, the CRSP has been obligated and has spent only $2.3 million in AID funds over its initial three years. The commitment by U.S. and host country institutions to this program is demonstated by their matching contributions which have added an additional 35 percent to the total AID funding, bringing total CRSP spending to more than $3 million. U.S. universities have contributed matching funds of about 40 percent of the contractually matchable AID funds.

A first version of a handbook for stock assessment and management methodologies and techniques for developing country fisheries managers will be completed by the end of the first five years of the CRSP. Accelerated funding over the next two years is requested. Promising developments suggest that a three year grant extension, to 1993, at a proposed cost of $2.5 million, will further contribute to increasing the developing country fish catch with new and improved fishery stock assessment and management methodologies.

The State of the World's Fishery Resources

"The present ... [world fish] catch totals some 76 million metric tons annually."

"The most generally accepted estimates of conventional resource potential are on the order of 100 million metric tons."

"It is highly unlikely that the actual catches will ever approach this potential figure. ...[T]his estimate of potential assumes that each stock is exploited at its optimum level."

"The outlook for marine fisheries is not bright. The factors that have caused recent problems--limited resources and excessive exploitation of these resources--are likely to continue."

"Overcapacity will remain a threat to many resources.... It will also be a major cause of conflict and reduced prosperity among fishermen, especially small-scale fishermen of developing countries."

"At the minimum, better management will require better trained people in stock assessment, economic analysis, and ... fisheries management. If the world fisheries are to be managed on a sustainable basis, much more work is going to be required."

--From Chapter 9, "Oceans and Coasts," World Resources 1986, World Resources Institute and International Institute for Environment and Development. Basic Books, New York, 1986. Technical editorial advisor: John Gulland, FAO.

Contents

		Page
	Executive Summary	iii
	Contents	v
	List of Tables	vi
I.	Introduction	1
II.	Research Overview: Past Accomplishments and Future Objectives	7
III.	The University of Maryland and The University of Costa Rica Program	23
IV.	The University of Washington and The University of Costa Rica Program	37
V.	The University of Rhode Island and The University of the Philippines Program	63
VI.	Program Coordination and Integration	79
VII.	Management Entity Activities	83
VIII.	Budgets, Expenditures, and Financial Plan	99
IX.	Project Overviews: Participating Institutions and Research Personnel	119

List of Tables

		Page
Table 1.	Technical Reports and Working Papers	90
Table 2.	CRSP-Sponsored International Travel	94
Table 3.	Institutional Budgets for Obligated Funds (7/1/85 - 4/27/89)	101
Table 4.	Institutional and Project Budgets for Obligated Funds (7/1/85 - 4/27/89)	102
Table 5.	Project Budgets for Obligated Funds (7/1/85 - 4/27/89)	103
Table 6.	UMCEES/UCR Project Budgets for Obligated Funds (7/1/85 - 4/27/89)	104
Table 7.	UW/UCR Project Budgets for Obligated Funds (7/1/85 - 4/27/89)	105
Table 8.	URI/UP Project Budgets for Obligated Funds (7/1/85 - 4/27/89)	106
Table 9.	Extimated Expenditures By Line Item, Years 1 - 3 (7/1/85 - 6/30/88)	108
Table 10.	Estimated Expenditures By Source and By Entity, Years 1 - 3 (7/1/85 - 6/30/88)	109
Table 11.	Distribution of Estimated Expenditures By Source and By Entity, Years 1 - 3 (7/1/85 - 6/30/88)	109
Table 12.	Project Budgets: Obligated Funds, Estimated Expenditures, and Unexpended Balances, 6/30/88	110
Table 13.	Institutional and Project Budgets By Line Item, Years 4 - 8 (7/1/88 - 6/30/93)	113
Table 14.	CRSP Research Personnel	119

Fisheries Stock Assessment CRSP

TRIENNIAL REVIEW AND CONTINUATION PROPOSAL

I. Introduction

The Fisheries Stock Assessment Title XII Collaborative Research Support Program (CRSP) is a global research program designed to develop new methodologies for stock assessment and management for small-scale multispecies tropical fisheries. Funded by the United States Agency for International Development, Bureau for Science and Technology, under Grant No. DAN-4146-G-SS-5071-00, the CRSP is a five year collaborative research program extending from July 1, 1985 to June 30, 1990.

This document reviews the first three years of CRSP research accomplishments, presents the objectives and work plans for the final two years of the current grant, and makes a proposal for the continuation of the CRSP research activities for an additional three years, until June 30, 1993.

The CRSP is approaching the end of its third year of operation. An elaborate network of international collaborative research linkages have been established and research efforts are underway at many institutions in many countries. The scientific development of new methodologies and techniques for fisheries stock assessment is a long and complex task. Preparing this triennial review and continuation proposal was a valuable exercise for CRSP participants. The research is on-going, however, and this status report and assessment of the future of the CRSP describes the dynamic and evolving nature of this scientific research program.

A. Goals, Objectives, and Rationale

The CRSP is developing stock assessment methodologies for use by fisheries managers in developing countries. Specific objectives for the program include the following:

1. Production of a Stock Assessment Handbook for fishery managers in tropical countries--a manual or manuals that will provide a "key" for optimal fishery stock assessment and management given the problem and available resources.

2. Testing and/or extension of existing methodology for stock assessment as it applies to tropical fisheries.

3. Development of new methodologies for stock assessment in tropical developing countries.

4. Development and testing of multispecies fishery assessment methods.

The CRSP is not formally engaged in stock assessement, rather it is engaged in developing new methodclogies for stock assessemnt. The program is one of developing new methods, new approaches, new technologies and new techniques of stock assessment in small-scale multispecies tropical fisheries which are typical along the coasts of the developing countries. Researchers are taking the science of stock assessment in new directions. The rationale for the program is quite clear: the application of standard approaches to fisheries management has not materially extended stock assessment knowledge in recent years and new methods of fisheries stock assessment are needed.

The CRSP is focused on a global problem. The world's fisheries are immensely important in providing food and employment. In fact, the annual world fish catch tonnage exceeds the combined annual world production of beef and poultry. With the developing countries being responsible for almost half of the world's fish catch, small-scale fisheries are an important source of food and employment in many coastal regions of the world. Artisanal fisheries, common throughout the developing world, are characterized by low technology, labor intensive, usually family-run, fishing operations which provide food for both the family and the market. These artisanal fisheries supply more than ten percent of the world's fish catch to the people of the developing countries, where fish provide 30 - 50 percent of their animal protein consumption.

In recent years, however, improved fishing technology and increased fishing intensity and effort have led to a state of over-exploitation of the fish stocks in many artisanal fisheries. This situation has long term implications for a country's employment and ability to feed itself. Fisheries stock assessment techniques employed by the developing countries often do not provide information needed to manage these small-scale fisheries effectively. This is particularly true in tropical regions where many different species are fished simultaneously by a variety of fishing gear. The CRSP is designed to address these global problems. It is focused on improving fisheries stock assessment methodology, providing stock assessment advice to fishery managers who operate under diverse conditions, and training U.S. and host country scientists.

Improved methodologies for fisheries stock assessment in tropical multispecies environments combined with improved fisheries management which raise the yields of the developing countries' fisheries by 10 percent could increase the animal protein consumption of their populations by almost 50 percent. Alternatively, increased fish catches could be exported to earn valuable foreign exchange.

Improving stock assessment methodologies can make a substantial contribution to generating incomes for and improving the nutrition of people in the developing countries. However, stock assessment is also concerned with the long run future of the fisheries resources of the world. It is at the core of the evolving science of sustainable resource development

Management of fisheries in tropical environments is enormously complicated by the paucity of biological knowledge of tropical marine ecosystems. Such facts as the complex patterns of reproduction and recruitment and a high number of interacting species make prediction and managment difficult. Mathematical models of such interactions are often the only way for scientists and managers to represent the multiple complex

processes involved. Quantitative expressions must, however, be based on firm biological, field, and capture data. The CRSP research program encompasses both field and modeling analyses directed at the key aspects of single and multiple species tropical environments.

Collaborative research by leading U.S. and host country scientists and researchers are extending fisheries stock assessment theory, methodologies and techniques to develop effective management techniques for tropical small-scale fisheries. The research will also contribute to improving fishing yields in the tropical and semi-tropical environments along the coasts of Hawaii, southern California, and the Gulf of Mexico, and in the U.S. territories in the South Pacific and the Caribbean Basin. Improved stock assessment and management techniques will also be applicable to other U.S. artisanal and multispecies fisheries. Improved scientific understanding of fish ecology and viable management practices of multispecies fisheries will further the development of temperate and boreal fisheries science as well. Systematic study of stock assessment methodologies, particularly in small-scale multispecies environments, has been extremely limited, and there is great promise that this collaborative research program will make significant developments in the global understanding of fisheries management.

The following report will show the progress that has already been made in addressing these global problems. It will also present the objectives and plan of work for another five years of research effort designed to solve these fundamental problems in fishery science and management.

B. Participating Institutions

Five U.S. land grant agricultural universities have joined forces with USAID/S&T and several host country institutions to collaborate on the Fisheries Stock Assessment CRSP, which is the eighth and most recently created Collaborative Research Support Program under the Title XII mandate. The Office of International Programs, College of Agriculture, University of Maryland-College Park (UMCP) serves as the Management Entity for the Fisheries Stock Assessment CRSP. The technical research efforts in eight separate projects, led by the University of Maryland-Center for Environmental and Estuarine Studies (UMCEES), the University of Rhode Island (URI), and the University of Washington (UW), are being conducted collaboratively with the University of Costa Rica (UCR) and the University of the Philippines (UP). Collaboration is being provided by the University of Maryland-College Park-College of Business and Management (UMCP-CBM), the University of Delaware (UDelaware), the University of Miami (UMiami), and the International Center for Living Aquatic Resources Management (ICLARM).

In addition to the principal institutions participating in the CRSP research efforts, there are many other fishery scientists, researchers, managers, and administrators from a variety of institutions and countries who are contributing to this work. For example, the government fishery departments in Costa Rica, the Philippines, Indonesia, and Thailand are contributing personnel and resources to the CRSP efforts. The U.S. National Marine Fisheries Service and the Canadian Department of Fisheries are contributing personnel to serve on the CRSP's External Evaluation Panel. Many others are involved in various ways in this global research program. (See Section IX concerning participating institutions and scientific personnel.)

The funding for the CRSP activities derives principally from the grant by the United States Agency for International Development, Bureau for Science and Technology. However, the collaboration by U.S. and host country universities is financial as well as scientific. U.S. university matching contributions are running at about 40 percent of the matchable AID funds, significantly beyond the required 25 percent. The host country universities are also making substantial matching contributions to the CRSP. During the first three years of the CRSP, U.S. universities and host country institutions have contributed about 35 percent to the total AID funding and almost 50 percent to the contractually matchable AID funding. (See Section VIII concerning financial contributions to the CRSP.) Lastly, many individuals and cooperating institutions have made contributions to the CRSP activities without CRSP financial support. Recognizing the importance of the CRSP's global research agenda, the fisheries research community has shown its commitment to support this vital program financially as well as intellectually.

C. Program Description

The CRSP is composed of eight interrelated research projects, listed below in association with the names of the lead U.S. and host country institutions.

The University of Maryland-Center for Environmental and Estuarine Studies and The University of Costa Rica (UMCEES/UCR):

1. Multiple Species Fisheries Research
2. Economic and Probabilistic Extensions of Standard Fishery Models

The University of Washington and The University of Costa Rica (UW/UCR):

1. Sampling Catch and Abundance
2. Age and Size Dependent/Independent Modeling
3. Age and Size Relationships and Consequences of Errors
4. Shallow Water Hydroacoustics

The University of Rhode Island and The University of the Philippines (URI/UP):

1. Empirical Analyses and Modeling
2. Multispecies Field Studies

Research on the eight projects at participating institutions is being coordinated toward the achievement of overall program objectives under the guidance of the CRSP Technical Committee in cooperation with the Management Entity. See Section VI concerning CRSP program coordination and integration efforts.

D. Structure of This Report

Section II presents an overview of the research accomplishments of the first three years of the CRSP, followed by summaries of the research objectives for the final two years of the initial grant and for a three year extension grant. This section is a summary of the highlights of the research efforts, and leaves the details to be addressed in the following sections.

Sections III, IV, and V of this report present detailed summaries of the

triennial review and continuation proposal with work plans for the coming five years for each of the three principal collaborative teams, Maryland/Costa Rica, Washington/Costa Rica, and Rhode Island/Philippines.

Section VI brings together in a single short section issues of program coordination and integration, addressing the concerns of how all the pieces of this complex research program are being linked together.

Section VII reviews the activities of the Management Entity, University of Maryland-College Park, and its respective offices and institutions, the Program Director, the Board of Institutional Representatives, the Technical Committee, and the External Evaluation Panel. This section also provides a list of all of the CRSP working papers and publications and summarizes the international travel undertaken by CRSP participants.

Section VIII presents CRSP budgets, expenditure history, and the financial plan for the coming five years.

Section IX presents project overviews, highlighting the participating institutions and research personnel.

II. Research Overview: Past Accomplishments and Future Objectives

The following presents the highlights of the accomplishments of the first three years of the collaborative research and the objectives and plan of work for the remaining two years of the initial grant and for a three year grant extension. This overview focusses on the research and the science, leaving the institutional, administrative, financial, and technical details to later sections of the report. Issues addressed in this section are dealt with in greater detail in Sections III - VI of this report.

A. Summary of Accomplishments--The First Three Years (July 1, 1985 - June 30, 1988)

1. The University of Maryland-Center for Environmental and Estuarine Studies and The University of Costa Rica Program

In advancing the fields of fisheries stock assessment and management, The University of Maryland-Center for Environmental and Estuarine Studies and The University of Costa Rica (UMCEES/UCR) research program has thus far developed a state-of-the-art expert system/decision support system for fishery management, advanced biological and economic fishery models, and contributed to the biodynamics of the sea theory. The efforts have been conducted in two projects, 1) the Multiple Species Fisheries Research Project and 2) the Economic and Probabilistic Extensions of Standard Fishery Models Project.

a. The Multiple Species Fisheries Research Project

The overall objectives of this project are to develop a better understanding of multispecies fisheries, to explore how they relate to community and population dynamics, and to contribute to fishery management in tropical small-scale fisheries.

The research into expert systems and decision support systems as a guide to understanding the complexity of multispecies fishery systems led to the development of CANOFISH, a unique, first-stage canonical fishery management system which is applicable to both small and large fisheries in single and multispecies contexts. This expert system/decision support system (ES/DSS) is designed to analyze fishery data, predict future harvests, and provide advice to fisheries managers on optimal management strategies of fish stocks.

The first-stage working version of the CANOFISH ES/DSS has been developed for use on a microcomputer. A stock assessment computer library has been converted for use on a microcomputer, complete with Spanish and English documentation, and has been distributed to the various CRSP researchers. Advances have been made in the development of a three-sector simulation model, which is comprised of fishery, institutional, and population sectors. Research completed to date includes a review of spawning and recruitment patterns of tropical marine fish stocks and an evaluation of techniques used to assess the tropical fishery system. The researchers have developed a recruitment pattern simulator and a continuous recruitment simulation model

for the tropical fishery system, abundance/density equations for age-structured multicohort populations, a yield-per-recruit Monte Carlo decision model for evaluating fishery mangement alternatives in simple-data situations, and an areal production model for multispecies fisheries.

The development of the population-dynamics process model set the stage for further work in multispecies fishery theory. Research in this area is focused on determining the biophysical processes, measured on appropriate time-space scales, which underlie predator-prey interrelationships in the plankton. Advances have been made in discovering the effects of small-scale turbulence on plankton contact rates, in determining the feasibility of relating recruitment to environmental variation, and in outlining the physical basis for recruitment variability in fish populations.

b. The Economic and Probablistic Extensions of Standard Fishery Models Project

The overall objective of this project is to extend standard fisheries models to increase their utility to managers of tropical small-scale fisheries. Three avenues of research have been pursued in obtaining this objective: 1) probabilistic extensions of fisheries models, 2) economic extensions of fisheries models, and 3) the development of new methodologies for providing useful bioeconomic information to fisheries managers.

Research completed in probabilistic extensions of fisheries models has yielded the following results: 1) development of a stochastic model for prediction of adult population size for use in fisheries management; 2) development of a difference equation simulation model of marine population dynamics, as well as simulated study of marine population dynamics; 3) construction of a simple renewal model of larval fish feeding; 4) research into the use of a partial differential equation model for fish population dynamics; and 5) critical analysis of the use of the spawning-stock biomass approach in determining recruitment-stock relationships.

A fixed and variable recruitment economic model has been developed in which the basic economic analysis of optimal harvesting is achieved without stock and recruitment information. In addition, the algorithm for implementing this economic model on a microcomputer has been developed.

The project has resulted in the compilation of a bibliography of extant optimization models in fisheries management. Research has also been completed on the application of the analytic hierarchy process (AHP) to fishery management decision-making. These approaches have led to the study of multistage fishery management decision frameworks.

The developments in this project will be integrated into the canonical expert system/decision support system being developed in the Multiple Species Fisheries Research Project.

2. The University of Washington and The University of Costa Rica Program

The University of Washington and The University of Costa Rica (UW/UCR) are working collaboratively on four CRSP projects: 1) Sampling Catch and Abundance, 2) Age and Size Dependent/Independent Modeling, 3) Age and Size Relationships and Consequences of Errors, and 4) Shallow-Water Hydroacoustics. The sampling catch and hydroacoustics projects deal principally with the collection and analysis of data, while the the other two projects deal mainly with modeling and interpretation. Together, the four projects make up an integrated investigation of stock assessment and involve various field, laboratory, and theoretical studies.

a. The Sampling Catch and Abundance Project

Substantial progress was made by acquiring and coding data from on-going and past sampling projects. New sampling projects have begun employing off-the-shelf data management software to organize the data. Sampling designs using these data have been compared to evaluate basic questions of variability and cost of sampling. Gill net and trawl experiments have been begun to address questions about net selectivity, recruitment and early growth. A computer software package to assist a user in the selection and use of an optimal sampling design has been assembled and is in the final stage of completion. Multivariate analyses of data already coded show a useful "biological dimension" that allows prediction of catch statistics with 85 percent accuracy. The comparison of old and recent catch data appears to reflect changes in effort.

b. The Age and Size Dependent/Independent Modeling Project

Accomplishments in this project include the development of new theory and software surrounding length cohort analysis, the derivation of a new length-based catch equation, and an analytical treatment of error in length conort analysis. Reports have been written presenting the sensitivities and dangers associated with the use of length cohort analysis, now very popular in tropical countries. These reports demonstrate the problems, present software suitable for use in developing countries for doing the analysis so that the errors or dangers are minimized, and develop for the first time a length-based cohort equation. A stochastic model for doing catch-at-size analysis (CASA) has been written. The model reduces to other well-known catch-at-size analysis models when age data is entered, and compares favorably. Thus, stock assessment computations based on length data can now be carried out with increased confidence.

c. The Age and Size Relationships and Consequences of Errors Project

This project, which has a natural interface with the Age and Size Modeling Project, is focused on the ageing of tropical fish and the development of age-length keys. Researchers have demonstrated that the tropical corvina-complex of species (the principal market species in the Gulf of Nicoya, Costa Rica) can be aged here using otoliths and have written training materials to share the techniques. The new information indicates

extremely rapid growth of the primary corvina species in the first year. The development of associated biological information about fecundity will point the way toward the specification of management criteria to forestall either growth or recruitment overfishing. Further, the establishment of an age determination facility at the University of Costa Rica is underway.

d. The Shallow-Water Hydroacoustics Project

This project has completed the initial development, testing and application of hydroacoustic systems for fish detection and abundance estimation in shallow water marine environments such as those associated with most artisanal fisheries, thus adding a new dimension to stock assessment. It has also been shown that fish movement is about equal to current speed, suggesting tidal movement of fish, and the dependence of fish upon diel chan[illegible] Further research will use these behavioral characteristics to help explain harvest susceptibility, spawning and feeding patterns, and in the interpretation of acoustic signals.

3. The University of Rhode Island and The University of the Philippines Program

The University of Rhode Island and The University of the Philippines (URI/UP) collaboration is focused on two projects, 1) the Empirical Analyses and Modeling Project and 2) the Multispecies Field Studies Project.

a. The Empirical Analyses and Modeling Project

One of highlights of this project in this first triennial review period was the successful conceptual development, testing, and formal publication of a new empirical multispecies model. Specifically, a method was developed for the analysis of observed changes in catch ratio of similar species or species groups over time from the Thailand data and from northwestern Atlantic groundfish data. Aggregated time series of research vessel data were treated as Markov chain models after a transition probability matrix was derived from them by quadratic programming. The matrices were projected to provide information about the stability and changes in multispecies assemblages. The model developed provides some short-term or tactical information, as well as longer-term or strategic management-related information. Further testing of the model and its utility are in progress, and extensions of this model are expected to be developed over the remainder of the project's life.

Other accomplishments by this project component include the application of geometric programming to solve a more realistic optimum harvesting problem than is possible using the standard linear programming approach. The specific case which can be handled only by geometric programming is the case where a constant proportion of all individuals above a certain limiting size are harvested while none below this value are taken. This work was extended to consider the relationship between optimal harvesting strategies and reproductive values. We believe that further work on the relation between reproductive value and optimal harvesting strategies is justified and is included in future project activities. Implications of this work relate to harvesting strategies and the relative value of restrictive regulations for

highly fecund, short-lived species, which are typical of many tropical environments.

An excellent overview of the Philippine demersal stocks has been developed by the Philippine counterparts which puts into perspective the significance of the fishery and the effects of uncontrolled development in some sectors and shows the need for fisheries management. In addition to the overview document, some substantial contributions have been made to optimum mesh size selection for multispecies trawl fisheries.

b. The Multispecies Field Studies Project

This project has involved the use and development of multivariate techniques for the analysis of multispecies fisheries data, and a field program 1) to develop and validate techniques for the estimation of fishery productivity in reef and shore-line tropical fisheries, and 2) to apply the resultant methodology to the estimation of the fishery potential within the study area.

A strategy for the objective intercomparison of fish communities in time and space is being developed. A pilot study of community structure in the Samar Sea (Philippines) fishery has been completed and is now in press. It has been demonstrated that a critical water depth of approximately 30 meters can be used to optimally divide the tropical demersal fish assemblages into two relatively homogeneous sub-communities. Ordination of mean times by species revealed that variability over time seemed to decrease over the study period. Variability was measured as the mean Euclidian distance among community states. Analyses are also in progress on the community structure of Indonesian shelf and northwest Australian shelf fisheries, and new multivariate techniques are being tested.

Considerable progress has been made in developing user-friendly microcomputer programs for multivariate analysis of ecological data.

A comprehensive review of Philippine trawl surveys has been conducted and evaluation of the effects of management and over-fishing have begun. This work provides a baseline study for potential yield estimates and exploitation effects, as well as providing a realistic appraisal of the relative importance of the Philippine demersal fisheries.

A significant highlight of the first triennial project period is the establishment of a permanent field laboratory at Bolinao, on the Lingayen Gulf about 300 km. north of Manila. The facility has been modestly equipped through CRSP support to include a 19-foot research boat and an ultralight aircraft, as well as laboratory supplies and computing equipment. This has resulted in an extensive but realistic field program, which is in progress and which is expected to continue over much of the CRSP's projected life. Indeed, these facilities will become a permanent field station for use by the University of the Philippines and others.

Several of the field activities which are underway are: 1) Studies in comparative yields and efficiencies of major fishing gears on a coral reef complex; 2) Comparisons of size and species distributions obtained by visual

assessements and those obtained by fish traps on a reef flat; 3) Studies on the recruitment and reproductive patterns of coral reef fishes, aimed at an empirical evaluation the ELEFAN (length-based) programs; and 4) Fishery sampling surveys.

B. Objectives and Expected Accomplishments--Years Four and Five (July 1, 1988 - June 30, 1990)

This section highlights the objectives and expected accomplishments of the collaborative research program over the final two years of the current grant period.

1. UMCEES/UCR

a. The Multiple Species Fisheries Research Project

The objectives of this project are to develop a better understanding of multispecies fisheries and how they relate to community and population dynamics, and to contribute to advancing fishery management in tropical small-scale fisheries. Following the research direction established in the first three years of the project, work in years four and five will focus on 1) the continued investigation of multispecies fishery system complexity, 2) the continued development of multispecies fishery theory and 3) the continued development and refinement of stock assessment techniques that are particularly applicable to small-scale, subtropical and tropical artisanal fisheries.

Future research will emphasize further enhancement of CANOFISH, a functional, first-stage, canonical expert system/decision support system (ES/DSS) for fishery management. The primary objective of the next version, CANOFISH II, is to continue the integration of sampling, estimation, optimization, and simulation that was begun in CANOFISH I. Emphasis will be placed on system design in years four and five.

The intent of CANOFISH II is to provide a tool which can be used to assess a fishery as cost-effectively as possible and to evaluate complex-fishery management schemes. The conceptual framework of CANOFISH II will continue to serve as the focal point for the CRSP research program, and as a means for integration of the various projects. The emphasis will now be directed towards examining the interactions between a real and simulated fishery, developing the concept and structure of a metasystem, incorporating more multispecies concepts and models, and adopting a modular expert system development approach. The research goals for the development of CANOFISH II are as follows: 1) incorporate a wide variety of sampling strategies, fishery and bioeconomic models, and optimization procedures into the appropriate components of the CANOFISH II system, 2) further enhance the simulation models and use them to test the performance of the various system components, and 3) expand the use of expert system technology in linking system components together in a complex network.

Further development of new stock assessment techniques and enhancement of extant models for applicability to tropical and subtropical small-scale

fisheries will continue. Research in the area of multispecies fishery theory will continue the study of the factors which drive recruitment processes and multispecies interactions.

b. The Economic and Probabilistic Extensions of Standard Fishery Models Project

The overall objectives of this project are to continue to develop stock assessment techniques and to extend standard fisheries models to increase their utility to managers of small-scale fisheries. Research in years four and five will be directed towards 1) the completion and implementation of economic models that address the fixed and variable recruitment problem, and 2) the development of a metasystem for fishery management utilizing the analytic hierarchy process (AHP).

A major focus of the work on both the economic and stochastic fishery models in years four and five will be to complete the design and testing phases of model development and to incorporate Gulf of Nicoya corvina fishery data into the models. The models will then be used to evaluate harvest policies and management alternatives for this Costa Rican fishery.

The development of a metasystem for fishery management will provide a powerful tool for managers of fisheries for which little or no data exists. This metasystem will contain information on the well-studied fish stocks and populations of the world. A search of the metasystem and its data base, using the analytic hierarchy process, will locate other "similar" systems and provide guides for stock assessment and fishery management, even as an actual data base on the actual fishery is evolved. Information obtained from this fishery management metasystem would also be used to elucidate past approaches and methodologies which were either successful or unsuccessful in assessing fish stock abundance, predicting future yields, determining mortality rates due to fishing, etc. Thus a fishery manager of an unstudied population is provided useful information on both designing and managing a stock assessment program.

Economic models that address the fixed and variable recruitment problem, stochastic models, and the fishery-management metasystem will all be incorporated into the CANOFISH II ES/DSS being developed in the Multiple Species Fisheries Research Project.

2. UW/UCR

The overall objective of the UW/UCR collaboration is to develop stock assessment and management concepts and methodology suitable for application in artisanal fisheries. The Gulf of Nicoya is the point of application and in a sense the laboratory in which experiments are carried out. Nevertheless, the viewpoint is that accomplishments should have regional and international implications. The UW/UCR efforts will continue on all four projects, with the inclusion of additional methods and the modification of methodology as a result of what was learned in years one to three.

a. The Sampling Catch and Abundance Project

The data in-hand was collected by the management agency, often with UCR-CIMAR assistance. Only a small part of these data have been entered onto floppy disks, so this activity will continue. Various sampling designs will be tested to determine the optimal combination of information transfer, in terms of cost and efficiency. A modified multistage systematic-stratified design, where the data available is considered as the universe, yields results comparable to universe (population) estimators. The enlarged data base will be used to test other hybrid designs, such as probability proportional to size, to evaluate the cost/efficiency ratio. Bayesian designs will be applied to simulated data with introduced variability and missing elements to evaluate the relative properties of Bayesian estimators. Box-Jenkirs time series methods will be applied to take advantage of their ability to identify periodicities and trend in the data. This permits a greater focus on the statistical nature of the processes generating the data, as well as predicting expected catches with standard errors. In addition to predicting and understanding the processes that generate catch, investigations of species assemblages will provide spatial and temporal information on species abundances in the Gulf. Small mesh gill nets will be used to gain information about selectivity, growth, time of recruitment, and fecundity.

b. The Age and Size Dependent/Independent Modeling Project

Length-cohort analysis on successive years of data will be applied to obtain initial parameter estimates. The CASA (catch-at-size analysis) model will be applied using these estimates to develop a fuller picture of the relationships between catch, effort, and abundance. Additional programming is needed to make CASA user friendly and more easily transferable. The distribution of effort over time will be examined to clarify the relationship between net selectivity, catchability, and effort. Recruitment to the fishery will be examined from the viewpoint of fishing mortality reference points. Although the determination of harvest levels should be set on the basis of recruitment strength the choice should depend upon more biological criteria than is behind F(0.1) or F(msy). Such criteria will be sought and a theoretical framework constructed. A part of this framework will be an age/length Leslie multistage model with harvest matrix and stochastic elements. A fishery management plan (FMP) for the Gulf will be developed and tested. Work will continue on an interesting new physiologically based model, especially with respect to parameter estimation and fitting.

c. The Age and Size Relationships and Consequences of Errors Project

The results from the ageing of the corvina species has raised concerns about the level of effort, in particular about mesh size. The ageing effort will continue in conjunction with the UCR/CIMAR ageing center. Otolith microstructure analysis will be carried out with the collection of fecundity data. This should clarify the growth relationships and lead to biomass productivity and turn-over rates in the Gulf. While this is the theme for the years six through eight, the initial research will be done at this stage. A benthic sampling program will be initiated to learn more about how energy flows from the mangroves to the sediment communities to the commercial catch of fish, molluscs and crustacea.

d. The Shallow-Water Hydroacoustics Project

This project completed the initial development and testing of hydroacoustic systems for estimation of abundance in shallow waters. A large-scale sampling effort is planned for year four involving transects and stations in the open waters of the Gulf of Nicoya and around artificial reefs. The researchers will make the first fish biomass estimate for the total Gulf of Nicoya. The transecting effort will also be closely coordinated with operations of the artisinal fleet and fishery catch data, which will be used to aid in separating the total biomass estimate into various species components. The stations in the open waters of the Gulf will add to the knowledge of fish movements and behavior and the evaluation of biases. The artifical reef observations will follow up on the inital observations made during 1987, and will allow more accurate quantification of the behavioral trends that were observed. In addition hydroacoustic estimates will be integrated into assessment models.

3. URI/UP

a. The Empirical Analyses and Modeling Project

The outputs expected from the Empirical Analyses and Modeling Project at the end of the initial five years of research include both tactical (short-term) and strategic (long-term) models, now in their first phases of development. The researchers expect to have made considerable progress toward Markov decision process model development. In a similar vein with respect to tactical models, researchers expect to have published some of their initial work on critical statistical comparisons of multispecies assemblages. This work commenced in the third year of the project. Suitable software for this activity has already been developed. It involves Monte Carlo techniques for developing empirical probability distributions which will be compared with observational data.

b. The Multispecies Field Studies Project

The results of the monitoring catch composition and production from specific fish habitat types in Bolinao, Pangasinan are expected to be published. However, researchers will continue to monitor the effects of differential applications of fishing pressure within each habitat type (by aerial surveys), and the variability over time in the in-situ fish composition. Extended monitoring to a series of nearshore and offshore reefs subject to different levels of fishing pressure will provide valuable comparative data. A data-base system to integrate this type of fishery information into a standard Geographic Information System (GIS) format will also be prepared. These results will contribute to the pilot management plan under development by the U.S. AID ASEAN Coastal Resources Management Program (CRMP) for the Bolinao area, where the University of the Philippines fisheries research laboratory and field testing sites are located.

The researchers will continue monitoring the reproductive and recruitment cycles of key fish species, and will obtain information on meteorological and oceanographic processes which might be responsible for the timing of these events. Efforts will continue and it is planned to expand studies of differential juvenile recruitment across the Bolinao reef complex. Other sub-projects include: 1) to determine if cycles of larval abundance correlate with cycles of reproduction and recruitment, and 2) to investigate the relationship, if any, between these cycles and mass spawning among corals, which may be important in providing food to enhance juvenile fish survival.

Efforts will also continue on comparing catch composition and community structure variations over time between coastal habitats with different levels of fishing pressure. Information for aggregating species assemblages will be gathered and assessed. Data will be supplied to other CRSP entities for analysis and model validation. The monitoring efforts will include all major finfish and invertebrate fisheries, as well as gleaning activities, in the study areas. Opportunities will be sought for offshore reef comparisons via other funded projects. Aggregation techniques for fish assemblages will also be investigated.

4. Program Coordination and Integration

More than 60 researchers from a dozen institutions in five countries are working on the eight CRSP research projects. These technical efforts are being coordinated by the efforts of the Technical Committee which is working closely with the Management Entity. Work plans are developed cooperatively by the Technical Committee. Communication among researchers and institutions is facilitated by the regular distribution of working papers, trip reports, minutes of meetings, etc. Regular research team meetings and the exchange of U.S. and host country research personnel are the principal means of directly coordinating the research efforts. In addition, the CRSP has given strong support to participation by researchers in international workshops, conferences, short-courses, and training programs to facilitate coordination along with dissemination of CRSP developments. Annual program-wide coordination meetings are planned.

One of the principal focuses for program integration is the planning for the production of the CRSP's final deliverable product under the grant, namely, the preparation of a CRSP Stock Assessment Handbook for fisheries managers in tropical developing countries. This handbook will provide a guide for optimal fishery stock assessment and management of small-scale tropical multispecies fisheries. The Technical Committee has begun planning for the preparation of the handbook. Current opinion is that this final deliverable product will not be a single manual or book, but instead will consist of several handbooks or manuals, often with associated microcomputer software and documentation, which will describe and explain models, methods, approaches, and limitations to tropical fisheries stock assessment and management, with emphasis on multispecies capture fisheries. Plans for merging the various CRSP activities have been made. It is believed that ultimately an expert system/decision support system for use on a microcomputer may be developed which could embrace a significant portion of the entire spectrum of the CRSP projects and activities.

It is anticipated that several specific tactical and strategic approaches to tropical multispecies stock assessment will have been completed within the initial five-year time frame. However, adequate field testing, sensitivity analysis, evaluation and recommendations for the application will require substantially more time. Hence, the proposal for continuation for research for an additional three years.

C. Objectives and Expected Accomplishments--Years Six Through Eight (July 1, 1990 - June 30, 1993)

1. UMCEES/UCR

The UMCEES/UCR collaboration proposes to continue research efforts on the two projects undertaken during the initial five years, namely, the Multiple Species Fisheries Research Project and the Economic and Probabilistic Extension of Standard Fishery Models Project.

a. The Multiple Species Fisheries Research Project

The research objectives in years six through eight will continue the investigation of multispecies fishery-system complexity in order to understand multispecies fisheries, to explore how they relate to community and population dynamics, and to continue contributing to the advancement of fishery management in small-scale tropical fisheries. A concrete objective is to complete, at the end of eight years, an integrated expert support system (ESS) incorporating advances in stock assessment and multispecies research.

Further enhancement of the CANOFISH ESS will be the focus of the UMCEES/UCR work in years six through eight. The efforts will build upon the completed network system linking sampling, model identification and estimation, optimization, and simulation which comprises CANOFISH II with the development of an expert system linking the modular ES to integrate the whole system. This expert system, called ADVISOR in CANOFISH II, will be the link between the user and the system and also provide management advice on 1) the operation of the fishery, 2) the most cost-effective sampling programs, 3) the optimal fishery/bioeconomic models to use in assessing a particular fishery, and 4) additional data requirements.

b. The Economic and Probabilistic Extensions of Standard Fishery Models Project

The research objectives in years six through eight will continue to be to develop stock assessment techniques, to extend standard fishery models, and to incorporate applicable techniques from other fields of study. Emphasis will be placed on metasystem development and incorporation of decision analysis techniques.

2. UW/UCR

During a three year extension of the CRSP, the UW/UCR program will be compressed into two components, reflecting progress anticipated from the first five years. The two components will be as follows: a) Management and Stock Assessment Sampling and b) Recruitment and Productivity. The hydroacoustics component will receive less effort, reflecting the progress there. The smaller effort will be incorporated into the Management and Stock Assessment Sampling Project. The development of management strategy and fisheries productivity in a tropical estuary, in a more generalized context than the Gulf of Nicoya, will receive increased focus because of the scientific depth of the subjects and the potential value of new results.

a. The Management and Stock Assessment Sampling Project

For convenience, this project can be partitioned into three highly linked components: Age/Size Modeling, Sampling Designs, and Hydroacoustics.

1) Age/Size Modeling

Effort will continue on the development of the age/size dependent models and these models will be applied in Costa Rica, the Philippines, and elsewhere. From these analyses different management tactics such as closing times, areas, and gear regulations will be theoretically evaluated. A considerable focus on the recruitment process will continue. This is developed further in the next component, but much of the modeling effort and the search for new conceptualizations and quantitative representations will appear as modeling results. Much of the current thinking on such investigations centers around the identification of biological and fishing mortality critical or reference points. These ideas will be applied to tropical fisheries, from which inferences can be drawn about the state of the fishery and its projected time course.

2) Sampling Designs

Research will focus on the following: 1) Evaluating efficient dissemination of sampling research outcomes to artisanal fisheries management entities; 2) Extending research on practical sampling methods, including Bayesian hybrid designs with classical multistage designs for managers of artisanal fisheries supporting, in particular, geographically isolated agencies with minimal computational and manpower resources; 3) Investigating the intertidal, nearshore and mangrove habitats to understand better concepts of energy flow and recruitment processes; 4) Analyzing the results of the trawl and benthic surveys and integrating them into an on-going stock assessment program; and 5) Incorporating these results into management models.

3) Hydroacoustics

Specific objectives of years six through eight are as follows: 1) Facilitating application of hydroacoustic techniques to artisanal fishery management in Costa Rica; 2) Verifying the general application of the techniques through a field exercise in another country, probably the Philippines; and 3) Continuing development of more cost-effective hydroacoustic systems from the viewpoint of hardware and software. Current

systems can be simplified and their transferability made easier.

b. The Recruitment and Productivity Project

This project can also be partitioned into three highly linked components: Growth and Ageing, Fecundity and Recruitment Timing, and Productivity.

1) Growth and Ageing

The established age determination center at the University of Costa Rica will carry out the length and age sampling, the age determination for the species of interest, and update the data base for common uses in the CRSP. The existing data base will enable us to estimate the growth rate over the entire life history for corvina species. These results will provide the primary data for productivity-turnover rate, reproductive effort, and age/size modeling.

2) FERET (Fecundity and Recruitment Timing)

Data from the first five years will be the basis for a strong focus on the implications of recruitment for the management of tropical fish. The major data base available is sex ratio, maturity proportion, gonad index, fecundity, and recruitment timing. Of a great practical concern is the prospect of recruitment overfishing from uninformed changes in legal gear and/or effort. Until we know more about reproductive effort vs. age or size, there is a real danger to tropical fisheries everywhere. General strategies based on fisheries critical and reference points for managing fisheries in tropical estuaries will result.

3) Productivity

Productivity will be put in the general framework of the establishment of procedures to guard against both recruitment and growth over-exploitation. Traditional fishery management methodology built around a theory of biological reference points and new methodology built around biological production and turn-over rate will be combined in an effort to construct a unique conceptualization and management model for tropical estuarine mangove areas. Our initial steps will certainly be based upon FERET for stock-recruitment modeling. As a part of the modeling section, a yield per recruitment dynamic pool model will also be built. Fishing mortality coefficients are examples of biological reference points that have been used in temperate fisheries. The fact that the initial stock-recruitment relationships and yield per recruitment model will exist prior to the beginning of a three year extension ensures that biological reference points and critical points will be a part of the developing theory.

The UW/UCR team will begin to apply the concepts and methods being developed in Costa Rica to the Philippines. This will serve as an enrichment of the ideas developed, a focus for integrating the accomplishments in the various CRSP components, an opportunity to evaluate results, and a training process for scientists in the Philippines.

All three of the components of the Recruitment and Productivity Project will contribute toward the updating and extension of the management manual

delivered after five years and each component will publish results in the literature, as technical reports, and at symposia.

Collaboration and coordination with the UMCEES researchers will continue, and increased collaboration with the URI and UP researchers is planned.

3. URI/UP

Research efforts of the URI/UP collaboration will continue to pursue the objectives of the two projects undertaken during the initial five year grant period.

a. The Empirical Analyses and Modeling Project

During the three year extension of research activities, this project is expected to have developed, tested, and utilized for field appreciation, an extended version of the previously developed Markov model, which consists of a dynamic optimal control model involving finite state, finite action, infinite discrete time-horizon Markov decision processes. It is believed that this model will adequately embody the important concepts of uncertainty, interaction, dynamic nature, and limited data availability which has been described as appropriate goals. This model is considered primarily as a strategic (long-term) model.

The additional three years will also allow the finalizing of the development of tactical (short-term) models, which were initiated during the initial years of the project. It is believed that critical comparisons of multispecies assemblages can be made over short space and/or time scales, utilizing computer assisted approaches which include the generation of empirical probability distributuons through Monte Carlo simulation. The first stages have been developed, and the researchers expect to complete these tactical models and provide and disseminate software and methodology during the final project period.

b. The Multispecies Field Studies Project

Studies of factors affecting soft-bottom small-scale fisheries, including natural fish habitats such as sponge communities, and artificial fish aggregating devices ("FAD's" and "Artificial Reefs") in conjunction with other Philippine and internationally sponsored programs, are expected to be completed during the three year extension.

The materials from the first handbook will be revised into a more flexible and user-friendly format.

Continued coral reef resource evaluation in the Philippines via remote sensing in conjunction with other funded programs, as a means of further developing and testing the approach for possible application in other countries, will be evaluated and documented.

The results of all coral reef studies will be presented in the Seventh International Coral Reef Symposium, in mid-1992. This periodic series of

congresses is the largest international gathering of coral reef scientisits, providing a focal point for the release of research results in many of the major integrated reef studies of the world. It is, therefore, the most appropriate forum for the culmination of our long-term studies. These presentations will be in a form suitable for publication.

All results will be summarized and finalized. Data will be assimilated into data reports and user-friendly data-base systems. Collaboration with other CRSP entities will permit the incorporation of the final results and data into management models. Final publications will be prepared.

4. Program Coordination and Integration

Throughout the three year extension period, program coordination efforts will continue. Scientific exchange visits, participation in conferences, workshops, and training programs, and the sharing of research findings through the dissemination of working papers will be encouraged. Most importantly, however, will be the continued development of the CRSP Stock Assessment Handbook(s). The handbook(s) are a dynamic product which will substantially improve through use, field testing, critical evaluation, sensitivity analysis of segments, improved coding and documentation, etc. The expert system/ decision support system, which is a major interfacing and integration mechanism, is also dynamic and will improve as its knowledge base becomes more accurate and precise, as well as more encompassing. The objectives and work plans for a three year extension of the CRSP grant are directed to developing the methodologies and technologies for stock assessment and management of multispecies tropical fisheries so that the handbook(s) and guides will truly be practical, appropriate, useable, and state-of-the-art.

III. The University of Maryland-Center for Environmental and Estuarine Studies and The University of Costa Rica Program

A. Program Description

The University of Maryland-Center for Environmental and Estuarine Studies (UMCEES) in collaboration with The University of Costa Rica (UCR) is carrying out two CRSP research projects, noted as follows:

1. Multiple Species Fisheries Research, and
2. Economic and Probabilistic Extensions of Standard Fisheries Models.

The principal host country institution collaborating on these two projects is UCR's Centro de Investigacion en Ciencias del Mar y Limnologia (CIMAR).

Additional collaboration on the Multiple Species Fisheries Research Project is being provided by The University of Maryland-College Park-College of Business and Management (UMCP-CBM) and by The University of Miami (UMiami); and additional collaboration on the Economic and Probabilistic Extensions of Standard Fisheries Models Project is being provided by The University of Delaware (UDelaware). While the above description of the collaboration focuses on the contractual relationships among institutions, it should be emphasized that the researchers from the five institutions are working as an integrated team.

The two projects will together focus on 1) the design of a decision support system, utilizing some expert systems (ES) features, to study population dynamics and management of small-scale multispecies fisheries and 2) the modification of standard fisheries models to increase their utility to managers of small-scale fisheries.

The following presents an overview of the accomplishments of the first three years of the UMCEES/UCR collaboration. This is followed by a discussion of the objectives and work plans for years four and five of the current grant and a summary of the plans for years six through eight under an extension of the current grant.

B. Triennial Review of Accomplishments

The following discussion briefly describes 1) the accomplishments of the first three years of this research program and 2) the relation of the research program with the Fisheries Stock Assessment CRSP research goals of developing new knowledge and methods in stock assessment and fisheries management, collaboration, contributed participation, and the transferability and dissemination of research results. In advancing the fields of fisheries stock assessment and management, this research program has thus far developed a state-of-the-art expert system/decision support system for fishery management, advanced biological and economic fishery models, and contributed to the biodynamics of the sea theory. These substantive achievements of the

UMCEES/UCR collaboration, in the form of CRSP Technical Reports and Working Papers, books, Ph.D. dissertations, and oral presentations, are listed in section III.B.4. below and are noted parenthetically in the text.

1. The Multiple Species Fisheries Research Project

The overall objectives of this project are to develop a better understanding of multispecies fisheries, to explore how they relate to community and population dynamics, and to contribute to fishery management in tropical small-scale fisheries.

The first task in meeting these objectives was to investigate multispecies fishery system complexity, including analyzing simple and complex ecosystems and examining system architecture. Two initial areas of research were followed which defined the direction of subsequent research. The first was to explore the use of artificial intelligence technology, namely expert systems, and operations research techniques, such as decision support systems, in examining multispecies fishery systems (2). The second area of research was an in-depth study of the present knowledge of marine fish population dynamics (28). This work systematically investigated the variability in both exploited and non-exploited fish stocks, described the adequacies and inadequacies of present fishery stock assessment theory, pointed out potentially fruitful and fruitless avenues of future research, and developed a population-dynamics process model.

The research into expert systems and decision support systems as a guide to understanding the complexity of multispecies fishery systems led to the development of CANOFISH, a unique, first-stage canonical fishery management system which is applicable to both small and large fisheries in single and multispecies contexts (3, 29, 32, 33). This expert system/decision support system (ES/DSS) is designed to analyze fishery data, predict future harvests, and provide advice to fisheries managers on optimal management strategies of fish stocks.

CANOFISH is comprised of five modules: MONITOR, ESTIMATOR, OPTIMIZER, SIMULATOR, and ADVISOR. Sampling data from the fishery are input into MONITOR, which then organizes the data to be input into the rest of the system. ESTIMATOR receives the data from MONITOR and estimates or computes the various parameters of the fishery stock assessment models. OPTIMIZER contains the stock assessment models. It receives the parameters from ESTIMATOR and optimizes both biologically and economically such parameters as maximum sustainable yield and maximum economic yield (which were used in the functional demonstration system). SIMULATOR takes the optimized parameters and extrapolates these values under probable future conditions in order to forecast the fishery in the future. ADVISOR integrates the whole system, providing the linkages among the other components and performing such functions as comparing the simulated fishery yields to the actual computed yields and detecting problems in the performance of the other components. It is also the link between the user and the system, and the module which provides management advice on the operation of the fishery, the most cost-effective sampling methods, and additional data requirements. Thus, activities which are fundamental to stock assessment (sampling, estimation, optimization, and simulation) are expressly linked and integrated by CANOFISH.

The first-stage working version of the CANOFISH ES/DSS has been developed for use on a microcomputer (29, 33). Other related work has been undertaken to elaborate upon the various modules comprising CANOFISH. A stock assessment computer library has been converted for use on a microcomputer, complete with Spanish and English documentation (12), and has been distributed to the various CRSP researchers. These programs will be incorporated into OPTIMIZER. Work undertaken on SIMULATOR has focused on the development of a three-sector simulation model, which is comprised of fishery, institutional, and population sectors (30). Research completed to date includes:

1) A review of spawning and recruitment patterns of tropical marine fish stocks, and an evaluation of techniques used to assess the tropical fishery system (19, 24, 30);
2) Development of a recruitment pattern simulator and a continuous recruitment simulation model for the tropical fishery system (18, 20, 21, 30);
3) Development of abundance/density equations for age-structured multicohort populations (23, 24, 30);
4) Development of a yield-per-recruit Monte Carlo decision model for evaluating fishery management alternatives in simple-data situations (17, 34); and
5) Construction of an areal production model for multispecies fisheries (27).

The development of the population-dynamics process model (28) set the stage for further work in multispecies fishery theory, part of which was the formulation of the biodynamics of the sea theory (11, 31, 38). The main idea behind this theory is that in order to predict fluctuations in marine organism abundance, it is necessary to account simultaneously for the variability induced by density-dependent population dynamic processes and the variability induced by the physical structure of the sea. Research in this area is focused on determining the biophysical processes, measured on appropriate time-space scales, which underlie predator-prey interrelationships in the plankton. Advances have been made in discovering the effects of small-scale turbulence on plankton contact rates (25), in determining the feasibility of relating recruitment to environmental variation (1), and in outlining the physical basis for recruitment variability in fish populations (16). Work of a more applied nature in multispecies fishery theory has also been completed, namely the organization and evaluation of the 1980-1983 biological sampling data of the Gulf of Nicoya corvina fisheries (7, 35). These data will be incorporated into both the CANOFISH ES/DSS and the three-sector simulation model.

2. The Economic and Probabilistic Extensions of Standard Fisheries Models Project

The overall objective of this project is to extend standard fisheries models to increase their utility to managers of tropical small-scale fisheries. Three avenues of research have been pursued in obtaining this objective: 1) probabilistic extensions of fisheries models, 2) economic extensions of fisheries models, and 3) the development of new methodologies for providing useful bioeconomic information to fisheries managers.

Research completed in probabilistic extensions of fisheries models has yielded the following results:

1) Development of a stochastic model for prediction of adult population size for use in fisheries management (27);
2) Development of a difference equation simulation model of marine population dynamics, as well as a simulated study of marine population dynamics (5, 9);
3) Construction of a simple renewal model of larval fish feeding (10);
4) Research into the use of a partial differential equation model for fish population dynamics (6); and
5) Critical analysis of the use of the spawning-stock biomass approach in determining recruitment-stock relationships (15).

Work on the economic extensions of fisheries models has focused on pursuing new applications of natural resource economic theory to fisheries. This approach has resulted in the development of a fixed and variable recruitment economic model in which the basic economic analysis of optimal harvesting is achieved without stock and recruitment information (13). In addition, the algorithm for implementing this economic model on a microcomputer has been developed (37).

The third area of research, the development of new methodologies for providing useful bioeconomic information to fisheries managers, has explored several operations research applications to fisheries management. The use of optimization procedures was studied, resulting in the compilation of a bibliography of extant optimization models in fisheries management (8). Research has also been completed on the application of the analytic hierarchy process (AHP) to fishery management decision-making (14). These approaches have led to the study of multistage fishery management decision frameworks (36).

The developments in this project will be integrated into the canonical expert system/decision support system being developed in the Multiple Species Fisheries Research project.

3. Relation of Research Program with CRSP Research Goals

a. Development of New Knowledge and Methods

As presented in the above discussion, both the Multiple Species Fisheries Research and the Economic and Probabilistic Extensions of Standard Fisheries Models projects have followed the CRSP research goals of developing new knowledge and methods in stock assessment and fisheries management. The significant achievements of the research collaboration, including the development of an expert system/decision support system for fishery management, the extension of biological and economic fishery models focusing on the multispecies problem, and the development of the biodynamics of the sea theory, have advanced the field of tropical small-scale fisheries stock assessment in particular, as well as the entire field of fisheries stock assessment in general.

b. Collaboration

Researchers participating in our program have interacted through planning meetings, scientific discussions, and joint research projects which have resulted in a number of CRSP Working Papers and oral presentations (4, 6, 7,

9. 10, 12, 35). In addition to the numerous meetings among researchers based in the U.S. (UMCEES, UMiami, UMCP-CBM, and UDelaware), researchers from both Costa Rica (UCR-CIMAR) and the U.S. have exchanged visits. A brief documentation of international travel is listed below: B. Rothschild and E. Houde to UCR, December 1985. B. Rothschild, B. Golden, W. Fox, Jr., E. Houde, L. Anderson, A. Assad, and C. Stagg to UCR, January 1986. J. Gracia and R. Estrada to UMCEES, May-June 1986. J. Gracia to UMiami, June 1986. J. Campos and J. Lobo to UMCEES, August 1986. M. Murillo to UMCEES, September 1986. C. Stagg to UCR, November-December 1986. M. Murillo to UMCEES, May 1987. Y. Wu and J. Ault to UCR, August 1987. C. Stagg and B. Golden to UCR, September 1987. B. Rothschild and W. Fox, Jr., to UCR, February 1988.

c. Contributed Participation

Researchers from outside the CRSP institutions have also collaborated on certain aspects of the UMCEES/UCR research program without receiving CRSP financial support. These researchers are: T.D. Dickey, University of Southern California; D.M. Farmer, Institute of Ocean Studies, British Columbia; M.J. Fogarty, Northeast Fisheries Center; T.R. Osborn, Johns Hopkins University; and E. Wasil, American University. Their collective input into this program has contributed significantly to its success thus far, and has expanded the visibility of CRSP activities in the scientific community at large. Support for the UMCEES/UCR research program has been donated by UMCP-CBM in providing the services of research assistants D. Levy, H. Trivedi, and Q. Wang. In addition, UMCEES has donated the services of research assistant S. Smith.

d. Transferability and Dissemination of Research Results

The transferability of our research is demonstrated by its applicability to many tropical fishery situations (7, 13, 17, 18, 19, 20, 21, 22, 23, 24, 27, 30, 34, 35, 37). Technology transfer has been achieved through the implementation of theoretical models and practical methodologies in the host country, Costa Rica. Distribution of CRSP Working Papers and Technical Reports to all of the researchers and institutions comprising the CRSP has enhanced the coordination and collaboration of the CRSP as a whole. Publication of results in scientific journals and as books and Ph.D. dissertations has informed the general scientific community of our research. Presentation of papers at national and international meetings has provided a forum for the distribution of our results and for critical review and discussion of the collaborative research program of the five universities, UMCEES, UCR, UMCP-CBM, UMiami, and UDelaware. The organizations to whom research has been presented include the American Fisheries Society, the International Council for the Exploration of the Sea (ICES), the American Association for the Advancement of Science (AAAS), the North Atlantic Treaty Organization-Advanced Research Workshop (NATO-ARW) the Operations Research Society of America (ORSA), and the European Congress on Operations Research.

4. References

a. CRSP Technical Reports and Working Papers

(1) Rothschild, B.J. 1986. Feasibility of relating recruitment to environmental variables. MDSACRSP No. 86-1. CRSP Working Paper No. 6.

Also presented at the International Council for the Exploration of the Sea (ICES) Annual Meeting, Copenhagen, Denmark.

(2) Assad, A.A. and B.L. Golden. 1986. Expert systems, microcomputers, and operations research. MDSACSP No. 86-2. CRSP Working Paper No. 7.

(3) Rothschild, B.J., B.L. Golden, and A.A. Assad. 1986. A microcomputer based decision support system for multispecies fishery management. MDSACRSP No. 86-3. CRSP Technical Report No. 1. Published In Lev, B., J.A. Bloom, A.S. Gleit, F.H. Murphy, and C. Shoemaker, eds. 1987. Strategic planning in energy and natural resources. Elsevier Science Publishers, 333-339. Also presented at the Operations Research Society of America Second Symposium on Analytical Techniques for Energy, Natural Resources, and Environmental Planning, Philadelphia, PA.

(4) Stagg, C. and J. Campos. 1986. Report of Workshop: San Jose, Costa Rica, January 21-24, 1986. MDSACRSP No. 86-4. CRSP Working Paper No. 17.

(5) Golden, B.L., B.J. Rothschild and H. Trivedi. 1986. A simulation study of marine population dynamics. MDSACRSP No. 86-5. CRSP Working Paper No. 18.

(6) Gracia-Bondia, J.M. 1986. Continuum-distribution population dynamics. MDSACRSP No. 86-6. CRSP Working Paper No. 19.

(7) Campos, J. and C. Stagg. 1986. A strategy for organizing and analyzing Golfo de Nicoya fishery data. MDSACRSP No. 86-8. CRSP Working Paper No. 20.

(8) Assad, A.A. and G.T. DiNardo. 1986. A bibliography of optimization models in fisheries management. MDSCRSP No. 86-9. CRSP Working Paper No. 21.

(9) Estrada, R.A. 1986. A difference equation simulation model of marine population dynamics. MDSACRSP No. 86-10. CRSP Working Paper No. 22.

(10) Lobo, J. 1986. A simple renewal model of larval fish feeding. MDSACRSP No. 86-11. CRSP Working Paper No. 23.

(11) Rothschild, B.J. and T.R. Osborn. 1986. Biodynamics of the sea: Preliminary observations on high dimensionality and the effects of physics on predator-prey interrelationships. MDSACRSP No. 86-12. CRSP Working Paper No. 24. Also presented at the ICES Annual Meeting, Copenhagen, Denmark.

(12) Restrepo, V.R., D. Die, W.W. Fox, Jr., and J. Chavarria. 1986. Fish stock assessment programs for the IBM-PC and compatibles. MDSACRSP No. 86-13. CRSP Working Paper No. 25.

(13) Anderson, L.G. 1986. A discrete dynamic fisheries utilization model: Towards the practical application of modern fisheries economics. MDSACRSP No. 86-14. CRSP Working Paper No. 26.

(14) DiNardo, G.T., D. Levy, and B.L. Golden. 1987. Using decision-analysis to manage Maryland's river herring fishery: An application of AHP. MDSACRSP No. 87-1. CRSP Working Paper No. 27. Published in J. Environmental Management. 1988. In Press.

(15) Rothschild, B.J. and M. J. Fogarty. 1987. Spawning-stock biomass: A source of error in recruitment-stock relationships and management advice. MDSACRSP No. 87-2. CRSP Working Paper No. 28. Published In J. Cons. int. Explor. Mer. 1988. In Press. Also presented at the ICES Annual Meeting, Santander, Spain.

(16) Rothschild, B.J., T.R. Osborn, T.D. Dickey, and D.M. Farmer. 1987. The physical basis for recruitment variability in fish populations. MDSACRSP No. 87-3. CRSP Working Paper No. 29. Published In J. Cons. int. Explor. Mer. 1988. In Press. Also presented at the ICES Annual Meeting, Santander, Spain.

(17) Restrepo, V.R. and W.W. Fox, Jr. 1988. Parameter uncertainty and simple yield per recruit analysis. MDSACRSP No. 88-1. CRSP Working Paper No. 30.

(18) Die, D., V.R. Restrepo, and W.W. Fox, Jr. 1988. Program REPSIM: A REcruitment Pattern SIMulator. MDSACRSP No. 88-2. CRSP Working Paper No. 31.

(19) Ault, J.S. and W.W. Fox, Jr. 1988. The spawning and recruitment patterns of tropical marine fish stocks. MDSACRSP No. 88-3. CRSP Working Paper No. 32.

(20) Ault, J.S. and W.W. Fox, Jr. 1988. The tropical fishery system model CORECS: COntinuous RECruitment Simulation. MDSACRSP No. 88-4. CRSP Working Paper No. 33.

(21) Ault, J.S. and W.W. Fox, Jr. 1988. User's guide to CORECS. MDSACRSP No. 88-5. CRSP Working Paper No. 34.

(22) Ault, J.S. and W.W. Fox, Jr. 1988. Abundance/density equations for age-structured multicohort populations: MCON (Multiple COhort N-dimensional model). MDSACRSP No. 88-6. CRSP Working Paper No. 35.

(23) Ault, J.S. and W.W. Fox, Jr. 1988. User's guide to MCON (Multiple COhort N-dimensional model). MDSACRSP No. 88-7. CRSP Working Paper No. 36.

(24) Ault, J.S. and W.W. Fox, Jr. 1988. On the efficacy of some techniques to assess the tropical fishery system. MDSACRSP No. 88-8. CRSP Working Paper No. 37.

(25) Rothschild, B.J. and T.R. Osborn. 1988. Small-scale turbulence and plankton contact rates. MDSACRSP No. 88-9. CRSP Working Paper No. 38. Published In J. Plankton Res. In Press.

(26) Golden, B.L., H. Trivedi, and Q. Wang. 1988. A density-dependent model for the prediction of adult population size in fisheries management. Also presented at the American Fisheries

Society/International Association of Fish and Wildlife Agencies (AFS/IAFWA) Annual Meeting, Winston-Salem, N.C. MDSACRSP No. 88-10. To become a CRSP Working Paper.

(27) Die, D., V. Restrepo, and W.W. Fox, Jr. 1988. An areal production model for multispecies fisheries. In Preparation.

b. Books and Ph.D. Dissertations

(28) Rothschild, B.J. 1986. Dynamics of marine fish populations. Harvard University Press, 277 pp.

(29) Stagg, C.M. 1987. The design of an expert system for fishery management. Ph.D. Dissertation, University of Maryland.

(30) Ault, J.S. 1988. Nonlinear simulation models for assessing tropical fisheries with continuously breeding multicohort populations. Ph.D. Dissertation. University of Miami.

c. Papers Given as Oral Presentations

(31) Rothschild, B.J. 1987. Biodynamics of the sea: The ecology of high dimensionality systems. NATO Advanced Research Workshop, Verduzan, France. Published In B.J. Rothschild, ed. 1988. Proceedings of NATO advanced research workshop: Toward a theory on biological-physical interaction in the world ocean. In Press.

(32) Rothschild, B.J. 1987. Canonical fishery management systems. AFS/IAFWA Annual Meeting, Winston-Salem, N.C.

(33) Stagg, C. 1987. CANOFISH: An expert system for fishery management. AFS/IAFWA Annual Meeting, Winston-Salem, N.C.

(34) Fox, W.W., Jr. and V.R. Restrepo. 1987. A monte carlo decision model for evaluating fishery management alternatives in simple data situations. AFS/IAFWA Annual Meeting, Winston-Salem, N.C.

(35) Campos, J., C. Stagg, J. Chavarria and E. Madrigal. 1987. Multispecies fishery management: Data needs versus data availability in the Gulf of Nicoya artisanal fishery. AFS/IAFWA Annual Meeting, Winston-Salem, N.C.

(36) DiNardo, G.T. 1987. The development of multistage fishery management decision frameworks. AFS/IAFWA Annual Meeting, Winston-Salem, N.C.

(37) Rogers, C.W. and L.G. Anderson. 1987. A computer model for determining the optimal harvest of a standing fish stock. AFS/IAFWA Annual Meeting, Winston-Salem, N.C.

(38) Rothschild, B.J. 1988. Biodynamics theory in relation to recruitment in large marine ecosystems. American Association for the Advancement of Science Annual Meeting, Boston, MA.

C. Objectives and Plans for Years Four and Five

1. The Multiple Species Fisheries Research Project

The objectives of this project are to develop a better understanding of multispecies fisheries and how they relate to community and population dynamics, and to contribute to advancing fishery management in tropical small-scale fisheries. Following the research direction established in the first three years of the project, work in years four and five will focus on 1) the continued investigation of multispecies-fishery system complexity, 2) the continued development of multispecies-fishery theory and 3) the continued development and refinement of stock assessment techniques that are particularly applicable to small-scale, subtropical and tropical artiisanal fisheries.

a. Description of Proposed Research

Our investigation of fishery system complexity in the first three years of our program led to the development of CANOFISH I (3, 29), a functional, first-stage, canonical expert system/decision support system (ES/DSS) for fishery management. Future research will emphasize further enhancement of CANOFISH; the primary objective of the next version, CANOFISH II, is to continue the integration of sampling, estimation, optimization, and simulation that was begun in CANOFISH I. Emphasis will be placed on system design in years 4 and 5.

The intent of CANOFISH II is to provide a tool which we can use to assess a fishery as cost-effectively as possible and to evaluate complex-fishery management schemes. There are three sources of information from which fishery management alternatives can be developed, namely: 1) the fishery itself, 2) a simulation of the fishery, and 3) other similiar fisheries. Research into the system design of CANOFISH II is based on the idea that a real fishery (RF) which we wish to assess and manage can be studied using data and information from all three sources.

One source of information other than the RF is a simulated fishery (SF) that is based wholly, or in part, on the information that exists on the RF. Since we are constrained physically and economically from obtaining perfect knowledge of the RF, we can simulate the fishery and use the simulation as a surrogate in studying the RF. This SF can then be "sampled" according to a variety of sampling strategies, the sampled data analyzed with a variety of fishery/bioeconomic and time-series models, and the resulting parameters utilized to identify an optimal sampling and management strategy. Comparing these optimal estimates with their "actual" value in the SF (of which we have perfect information since we created it) lends insight into how accurately each sampling strategy-parameter estimation-optimization path describes the SF. From this information, the optimal sampling program(s) in terms of parameter-estimation accuracy and cost-effectiveness can be chosen to evaluate the RF.

The other source of information other than the fishery itself are similar fisheries, for which a metaystem classification can be constructed. (The development of a fishery management metasystem is described in the Economic

and Probabilistic Extensions of Standard Fishery Models project.)

An additional capacity of the CANOFISH II system will be the ability to evaluate the performance of the various fishery models for both accuracy of parameter estimation and practicability of implementation. For example, the study of a SF may reveal certain fishery models which do not accurately assess mortality or growth rates or fishery yields, even though intensive sampling has been carried out. Conversely, a model may be theoretically sound but its data requirements may render it impractical for implementation in real-life situations. These evaluation methods could also be used to test the performance of different optimization procedures. or any other component of the system.

The conceptual framework of CANOFISH remains unchanged. CANOFISH II will continue to serve as a focal point for the entire research program, and as a means for integration of projects. (On Program Coordination Integration, see Section VI of this report.) The emphasis will now be directed towards examining the interactions between a real and a simulated fishery, developing the concept and structure of a metasystem, incorporating more multispecies concepts and models, and adopting a modular ES development approach. The research goals for the development of CANOFISH II are as follows: 1) incorporate a wide variety of sampling strategies, fishery and bioeconomic models, and optimization procedures into the appropriate components of the CANOFISH II system, 2) further enhance the simulation models and use them to test the performance of the various system components, and 3) expand the use of expert system technology in linking system components together in a complex network.

Further development of new stock assessment techniques and enhancement of extant models for applicability to tropical and subtropical small-scale fisheries will continue (14, 17, 18, 19, 20, 21, 22, 23, 24, 30). This research will be integral to CANOFISH II; however, it is intended that these techniques will be able to be used independently of CANOFISH II.

Research in the area of multispecies fishery theory will continue the study of the factors which drive recruitment processes and multispecies interactions (5, 6, 9, 10, 11, 15,16, 25, 28). This will include a review and synthesis of biological, physical, chemical, and geologic interrelationships in a continuing study of the biodynamics of the sea.

b. Work Plans for Year Four

1) <u>CANOFISH II</u>

a) Develop the modules that comprise CANOFISH II.
b) Link simulation, metasystem, and AHP components within CANOFISH II.
c) Develop small-scale, modular expert systems to aid in implementation and interpretation in a) and b).
d) Examine the behavior and interactions of a real fishery-simulated fishery system, and implement related computer software.

2) <u>Assessment Techniques</u>

a) Bench test standard assessment techniques with REPSIM computer model.

b) Apply two computer programs, YPERSIM and PRODAREA, to the Gulf of Nicoya sciaenid aggregation.

3) Multispecies Fisheries Theory

a) Begin research for preparation of a monograph on the relationship between physical oceanographic factors and both multispecies interactions and recruitment variability.

c. Work Plans for Year Five

1) CANOFISH II

a) Continue the development of the modules that comprise CANOFISH II.
b) Continue to link simulation, metasystem, and AHP components within CANOFISH II.
c) Continue to develop small-scale, modular expert systems to aid in implementation and interpretation in a) and b).
d) Complete examination of the behavior and interactions of a real fishery-simulated fishery system, and implementation of related computer software.
e) Incorporate CANOFISH II into handbook.

2) Assessment Techniques

a) Complete bench testing of standard assessment techniques with REPSIM computer model.
b) Link several single species simulation modules together to construct hypothetical multispecies aggregations based on various ecological interrelationships.
c) Incorporate a) and b) into handbook.

3) Multispecies Fishery Theory

a) Begin writing monograph on the relationship between physical oceanographic factors and both multispecies interactions and recruitment variability.

2. The Economic and Probabilistic Extensions of Standard Fisheries Models Project

a. Description of Proposed Research

The overall objective of this project is to continue to develop stock assessment techniques and to extend standard fisheries models to increase their utility to managers of tropical small-scale fisheries. Research in years four and five will be directed towards 1) the completion and implementation of economic models that address the fixed and variable recruitment problem, and 2) the development of a metasystem for fishery management utilizing the analytic hierarchy process (AHP).

A major focus of the work on both the economic and stochastic fishery models in years four and five will be to complete the design and testing

phases of model development and to incorporate Gulf of Nicoya corvina fishery data into the models. The models will then be used to evaluate harvest policies and management alternatives for this Costa Rican fishery.

The development of a metasystem for fishery management will provide a powerful tool for managers of fisheries for which little or no data exists. This metasystem will contain information on the well-studied fish stocks and populations of the world. A hypothetical example of how this system may be used is as follows: Suppose we have an actual corvina population which we wish to assess by time-series analysis, yet we have no time-series information for this particular stock. A search of the metasystem using AHP is performed which locates other "similar" systems, such as other sciaenid populations. Once similar systems are located within the metasystem, another search is performed to locate information, in this case, the results of time-series analyses, which we can use as a guide in forecasting how our corvina population might behave over time. Time-series analysis is but one of a wide range of existing fishery and bioeconomic models which could be examined in the metasystem to identify and classify systems which are similar to the system under study, a corvina population in our example.

Information obtained from this fishery management metasystem would also be used to elucidate past approaches and methodologies which were either successful or unsuccessful in assessing fish stock abundance, predicting future yields, determining mortality rates due to fishing, etc. Thus, a fishery manager of an unstudied population is provided useful information on both <u>designing</u> and <u>managing</u> a stock assessment program.

Economic models that address the fixed and variable recruitment problem, stochastic models, and the fishery-management metasystem will all be incorporated into the CANOFISH II ES/DSS being developed in the Multiple Species Fisheries Research Project.

b. Work Plans for Year Four

1) <u>Fixed and Variable Recruitment Economic Models</u>

a) Complete development and testing of fixed and variable recruitment economic computer model.
b) Incorporate Costa Rican fishery data into the model and determine optimal harvest policies.
c) Link completed model to CANOFISH II.
d) Finalize manuscripts and publish papers on the empirical applications of the fixed and variable recruitment economic model.

2) <u>Metasystem for Fishery Management</u>

a) Begin assembling extant stock assessment information, analyzed both parametrically (e.g., yield per recruit, production methods) and nonparametrically (e.g., ARIMA methods), for a variety of fish populations around the world.
b) Develop an AHP procedure to locate "similar" systems within the metasystem.
c) Develop an AHP procedure to locate the pertinent information within "similar" systems.

c. Work Plans for Year Five

1) Fixed and Variable Recruitment Economic Models

a) Incorporate the model into the handbook.

2) Metasystem for Fishery Management

a) Complete the assemblage of stock assessment information for various well-studied fish population.
b) Refine the AHP procedures for locating 1) "similar" systems within the metasystem and 2) information within "similar" systems.
c) Integrate the metasysytem into the fishery/bioeconomic model identification and estimation component of CANOFISH II.
d) Incorporate the metasystem into the handbook.

D. Objectives and Work Plans for Years Six Through Eight

1. The Multiple Species Fisheries Research Project

a. Research Objectives

The research objectives in years six through eight will continue to be the investigation of multispecies fishery-system complexity in order to understand multispecies fisheries, how they relate to community and population dynamics and to continue contributing to the advancement of fishery management in small-scale fisheries. A concrete objective is to complete, at the end of eight years, an integrated expert support system (ESS) incorporating advances in stock assessment and multispecies research.

b. Description of Proposed Research

Further enhancement of the CANOFISH ESS will be the focus of our work in years six through eight. Research will build upon the completed network system linking sampling, model identification and estimation, optimization, and simulation which comprises CANOFISH II with the development of an expert system linking the modular ES to integrate the whole system. This expert system, called ADVISOR in CANOFISH II, will be the link between the user and the system and also provide management advice on 1) the operation of the fishery, 2) the most cost-effective sampling programs, 3) the optimal fishery/bioeconomic models to use in asssessing a particular fishery, and 4) additional data requirements.

c. Work Plans for Years Six Through Eight

1) CANOFISH II

a) Coordinate various elements of our research and link to appropriate CANOFISH II modules.
b) Complete integration of a fishery management expert support system (ESS), CANOFISH II.

2) Assesssment Techniques

a) Bench test assessment techniques with the multispecies model.
b) Conduct research to determine the optimal fracture planes for disaggregating multispecies catches based on common assessment techniques.
c) Optimize fracture planes for disaggregating multispecies catches based on common assessment techniques.

3) Multispecies Theory

a) Explore applications of multispecies findings to fishery management.

2. The Economic and Probabilistic Extensions of Standard Fisheries Models Project

a. Research Objectives

The research objectives in years six through eight will continue to be to develop stock assessment techniques, to extend standard fishery models, and to incorporate applicable techniques from other fields of study. Emphasis will be placed on metasystem development and incorporation of decision analysis techniques.

b. Work Plans for Years Six Through Eight

1) Economic Models and Decision Analysis Techniques

a) Continue research on applicability of decision analysis techniques to fishery management.

2) Metasystem Development

a) Continue development of metasystem models.

IV. The University of Washington and The University of Costa Rica Program

A. Program Description

The University of Washington (UW) in collaboration with The University of Costa Rica (UCR) is carrying out four CRSP research projects, noted as follows:

1. Sampling Catch and Abundance,
2. Age-Size Dependent/Independent Modeling,
3. Age and Size Relationships and Consequences of Errors,
4. Shallow-Water Hydroacoustics.

The principal host country institution collaborating on these four projects is UCR's Centro de Investigacion en Ciencias del Mar y Limnologia (CIMAR). Additional collaboration on the Sampling Catch and Abundance Project is being provided by The University of Delaware (UDelaware).

The four projects compose an integrated investigation of stock assessment and prediction that has as its objective the adaptation of concepts and methods of temperate fisheries management and the development of new methodologies to tropical, artisanal fisheries. The work involves the integration of various field, laboratory and theoretical studies.

B. Triennial Review of Accomplishments

The University of Washington and The University of Costa Rica (UW/UCR) are working cooperatively on the Fisheries Stock Assessment CRSP in the Gulf of Nicoya, Costa Rica. This project is coordinated with the UMCEES/UCR project, details of which are found elsewhere in this document.

The UW/UCR collaboration is concerned with two aspects of the management process, the collection of data and its use and interpretation, especially through the application of quantitative models. This section describes and reviews the accomplishments of the first three years of research on the four projects that are contributing new insights into the theory and practice of fisheries management in tropical shallow water estuaries. Later sections review the objectives and plans for the next two years of the CRSP and for a three year extension of these activities to allow a fuller development of the scientific concepts and the testing of methodology.

The several components of the UW/UCR project are conveniently partitioned into two dealing with the collection of data and two dealing with modeling and interpretation. These are:

Collection of Data:	Project 1:	Sampling Catch and Abundance
	Project 4:	Shallow-Water Hydroacoustics
Modeling and Interpretation:	Project 2:	Age and Size Dependent/ Independent Modeling
	Project 3:	Age and Size Relationships and Consequences of Errors

Before presenting detailed descriptions of the development of new ideas and methodology in each of the four projects, some highlights of the research accomplishments over the past three years are described. Reports have been written presenting the sensitivities and dangers associated with the use of the now very popular (in tropical countries) length cohort analysis. These reports demonstrate the problems, present software suitable for use in developing countries for doing the analyses so that the errors or dangers are minimized, and develop for the first time a length based cohort equation. Researchers have also demonstrated conclusively that the tropical corvina-complex of species can be aged and have written training materials to share the techniques. The new information indicates extremely rapid growth of the primary corvina species in the first year. The development of associated biological information about fecundity will point the way toward the specification of management criteria to forestall either growth or recruitment overfishing. Researchers have demonstrated new techniques for doing shallow-water hydroacoustics and thus added a new dimension to stock assessment in such environments. Sampling projects have been started in the Gulf of Nicoya to acquire needed new data, and data from existing or past sampling projects have been acquired and data management software is being used.

1. The Sampling Catch and Abundance Project

The project objective is to develop statistical sampling methodology for the assessment of tropical fish stocks exploited via artisanal fisheries. The discussion of the accomplishments are partitioned into four parts: management data, biological data, decision-support sampling software package, and summary of progress.

a. Management Data

Catch slip data have been acquired that are composed of slips filled out as part of the landing transaction. The information includes data on weight of catch by categories, rather than by species, fuel consumption, vessel power, and length of time fished. These data were generated by the sale of the fish at the point of landing and were managed and stored by the Ministry of Fisheries. These data are of two types: 1) Old catch slip data that were entered onto magnetic tape several years ago (late 1970s) and 2) Catch slip data that are now being entered into the data management program.

Additional landing site data collected from specific vessels at points of landing include information aggregated by species and weights, subsampled data on length, and information on effort and on where the fish were caught based on interviews with fishermen. These data are collected primarily by the Department of Fisheries and, more recently, by CIMAR.

Although much of this data was available before, the UW/UCR team's success in bringing the data together and putting them into a useful format was a formidable task. Some of the old catch slip data was written with an early SAS program no longer readily available. It was finally read at UW. More recent catch slip data was on neither magnetic tape nor disc but are on individual slips of paper. The entry of these data onto disc so they can be used continues to be a major effort. A sufficient amount of analysis has been

done on the data to ensure that they are coherent and consistent, and very preliminary data analysis has begun. Data are being entered in a way so use can be made of the time series well before it is completely entered. Analysis of a small part of the data that will be available in years four and five has already shown that the species abundance data in the old data is different from the recent data, probably reflecting changes in effort. In the older data one can predict species-month associations with better than 50% accuracy. A useful "biological dimension," other than wet-season/dry-season, has been defined from the multivatiate analysis that allows prediction of the other catch statistics with as high as 85% accuracy in some years.

Sampling designs using these data are now being compared to evaluate basic questions of variability and cost of sampling. One protocol that incorporates elements of both systematic sampling and stratified random sampling gives satisfactory results with respect to efficiency and cost. This is one step in designing a protocol to reduce the current level of sampling and simultaneously retain the same efficiency. Bayesian based designs that will be introduced in years four and five will further reduce the cost of the sampling effort and increase the chances of dealing with noisy and missing data. A related multistage sampling design for stock assessment of artisanal fisheries in the south of Italy is being implemented in 1988.

b. Biological Data

Observer data on about 200 fish has been collected by CIMAR and is being analyzed. Observers were on board with fishermen collecting data that include tide, time, location, and fish information such as sex, sexual maturity, length and weight.

The management of tropical fisheries requires that certain critical scientific-biological questions be answered. In this case, the questions are about recruitment and early growth. Experiments to address these questions require special gear (e.g., one inch stretch mesh gill net), are tedious work by large numbers of people, and must be systematically carried out. Both gill net and trawl experiments are being done, and data on the resulting fish are becoming available.

c. Decision-Support Sampling Software Package

A computer software package to assist a user in the selection and use of an optimal sampling design has been assembled and is in the final stage of completion. It is a menu driven system where the user interacts with the program responding to a series of questions that successively channel him/her to an appropriate analysis.

d. Summary of Progress

Progress in this component is not measured in written reports or papers but is measured by having successfully surmounted the numerous difficulties of the acquisition of the data and its movement into a framework where its value can be utilized. It has required significant effort on the parts of many persons to first acquire the data from the Department of Fisheries in the

Ministry of Agriculture and then to begin the transcription from either paper slips to disc or from old magnetic tapes to disc. There are very large investments of time and money in this aspect of the sampling project, the true value of which is only now becoming evident. The abstracts that appear below are some evidence of this. The excellent demonstration computer package that CIMAR uses to illustrate the CRSP program and some of this data are further evidence. Abstracts with the following titles have been written for presentation at the 1988 American Fisheries Society Annual Meeting. These reflect results either from this component or are heavily based on this component. These papers will also appear as a refereed symposium volume.

1) "Selection of 'Indicative' Species Groups for Management in the Gulf of Nicoya", by Jorge Campos and Juan Chavarria.

2) "Results on Age Structure and Recruitment in Tropical Corvina", by Robert Donnelly, Han Lai, and Vincent Gallucci.

3) "Data Collection, Survey Problems and Preliminary Results in the Gulf of Nicoya: a Cost-Benefit Analysis," by Juan Charvarria, Robert Burr, and Loveday Conquest.

2. The Age and Size Dependent/Independent Modeling Project

Accomplishments of this component of the UW/UCR collaboration include the development of new theory and software surrounding length cohort analysis, the derivation of a new length-based catch equation and an analytical treatment of error in length cohort analysis. User friendly software and manuals have been written to transfer methodology and have been tested in the classroom. A stochastic model for doing catch-at-size analysis (CASA) has been written. The model reduces to other well-known catch-at-size analysis models when age data is entered and compares favorably. Thus, analogous stock assessment computations can now be carried based on length data. In addition, Drs. J.M. Gracia-Bondia and J.C. Varilly have drafted a technical report that derives a physiologically structured model that holds promise for becoming a standard part of stock assessment.

During the period 1985-1988, UW/UCR has completed the research for the following technical reports and publications:

1) "Effect of variability on estimates of cohort parameters using length-cohort analysis: with a guide to its use and misuse," by Han Lai and Vincent Gallucci. CRSP Technical Report No. 2.

2) "A comparative study of postlarval life-history schedules in four sympatric Cancer species (DECAPODA: BRACHYURA: CANCRIDAE)," by Jose Orensanz and Vincent Gallucci. J. Crust. Biol. (in press).

3) "User's guide for the program 'LCAN' (length-cohort analysis) and an overview of the underlying analysis," by Han Lai and Vincent Gallucci. CRSP Working Paper No. 12.

4) "Effects of parameter variability of length-cohort analysis," by Han Lai and Vincent Gallucci. J. du Conseil (in press).

5) "Catch at size analysis for fishery data (CASA)," by Patrick Sullivan, Han Lai, and Vincent Gallucci. (Submitted to Canad. J. Fish. Aquat. Sci.) Will appear as a CRSP working paper.

6) "Users' guide for program 'CASA' (catch at size analysis)," by Han Lai. (In ms.) Will appear as a CRSP working paper.

7) "The significance of physiologically structured models for fish stock dynamics, II," by Jose M. Gracia-Bondia and Joseph C. Varilly. CRSP Working Paper No. 40. Will appear as a professional publication.

8) "The Use of Length and Age Distributions to Infer Stock Structure Parameters," by Vincent Gallucci and Han Lai. A volume to be written from the 1988 Fish Marking Symposium, U.S. Fish and Wildlife Service.

Abstracts with the following titles have been written for presentation at the 1988 American Fisheries Society Annual Meeting. These reflect results either from this component or are heavily based on this component. These papers will also appear as a refereed symposium volume to be edited by Vincent Gallucci (UW) and William Fox (UMiami).

1) "The Corvina Fishery in the Gulf of Nicoya: A Subject for Stock Assessment", by Manuel Murillo.

2) "The Strengths and Weaknesses of Length Based Analyses", by Han Lai and Vincent Gallucci.

3) "Physiologically Structured Models for Tropical Fisheries", by Jose M. Gracia-Bondia and Joseph C. Varilly.

4) "Analysis of Tropical Fishery Data with a Stochastic Catch-at-Length Model", by Patrick Sullivan, Han Lai, and Vincent Gallucci.

3. The Age and Size Relationship and Consequences of Errors Project

This component has a natural interface with the modeling component. Reasons for the investigation of the age of fish include the necessity to standardize, at least for one period of time, the relationship between age and length. In addition, information about characteristic growth of the corvina species, age at first capture, age composition in the commerical fishery, and the variability of lengths about age are important considerations in modeling and parameter estimation. The newly-recognized extremely rapid growth in the first year raises concerns also seen in sample data on the size distribution of fish in the catch. The mean size caught in the gill net fishery (Sampling Catch and Abundance Project) is about a year of age and ageing data indicate that these fish live to about seven years. The implication depends upon reproductive data now being collected. Nevertheless, either growth or recruitment overfishing are real prospects, especially if effort continues to increase. These prospects will be investigated as part of the modeling and interpretation efforts in years four and five.

One of the highlights of this first triennial review period is the determination that the corvina species in the Gulf of Nicoya can be aged. Several hard structures of the fish were examined and it was determined that

the otoliths were the best for reading age data. The necessary methodology was developed and made generalizeable to the facilities at UCR-CIMAR. As part of the process, over 500 fish were examined. A technical report on this work is in preparation. Nevertheless, a great deal of ageing remains to be done. With the transfer of this ageing methodology to UCR-CIMAR, however, a significant step has been taken towards establishing a regional age determination facility at UCR-CIMAR.

Most of the objectives we proposed in the previous years were accomplished and are represented in the following reports:

1) "Age determination of corvina species from the Gulf of Nicoya," by Han Lai and Jorge Campos. (In ms.) Will become a CRSP Working Paper.

2) "A general review of age determination in biology, with the emphasis on fishery resources," by Han Lai and Vincent Gallucci. (In ms.) Will become a CRSP Working Paper. This and the preceding report will be the major references for a short training course entitled "Age Determination of Tropical Fish: Theory and Techniques," to be held at UCR in May or June 1988.

3) "Optimum allocation for estimating age composition using age-length key," by Han Lai. Fish. Bull. U.S. 85: 179-185.

4) "Effects of ageing errors on estimates of growth, mortality and yield per recruit for walleye pollock (Theragra chalcogramma)," by Lai and Gunderson. Fish. Res. 5: 2878-302, by Lai and Gunderson.

5) "Age determination of Pacific cod, Gadus macrocephalus, using five ageing methods, by Lai, Gunderson, and Low. Fish. Bull. U.S. 85: 713-724.

6) "Age determination and growth of sablefish, Anoplopoma fimbria, in the Gulf of Alaska, by Lai, Gunderson, Low, Stauffer, and Lynes. Fish. Bull. U.S. 86: (In press).

7) "Optimal sampling for the estimation of age composition with an age-length key: analysis and the program, AGECOMP," by Han Lai and Vincent Gallucci. CRSP Working Paper No. 11.

4. The Shallow-Water Hydroacoustics Project

This project has completed the initial development, testing and application of hydroacoustic systems for fish detection and abundance estimation in shallow water marine environments such as those associated with most artisanal fisheries. The project used a Simrad EYM echosounder and developed computer software to accompany a Summagraphics digitizing tablet to analyze fish targets from echopaper. By measuring current speeds and analyzing acoustic data it was found that fish move at about the same speed as the tidal current and that they are highly responsive to diel variation. Bias due to the sampling vessel's presence was also quantified to correct density estimates. Acoustic sampling in conjunction with drifting gillnets in night and day times was done for groundtruthing. A microcomputer-based system consisting of an analog-to-digital converter, signal processor for analysis of the tape recordings, and associated software is under development.

The results on fish behavior will greatly benefit the interpretation of CPUE data and hydroacoustic measurements. The technological innovations will allow these methods to be applied in shallow waters and the data to be interpreted. The computer programs will facilitate analysis, remove some of the necessity for high levels of training in hydroacoustics, and assist in interpretation. A substantial amount of data from the latest field effort is undergoing analysis as part of a Ph.D. dissertation being completed at UW by J. Hedgepeth. The following working papers have been written, and each will also appear as a refereed publication.

1) "Some Impacts of Remote System Technology on Future Fisheries Management," by R. E. Thorne. CRSP Working Paper No. 8.

2) "Hydroacoustics and Ground Truth," by R. E. Thorne. CRSP Working Paper No. 9.

3) "The Use of Stationary Hydroacoustics Transducers to Study Diel and Tidal Influences on Fish Behavior," by R. E. Thorne, J. Hedgepeth, and J. Campos. CRSP Working Paper No. 10.

4) "Hydroacoustic Observations of Fish Abundance and Behavior Around an Artificial Reef in Costa Rica," by R. E. Thorne, J. B. Hedgepeth, and J. Campos. CRSP Working Paper No. 14.

5) "Hydroacoustics Observations of Fish Abundance and Behavior Around Reefs and Structures," by R. E. Thorne and G. Thomas. CRSP Working Paper No. 15.

These working papers form some of the essential documents for a short training course entitled "Shallow Water Hydroacoustics: Theory and Techniques" to be taught at the UCR in year four, 1989.

Abstracts with the following titles have been written for presentation at the 1988 American Fisheries Society Annual Meeting. These reflect results from this component.

1) "Shallow Water Hydroacoustics for Management and Fish Behavior," Richard Thorne and John Hedgepeth, School of Fisheries, University of Washington; and Jorge Campos, CIMAR, University of Costa Rica.

2) "Hydroacoustic Observations in the Vicinity of a Gillnet Fishery in the Gulf of Nicoya," by John Hedgepeth and Richard Thorne, School of Fisheries, University of Washington; and Jorge Campos, CIMAR, University of Costa Rica.

5. Program Coordination and Impact

There are several types of integration within the CRSP, and exterior to it. Within the CRSP the primary coordination is between the UMCEES and UCR programs which takes place as part of the shared interest in the Gulf of Nicoya. The UCR group carries out experiments with UW and UMCEES assistance that yield results needed by either the UW or UMCEES projects, or both. The UW and UMCEES interaction includes interactions with UDelaware with whom both UW and UMCEES have subcontracts. The efforts at modeling at UMiami are coordinated with the UW efforts so that there is adequate intersection to allow interaction and comparison, but little or no repetition of effort.

Staff and students from the UCR have visited the UW for weeks at a time for consultation, symposia and short courses and UW personnel have visited UCR for consultation, short courses, and field work. These interactions are extensive and have been documented fully in earlier reports and are not repeated here.

In addition, UW has exchanges of information with the UDelaware and the UMiami. For example, in 1987 Dr. Anderson was invited to participate in a short course at UW and also met with UW CRSP researchers to review progress by the UDelaware and UW research teams. Drs. Fox and Gallucci have exchanged research materials, have corresponded on various research points and the UMiami team has provided software that UW researchers were unable to obtain directly. Even more direct collaboration is planned for years four and five.

UW has also had a fruitful interaction with URI from whom a) initial tropical fish growth data was acquired to test early models of growth and in CASA and b) recent work on length cohort analysis has contributed to and extended some of UW's work. This interaction has encouraged us to plan for a small effort of the UW project to be carried out in the Philippines during the extension of the CRSP, years six through eight.

Exterior to the CRSP, but an important part of our efforts to have international impact, are the following:

1) An MOU with Argentina has been signed to extend some of our results to Argentinan fisheries. Several Argentinan students are being trained at UW and interact in the CRSP (at no cost to the project). This was facilitated by Vincent Gallucci.

2) A symposium will be held in 1989 in Buenas Aires entitled: "The All Latin American Symposium on the Management of Small Scale and Artisanal Fisheries." CRSP participation is anticipated in addition to participation from most Latin American countries with coastal fisheries. The principal organizers are V. Gallucci and J. Orensanz, and the principal sponsors are CONICET in Argentina and the Tinker Foundation.

3) A symposium entitled, "Fisheries Management in Developing Countries: Problems and Opportunities" has been organized by V. Gallucci to take place at the 1988 Annual Meeting of the American Fisheries Society. CRSP research is very prominently represented.

4) A short course at UW in 1987 brought together scientists from Costa Rica, Argentina, Panama, Chile, Peru and Italy. The course, entitled "Quantitative Management of Artisanal Fisheries," was two months long and was taught in English and Spanish. The principal organizers were V. Gallucci and J. Orensanz.

These and other interactions not listed here illustrate that the CRSP and spinoff activities are indeed having a regional impact. In addition, much of what is being accomplished has application beyond the developing countries. For example, Italy is a country with a short history of fisheries management. However, in the last five years a national effort has been in place to assess the status of their exploited stocks. The absence of specific management plans has not led to harvesting catastrophes, analogous to their pollution catastrophes, because the fisheries are highly productive and essentially small scale in nature. As a consequence, in 1985 an invitation was extended

to V. Gallucci to lecture at a workshop on the Italian stock assessment plan. More recently, in 1988 the National Center for Research (CNR) organization sponsored a five laboratory lecture/consulting trip to discuss advances in small scale fisheries management and ecology. Lecture titles prepared for the presentations were:

1) New results in the mathematical modeling of the effects of harvesting, especially for non-industrial fisheries.

2) Recent results in length cohort analysis: what we wanted to know but were afraid to ask.

3) Estimation of stock dynamics parameters especially for non-industrial fisheries: a review and some very recent work.

4) Integrated sampling designs for stock assessment in small scale fisheries.

5) Perspectives on marine ecology and fisheries management: views from industrial and developing countries.

6) Aspects of the evolution of hermaphroditism in marine invertebrates.

6. Training Activities

Some of the more obvious training activities are seen in the preceding section on Program Coordination and Impact. In addition, there have been the multiple visits of UCR personnel to UW for discussions on research and for the short course on hydroacoustics. The short course on ageing of fish techniques at UCR is another example, as are the steps toward establishing UCR as a regional center for fish ageing.

There is also a more subtle aspect which is as significant as actual courses. The presence of the CRSP at UCR has stimulated and encouraged work in fisheries management that might not have evolved otherwise. The excellent paper by two mathematicians at UCR on "physiologically structured models" is a good example, as is the presence of students from statistics and computer science in the UCR-CIMAR research team.

7. Supplemental Assistance

The CRSP has attracted the attention of scientists and organizations that are pleased to participate at no cost to the CRSP. The Tinker Foundation contributed by funding the two month short course in 1987 on quantitative management of small scale fisheries, where students from Latin America dominated and students from UCR participated at greatly reduced costs. UW is providing direct assistance for UW CRSP participants to attend the symposium at the 1988 AFS meeting. The Washington Sea Grant organization funded a post-doctoral position for modeling. Numerous other minor forms of assistance have been received from the NMFS, the WDF and elsewhere.

C. Objectives and Plans for Years Four and Five

1. The Sampling Catch and Abundance Project

a. Goals and Objectives for Years Four and Five

1) Management Data

The total catch of the artisanal fleet in the Gulf of Nicoya appears to be undergoing a slow-but-steady geometrical growth since the early 1950's and there is evidence of a declining CPUE in the most profitable commercial catch categories. Thus, it is important for managers to have timely and accurate information about the system.

Effective management requires control of fishing effort, and information on stock productivity and composition, desiderata that may be difficult to achieve in a highly distributed multispecies fishery. As a result, there are very few examples of extensive monitoring of tropical marine artisanal fisheries. A significant exception to this dearth of generalizable information can be found in Costa Rica where the Department of Fisheries of the Ministry of Agriculture has collected information on the commercial landings of the artisanal fishermen in the Gulf of Nicoya since the 1970s. Because of the volume of the data (2000-8000 vessel landings per month), the extremely high percentage of participation, and the length of time that the ongoing data collection program has been in place, this evolving data set may be the most complete record of a tropical artisanal fishery available.

In a sense, the very success of this information gathering has been the principal impediment in its timely entry, analysis, and utilization by fisheries managers. The volume of the resulting data set can seriously tax the human and computer resources of the data processing unit of the Department of Fisheries. In fact, much of the historical record of this invaluable data set has not yet been entered or analyzed. Apparently, the Department of Fisheries' response to this information overload is to rely on a sense of intuition about the system coupled with spot sampling of current catch slips. The general goal of the activities proposed in this component is to establish an alternative, economically feasible protocol for monitoring long-term trends and for short term decision-making in the Gulf of Nicoya artisanal fishery. The commercial catch slips offer this project a comprehensive picture of the artisanal fishing activity in the Gulf for minimal collection cost. However, given the volume of the data, the costs of handling, entry, and analysis are not in line with the available human and computer resources, nor is every scrap of available data necessary for effective management of the fishery. One more specific goal is to help develop a sub-sampling protocol that will allow maximum information to be processed, in a short enough time to be useful, and at a minimal cost.

The Gulf of Nicoya fishery presents an extraordinary laboratory for the evaluation of sampling plans because of the large historical data set, the ongoing data collection program, and the perceived needs expressed by the resident fisheries managers. While some of the research done will necessarily

be specific to the Gulf of Nicoya artisanal fishery, much of the philosophy and method will be applicable to other complex tropical artisanal settings.

a) Catch Slip Data

The primary sampling elements are individual catch slips, each representing the landed commercial catch of one boat. The slips are collected each month from at least a score of landing sites around the Gulf and are brought together at a central location for processing by the Department of Fisheries. Between 2,000 and 8,000 slips are generated each month, requiring between one and three megabytes of storage for full representation of each month's data.

The existing collection and reporting system of the Department of Fisheries drives an implicit temporal stratification by month. This degree of granularity is probably sufficient to delineate the major systematic temporal variations in the data, which are assumed to be related to the annual wet-season, dry-season cycle. Another procedurally convenient stratification is by landing site since the slips are collected in bundles each month from each such site. While not as biologically specific as the fishing ground, nor as sociologically relevant as the home community, the landing site appears to induce a geographic partition because of the limited mobility of the artisanal fishermen. Initial explorations of the historical data have noted interesting differences in the number of landings, gear, effort, and catch category profiles at the different landing sites, all as a function of time (month). Sub-sampling methods that exploit such background information to reduce the variance of the sample estimates for a given fixed sample size or cost thus become possible.

In years four and five researchers plan to use the catch slip data in several different ways, each briefly described below.

(1) Much, if not all, of the data will be transcribed. The optimal method for the selection of slips to transcribe is already under evaluation and will be determined. The major consideration is whether it is optimal to proceed sequentially, starting either with the oldest or the most recent slips, to random sample slips or systematically sample the slips to transcribe.

(2) Sampling can be viewed as an economic optimization, trading off precision, bias, and timeliness of the developed information, for cost. The cost of precision needs to be carefully considered with respect to the potential use of the estimates. There are significant limits to what access to even all of the catch slip data can communicate about the future of the fishery and the appropriate management adaptations. In realistic settings where a fishery is tracked over a long baseline, there is considerable tolerance for sampling imprecision and bias so long as there are reasonable assessments of the magnitude of the error. Formal sampling theory prescribes methods to optimize precision with respect to a fixed cost, or to minimize cost for a given required precision. Alternative sampling designs of the classical type would be evaluated in a multistage design that would have as its objective the economical and efficient presentation of the minimally acceptable information. These designs include systematic, stratified, probability proportional in a variable, etc.

(3) Since the application of standard designs alone has not generally been satisfactory in applications such as artisanal fisheries, designs based on Bayesian principles which use prior distributions as a basis for making inferences would be introduced. These decision theoretic methods could be applied in the catch slip scenario where the extensive existing data would serve to define Bayesian prior densities, thereby reducing the need for additional sample data of the highest quality. Such methods hold great promise because artisanal fisheries data is often characterized by being extremely noisy with frequent breaks in continuity, circumstances that invariably frustrate the application of standard designs.

(4) Researchers propose using Box-Jenkins time series techniques on catch and effort data to develop a forecasting model for the corvina fishery. Box-Jenkins ARIMA (autoregressive integrated moving average) models form a group of linear, stochastic models that can describe fairly complex dynamic behavior in the presence of correlated errors. Since a time series like this is shaped by both deterministic and stochastic events, the analysis consists of removing deterministic trends from the series so that the the resulting values fluctuate around a mean with constant variance (a stationary series). These models have been successfully used previously with various types of fisheries data (Saila and Lermit, 1979; Keller, 1987; Roff, 1983; Mendelssohn, 1981).

In addition, Box-Jenkins Forecasting models can be used to describe the relationship between input variables (e.g., effort) and output variables (e.g., catch). Using the three-step process of model identification (using autocorrelation and partial autocorrelation results), parameter estimation, and diagnostic checking (removal of insignificant components from the model and testing residuals for departure from white noise), a forecasting model can be developed. Accurate forecasting models would clearly be useful to CIMAR and the Ministry of Fisheries for management of their fishery resources. The Box-Jenkins approach depends upon the availability of suitable computer programs to complete the analyses, not all of which are off the shelf products. These will have to be written for use in the U.S. and in the host country.

2) Assemblages

The biological resource in many artisanal fisheries, including that of the Gulf of Nicoya, is composed of a large number of commercial species imbedded in an even more diverse ecosystem. We intend to explore the sampling implications of the strong phenomenological structure in the species catch co-occurrence data. The pattern reduces the uncertainty we have about the system, and theoretically, we should need to collect less data to achieve a given state of knowledge. Coming up with a sampling plan that fully utilizes the structural knowledge is difficult, but the clustering and scaling methodologies for identification of species assemblages can be very helpful in the specification of strata and clusters for classical sampling designs.

Ideally, we would like to go beyond noting phenomenological assemblages of species, and attempt to explain these structures evidenced by the clustering and scaling techniques with relevant bio-oceanograpnic information (location, temperature, salinity, depth, etc.), as is done in ecosystem ordination. However, apart from general knowledge of the gear, the fishing ground and the tidal sequence, we are unlikely to be able to have the

corresponding information to consider explanatory models of the relationship of the assemblages to the ecosystem and environment.

The researchers have real concerns about the concept of assemblages, about the somewhat disreputable techniques for their empirical definition, and about their potential for utilization by artisanal fisheries managers. However, the Culf of Nicoya fishery offers an excellent opportunity for exercising the concept in an applied setting, and the number of practical alternative methodologies for comprehending fisheries with several hundred commercial species is quite limited.

3) Biological Data

a) Recruitment and Selectivity

Artisanal fisheries are characterized by mixed gears and mixed species. Different passive gears such as gillnets and hook and line are very selective for certain sizes and species thus requiring that abundance and mortality estimates based on catch be adjusted for selectivity. Different mesh size gillnets are being acquired to evaluate net selectivity. Small mesh-size nets will also be an important source of unbiased information about species aggregation, growth rates, recruitment timing, and the relationship between age, size and fecundity for juvenile fish. A small trawl was also tried recently since small mesh gillnets are difficult to work with and selectivity is never truly removed. These data are not yet available. Information gained by the use of small mesh gillnets and trawls will be used in several components of the project, primarily those involving CASA, recruitment and growth.

b) Benthic Sampling

This work would lead to better understanding of the interface between the benthos and the corvina. The benthic invertebrates are probably driving the system but not enough is known about the interface to be able to even tentatively link the mangroves with the benthos and the corvina fishery--especially the role of the mangroves in the recruitment process. Investigations into the dynamics of selected harvested bivalves and crabs will widen understanding of the benthos' role in the system.

b. Work Plans for Year Four

1) Continue the compilation of the catch slip data and analyze the measures of effort and CPUE trend.

2) Do a simulation study to test different sampling schemes using the existing information about fisheries operations. The results will then applied to the catch slip data to optimize sampling efforts.

3) Begin development of decision theoretic methods for comparison to standard sampling designs.

4) Acquire monthly reports on the Gulf of Nicoya fisheries from the Ministry of Agriculture and carry out time series analysis.

5) Create sampling designs and begin to collect data on length, weight, sex ratio, gonads, and otoliths of corvina species.

c. Work Plans for Year Five

1) Continue the compilation of the catch slip data and publish and distribute for CRSP users.

2) Finish an analysis of effort and CPUE measures and publish the results.

3) Finish a time series analysis on fisheries data and publication.

4) Apply the results of previous years to decision theoretic sampling designs.

5) Start and complete handbook/manual chapters.

2. The Age and Size Dependent/Independent Modeling Project

a. Goals and Objectives for Years Four and Five

The previously described accomplishments serve as the foundation for the work that will follow in years four and five. The difficulties encountered in artisanal fisheries management in the world always arises by (1) lack of management catch-effort data, (2) lack of biological information for the target species, and (3) lack of stock assessment as the basis for monitoring fishing pressure. UW/UCR have overcome one of these difficulties in the past years in order to acquire the necessary data for fishery management. Part of the planned work continues to be to refine and develop stock assessment methodology and part begins to deal with fisheries management plans (FMP) to specify future exploitation guidelines from assessment results.

1) Application and Improvement of CASA

In the first three years researchers have developed a new model, catch at size analysis (CASA) which is a state-of-the-art product that does stochastic length based modeling. The model reconstructs the abundance of populations as well as making estimates of (stochastic) growth, fishing mortality, selectivity and recruitment fluctuation. CASA has been applied to commercial catch data of *Decapterus russelli* in the Java Sea, Indonesia, survey catch data of *Nemipterus japonicus* in the Philippines, and simulated commercial catch data of Eastern Bering Sea Pacific cod. The analyses have been successful and have contributed interesting management perspectives.

These results need to be synthesized and written, which will contribute to fine tuning of CASA for the Gulf of Nicoya applications. Further programming work is needed to make the model maximally friendly and to incorporate the flexibility to add new results as they evolve in the Gulf of Nicoya, either for the Gulf as a whole or for individual species. One of the important advantages of CASA will be the ability to incorporate the results of other research on biological reference and critical points associated with recruitment to the fisheries.

2) Continuation of Work on Physiological Structured Models (PSM)

This is an effort carried out by UCR scientists, Drs. Gracia-Bondia and Varilly. This sophisticated model has the potential to significantly improve models in current use that describe the growth and dynamics of fish stocks. The model is a result of a collaborative effort of two of the Costa Rican counterparts in the Department of Mathematics and in CIMAR, and demonstrates the effectiveness of this project. It is considered a positive result when mathematicians successfully work with biologists.

Based on existing accomplishment, the following tasks will be undertaken in years four and five: (1) Exploration of how the PSM results are input into dynamic pool models; (2) Application of the model once the parameters are available from the Gulf of Nicoya; and (3) Evaluation and improvement of the model and programming.

3) Identification of Fishing Effort for Stock Assessment

Fishing mortality can be estimated from either an age structured model, e.g. VPA or age cohort analysis, or from a length structured model, e.g. LCA or CASA. Historical information, such as a time series of catch-effort data, are usually combined with assumptions such as: known natural mortality, uniform catchability, consistent selectivity, homogeneous catch at age and size data for all the fishing operations, etc. A separable model can be used to represent these assumptions by partitioning fishing mortality in two dimensions (age/size, time) into (age/size selectivity) and (overall fishing mortality) at time and partitioning (overall fishing mortality) into (catchability) and (fishing effort).

The objective of this section is to use additive and multiplicative models to aggregate and to disaggregate fishing mortality over seasonal and fleet factors. It would then be possible to relate an index of effort with fishing mortality and abundance estimates from VPA or CASA. The result would be an index of effort for mixed fisheries management. It would then be possible to identify the percent effort per gear type per segment of the stock, thus moving toward a practice of management based on appropriate use of limited entry, limit by quota, limit by catch, limit by size. These data are now becoming available; see the Management Data section of the Management and Stock Assessment Sampling Project.

4) Biological Reference Points in Recruitment

Biological reference points, F(0.1), F(msy), F(mey) as examples, are traditional management concepts. The theoretical relationships between these points and other points have been elucidated with the use of specific stock-recruitment and yield per recruit models. We plan to further develop these relationships while focusing upon artisanal fisheries.

The selection, in temperate fisheries, of F(0.1) is based more upon intuitive criteria of what constitutes a conservative strategy with significant yields than upon scientific criteria. In this section a theory behind the selection of a fishing mortality will be initiated. It will require the formulation of the Beverton-Holt yield per recruit model in a form

that more explicitly represents size-based parameters, and upon a better understanding of the recruitment process.

In an artisanal fishing context, a criterion for a critical point that rests upon the slope of a curve at a particular F-value may be too stringent. Research into the selection of critical points based upon the data itself without the necessity to fit a particular curve looks promising, and may be more indicative of the actual processes. Further, research into cases where recruitment peaks occur multiple times in a year rather than one peak per year, all need to be investigated. These are the first aspects of the critical points investigation that is planned and will be continued in the planned extension.

5) An Age/Length Based Leslie Model

Traditional age/length structured models for stock assessment concentrate on fully recruited maternal stock. The CASA model uses an ad hoc stochastic recruitment pattern because appropriate real estimators of recruitment success have not been developed. Since we now know about the extremely rapid growth in corvina in the first year, we can hypothesize that juvenile survival is a major factor in recruitment to the fishery.

A Leslie model allows the explicit expression of juvenile abundance and survival to recruitment. Further, size specific fishing mortality can be introduced explicitly from data available in the sampling component. Such modeling to predict year class strength and decline under exploitation can be formalized with the addition of a harvest matrix to express length-specific exploitation rates. This revised Leslie formulated model will provide an alternative interpretation of the impact of fishing, provide a useful verification of the validity of LCAN, the length based catch analysis, and provide a way to estimate errors in estimates from a length cohort analysis.

In all of these models, the conceptual advances are made practical only by the use of data collected under protocols defined in the sampling and other sections of this project.

b. Work Plans for Year Four

1) Acquire the time series of length-frequency distributions, catch and effort statistics, and growth data for corvina species. These data will be input into CASA. Later, the results of CASA will be compared to other methods, e.g., ELEFAN, length-cohort analysis. The results will be also compared with VPA, cohort analysis, and other age-structured models when age-length keys are available.

2) Develop a computer program for the physiological model (PSM). Acquire data required for the model.

3) Identify useful indices for measuring fishing effort in the Gulf of Nicoya based on the existing catch slip data base. Identify seasonal and temporal patterns in the indices of fishing effort.

4) Use existing fishery and biological data with the methods for estimation of biological reference points for management of corvina species. Compare with

existing strategy of harvest.

5) Further develop the theory of age/length based Leslie models for stock assessment.

c. Work Plans for Year Five

1) Continue the application of CASA. The evaluation will be carried out when more complete fishery and biological data, e.g., recruitment, growth, selectivity, fishing effort, and hydroacoustics, are available. Fine tune the computer program to be user friendly. Finish technical reports on applications of CASA in Costa Rica and the users' manual for CASA computer program.

2) Continue the application of physiologically structured modeling. Explore how the PSM are input into dynamic pool models. Finish technical reports for the applications and computer program.

3) Apply additive and multiplicative models to aggregate and disaggregate fishing effort and CPUE data over seasonal and fleet factors. Finisn technical report and computer program.

4) Continue the development, application, and programming for the age/length Leslie model.

5) Propose a preliminary fisheries management plan for corvina species with the existing results from stock assessment and biological reference points. Write a technical report at end of the year.

6) Complete handbook/manual chapters.

3. The Age and Size Relationships and Consequences of Errors Project

a. Goals and Objectives for Years Four and Five

1) Ageing

In years four and five, we will build upon the accomplishments described above. In the first half of the grant we will have successfully transferred some of the necessary methodology and equipment to the UCR, so they can carry out much of the ageing investigation and build a tropical age determination center in Costa Rica. We will train one UCR-CIMAR biologist in the age determination of hard structures and continue with the otolith collection of corvina until the age-length keys are ready to be used in the estimation of the important population parameters such as age composition, mortality, and growth. We also would consider extending the established ageing methodology to other commercially important species in Costa Rica.

2) Recruitment and Productivity

It has been established that growth in the first year is unusually rapid. This opens the prospect for the phenomenon known as growth overfishing. It

also raises questions about recruitment overfishing. Whether either overfishing occurs or not depends on the growth and on the timing and degree of fecundity in 0-year fish, which are now being collected under the Biological Sampling component of the project. From the data and the von Bertalanffy growth model, K values of 0.5-0.8 are likely, which is a point of concern until more is known about reproductive processes, species-by-species.

To investigate the prospects for growth overfishing, we are proposing to do an otolith microstructure analysis which will be correlated with the fecundity data in order to better understand the growth in the first year and its relation to growth in later years. These results are a major part of the determination of biological productivity and biomass turn-over rates in the Gulf of Nicoya.

After our first year in the investigation of this project, it became clear that it was necessary to give visibility to the role of recruitment timing and the allocation of reproduction effort with age. Since that time FERET has been an explicit part of this project. The determination of turn-over rate is a well established part of the management of lakes but has not been a major tool for marine fishery management. However, due to the apparent high productivity of the environment and the common use of turn-over rates in non-management tropical studies, the introduction of the concept is a potential new step forward for managing tropical stocks.

Specific investigation of both growth and recruitment overfishing is a planned component for the three year extension. The data base to evaluate the prospects of either condition occurring in tropical fisheries in general, and in the Gulf of Nicoya in particular, needs to be collected over a several year period. Therefore, the biological sampling project will subsample to collect data on fecundity such as gonad index, temporal variation and sex ratio of juveniles prior to full recruitment to the fishery.

Benthic sampling will begin during this period. The Gulf of Nicoya's highly productive environment depends upon the water column-sediment interface. The role of benthic species in the dynamics of the fish of interest needs to be clarified. Analyses of fish stomach contents are already underway in CIMAR. Preliminary analyses of the growth rates of selected bivalves has already demonstrated that some of these can be aged and age composition is beginning to be known. The investigation of the productivity of the macro infaunal and epifaunal bivalves and crustacea will provide insights into: (1) productivity at the water column/sediment interface and (2) the dynamics of harvested species that appear in the markets.

b. Work Plans for Year Four

1) Develop the regional center for age determination of fish at CIMAR. This will include personnel training, facility setup, and data base management.

2) Continue the data collection, ageing, and analysis to estimate population parameters.

3) Collect sex ratio, gonads data, and recruitment timing data for FERET.

4) Develop techniques for otolith microgrowth increment analysis.

c. Work Plans for Year Five

1) Continue the development of the age determination center in CIMAR. This will include quality control of age readings, extending the methods to other species, and improving data base management.

2) Analyze the existing data and integrate the results with other CRSP components. Publish the results from existing ageing data and related analyses.

3) Continue the data collection and analysis for FERET. A technical report will be available at end of the year.

4) Develop methods for the analysis of productivity in the Gulf of Nicoya. The results will be integrated with age and size dependent/independent modeling.

5) Develop handbook/manual chapters.

4. The Shallow-Water Hydroacoustics Project

a. Goals and Objectives for Years Four and Five

The specific objectives of year four include the conduct of the third and last major field effort in Costa Rica, and completion of the majority of the data analysis and two or three manuscripts.

The field effort is planned for August 1988. This will be one of the major field efforts of the project and will include a large-scale transecting effort at stations in the open waters of the Gulf of Nicoya and observations around artificial reefs. On the basis of our initial successes, we plan to make the first fish biomass estimate of the effective fishing areas of the Gulf of Nicoya. The primary data for this purpose will be the transect effort. The effort will also be closely coordinated with operations of the artisanal fleet so we can correlate our observations with the fishery catch, and use the fishery catch to aid separation of the total biomass estimate into various species components. The stations in the open waters of the Gulf will add to our knowledge of fish and behavior and will further aid our species identification effort as well as the evaluation of biases. The artificial reef observations will follow on initial observations during 1987 and will allow more accurate quantification of the behavioral trends we observed and reported on from that effort. In addition, hydroacoustic estimates will be integrated into assessment models.

The specific objective of year five will be to complete the data analysis and several manuscripts and the handbook, which will detail the techniques developed over the five years of the project. This effort will focus on the techniques developed for the assessment of fish in the Gulf of Nicoya, including interactions with the artisanal fishery, but will also include the novel developments for assessment of fish abundance and behavior around natural and artificial reefs. The effort includes considerable collaboration

through field season sampling and associated meetings. In addition, John Hedgepeth will complete a Ph.D. dissertation at UW on this component of the project. Current planning will put somewhat less emphasis upon hydroacoustics than in the preceding years since most of the methodology has been developed over these years and we are entering the "production" phase for a good deal of the project. It is certain, however, that even in this stage further refinement will be required as data are collected and interpreted.

b. Work Plans for Year Four

1) Field trip to the Gulf of Nicoya in August 1988 with a focus on density estimation.

2) Introduce use of analog digital signal board to analyze field data at UW and UCR to speed analysis. Introduce use of contour digitizer to UW and UCR teams. Begin development of corrections to estimations as required by shallow water environment.

3) Analyze the data and compare with the results from previous field trips, especially with respect to seasonal changes as measured by physical measurements.

4) Teach a short course in hydroacoustic theory and practice.

c. Work Plans for Year Five

1) Complete data analysis, provide corrections to estimates, and discuss and share refinements of methodology to CIMAR scientists.

2) Develop handbook/manual chapters.

5. Production of Research and Training Materials

a. Goals and Objectives for Years Four and Five

All four of these components will be oriented toward the production of results that shed light upon how the ecosystem works and how managers may monitor and utilize the system. Research results will be written in accessible technical reports and will be published in refereed journals when appropriate. In addition, each component's methodology and software will be expressed in the framework of the handbook being produced for the CRSP. Although most of the handbook writing will take place in year five, a great deal of the software writing will take place in year four since programs need to be de-bugged and field tested. Toward the end of maximizing the ease of distribution of software, we have asked USAID to investigate the prospect of allowing a commercial company to assume responsibility for distribution. We await the decision on this.

b. Work Plans for Year Four

1) Organize the AFS symposium in October 1988 and write technical reports and refreed publications for the symposium.

2) Graduate student from UCR arrives for degree training in School of Fisheries.

3) Begin arrangements for August 1989 symposium in Argentina.

c. Work Plans for Year Five

1) Continue the editing and publication of 1988 AFS symposium.

2) Identify the research project for the graduate student from UCR.

3) Organize and carry out Argentinan symposium. Prepare papers for presentation.

6. Program Coordination and Training

Years four and five will see an increased level of coordination and training. The simple fact that the handbook needs to be written will require additional correspondence between the groups. In addition, several other types of interaction are planned, including the following:

1) In 1988 and 1989, Drs. Fox and Gallucci will collaborate on editing a volume of papers based on the 1988 symposium, "Fisheries Management in Developing Countries: Problems and Opportunities". With the significant representation of the CRSP and mutual interests in Costa Rica, collaboration and coordination will be a specific part of the interaction.

2) This interaction between UW and UMiami groups will extend to UW interactions with both the UMCEES, URI and the UCR teams as the contents of papers are updated and elaborated.

3) In years four and five UW will fund a research assistant position for a graduate student from the UCR to work on problems of concern to the CRSP. The initial obligation is for an M.Sc. but may extend to a Ph.D., circumstances permitting.

4) The symposium at the Annual Meeting of the American Fisheries Society in October 1988 entitled "Fisheries Management in Developing Countries" contains numerous papers from the CRSP. It is anticipated that a high proportion of the CRSP participants will attend the symposium and present papers. Additional meetings between other participants are planned while everyone is at the symposium. These meetings will provide a more relaxed context in which to exchange ideas and future research plans. It is anticipated that this meeting will facilitate increased interactions among all units, including UP and UCR scientists, and will enhance communication for years four and five and potentially years six through eight. Since UW plans to test some of its results in the Philippines in years six through eight, the symposium will also facilitate the development of these research plans.

5) A symposium will be held in August 1989 at Buenas Aires, Argentina, entitled "The All Latin American Symposium on the Management of Small Scale and Artisanal Fisheries". The principal organizer is V. Gallucci and the principal sponsors are CONICET, Argentina and the Tinker Foundation. This conference will attract participants from most of the Latin American countries and will consist of specific training workshops and research presentations. CRSP participation is anticipated.

D. Objectives and Plans for Years Six Through Eight

The UW/UCR projects will undergo substantial restructuring as the CRSP enters a three year extension, years six through eight. The age determination work will have experienced substantial progress, and UCR-CIMAR will have started to develop its capabilities as a regional age determination laboratory. Hence, the work on age determination will thereafter play a less visible role in the CRSP research agenda. Similarly, the hydroacoustics work, following a major effort in earlier years will have reached a plateau, allowing us to devote fewer resources to the hydroacoustics component in the future. In fact, beginning in year six, the hydroacoustics component will be an element in the "Management and Stock Assessment Sampling" component.

Thus, the progress made by the UW/UCR researchers in the first five years of the CRSP should permit this refocus and allow the UW/UCR effort to be partitioned into two components beginning in year six, "Management and Stock Assessment Sampling" and "Recruitment and Productivity".

1. The Management and Stock Assessment Sampling Project

a. Goals and Objectives for Years Six Through Eight

By year six it is anticipated that appropriate stock assessment models such as CASA will be operational and tested in the Gulf of Nicoya. Further, it is reasonable to assume that an efficient and not overly expensive sampling scheme will provide data on catch. It is these data that will enter into a length based assessment model to be used with CASA to provide estimates of stock abundance. Further, it is anticipated that enough experience will have been gained to allow periodic biological sampling programs to evaluate recruitment strength and an index of stock abundance. These data would be supplemented with biomass estimates from hydroacoustic surveys that are conducted at least semi-annually.

Over the years six through eight, the above sketch for stock assessment would begin to feed into a preliminary strategic framework for managing the fishery. It is not clear at this time what tactical combination of regulations will be most efficient in reducing the anticipated over exploitation. Possibilities for effort regulation range from mesh size control to limited entry and include quota and closed season constraints.

The framework would be called a fishery management plan (FMP) for the Gulf of Nicoya but, in fact, every effort will be made to keep the concepts general and widely applicable to other artisanal fisheries of similar

circumstances. Part of the process of defining a FMP will be the specification of well-defined procedures (adapted to tropical fisheries) to compute annual TACs (total allowable catchs). The years six through eight would also include the introduction of market and fisheries economics forces. Basic data and preliminary analyses of income and expenses for the different types of fishing effort in the Gulf would allow the introduction of a bioeconomic component into the FMP.

After considerable progress has been made in the definition of a FMP it is proposed that a workshop be held at UW or some other convenient location to review and debate fisheries management frameworks in developing countries. The best guess is that year seven would be an appropriate year. This workshop would supplement the de facto year four workshop taking place in Toronto at the AFS symposium.

The FMP sketched above is a realistic objective but the degree to which it is accomplished will depend upon the degree to which biological problems concerning recruitment and biomass productivity can be resolved and the degree to which progress is made in the specification of biological reference or critical points that allow the setting of levels of exploitation. Further, some of the research plan outlined for this component requires integration of efforts with the Recruitment and Productivity Project as well as with the UMCEES/UCR efforts.

Finally, UW has incorporated in its budget a small effort in the Philippines, part of which will go to planning or adapting a FMP, or to make a field comparisons to what was derived for the Gulf of Nicoya. Not only would the plan include the field testing of a FMP but the testing of the hydroacoustic techniques, the CASA model and sampling designs. The prospects of needing to redesign or to adjust methodology is expected and is part of the planning.

b. Work Plans for Years Six Through Eight

1) Application of CASA, PSM, and age/length based Leslie models in the Gulf of Nicoya.

2) Continue the analysis to establish indices of fishing effort.

3) Continue the development of biological reference points incorporating the results from stock assessment modeling to monitor fishing pressure on the exploited stock in the Gulf of Nicoya.

4) Continue the compilation of catch slip data and sampling for biological and benthic data. Publish the data and results in CRSP working papers.

5) Hold a CRSP workshop to review and debate fisheries management frameworks in developing countries.

6) Establish a Fisheries Management Plan for the exploited stock in the Gulf of Nicoya.

7) Test and extend results in the Philippines.

8) Update handbook/manual.

2. The Recruitment and Productivity Project

a. Goals and Objectives for Years Six Through Eight

1) Growth and Ageing

It is anticipated that the new age determination center at UCR-CIMAR will carry out the length and age sampling, age determination for the species of interest, and the update of the data base for common uses in the CRSP. The existing data base includes an age-length key and enables the estimation of age composition and growth rate for corvina over their lifetimes. This component will extend the investigation of otolith microgrowth increment width. The present investigation of otolith width and growth rates has already shown extremely rapid growth and appears to show correlation with the environment. Density or environment-dependent growth and survival of larval-juvenile stages of the fish are frequently considered the primary determinants of year class strength. The prospect of estimating year class strength a half year to a year prior to recruitment to the fishery is an attractive management concept that could supplement survey estimates of abundance.

2) FERET (Fecundity and Recruitment Timing)

The data of the first five years will be the basis for a strong focus on the mechanisms and representations of recruitment in the management of tropical fish. The major data base available would be for sex ratio, maturity proportion, gonad index, fecundity, and recruitment timing. Of a great practical concern is the prospect of recruitment overfishing from uninformed changes in the legal gear and effort; for example, hook-line fishing appears to result in the capture of very large fish. Until we know more about reproductive effort vs. age or size, there is a real danger to tropical fisheries everywhere. The intent here is to link the research started in years four and five on biological reference points, and concerns over both recruitment and growth overfishing, to the computation of a conservative harvesting strategy and to an understanding of the processes behind recruitment. Researchers have introduced some traditional fishery management methodology built around theory of biological reference points, and will develop new methodology based upon biological production and turn-over rate. It should be emphasized that based on the preliminary examination of growth rate from otoliths and biological samples (not catch data) and the suggestion of increasing effort, growth overfishing is not an abstract speculation. Gonad data on juveniles is now beginning to be collected so it is too early to evaluate this prospect but the concern is a real one for the fishery. Naturally, if evidence in the next year indicates an imminent danger, adaptive management will occur and the problem will be dealt with immediately.

b. Work Plans for Years Six Through Eight

1) Continue sample collection and data analysis for FERET.

2) Continue otolith microgrowth increment analysis.

3) Update data base for FERET, ageing, and growth.

4) Develop the methodology and software to use and compute productivity and turn-over rates. Apply the results in stock assessment and management.

5) Test and extend results in the Philippines.

6) Update handbook/manual.

3. Program Coordination and Training

A workshop is proposed for year seven for participation by all elements of the CRSP. The focus will be upon the formulation of stock assessment and management plans for artisanal fisheries.

UW plans to continue to support at least one research assistant from the UCR in years four to eight. Over the first three years, many exchanges of personnel have taken place at both UW and UCR. This interaction will continue and, subject to budget, the level of activity in this area would increase.

Years six through eight budgets contain provision for UW participation in the Philippines. Correspondence is currently being exchanged to determine optimal locations. Since UW would be testing and evaluating products different from that developed in the Philippines, it is anticipated that a sequence of short courses be arranged during each research visit.

Looking ahead three to six years, it is difficult to anticipate what symposia participants will attend, but, the same high level of professional interaction will occur as has been the case in years one to three. During these years CRSP participants gave relevant papers at two AFS national meetings, one reef symposium and one biometrics symposium.

The plans for years six through eight include the following: (1) Continue to support at least one Graduate Research Assistant from UCR at UW; (2) Interact with UCR and other CRSP components for exchange of personnel; (3) Visit the Philippines to determine optimal locations and fishery problems for cooperative research and to hold short courses; and (4) Update handbook/manual.

V. The University of Rhode Island and The University of the Philippines Program

A. Program Description

The University of Rhode Island (URI) in collaboration with The University of the Philippines (UP) is carrying out two CRSP research projects, noted as follows:

1. Empirical Analyses and Modeling, and
2. Multispecies Field Studies.

The principal host country institution collaborating on the Empirical Analyses and Modeling Project is The University of the Philippines in the Visayas, College of Fisheries (UPVCF), and the principal host country institution collaborating on the Multispecies Field Studies Project is The University of the Philippines (Diliman), Marine Science Institute (UPMSI). Additional collaboration is being provided by the International Center for Living Aquatic Resources Management (ICLARM) which is based in the Philippines. The work is being coordinated with fisheries stock assessment activities undertaken by the Bureau of Fisheries and Aquatic Resources (BFAR) and the USAID/ASEAN Coastal Resources Management Program (CRMP), and institutions in Thailand and Indonesia are sharing in the exchange of fisheries data bases and research developments.

The two projects will integrate modeling and field studies to address tropical fisheries stock assessment issues. The two projects, respectively, will 1) use existing fisheries data to develop mathematical models addressing the relationship among harvests, fishing effort, and species composition, and 2) develop and validate techniques for estimating fishery productivity and potential in reef and shore-line fisheries based on field studies

The following presents an overview of the accomplishments of the first three years of the URI/UP collaboration. This is followed by a discussion of the objectives and work plans for years four and five of the current grant and a summary of the plans for years six through eight under an extension of the current grant.

B. Triennial Review of Accomplishments

The following discussion briefly describes the accomplishments of the first three years of this research program.

1. The Empirical Analyses and Modeling Project

The goal of the project was explicitly defined in the joint proposal submitted by the three participating universities entitled "The Stock Assessment CRSP - A Search for New Methods in Fisheries Stock Assessment." It was stated as follows: "The goal of this project is to contribute to the

development of relatively simple stock assessment models, which can be effectively tested and evaluated, leading to both the provision of immediately usable tools for progressively improved management - as well as the development of more realistic models over an extended time frame." The material which follows is a brief description of some of the highlights and accomplishments from the first three years of project operations.

It was determined at the inception of the project that research vessel trawl survey data were available from the Philippines, Indonesia, and Thailand, with the Thai data base consisting of approximately 18 years of records. Memoranda of Understanding (MOUs) have been established between the project personnel and the marine fisheries departments of the Governments of Thailand and Indonesia during this project period, and data have been made available for cooperative studies from both countries. The project has also utilized data from the Philippine Samar Sea survey, and a Memorandum of Understanding is pending with the Bureau of Fisheries and Aquatic Resources (BFAR) of the Philippine Department of Agriculture and Food. These and other data bases have been utilized for various empirical modeling activities which will be described in material which follows.

One of the highlights of this first triennial review period was the successful conceptual development, testing, and formal publication of a new empirical multispecies model. Specifically, a method was developed for the analysis of observed changes in catch ratio of similar species or species groups over time from the Thai data and from northwestern Atlantic groundfish data. Aggregated time series of research vessel data were treated as Markov chain models after a transition probability matrix was derived from them by quadratic programming. The matrices were projected to provide information about the stability and changes in multispecies assemblages. The model developed provides some short-term or tactical information, as well as longer-term or strategic management related information. Further testing of the model and its utility are in progress and is expected to continue over the next two years.

Other accomplishments by this project component included the application of geometric programming to solve a more realistic optimum harvesting problem for a Leslie-matrix than is possible using the standard linear programming approach. The specific case which can be handled only by geometric programming is the case where a constant proportion of all individuals above a certain limiting size are harvested while none below this value are taken. (See Working Paper No. 2 for details.) This work was extended to consider the relationship between optimal harvesting strategies and reproductive values. (See Working Paper No. 5 for details.) We believe that further work on the relation between reproductive value and optimal harvesting strategies is justified. Implications of this work relate to harvesting strategies and the relative value of restrictive regulations for highly fecund, short-lived species, such as are found in tropical latitudes.

With respect to our counterparts in the Philippines, an excellent overview of the Philippine demersal stocks has been developed as Working Paper No. 4. This puts into perspective the significance of the fishery and the effects of uncontrolled development in some sectors. In addition to the overview document, some substantial contributions have been made to optimum mesh size selection for multispecies trawl fisheries (see, for example, Working Paper No. 5).

One of the more interesting examples of effective coordination, not only between the U.S. participating institutions but also between a U.S. university and its counterpart institution in the Philippines, is based on the technical report by Lai and Gallucci of the University of Washington, which suggested that length-based cohort analysis was very sensitive to the choice of a value for L-infinity. This prompted some work on extreme value theory by Dr. Formacion of the University of the Philippines which has led to a more rational choice of L-infinity. Collaboration with ICLARM has permitted us to aid in the evaluation of ELEFAN series of programs for length-frequency based analyses. This prompted a study on our part which resulted in Working Paper No. 13, which is a comparison of two length-frequency based packages for obtaining growth and mortality parameters using simulated samples with varying recruitment patterns. This study has been accepted for publication in the Fishery Bulletin.

2. The Multispecies Field Studies Project

As stated on the initial proposal "The Stock Assessment CRSP - Search for New Methods in Fisheries Stock Assessment," this project has involved the use and development of multivariate techniques for the analysis of multispecies fisheries data, and a field program to (a) develop and validate techniques for the estimation of fishery productivity in reef and shore-line tropical fisheries, and (b) to apply the resultant methodology to the estimation of the fishery potential within the study area.

A strategy for the objective intercomparison of fish communities in time and space is being developed. A pilot study of community structure in the Samar Sea (Philippines) fishery has been completed. It has been demonstrated that a critical water depth of approximately 30 meters can be used to optimally divide the fish assemblages into two relatively homogeneous sub-communities. Ordination of mean times by species revealed that variability over time seemed to decrease over the study period. Variability was measured as the mean Euclidian distance among community states. Analyses are also in progress on the community structure of Indonesian shelf and northwest Australian shelf fisheries for comparative purposes.

A benchmark study has been initiated into the fisheries of the Bolinao Coral Reef Complex. This is an extremely complex fishery with a least fifteen types of interacting fishing gears being used to extreme levels of overfishing by over 5,000 small scale fishermen. Over 400 commercially important species are harvested. This fishery is typical of many throughout the Philippines and eastern Indonesia, and represents the future situation in many rapidly growing developing countries. No other comprehensive study of this type of coral reef fishery has ever been conducted. Two primary objectives of the study are: 1) To determine the effects of fishing pressure on the catch composition and fishery production, and 2) To provide categorical information on catch composition and production by gear and habitat type, in order to permit estimation of potential fishery resources from Satellite Image Analysis and fishing effort surveys.

Fishery dependent sampling includes weekly samples of catch of each major gear, and maintaining daily records of shore landings. Fishery independent sampling includes bimonthly underwater visual transect sampling and seagrass

sampling via an encircling net. One year of data has been gathered for the whole fishery, although data on a few selected gears and species is available for two years. Data analysis is underway concurrently with continued sampling to provide initial results and to determine priority areas for long term monitoring. Sites in other parts of the Philippines are being identified to provide comparisons with reefs under lower levels of fishing pressure.

Considerable progress has been made in developing user-friendly microcomputer programs for multivariate analysis of ecological data. These are expected to be available prior to the end of the five year period.

A comprehensive review of Philippine trawl surveys have been carefully examined, and the effects of management and over-fishing have been evaluated. This work has resulted in Working Paper No. 4, entitled "Status of Philippine Demersal Stocks: An Overview." This document is considered to be a baseline study for potential yield estimates and exploitation effects.

We believe that a significant highlight of the first triennial project period is the establishment of a permanent field laboratory at Bolinao. This facility has been modestly equipped through CRSF support to include a 19-foot research boat, an ultralight aircraft, as well as laboratory supplies and computing equipment. This has resulted in the following activities, which are in progress and which are expected to continue:

1) Studies on comparative yields and efficiencies of major fishing gears on a coral reef complex.

2) Comparisons of size and species distributions obtained by visual assessments and those obtained by fish traps on a reef flat.

3) Studies on the recruitment and reproductive patterns of coral reef fishes. These are aimed at an empirical evaluation of the ELEFAN programs, and the relative recruitment values extracted from them.

4) Fishery sampling surveys have been initiated and are continuing as a basis for some forms of management decisions.

5) Preliminary studies of blast fishing and its potential impact.

In summary, we believe that the contribution of the Bolinao laboratory to the multispecies field studies will substantially increase with time. For coordination purposes, it is highly desirable to have facilities which permit evaluation of models as well as providing sources of real data for analysis and testing in a typical tropical fishery environment.

3. Program Coordination and Integration

Several examples of program coordination and integration were presented in the listing of URI/UP activities. These included the coordination with the University of Washington project personnel concerning length-related cohort analysis and the development of better asymptotic length (L-infinity) estimates for length-based methodologies through the use of extreme value

theory. This latter work was done by UP personnel with only a modest amount of advice and assistance from URI personnel. Coordination of our research within the southeast Asian region is considered excellent, and the University of the Philippines is becoming a regional center of excellence in fishery science. We have established memoranda of understanding with the marine fisheries departments of the Governments of Indonesia and Thailand, and one is forthcoming with the Government of the Philippines through BFAR, the Bureau of Fisheries and Aquatic Resources. In addition to the above, informal collaboration with Australian fisheries and reef ecologists is active. Collaboration with ICLARM has resulted in Working Paper No. 13 which relates to testing the ELEFAN series of programs. Furthermore, collaboration in teaching has involved participation of URI and ICLARM scientists in teaching fisheries-related workshops. Participants have been from the entire Southeast Asian region, including Brunei.

4. Training Activities

It should be remembered that the URI/UP collaboration in training involves a full-time on-site URI scientist who is continuously involved in some aspect of training through virtually daily contacts with research assistants, host-country counterparts, and other host-country project-related personnel. John McManus, the on-site scientist, provides this training in topics such as field sampling, data analysis, SCUBA research methods, ecological theory, fisheries biology, and computer programming.

Dr. McManus has taught a formal full semester course on "Community Ecology Concepts." In addition, short courses have been taught by D. Pauly, J. McManus, and S.B. Saila on various aspects of tropical multispecies fisheries on two separate occasions.

Several other areas of special training have been attempted in the Philippines. These include a "Workshop on Remote Sensing," ultralight aircraft operation and maintenance, and related matters.

In summary, nine Philippine nationals are receiving graduate level training which is related in some manner to the CRSP-sponsored project in the Philippines. In addition, at least four faculty members of the University of the Philippines are receiving partial support for research, related to the CRSP.

C. Objectives and Plans for Years Four and Five

The following presents the objectives and specific work plans for years four and five of the current grant.

1. The Empirical Analyses and Modeling Project

a. General Goals and Objectives

The ultimate goal of the empirical modeling study is the development of rational management tactics and strategies for tropical multispecies

fisheries. In this context, rational management refers to exploitation at an optimal or specific level with a minimum negative impact to the ecosystem.

Our work to date has clearly indicated that the tropical multispecies fisheries we have examined are very complex and only limited historical data are available. Analysis of such fisheries must contend with high species diversity, considerable environmental variability, many interacting components, and very poorly known structures or functions. In addition, management should include complex socioeconomic factors. However, we have already developed an empirical management model (Saila and Erzini 1987) which has some tactical as well as strategic components. That is, the model has utility for both short-term and long-range projections. It is based on aggregated time series of research vessel survey data, which are reduced to a transition probability matrix and analyzed. This work remains to be expanded and further tested with other data during the next two years.

Our work to date is also providing guidance on approaches we should not pursue. For example, we are now convinced that extensions of deterministic models, such as those developed by Anderson and Ursin (1977), are unrealistic for our application. On the other hand, there is some reason to believe that extensions of the so-called stock production model may have utility for some applications. We believe that the approach we have developed (based on probabilistic models) is appropriate for continuation.

In order for our understanding of tropical multispecies fisheries to advance from a natural history and descriptive approach to a point where some control is feasible, we must include certain vital elements or concepts in our model formulations. The following concepts are considered to be important for incorporation into future research related to controlling multispecies systems: 1) Uncertainty, 2) Complexity and interaction, 3) Dynamic system optimization, and 4) Limited data and management information. Each of the above will be given some attention in our future work.

b. Description of Proposed Research: Specific Goals, Objectives and Methods

The empirical modeling project has two basic objectives: 1) to develop tactical (short-term) models and methodologies, 2) to develop strategic (long-term) models and methods, and 3) to increase host country institutional capabilities.

The proposed extension of work related to tactical models will address specific problems concerning how to test for significant differences between multispecies fish assemblages over space and time. Our approaches will include fitting certain known distributions to data, and testing for the goodness-of-fit. They will also involve Monte Carlo simulation of assemblages to establish empirically derived probability distributions which will be compared to the expected overlap of paired multispecies samples.

The proposed extension of strategic models will become oriented toward finite state, finite action, infinite discrete time horizon Markov decision processes. It is believed that these form a class of optimal control processes sufficiently broad to be generally applicable to multispecies fisheries. The focus will be on infinite time processes because it is believed they fit into

the framework of marine fisheries management, wherein protection against long-term degradation of the system is a necessary component. It should be pointed out that the above-mentioned Markov decision processes do take into account the major elements mentioned previously, namely uncertainty, complexity, and dynamic solutions, and they can be utilized with limited information.

No effort will be made at this time to attempt to describe the Markov decision process. However, Bertsekas (1976) provides a good foundation for this class of optimization problem.

Literature Cited:

Anderson, K.P. and E. Ursin. 1977. A multispecies extension to the Beverton and Holt theory of fishing with accounts of phosphorous circulation and primary production. Medd. Dan. Fisk-Havunders (NySer) 7:319-435.

Bertsekas, D.P. 1976. Dynamic programming and stochastic control. Academic Press, New York. 398 pp.

Saila, S.B. and K. Erzini. 1987. Empirical approach to multispecies stock assessment. Trans. Amer. Fish. Soc. 116:601-611.

c. Specific Work Plans for Year Four

1) Statistical Modeling

a) Continue the development of statistical techniques for the estimation of parameters relevant to tropical fisheries management including work on the statistical distribution of the maximum lengths of fish; develop user-friendly microcomputer programs for the estimation of parameters and validate on Philippine data sets.

b) Continue the development of discrete-time Markov models for assessing species composition and stability of tropical fish stocks, including extension of the Markov model to include dynamic optimization. Consider methodologies for grouping (aggregating) fish assemblages in some objective fashion.

2) Empirical Studies -- Philippines

a) Expand current studies on the effects and management implications of blast fishing. Include field interviews, studies of mortality range, and acoustic monitoring for frequency by blast type.

b) Continue to compile and analyze existing fishery data from various agencies in the Philippines. Offer opportunities for personnel from Bureau of Fisheries and Aquatic Resources, Philippine Fisheries Development Authority, etc., for training at UPVCF to allow for more effective information exchange.

c) Continue studies into the relationships between reproductive cycles and recruitment patterns for selected soft-bottom fish species.

d) Continue length-frequency, catch-effort, and community structure studies of existing Philippine data sets.

e) Initiate field sampling for study of comparative morphology of otoliths.

f) Review of studies in the literature dealing with stomach analysis, preparatory to initiating studies aimed to facilitate the grouping of species by feeding classes in quantitative analyses and fisheries models.

g) Initiate selection studies for soft-bottom species in Lingayen Gulf (in cooperation with CRMP).

h) Initiate studies in variation of market prices of fish with size and season.

i) Incorporation of market prices in optimal mesh size analysis.

j) Review of exploitation and management of Philippine marine fisheries.

3) Comparative Studies, Methods, Training

a) Complete analyses of spatial patterns in Indonesian demersal fisheries. Complete manuscript of book on Indonesian fisheries in comparison with other Southeast Asian and Tropical Australian fisheries.

b) Complete working prototype of TACO microcomputer package, designed to facilitate catch composition and community structure analyses based on large fishery and benthic data sets.

c) Continue analyses of trawl data from Thailand and Northern Australia to determine optimal species/site groupings to simplify area-based management and to minimize variables in modeling regional fisheries processes.

d) Continue annual training programs in community structure analysis and other specialty fisheries methods. Include participants from U.S. AID CRMP and Rainfed Resources projects. Assist these projects in data analysis and interact through data exchange.

e) Complete first version of FSAS, a Fishery Science Analyst in System for field use. Provide training in FSAS applications to fishery managers in developing countries.

d. Specific Work Plans for Year Five

1) Statistical Modeling

a) Continue work on the statistical estimation of parameters relevant to tropical fisheries management.

b) Further development of the discrete-time Markov model.

2) Empirical Studies -- Philippines

a) Continue blast fishing studies. Compile results and publish with recommendations for management and further research.

b) Continue to compile and analyze existing fishery data from various agencies in the Philippines. Continue the training program for personnel from BFAR, PFDA, etc., to maintain an effective information exchange.

c) Continue length-frequency, catch-effort, and community structure studies of existing Philippine data sets.

d) Compilation and critical review of fish length/growth parameters available in the literature and those generated from existing Philippine data sets.

e) Continue field sampling for study of comparative morphology of otoliths.

f) Initiate field sampling for stomach contents analysis utilizing keys developed from otolith studies.

g) Initiate field sampling for the study of reproductive cycles and recruitment patterns of soft-bottom fish species (in cooperation with U.S. AID CRMP).

h) Initiate length-based cohort analysis using existing Philippine data sets.

i) Conduct study on fishing effort as index of gear seasonality, interaction and competition.

j) Quantification of natural mortality (M) for exploited fish species using available techniques and data.

k) Review of exploitation and management of Philippine marine fisheries.

3) Comparative Studies, Methods, Training

a) Publish book on trawl fisheries of Indonesia through GTZ and ICLARM.

b) Distribute TACO microcomputer package for field testing at selected research stations. Compile comments for revisions in a version for general distribution.

c) Complete analyses of Thailand and Australian trawl data sets. Determine optimal species/area groupings to facilitate area-based management and empirical modeling. Report results at Second Asian Fisheries Forum, Japan.

d) Continue annual training programs in community structure analyses and other speciality fisheries areas.

2. The Multispecies Field Studies Project

a. Goals and Objectives

The overall goals and objectives of this project are the following: 1) To determine the effects of applying various levels and types of fishing effort on the catch composition and harvestable production of Southeast Asian coral reefs and associated shallow-water ecosystems; 2) To determine to what extent the potential catch composition and fishery production of a coastline can be predicted from habitat information obtained from satellite imagery, aerial photographs from low-cost aircraft, chart information, bathymetry, and environmental parameters obtained from site sampling. Morphocedaphic indices will be developed from the above, if possible; 3) To disseminate this information to countries involved in multispecies fisheries management, including the United States and developing countries; and 4) To develop within the host country collaborating institutions the capability to continue independently to investigate and to refine the assessment and management aopproaches which are developed within the CRSP. This includes augmenting the faculty of the Marine Science Institute and funding up to eight CRSP researchers each year for advanced degree training in this institute.

b. Specific Work Plans for Year Four

1) Release and prepare for publication the results of two years of coral reef fishery studies in the form of a series of papers by five researchers at the August 1988 Sixth International Coral Reef Symposium in Townsville, Australia.

2) Monitor catch composition and production from specific fish habitat types in Bolinao, Pangasinan. Monitor the effects of differential applications of fishing pressure within each habitat type (by aerial surveys), and the variability over time in the in-situ fish composition. Extend monitoring to a series of nearshore and offshore reefs subject to different levels of fishing pressure. Involve and help train one or more U.S. Peace Corps Volunteers to assist with the monitoring. Prepare a data-base system to integrate this type of fishery information into a standard Geographic Information System (GIS) format. Contribute results to the pilot management plan under development by the U.S. AID ASEAN Coastal Resources Management Program (CRMP) for the Bolinao area.

3) Initiate studies of trophic relationships among the major coral reef fish species on which to base a trophic-dynamic model to increase the predictability of fishing pressure changes on catch composition and production.

4) Extend fishery monitoring to include more extensive studies of gleaning and fisheries for crustaceans, molluscs, echinoderms, and seaweeds. Methodologies and objectives will parallel and compliment those described above for coral reef fish.

5) Initiate regular sampling of the network of the wier-like fish traps, "baklads," distributed across the region adjacent to the large estuary of Tambak Bay to yield information on fish migrations and the importance of this

estuary to local fish production.

6) Monitor the reproductive and recruitment cycles of key fish species, and obtain information on meteorological and oceanographic processes which might be responsible for the timing of these events. Continue and expand studies of differential juvenile recruitment across the Bolinao reef complex. Determine if cycles of larval abundance correlate with cycles of reproduction and recruitment. Investigate the relationship, if any, between these cycles and mass spawning among corals, which may be important in providing food to enhance juvenile fish survival.

7) Continue developing methods to facilitate the determination of fishery potentials by remote sensing. Complete a package of programs to facilitate the determination of shallow-water geomorpholopgy and fish habitat types from satellite data. Develop improved methods for mapping shallow-water fish habitats and monitoring fishing pressure from light aircraft and remote-controlled aerial photography planes. Use satellite and aerial mapping as a basis for the broad-area extrapolation of estimates of reef fishery potentials determined in the field studies. Provide mapping support for the U.S. AID ASEAN CRMP.

8) Conduct training programs for developing country scientists on shallow-water satellite image analysis and coral reef fishery analysis and management. Include trainees from the U.S. AID CRMP, the U.S. AID Rainfed Resources Program, and other U.S. sponsored programs.

c. Specific Work Plans for Year Five

1) Continue comparing catch composition and community structure variations over time between coastal habitats with different levels of fishing pressure. Provide data for analysis to other CRSP entities for model validation. Disseminate findings in data reports and publications. This monitoring will include all major finfish and invertebrate fisheries, as well as gleaning activities, in the study areas. Opportunities will be sought for offshore reef comparisons via other funded projects. Aggregation techniques for fish assemblages will also be investigated.

2) Continue estuarine fish migration study at Bolinao using baklad sampling and tagging.

3) Continue fecundity--recruitment studies and feeding relationships studies.

4) Collaborate with Philippine national programs to make national coral reef fishery estimations based on remotely sensed data.

5) Continue annual training in remote sensing and coral reef analysis and management.

6) Initiate studies of factors affecting soft-bottom small-scale fisheries including natural fish habitats such as sponge communities, and artificial fish aggregating devices ("FAD's" and "Artificial Reefs") in conjunction with other Philippine and internationally sponsored programs planned for this period.

7) Determine the nature of tropical stock boundaries via studies of electrophetic protein patterns, mitochondrial RNA, and scale morphometrics in collaboration with other projects of the Marine Science Institute planned for this period.

8) Prepare materials in first handbook format.

D. Objectives and Plans for Years Six Through Eight

This sections reviews the objectives and general work plans for a three year extension of the current grant.

1. The Empirical Analyses and Modeling Project

a. Project Objectives

The project will continue to pursue the objectives summarized in Sections C.1.a. and C.1.b., above.

b. Work Plans for Year Six

1) Statistical Modeling

a) Start work on analysis of the distribution over time and space of the various fish species of the Philippines. Consider non-linear mapping and/or clustering of the various fish species of the Philippines using techniques which are independent of sample size.

b) Continue work on developing continuous-time Markov models relevant for tropical fisheries management.

2) Empirical Studies -- Philippines

a) Continue to compile and analyze existing fishery data from various agencies in the Philippines. Continue the training of personnel from these agencies.

b) Continue length-frequency, catch-effort, and community structure studies of existing Philippine data sets.

c) Continue study on multispecies population analysis using existing Philippine data sets.

d) Comparative analysis of hard and soft-bottom recruitment and reproductive patterns.

e) Analysis of food web structure of soft-bottom fish communities.

f) Continue study on fishing effort as index of gear seasonality, interaction and competition.

g) Initiate field sampling in slightly exploited area for quantification of natural mortality (M).

h) Continue quantification of natural mortality (M) for exploited and less exploited fish species using available techniques and collected data.

i) Review of exploitation and management of Philippine marine fisheries.

3) Comparative Studies, Methods, Training

a) Begin catch composition and community structure analyses of other Southeast Asian fisheries data sets.

b) Update TACO Microcomputer Package to include an expert system interface to assist with analytical strategy formulation.

c) Continue regional training programs on specialty fisheries methods.

c. Work Plans for Year Seven

1) Statistical Modeling

a) Continue work on space and time distribution of Philippine fish species.

b) Continue work on discrete-time Markov decision models.

2) Empirical Studies -- Philippines

a) Continue to compile and analyze existing fishery data from various agencies in the Philippines.

b) Continue length-frequency, catch-effort, and community structure studies of existing Philippine data sets.

c) Comparative analysis of food web structure in soft and hard-bottom fish communities.

d) Continue study on fishing effort as index of gear seasonality, interaction, and competition.

e) Continue quantification of natural mortality (M).

f) Review of exploitation and management of Philippine marine fisheries.

3) Comparative Studies, Methods, Training

a) Continue analyses of multispecies fishery data sets from Southeast Asia and Tropical Australia. Prepare manuscript of a book on the

fisheries of the Southeast Asian Region.

b) Revise and update TACO as necessary.

c) Continue regional training programs on specialty fishery management approaches.

d. Work Plans for Year Eight

1) Statistical Modeling

a) Start investigating relatinships between space and/or time distributions of the various Philippine fish species and environmental factors.

b) Apply developed discrete-time Markov decision models to Philippine data sets.

2) Empirical Studies -- Philippines

a) Continue to compile and analyze existing fishery data from various agencies in the Philippines.

b) Continue length-frequency, catch-effort, and community structure studies of existing Philippine data sets.

c) Continue the comparative analysis of food web structure in soft and hard bottom fish communities.

d) Production of manuscripts on the following: 1) Philippine capture fisheries, 2) Compilation of stock assessment methods applicable to tropical development country situations, and 3) Compilation of computer programs.

3) Comparative Studies, Methods, Training

a) Publish book on marine capture fisheries of the Southeast Asian Region.

b) Publish final version of TACO (Table Analysis by Classification and Ordination) for microcomputers.

c) Prepare chapters for CRSP major handbook on fisheries methodologies.

d) Conduct final training programs in southeast Asia and elsewhere.

2. The Multispecies Field Studies Project

a. Project Objectives

The project will continue to pursue the objectives summarized in Section C.2.a. above.

b. Work Plans for Year Six

1) Evaluate long-term monitoring tasks to determine which facets should be expanded, reduced or otherwise modified to provide the data most critically needed for various management schemes, including the expert systems and bioeconomic models under development by the other project components in the U.S. and Costa Rica.

2) Continue coral reef resource evaluation of the Philippines via remote sensing in conjunction with other funded programs, as a means of further developing and testing the approach for possible application in other countries.

3) Adapt scheduled work on stock boundaries and soft bottom fisheries to the time frames and funding available in collaborative projects intended for this time frame.

4) Continue annual conferences and training programs on remote sensing and coral reef analysis and management.

c. Work Plans for Year Seven

1) Present results of all coral reef studies in the Seventh International Coral Reef Symposium. This periodic series of congresses is the largest international gathering of coral reef scientists, providing a focal point for the release of research results in many of the major integrated reef studies of the world. It is, therefore, the most appropriate forum for the culmination of our long-term studies. The Seventh ICRS is tentatively scheduled for sometime in mid-1992, and will probably be held in either the Caribbean, the Red Sea, or Okinawa.

2) Continue monitoring tasks initiated above.

3) Seek collaborative support from other countries in Southeast Asia to provide one or more other regions to test and further refine the approach of using remote sensing information to facilitate fisheries potential estimation.

4) Continue collaborative research on stock boundaries and soft-bottom fisheries as appropriate.

5) Continue annual conference and training program activities as per regional demands and research results available for release.

d. Work Plans for Year Eight

1) Continue long-term monitoring tasks for six months, then conclude or prepare for continuation under other project funding sources if available.

2) Continue collaborative work on remote sensing, stock boundaries, and soft-bottom fisheries as appropriate to the schedules of cooperating projects for that year.

3) Summarize and finalize all results. Assimilate data into data reports and user-friendly data-base systems. Collaborate with other CRSP entities to permit the incorporation of the final results and data into management models. Prepare final publications.

4) Present results in a series of training programs regional conferences and lecture tours.

5) Integrate all results into the end-product manual format, and assist in manual preparation.

VI. Program Coordination and Integration

The CRSP research efforts over the past three years have involved many researchers, institutions, and countries. Many have contributed generously to the CRSP efforts. Even taking a narrow view of CRSP participation, that involving financial linkages, the CRSP has involved more than 60 researchers, a dozen institutions, and five countries. Research efforts have been spread over eight separate projects. The scientific coordination and integration of this extensive international network of researchers and institutions working on many aspects of a global problem is being principally carried out by the work of the CRSP Technical Committee working closely with the Program Director of the Management Entity. This section addresses the coordination and integration issues.

A. Research Coordination

The various research efforts are being coordinated through continuing communication among members of the Technical Committee and other principal researchers. The Technical Committee, responsible for the technical guidance of the project, has met twice a year to share information and engage in planning activities. Research outputs are shared through regular production and distribution by the Management Entity of the scientific working papers written by the researchers from the various institutions. The Management Entity also distributes to all CRSP participants regular communications such as researcher trip reports, minutes of meetings, an occasional newletter, annual reports, annual work plans, and other communications, including published scientific reports.

One of the principal means of coordinating research efforts has involved the exchange of research personnel between the U.S. and host country institutions and team meetings of the principal research institutions. These activities naturally involve travel expenses and have therefore not be carried out at the level which would be more desirable due to financial considerations. However, the research teams have made maximum use of these exchanges within the limited financial resources, and they have benefitted substantially from them.

Participation in international workshops, conferences, and training programs has also been encouraged. There have been numerous small training efforts for host country personnel on specific techniques or procedures, for example, one-on-one training on fish ageing techniques in Costa Rica or small group training activities on species identification in the Philippines, along with microcomputer software training at several sites. In addition, however, CRSP researchers from U.S. and host country institutions have participated in large-scale training programs at the University of Washington, the University of Rhode Island, and the University of the Philippines. Examples include the University of Washington two-month long short-course on "Quantitative Management of Artisanal Fisheries," held in the fall of 1987, and three training programs held at the University of Rhode Island in the summer of 1987. In addition, ITROFIC (the International Tropical Fish Conference) was a CRSP-sponsored conference and workshop held in October, 1987, in the Philippines. Further, workshops on remote sensing, community structure

analysis, and coral reef management have been provided at the University of the Philippines by CRSP researchers.

Future training workshops are planned to be held in Costa Rica by UW personnel on fish ageing techniques early in the summer of 1988 and on hydroacoustics techniques in the summer of 1989. Additional training workshops led by URI and ICLARM researchers are planned to be conducted in the Philippines on coral reef analysis and community structure analysis.

There has been extensive participation by CRSP researchers in professional meetings to share CRSP research. Examples include the following. CRSP researchers from the University of Rhode Island and the University of the Philippines made presentations at the First Asian Fisheries Society Forum in June, 1987. Researchers from four of the five principal CRSP universities presented papers at the American Fisheries Society annual meetings in Sepember, 1987, in Winston-Salem, North Carolina. For the future, a symposium entitled "Fisheries Management in Developing Countries: Problems and Opportunities," at which CRSP research is very prominently represented, is planned to be held in conjunction with the AFS meetings in Toronto in September, 1988. Five papers by URI/UP researchers will be presented at the Sixth International Coral Reef Symposium in Townsville, Australia, in August, 1988. Related to the CRSP efforts, the University of Washington is working on "The All Latin American Symposium on the Management of Small Scale and Artisanal Fisheries," principally funded by CONICET, Argentina, and the Tinker Foundation to be held in Buenas Aires in 1989.

Participation in training programs, professional society meetings, conferences, symposia, and workshops provide excellent opportunities for sharing CRSP approaches, findings, and developments. However, they also provide opportunities for interaction and communication among CRSP and related researchers which contribute to the developing research program. All of these efforts facilitate the coordination of the CRSP activities.

A CRSP-wide program coordination meeting, initially planned for the summer of 1987 in the Philippines, was cancelled due to financial considerations. However, a CRSP program coordination meeting was held in Costa Rica in February, 1988. This meeting was extremely valuable, leading to the development of concrete planning for program coordination and integration activities. In particular, the Management Entity and the Technical Committee agreed to attempt to facilitate annual program-wide coordination meetings in the future.

B. Research Integration

The various CRSP research efforts are being integrated through several mechanisms, principally in the plans for the production of the CRSP's final deliverable product, the production of a CRSP Stock Assessment Handbook or manuals for fishery managers in tropical developing countries. The terms of reference for the CRSP emphasize that this handbook (or manuals) will provide a guide or a "key" for optimal fishery stock assessment and management given the problem and the available resources. The Principal Investigators have specifically addressed the problem of the production of the CRSP Stock Assessment Handbook, and of how the various CRSP efforts will be integrated. It is now understood by the participants that this final deliverable product

will not be a single manual or book, but instead will consist of several handbooks or manuals, often with associated microcomputer software and documentation, which will describe and explain specific models, methods, approaches, and limitations to tropical fisheries stock assessment and management, with emphasis on multispecies capture fisheries.

The Technical Committee has specifically addressed the issue of the production of the CRSP Stock Assessment Handbook at various meetings. During the fall of 1987, the three key U.S. Principal Investigators and the Program Director exchanged various communications regarding the mechanisms for merging the eight projects into the final product, finally developing a preliminary program integration plan which has been circulated among other key CRSP participants for further commentary and development. Then, in February, 1988, at the program coordination meeting held in Costa Rica, the Technical Committee came to substantial agreement on several merging activities for the various project components. These merging activities include the following:

1) Providing empirical information from the Philippine field activities as inputs to area based production models being developed by the University of Maryland-CEES and the University of Miami researchers;

2) Specific collaboration on length and partial age based stock assessment methods between the University of Washington, the University of Rhode Island, the University of Costa Rica, and the University of the Philippines researchers in the form of data exchange and field testing and evaluation of parameter sensitivity;

3) Collaboration among all U.S. institutions with the University of Costa Rica in efficient utilization of the developing Costa Rica data base;

4) Dissemination to all participants of the results and methodologies (programs) relating to multivariate analysis (classification and ordination) of multispecies fisheries being developed in the Philippines, as well as dissemination of all completed materials among the participants in a timely manner; and

5) Planning for future coordination meetings annually, along with planning CRSP-wide symposia and workshops for sharing developments; as exemplified by the planning for the principally CRSP-related symposia on Fishery Management in Developing Countries to be held in conjunction with the American Fishery Society annual meetings in Toronto, Canada in September, 1988.

Further, there is substantial agreement by the Principal Investigators on the nature, content, and format of the proposed CRSP Stock Assessment Handbook(s), as well as the nature of the specific deliverables which will comprise the handbook(s). These include methodologies, software documentation, examples, preliminary evaluation results, program listings, and/or software in the form of MS-DOS (Microsoft Disk Operating System) diskettes. At this point in the CRSP activities, the researchers envision a variety of "manuals or handbooks." One set of manuals would be designed to provide documentation and evaluations of various microcomputer software programs, explaining when a program works well or poorly, when to use it and when not to. Another set of manuals would deal with the advances in such areas as the ageing of tropical fish, shallow-water hydroacoustics techniques,

the development of sampling designs, and the design of fishing gear experiments. Yet another set of manuals would deal with methodology developments, such as approaches to age and size modeling or dynamic optimal control modeling. Lastly, the handbook(s) will include the developments by the University of Maryland-University of Costa Rica researchers on a first stage fishery management expert system/decision support system (ES/DSS) for use on a microcomputer. It is believed that ultimately an ES/DSS will be developed which could embrace a significant portion of the entire spectrum of the CRSP projects and activities.

A full-scale operational ES/DSS for fisheries stock assessment is a formidable undertaking. The consensus of the Technical Committee is that there are uncertainties involved in some of the system elements, such as the knowledge base, which may preclude a full-scale operational system during the first five years of the project activities, particularly in view of the reduced funding levels at which the CRSP is operating. However, the ES/DSS is considered an important mechanism for merging and integrating the various CRSP elements, which will increase in value as more of its elements and information requirements are made explicit.

It is anticipated that several specific tactical and strategic approaches to tropical multispecies stock assessment will have been completed within the initial five-year time frame. However, adequate field testing, sensitivity analysis, evaluation and recommendations for the application will require substantially more time. In the interim the real merging mechanism for the CRSP activities will be the continuing exchange of information among participants through working papers, computer programs, field tests, and evaluation exercises through simulations, revisions, and the ultimate incorporation in handbook(s) and a final state-of-the-art expert system/decision support system.

Further, there is unanimity among the Principal Investigators concerning the belief that the handbook(s) are a dynamic product which will substantially improve through use, field testing, critical evaluation, sensitivity analysis of segments, improved coding and documentation, etc. The expert system/decision support system is a major interfacing and integration mechanism in addition to requiring possible conceptual developments in some aspects of artificial intelligence. The ES/DSS is also dynamic and will improve as its knowledge base becomes more accurate and precise, as well as more encompassing. The objectives and work plans for a three year extension of the CRSP beyond its initial five year grant period are clearly directed to developing the methodologies and technologies for stock assessment and management of multispecies tropical fisheries so that the handbook(s) and guides will truly be practical, appropriate, useable, and state-of-the-art.

VII. Management Entity Activities

This section of the Trienniel Review and Continuation Proposal reviews the activities of the CRSP Management Entity, its Program Director, and several institutions which serve in an advisory capacity to the Program Director.

A. Introduction

The Fisheries Stock Assessment CRSP was established under USAID Grant No. DAN-4146-G-SS-5071-00, which was signed on August 23, 1985, by the University of Maryland-College Park, the assigned Management Entity. This grant established the CRSP for a five-year period, July 1, 1985 - June 30, 1990, at a funding level of $5 million.

The Management Entity is located in the Office of International Programs, College of Agriculture, University of Maryland-College Park, and is headed by the CRSP Program Director, Dr. John Rowntree. The Program Director is assisted in the administration and management of the CRSP by several advisory, technical, and policy-making institutions. A three member Board of Institutional Representatives, hereinafter referred to as the Board, represents the principal U.S. research institutions and sets general policy for the CRSP. A five person Technical Committee, composed of the Principal Investigators from the three principal U.S. and two principal host country institutions, provides technical guidance for the CRSP. A two person External Evaluation Panel, composed of leading researchers and administrators in the field of fisheries, has been established to provide on-going review and evaluation of the CRSP activities. The Board, the Technical Committee, and the External Evaluation Panel are the critical institutions on which the Program Director depends to effectively administer the research program. The activities of the Program Director and each of the advisory institutions over the past three years are highlighted below.

In establishing these institutions and in other policy matters, the CRSP has been implemented according to the "CRSP Guidelines," June 21, 1985, drafted by the Board for International Food and Agricultural Development (BIFAD).

B. The Board of Institutional Representatives

The Board was created within days of the signing of the grant by the University of Maryland. Initially, the Board was composed of four members, one from each of the three principal U.S. research institutions plus one "outside" member to represent the Management Entity. The Board membership is as follows:

- Dr. Gerald Donovan, Chair, Dean, School of Natural Resources, University of Rhode Island
- Dr. Ian Morris, Director, University of Maryland-Center for Environmental and Estuarine Studies
- Dr. Robert Stickney, Dean, School of Fisheries, University of Washington
- Dr. Peter Larkin, Vice President for Research, University of British

Columbia (outside member) (first two years only)

Unfortunately, Dr. Peter Larkin, a world renown expert in the field of multispecies fishery sciences and a strong contributor to the CRSP program, was unable to continue on the Board after the first two years because of pressing commitments at the University of British Columbia. Even though Board members serve without compensation, the Management Entity does incur the costs of transportation and expenses for attending Board meetings. Thus, as an economy measure, when Dr. Larkin stepped down from the Board, the Program Director decided to forego the appointment of an "outside" member of the Board.

At the end of the third year of the CRSP, Dr. Gerald Donovan will step down as the University of Rhode Island Board representative, to be replaced by Dr. Spiros Constantinides, the new Deputy Director of the International Center for Marine Resource Development at URI.

The Board also has three ex-officio members: the Program Director, Dr. John Rowntree; the AID Program Manager, Dr. Richard Neal, Senior Fisheries Officer, Bureau for Science and Technology, United States Agency for International Development (AID/S&T); and Dr. Wm. Fred Johnson, International Research Program Officer, BIFAD. Dr. Lamarr Trott, Senior Fisheries Advisor, AID/S&T, has also worked closely with the Program Director, the Board, and other CRSP institutions and participants in an advisory capacity, frequently substituting for Dr. Richard Neal as AID's ex-officio representative to the Board and Technical Committee. Dr. Kenneth Tenore, Director, Chesapeake Biological Laboratory, University of Maryland-Center for Environmental and Estuarine Studies, has served as acting Board member, replacing Dr. Ian Morris, on several occasions.

The Board has met on several occasions during the past three years. The meeting dates, along with brief description of major considerations and actions, are listed as follows:

December 9, 1985 --at which the Board tentatively approved the CRSP "Bylaws and Operating Guidelines" as drafted by the Program Director and approved the initial budget allocations among the various CRSP entities; members of the Technical Committee attended the meeting.

August 4, 1986 --at which the Board reviewed the status of the CRSP and reviewed and approved the Technical Committee recommendations concerning the reprogramming of the CRSP in light of the budget reductions.

January 20, 1987 --at which the Board, meeting jointly with the Technical Committee, was briefed on the status of the CRSP research program, and approved the program planning and budget allocations for the coming period, along with the establishment of the External Evaluation Panel.

March 31, 1988 --at which the Board, meeting jointly with the Technical Committee approved work plans and budget allocations for the next year's activities, and was

briefed on the status of the CRSP, the plans for the upcoming Triennial Review, and the contents of the five-year forward planning contained in the draft Continuation Proposal; additional discussions focused on actions to support the acceleration of the CRSP research and funding, and on programmatic restructuring to deal with the problem of limited finances.

The Board Chair, Dr. Gerald Donovan, has been an active participant in the CRSP Council, an organization of the Board Chairs and Program Directors of the eight CRSP's. Dr. Donovan chaired a CRSP Council committee which prepared a Congressional briefing on CRSP accomplishments held in the Capitol Building on July 25, 1986. Dr. Donovan has also been active in the Committee for International Fisheries Research and Assistance Institutions (CIFRAI), an informal network of the seven AID/S&T fisheries projects. Dr. Donovan also participated in a one-day meeting on April 28, 1987, at which CIFRAI representatives briefed AID personnel, including selected Agricultural Development Officers, on their activities. He also joined the Program Director, Dr. John Rowntree, and University of Washington CRSP Principal Investigator, Dr. Vincent Gallucci, in a two-day all-CRSP administrative review meeting held in Virginia on July 17-18, 1987.

C. The Technical Committee

The Technical Committee provides technical guidance for the CRSP. Within the framework of the "CRSP Guidelines," the Management Entity has supported the establishment of a strong Technical Committee. It sets the technical directions of the research efforts, and is responsible for coordinating and integrating the technical activities, for reviewing and evaluating the technical progress made in various components and the overall CRSP, for preparing the annual technical work plans and the technical components of the annual reports, and for approving technical publications of the CRSP. The Program Director has served as the secretariate for the Technical Committee and has promoted coordination and integration of the planning and technical efforts of the various researchers and institutions.

The preparation of this Triennial Review and Continuation Proposal is an example of the cooperation of the Program Director and the Technical Committee in action. Initial planning for this report was conducted during a program coordination meeting held in Costa Rica in early February, 1988. A draft outline was prepared and distributed by the Program Director. Each of the collaborative research teams associated with the principal U.S. universities developed and circulated drafts of research accomplishments and work plans. A two-day Technical Committee meeting held in College Park, Maryland at the end of March, 1988, provided a forum for the sharing and revisions of the draft documents concerning future objectives, work plans, expected accomplishments, and integration of the components of the program. Host country Technical Committee representatives also participated in these meetings. These revised plans were then outlined to the Board at a one-day joint Board and Technical Committee meeting. The Board made additional suggestions, especially concerning project emphases, subcontracting components, and adaptation of the research program to the financial constraints. Draft technical contributions were then integrated into a whole coherent report, the research overview was

redrafted, and the introductory, program coordination, and administrative and financial components were drafted and added to the report by the Program Director. This draft of the programmatic sections was then circulated to the U.S. Principal Investigators for final revisions and commentary. This cooperative approach by the Technical Committee and the Program Director has been explained in detail concerning the drafting of this report to highlight how the diverse scientific interests and the several project components are being coordinated in a collegial fashion within the CRSP.

The membership on the Technical Committee is listed below:

Dr. Efren C. Flores, CRSP Principal Investigator and Dean, University of the Philippines in the Visayas, College of Fisheries (beginning in November, 1987)
Dr. Vincent F. Gallucci, CRSP Principal Investigator and Director, Center for Quantitative Science, School of Fisheries, University of Washington
Dr. Edgardo Gomez, CRSP Principal Investigator and Director, Marine Science Institute, University of the Philippines, Diliman Campus (from the inception of the CRSP until November, 1987; alternates every two years with the UPVCF representative.)
Dr. Manuel M. Murillo, CRSP Principal Investigator and Director, Centro de Investigacion en Ciencias del Mar y Limnologia (CIMAR), University of Costa Rica
Dr. Brian Rothschild, CRSP Principal Investigator and Research Professor, Chesapeake Biological Laboratory, University of Maryland-Center for Environmental and Estuarine Studies
Dr. Saul Saila, CRSP Principal Investigator and Professor, Graduate School of Oceanography, University of Rhode Island

Since the CRSP is working with two separate University of the Philippines institutions, the Technical Committee representation alternates between the Principal Investigators at the two institutions. The Program Director, the AID/S&T Program Manager, and the BIFAD International Research Program Officer are also ex-officio Technical Committee members. Dr. Lamarr Trott has also worked closely with the Technical Committee, substituting as AID's ex-officio member in Dr. Richard Neal's absence.

The Technical Committee has met on the following occasions:

September 17, 1985	--Initial Technical Committee organizing meeting held in College Park, Maryland.
December 9, 1985	--Meeting with the Board in College Park, Maryland.
July 17-18, 1986	--Planning and Coordination meeting in Kingston, Rhode Island.
January 20, 1987	--Joint Meeting with the Board in Chicago.
September 15, 1987	--Coordination meeting at the American Fishery Society annual meetings in Winston-Salem, North Carolina
February 3-5, 1988	--Program coordination meeting in San Jose, Costa Rica
March 29-31, 1988	--Continuation proposal development meeting held in College Park, Maryland, followed by a one-day joint meeting with the Board.

The Technical Committee in cooperation with the Program Director has devoted considerable attention to the coordination and integration of the CRSP activities. These efforts are summarized in Section VI of this report.

D. The External Evaluation Panel

The External Evaluation Panel is an essential and unique feature of the CRSP programs. According to the "CRSP Guidelines," the External Evaluation Panel is composed of senior scientists with expertise in related fields designed to provide on-going review and evaluation of CRSP activities. The members receive no compensation and are not personally involved in CRSP research activities. Thus, the members are external technical advisors who become deeply involved in the internal affairs of the CRSP.

The CRSP is fortunate to have two outstanding fisheries scientists and administrators serving on its External Evaluation Panel:

Dr. Michael Sissenwine, Director, Fisheries Ecology Division, North East Fisheries Center (NEFC), National Marine Fisheries Service (NMFS), Woods Hole, Massachusetts

Dr. Albert Tyler, Head, Groundfish Assessment Program, Pacific Biological Station, Canada Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada

While it would have been useful to have had the continuing advice and counsel of the External Evaluation Panel from the very beginning of the CRSP, due to financial considerations, and based on the experience of some other CRSP's, we delayed the appointment of the panel members until near the end of the second year of operation. In addition, the CRSP had initially planned to have a three person External Evaluation Panel; however, in the interest of economy and on advice of the Board and the Technical Committee and approval by the AID Program Manager, the Program Director decided to limit the panel to only its two current members.

Dr. Tyler made an initial site visit to the University of Washington in October, 1987, following which, he participated in the program coordination meetings in San Jose, Costa Rica in February, 1988. During that visit to Costa Rica, Dr. Tyler made an initial review of the Costa Rica CRSP components. Dr. Sissenwine had some interactions with the UMCEES and URI Principal Investigators prior to his first formal participation in CRSP activities at the Technical Committee meeting in Winston Salem, North Carolina in September, 1987. Then, in March, 1988, Dr. Sissenwine visited the Philippines where he made a formal evaluation of the CRSP activities underway there.

The External Evaluation Panel has now become an integral part of the CRSP, will join two external evaluators in conducting the Triennial Review of the CRSP, and is expected to continue to make important contributions to the CRSP research performance in the future.

The two external evaluators who will join the External Evaluation Panel members in conducting the Triennial Review during late June, 1988, are Dr. Serge M. Garcia, Service Chief, Marine Resources Service, U.N. Food and Agriculture Organization (FAO), Rome, Italy, and Dr. L. Harlan Davis, Deputy

Director General, Inter-American Institute for Cooperation on Agriculture (IICA), San Jose, Costa Rica.

E. Activities of the Program Director

The CRSP Program Director, Dr. John Rowntree, heads the CRSP Program Management Office for the Office of International Programs, College of Agriculture, University of Maryland, College Park, Maryland. The Program Director serves as the coordinator of CRSP activities and is responsible establishing CRSP operating policies and management and financial oversight; acts as liaison with USAID, BIFAD, the AID Missions, and host country institutions; produces and disseminates CRSP publications; and coordinates the activities of the Board, the Technical Committee, and the External Evaluation Panel.

The Program Director is employed half-time by the CRSP. Intially, the Program Director was assisted by a half-time Administrative Assistant and a full-time secretary. The Management Entity absorbed budget reductions proportionately with those absorbed by the research entities, and, consequently, is now supported only by a half-time secretary, Ms. Patti Nitowitz. In addition to ordinary supplies and office expenses, the Management Entity budget also covers the expenses of the Board meetings and associated travel, the expenses of Technical Committee meetings and associated travel of host country representatives, the expenses of the External Evaluation Panel and the Triennial Review, the travel expenses of the Program Director, and the costs of producing and disseminating CRSP publications, brochures, newsletters, international trip reports, and so forth.

Selected activities of the Program Director during the first three years of the CRSP include the following:

1) The Program Director prepared draft "Bylaws and Operating Guidelines" for the CRSP which were given tentative approval by the Board at the December, 1985, meeting; draft Publications Guidelines for the CRSP, establishing procedures for the peer review and publication of Technical Reports and Working Papers; and Travel Guidelines for CRSP participants, establishing travel request and trip report procedures.

2) The Program Director has been responsible for the preparation of the Annual Reports for 1985-86 and 1986-87 and Annual Work Plans for 1986-87 and 1987-88, as well as this Triennial Review and Continuation Proposal, in cooperation with the Technical Committee.

3) The Program Director has been responsible for establishing and coordinating the activities of the Board, the Technical Committee, and the External Evaluation Panel, participating in all the meetings and acting as the secretariate for these institutions. The Program Director has worked closely with the Technical Committee to ensure that the technical components of the CRSP are integrated into a coherent program, encouraging and organizing coordination meetings and multi-institutional activities.

4) The Program Director has acted as liaison with host country institutions, including the USAID Missions, and was instrumental in finalizing the Memoranda of Understanding with the host country institutions and in preparing the

subcontracts with all participating institutions. During the first three years of the CRSP, the Program Director made three trips to the Philippines and two trips to Costa Rica, linking his travel with that by Dr. Lamarr Trott, Senior Fisheries Advisor, AID/S&T, when possible. These international trips have facilitated communications with the USAID Missions, strengthened the linkages of the CRSP to other USAID fisheries-related projects, and promoted greater cooperation between the CRSP and host country government and university fisheries scientists, researchers, and administrators.

5) The Program Director produced a CRSP Program Overview and a CRSP brochure for worldwide dissemination, and has been responsible for establishing an occasional CRSP newletter, the first issue of which was produced in February, 1987.

6) The Program Director has participated in four meetings (three in Washington, D.C. and one in Rhode Island) of the Committee for International Fisheries Research and Assistance Institutions (CIFRAI), an informal network of the seven AID/S&T fisheries projects, and has served as the Executive Secretary of CIFRAI, producing its occasional newsletter. In April, 1987, the Program Director, the Board Chair, and Dr. Donald McCreight (URI) participated in a one-day CIFRAI meeting at which representatives of each of the fisheries projects briefed AID personnel, including selected Agricultural Development Officers, on their activities. Dr. Rowntree joined Dr. Lamarr Trott (AID/S&T) and Dr. Chris Jones (NMFS) in a joint presentation on fisheries issues and activities to the Executive Board of BIFAD during the AUSUDIAP annual meetings held in Rhode Island in June, 1987.

7) The Program Director, along with the Board Chair, has participated in several meetings (in Illinois, in Washington, D.C., and in Rhode Island) of the CRSP Council, an organization of CRSP Program Directors and Board Chairs. Dr. John Rowntree and his assistant, Ms. Sue Schram, in cooperation with Ms. Margaret Fahs, NASULGC, and Dr. John Stoval, BIFAD, jointly prepared a slide presentation on the scope and accomplishments of the eight CRSP programs funded by AID's Bureau for Science and Technology. Dr. Rowntree presented this slide presentation at the CRSP Council sponsored Congressional briefing, held in the Capitol Building in July, 1986, at which the Board Chair, Dr. Gerald Donovan, presided. Dr. Rowntree has continued his participation in a recently newly constituted CRSP Council.

8) The Program Director has maintained regular contact with the AID/S&T Program Manager, the AID/S&T Senior Fisheries Advisor, and the BIFAD International Research Program Officer. Along with the Board Chair and Dr. Vincent Gallucci (University of Washington CRSP Principal Investigator), Dr. Rowntree participated in a two-day all-CRSP administrative review meeting held in Virginia in July, 1987. This was followed by a one-day financial management workshop in November, 1987, held in Washington, D.C., attended by the Program Director and Ms. Anne Slater, Office of Sponsored Programs, University of Maryland-College Park.

9) The Program Director organizes, reviews, and maintains the financial management and reporting of the CRSP, with its complicated subcontracting arrangements with numerous institutions. In addition, the Program Director approves international travel by CRSP participants, facilitating USAID approvals, and disseminates trip reports.

F. Technical Reports and Working Papers

In September, 1985, the Program Director drafted publications guidelines for the CRSP. Initial plans suggested that the CRSP would carry two types of publications, Technical Reports and Working Papers. The agreed upon procedures for obtaining Technical Committee peer review of Technical Reports led the Technical Committee to decide at its September, 1987, meeting to postpone further production of Technical Reports and to focus, henceforth, only on the production of Working Papers. It was felt that the peer-reviewed publications in professional journals was superceding the internal review efforts, and that it was more important to promote speedy production and dissemination of the working papers. The Management Entity has officially released the CRSP Technical Reports and Working Papers as detailed in the following Table 1.

Table 1. Technical Reports and Working Papers

CRSP Technical Reports

Technical Report Number	Institutions/ Date	Title	Author(s)
1	UMCESS/UCR 5/87	"A Microcomputer-Based Decision Support System for Multispecies Fisheries Management"	Bruce Golden Brian Rothschild
2	UW/UCR 5/87	"Effect of Variability on Estimates of Cohort Parameters Using Length-Cohort Analysis: With a Guide to Its Use and Mis-Use"	Han-Lin Lai Vincent Gallucci

CRSP Working Papers

Working Paper Number	Institutions/ Date	Title	Author(s)
1	URI/UP 5/87	"An Empirical Approach to Multispecies Stock Assessment"	Saul B. Saila Karim Erzini
2	URI/UP 5/87	"Geometric Programming Applied to Some Optimal Harvesting Problems"	Saul B. Saila Karim Erzini
3	URI/UP 5/87	"A Comparison of the Relationship Between Optimal Harvesting Strategies and Reproductive Values in Four Marine Species with Different Life History Characteristics"	Saul B. Saila Karim Erzini

Table 1. Technical Reports and Working Papers
(continued)

CRSP Working Papers

Working Paper Number	Institutions/ Date	Title	Author(s)
4	URI/UP 6/87	"Status of Philippine Demersal Stocks: An Overview"	G.T. Silvestre S. Ganaden
5	URI/UP 6/87	"Effect of Incorporating Sigmoid Selection on Optimal Mesh Size Estimation for the Samar Sea Multi-species Trawl Fishery"	G.T. Silvestre M.L. Soriano
6	UMCEES/UCR 5/87	"Feasibility of Relating Recruitment to Environmental Variables"	Brian Rothschild
7	UMCEES/UCR 5/87	"Expert Systems, Microcomputers, and Operations Research"	Arjang A. Assad Bruce L. Golden
8	UW/UCR 5/87	"Some Impacts of Remote System Technology on Future Fisheries Management"	R.E. Thorne
9	UW/UCR 5/87	"Hydroacoustics and Ground Truth"	R.E. Thorne
10	UW/UCR 10/87	"The Use of Stationary Hydroacoustic Transducers to Study Diel and Tidal Influences on Fish Behavior"	R.E. Thorne John B. Hedgepeth Jorge Campos
11	UW/UCR 10/87	"Optimal Sampling for the Estimation of Age Composition with an Age-Length Key: Analysis and the Program, 'AGECOMP'"	Han-Lin Lai Vincent Gallucci
12	UW/UCR 10/87	"Users' Guide for the Program 'LCAN' (Length Cohort Analysis) and an Overview of the Underlying Analysis"	Han-Lin Lai Vincent Gallucci
13	URI/UP 12/87	"Comparison of Two Length Frequency-Based Packages Used to Obtain Growth and Mortality Parameters Using Simulated Samples with Varying Recruitment Patterns"	Margarida Castro Karim Erzini
14	UW/UCR 12/87	"Hydroacoustic Observations of Fish Abundance and Behavior Around an Artificial Reef in Costa Rica"	R.E. Thorne John B. Hedgepeth Jorge Campos

Table 1. Technical Reports and Working Papers
(continued)

CRSP Working Papers

Working Paper Number	Institutions/ Date	Title	Author(s)
15	UW/UCR 12/87	"Hydroacoustic Observations of Fish Abundance and Behavior Around Reefs and Structures"	R.E. Thorne Gary L. Thomas
16	URI/UP 3/88	"Extreme Value Theory Applied to the Statistical Distribution of the Largest Length of Fish	S.P. Formacion J.M. Rongo V.C. Sambilay, Jr.
17	UMCEES/UCR 3/88	"Report of Workshop: San Jose, Costa Rica, January 21-24, 1986"	C. Stagg J. Campos
18	UMCEES/UCR 3/88	"A Simulation Study of Marine Population Dynamics"	B.L. Golden B.J. Rothschild H. Trivedi
19	UMCEES/UCR 3/88	"Continuum-Distribution Population Dynamics"	J.M. Gracia-Bondia
20	UMCEES/UCR 3/88	"A Strategy for Organizing and Analyzing Golfo de Nicoya Fishery Data"	J. Campos C. Stagg
21	UMCEES/UCR 3/88	"A Bibliography of Optimization Models in Fisheries Management"	A.A. Assad G.T. DiNardo
22	UMCEES/UCR 3/88	"A Difference Equation Simulation Model of Marine Population Dynamics"	R.A. Estrada
23	UMCEES/UCR 3/88	"A Simple Renewal Model of Larval Fish Feeding"	J. Lobo
24	UMCEES/UCR 3/88	"Biodynamics of the Sea: Preliminary Observations on High Dimensionality"	B.J. Rothschild T.R. Osborn
25	UMCEES/UCR 3/88	"Fish Stock Asseessment Programs for the IBM-PC and Compatibles"	V.R. Restrepo D. Die W.W. Fox, Jr. J. Chavarria
26	UMCEES/UCR 3/88	"A Discrete Dynamic Fisheries Utilization Model: Towards the Practical Application of Modern Fisheries Economics"	L.G. Anderson

Table 1. Technical Reports and Working Papers
(continued)

CRSP Working Papers

Working Paper Number	Institutions/ Date	Title	Author(s)
27	UMCEES/UCR 3/88	"Using Decision - Analysis to Manage Maryland's River Herring Fishery: An Application of AHP"	G.T. DiNardo D. Levy B.L. Golden
28	UMCEES/UCR 3/88	"Spawning-Stock Biomass: A Source Of Error In Recruitment-Stock Relationships and Management Advice"	B.J. Rothschild M.J. Fogarty
29	UMCEES/UCR 3/88	"The Physical Basis for Recruitment Variability In Fish Populations"	B.J. Rothschild T.R. Osborn T.D. Dickey D.M. Farmer
30	UMCEES/UCR 3/88	"Parameter Uncertainty and Simple Yield Per Recruit Analysis"	V.R. Restrepo W.W. Fox
31	UMCEES/UCR 3/88	"Program REPSIM: A REcruitment Pattern SIMulator"	D. Die V.R. Restrepo W.W. Fox, Jr.
32	UMCEES/UCR 3/88	"The Spawning and Recruitment Patterns of Tropical Marine Fish Stocks"	J.S. Ault W.W. Fox, Jr.
33	UMCEES/UCR 3/88	"The Tropical Fishery System Model: CORECS: COntinuous REcruitment Simulation"	J.S. Ault W.W. Fox, Jr.
34	UMCEES/UCR 3/88	"User's Guide to CORECS"	J.S. Ault W.W. Fox, Jr.
35	UMCEES/UCR 3/88	"Abundance/Density Equations for Age-Structured Multicohort Populations: MCON (Multiple COhort N-dimensional model)"	J.S. Ault W.W. Fox, Jr.
36	UMCEES/UCR 3/88	"User's Guide to MCON (Multiple COhort N-dimensional model)"	J.S. Ault W.W. Fox, Jr.
37	UMCEES/UCR 3/88	"On the Efficacy of Some Techniques to Assess the Tropical Fishery System"	J.S. Ault W.W. Fox, Jr.
38	UMCEES/UCR 3/88	"Small-Scale Turbulence and Plankton Contact Rates"	B.J. Rothschild T.R. Osborn

Table 1. Technical Reports and Working Papers
(continued)

CRSP Working Papers

Working Paper Number	Institutions/ Date	Title	Author(s)
39	URI/UP 4/88	"Philippine Coral Reef Fisheries Management"	J.W. McManus C.C. Arida
40	UMCEES/UCR UW/UMCP 4/88	"The Significance of Physiologically Structured Models for Fish Stock Dynamics"	J.M. Gracia-Bondia J.C. Varilly

G. CRSP Sponsored International Travel

CRSP sponsored international travel is requested in writing in advance of travel and is approved by the Program Director and by the AID/S&T Program Manager. Host country AID Mission clearance is required prior to travel, and CRSP participants are encouraged to brief Mission personnel on their activities while in the host country.

Table 2 is a summary of the international trips undertaken by CRSP participants during the first three years which were financed by AID funding. In addition to these trips, it is anticipated that a substantial number of additional international trips will be undertaken during June, 1988, relating to the conduct of the Triennial Review. During the three years of the CRSP, there were 66 international trips. The Management Entity financed 15 international trips associated with duties of the Program Director, the Board, the Technical Committee, and the External Evaluation Panel. The remaining 51 international trips were undertaken by researchers on the programmatic budgets. For programmatic purposes, 19 international trips were initiated in year one, 18 trips were initiated year two, and only 14 were initiated in year three.

Table 2. CRSP-Sponsored International Travel
(July 1, 1985 - June 30, 1988)

	Dates of Travel	Institution	Individual	Destination
Year One -- July 1, 1985 - June 30, 1986				
1.	9/12 - 9/19/85	UCR	Manuel Murillo*	UW & UMCP
2.	12/16 - 12/20/85	UMCEES	Brian Rothschild	Miami & UCR
3.	9/23 - 10/5/85	UMCP	John Rowntree*	UP
4.	12/18 - 12/20/85	UMCEES	Edward Houde	UCR
5.	1/20 - 1/25/86	UDelaware	Lee Anderson	UCR
6.	1/20 - 1/25/86	UMiami	William Fox	UCR
7.	1/20 - 1/25/86	UMCP/CBM	Bruce Golden	UCR
8.	1/20 - 1/25/86	UMCP/CBM	Arjang Assad	UCR

Table 2. CRSP-Sponsored International Travel
(July 1, 1985 - June 30, 1988)
(continued)

	Dates of Travel	Institution	Individual	Destination
Year One -- July 1, 1985 - June 30, 1986				
9.	1/20 - 1/25/86	UMCEES	Brian Rothschild	UCR
10.	1/20 - 1/25/86	UMCEES	Cluney Stagg	UCR
11.	1/20 - 1/25/86	UMCEES	Edward Houde	UCR
12.	2/86 -	URI	Liana McManus	UP
13.	2/86 -	URI	John McManus	UP
14.	2/23 - 2/24/86	UCR	Manuel Murillo	Miami
15.	2/23 - 2/25/86	UCR	Juan Chavarria	Miami
16.	2/24 - 3/1/86	UMCP	John Rowntree*	Miami & UCR
17.	2/25 - 3/4/86	UW	Vincent Gallucci	Miami & UCR
18.	2/25 - 3/4/86	UW	Richard Thorne	Miami & UCR
19.	2/25 - 3/4/86	UW	Han-Lin Lai	Miami & UCR
20.	5/19 - 7/17/86	URI	Conrad Recksiek	UP
21.	5/19 - 10/1/86	URI	Alejandro Acosta	UP
22.	5/19 - 10/1/86	URI	Ralph Turingan	UP
Year Two -- July 1, 1986 - June 30, 1987				
23.	7/11 - 3/19/86	UCR	Manuel Murillo*	UW, UMCEES, & URI
24.	7/12 - 7/19/86	UP	Edgardo Gomez*	URI
25.	7/26 - 8/3/86	UCR	Juan Chievarra	UW
26.	8/3 - 8/4/86	UDC	Peter Larkin*	Chicago
27.	8/11 - 8/30/86	UCR	Jorge Campos	UMCEES
28.	8/17 - 8/30/86	UCR	Jaime Lobo	UMCEES
29.	10/6 - 10/31/86	URI	Saul Saila	UP & Indonesia
30.	9/12 - 10/22/86	UMCP	John Rowntree*	UP
31.	11/15 - 12/5/86	UMCEES	Cluney Stagg	UCR
32.	12/7 - 12/13/86	URI/UP	John McManus	Australia
33.	1/8 - 1/18/87	UCR	Jorge Campos	UW
34.	1/15 - 1/30/87	UW	John Hedgepeth	UCR
35.	1/15 - 1/30/87	UW	Richard Thorne	UCR
36.	1/15 - 6/30/87	URI	Conrad Recksiek	Puerto Rico
37.	1/30 - 3/31/87	URI	Ralph Turingan	Puerto Rico
38.	1/19 - 1/21/87	UCR	Manuel Murillo*	Chicago
39.	2/24 - 3/6/87	URI	Donald McCreight	UP & Thailand
40.	3/1 - 3/9/87	UCR	J. Varilly	UW
41.	4/1 - 4/30/87	URI	Alan Cournoyer	UP
42.	5/3 - 5/10/87	URI	Brian Crawford	Indonesia
43.	5/10 - 5/12/87	UCR	Manuel Murillo	UMCEES
44.	6/13 - 6/28/87	UCR	Fiorella Donato	URI
45.	6/21 - 6/28/87	UCR	Jorge Campos	UW
Year Three -- July 1, 1987 - June 30, 1988				
46.	7/1 - 8/31/87	UMiami	Jerry Ault	UCR
47.	8/2 - 8/30/87	UDelaware	Yang Gru Wu	UCR
48.	10/11 - 11/3/87	URI	Saul Saila	UP, Thailand, & Indonesia

Table 2. CRSP-Sponsored International Travel
(July 1, 1985 - June 30, 1988)
(continued)

	Dates of Travel	Institution	Individual	Destination
Year Three -- July 1, 1987 - June 30, 1988				
49.	8/30 - 9/3/87	UMCP/CBM	Bruce Golden	UCR
50.	8/25 - 9/3/87	UMCEES	Cluney Stagg	UCR
51.	9/8 - 9/23/87	UW	John Hedgepeth	UCR
52.	9/16 - 9/20/87	UCR	Manuel Murillo*	Los Angeles
53.	9/1 - 10/31/87	UCR	Fiorella Donato	UW
54.	9/18 - 10/18/87	UCR	Juan Chavarria	UW
55.	11/2 - 11/6/87	UCR	Jorge Campos	UMiami
56.	2/2 - 2/6/88	URI	Saul Saila	UCR
57.	2/1/ - 2/7/88	PBS/Nanaimo	Al Tyler*	UCR
58.	1/31 - 2/6/88	UW	Vincent Gallucci	UCR
59.	1/31 - 2/5/88	UMCEES	Brian Rothschild	UCR
60.	1/31 - 2/5/88	UMiami	Wm. Fox	UCR
61.	1/31 - 2/6/88	UMCP	John Rowntree*	UCR
62.	3/16 - 4/6/88	URI	Alan Cournoyer	UP
63.	3/4 - 3/15/88	UMCP	John Rowntree*	UP
64.	3/4 - 3/13/83	NEFC/NMFS	M. Sissenwine*	UP
65.	3/26 - 4/3/88	UPVCF	E. Flores*	URI & UMCP
66.	3/28 - 4/2/88	UCR	Manuel Murillo*	UMCP

Additional international travel to be undertaken to conduct Triennial Review in June, 1988; and one UW researchers may travel to UCR in June,1988.

* International travel financed by Management Entity.

H. CRSP Implementation Issues

The USAID grant to the Management Entity, the University of Maryland-College Park, was signed on August 23, 1987, establishing the CRSP retroactively as of July 1, 1985. Some CRSP research efforts had already begun in the summer of 1985 in anticipation of the grant approval. The CRSP Planning Entity, under the direction of Dr. Brian Rothschild, University of Maryland-Center for Environmental and Estuarine Studies, had devoted almost three years to the development of the CRSP, and the CRSP researchers and institutions were ready to begin activities at a fast pace upon receipt of the grant. Accordingly, the Fisheries Stock Assessment CRSP got off to a more rapid start that most of the earlier CRSP's, with most of the subcontracting to participating institutions and Memoranda of Understanding with host country institutions in place within months of the grant signing.

The Fisheries Stock Assessment CRSP is the newest of all of the CRSP programs, and, being developed during a period of USAID budget reductions, is the smallest of the CRSP's in financial terms. As will be outlined in more detail in Section VIII of this report, the CRSP experienced four budget reductions in the first eighteen months of operation. This was a particularly difficult period for the CRSP. Operating procedures were being established, the Management Entity advisory institutions were being created, Memoranda of

Understanding and subcontracts to participating institutions were being developed and signed, initial collaboration was being established with the host country researchers, and research was being begun at the various institutions. The start-up activities were hindered by the uncertainties generated by the recurrent, though unavoidable, budget reductions. Despite these problems, the CRSP activities were being implemented quite rapidly.

The Program Director provides management and financial oversight for the CRSP. The Principal Investigators at each of the principal participating institutions manage their own research programs and allocate funds to various components in accordance with CRSP Guidelines, AID and CRSP Board policies, Management Entity procedures, and their own universities' financial and managment control policies. Continued effort by the Program Director is required to ensure that there is regular and timely financial reporting by the participating sub-contracting institutions.

I. Management Entity Priorities for the Future

Approaching the end of its third year of operation, the CRSP has firmly established itself as an international institution engaged in collaborative research on global artisanal multispecies fisheries stock assessment methodologies. Extensive scientific and institutional linkages have been developed, and the research has achieved sufficient momentum to ensure that continued efforts will yield the expected positive results.

However, efforts must continue to promote programmatic coordination and integration, to further develop scientific and institutional domestic and international linkages, and to improve the dissemination of CRSP research findings. While initial planning has been done for the production of the CRSP Stock Assessment Handbook at the end of the initial five-year grant, continued attention to the coordination and logistics of the planning, drafting, editing, and production of the handbook is required. The External Evaluation Panel will certainly play an increasing role in determining the priorities for the continuing research.

Beyond routine financial and management monitoring, the Management Entity with support from the Board and the Technical Committee will encourage the accelerated funding by AID during the final two years of the current grant. Equally important, increased efforts will be devoted to seeking additional financial support for the CRSP, particularly in encouraging USAID Mission buy-ins through the newly created mechanism of Basic Ordering Agreements (BOAs).

The Program Director will continue supporting and participating in CIFRAI and the CRSP Council. The CRSP recognizes that it has responsibilities to AID/S&T in helping shape new policy directions and in promoting science in the service of development efforts, responsibilities which go beyond its specific research agenda.

Should financial constraints on the Management Entity be eased, there are several activities which would be strengthened. For example, production and distribution of the occasional newsletter would be expanded, a CRSP directory of research personnel and institutions would be produced, and additional support would be forthcoming for host country researcher participation in international conferences, workshops, and training programs.

VIII. Budgets, Expenditures, and Financial Plan

This section presents a triennial review of the financial dimensions of the CRSP. Following the highlighting of the budget allocations among institutions and projects, the three-year expenditure history of the CRSP is reviewed. This is followed by a detailed financial plan for the final two years of the current grant and for a three year extension of the CRSP.

A brief overview of the financial history and plans of the CRSP is provided below.

The CRSP was initially planned as a five-year, five-million dollar program. The first two years of the CRSP were years in which the federal budget in general and AID's budget in particular were being pared. Accordingly, the CRSP experienced several funding reductions during that period. The CRSP is now operating on an annual AID allocation of $704,000.

Expenditures from AID funds for the first three years of the CRSP are estimated at about $2.3 million. During this period, U.S. university and host country matching contributions to this research program added an additional 35 percent to the AID funding, bringing the total CRSP spending to more than $3 million. The contractually required U.S. university matching contribution is 25 percent of the AID funds spent in the U.S., excluding training. However, the U.S. university commitment to this vital research program has been demonstrated by the fact that the U.S. university matching contribution amounted to about 40 percent of the matchable AID funds. Similarly, the host countries have also demonstrated their commitment to the CRSP research. Although not required to make matching contributions to the CRSP, the host country institutions have contributed more than six percent of the total programmatic funding. More dramatically, the host countries have contributed more than 30 percent of the total CRSP spending in the host countries during the past three years. U.S. and host country matching contributions to the CRSP have brought total expenditures to about 135 percent of the total AID funding and to about 150 percent of the contractually matchable AID funding.

Despite the substantial U.S. and host country university contributions, the CRSP has been limited in its activities by the severe AID budget reductions. As the CRSP enters its fourth and fifth years, the progress of the research program is vitally dependent on the speedy execution of the field studies, data collection, and other efforts being conducted in the host countries if the necessary field experience, experiments, and data are obtained in a timely fashion. Accordingly, the CRSP's financial plan is requesting an acceleration in CRSP funding, to support these field and training activities, particularly in the next two years. Approximately $1.8 million in AID funds are requested for years four and five, and an additional $2.5 million in AID funds are requested for continuing the research activities for an additional three years, to June 30, 1993.

In the following, the discussion is brief, but the budget and expenditure tables have been designed to highlight some of the critical allocational and distributional decisions concerning the CRSP funding.

A. Budgets

A brief chronology of AID's funding obligations to the CRSP is outlined below. Under the terms of USAID Grant No. DAN-4146-G-SS-5071-00, approved on August 23, 1985, the CRSP was planned to be a $5 million, five-year program. Following the signing of the grant agreement, AID obligated the sum of $500,000 to the University of Maryland-College Park, the Management Entity, for the first six months of the CRSP, the period July 1, 1985-December 31, 1985. An amendment in December, 1985, added $600,000 to the CRSP, extending the period of performance to July 31, 1986. The Management Entity was notified by letter in February, 1986, that the additional $600,000 would have to last beyond July 31, 1986, and an additional $200,000 was obligated in July, 1986, to carry the work through January 23, 1987. In January, 1987, AID obligated an additional $895,000 for the period January 24, 1987-April 30, 1987. There were four separate obligations of funds by AID to the CRSP during its first 18 months, gradually reducing the AID obligation from the level of $1,000,000 to $704,000 per year. Adapting to the reduced funding was made more difficult by the short planning horizon and repeated rebudgeting that was required. However, following this period, the funding situation became more stable. In April, 1988, AID further augmented the obligated funds to the CRSP by $700,000, extending the period of performance to April 27, 1989.

The total obligated funds of $2,895,000, from the inception of the grant on July 1, 1985, to April 27, 1989, were allocated to the participating institutions, in accordance with guidelines of the Board, as indicated in the following budget tables for obligated funds, Tables 3-8.

Table 3. Institutional Budgets for Obligated Funds
(7/1/85 - 4/27/89)

Institutions		AID Funds ($)
Programmatic Budgets		
U.S. Institutions		
UMCEES	431,660	
UW	683,031	
URI	725,012	
UDelaware	95,763	
UMiami	106,498	
Total U.S. Institutions		2,041,964 (1)
Host Country Institutions		
UCR	247,155	
UP	125,541	
Thailand/Indonesia	5,450	
ICLARM	10,000	
Total Host Country Institutions		388,146 (2)
Total Programmatic Budgets		2,430,110
Management Entity Budget		464,890 (3)
Total All Institutions		2,895,000

(1) U.S. institutions' programmatic budgets equal 84.0% of total programmatic budgets and 70.5% of total AID funds.
(2) Host Country institutions' programmatic budgets equal 16.0% of total programmatic budgets and 13.4% of total AID funds.
(3) Management Entity budget equals 16.1% of total AID funds.

Table 4. Institutional and Project Budgets for Obligated Funds By Line Item (7/1/85 - 4/27/89)

Budget/Line Item	Institution			
	UMCEES/UCR ($)	UW/UCR ($)	URI/UP ($)	Total ($)
Programmatic Budget				
Personnel	265,516	397,498	288,367	951,381
Supplies/Expenses	9,386	56,563	171,478	237,427
Travel	28,701	31,304	77,026	137,031
Equipment	8,136	16,100	13,622	37,858
U.S. Subcontracts	141,788	60,973	0	202,761
H.C. Subcontracts	130,456	116,699	140,991	388,146
Indirect Costs	119,921	181,566	174,519	476,006
Total Costs (AID)	703,404	860,703	866,003	2,430,110
U.S. Univ. Match	179,752	192,522	192,952	565,226
Total Programmatic	883,156	1,053,225	1,058,955	2,995,336
Management Entity Budget				
Personnel				205,383
Supplies/Expenses				41,770
Travel				74,633
Equipment				3,378
Indirect Costs				126,910
Contingency				12,816
Total Management Entity				464,890
Total CRSP (AID Funds: Program + Management Entity)				2,895,000
U.S. Univ. Match				565,226
Total CRSP (AID Funds + U.S. Univ. Match)				2,460,226

Table 5. Project Budgets for Obligated Funds
(7/1/85 - 4/27/89)

Institution/Project	AID Funds ($)	U.S. University Matching Contributions ($)
Programmatic Budgets		
UMCEES/UCR		
Multiple Species Fisheries Research Project	430,828	116,607
Economics and Probabilistic Extensions Project	272,576	63,145
UW/UCR		
Sampling Catch Project	335,676	88,931
Age/Size Modeling Project	234,557	59,483
Age/Size Relationships Project	133,292	17,594
Hydroacoustics Project	157,178	26,514
URI/UP		
Empirical Analyses and Modeling Project	292,147	65,455
Multispecies Field Studies Project	573,856	127,497
Total Programmatic Budgets	2,430,110	565,226
Management Entity Budget (UMCP)	464,890	--- (1)
Total CRSP Budget	2,895,000	565,226 (2)

(1) Although the Management Entity has been making some matching contributions to the CRSP, they are not required and, hence, are unbudgeted.

(2) U.S. university matching contribution equals 27.2% of matchable AID funds of $2,071,964.

Table 6. UMCEES/UCR Project Budgets for Obligated Funds (7/1/85 - 4/27/89)

Institution/Project	AID Funds ($)	U.S. University Matching Contributions ($)
Multiple Species Fisheries Research Project		
UMCEES	259,102	81,958
UCR	65,228	---
UMiami	106,498	34,649
Total Project	430,828	116,607
Economic and Probabilistic Extensions Project		
UMCEES	172,558	55,809
UCR	65,228	---
UDelaware	34,790	7,336
Total Project	272,576	63,145

Total UMCEES/UCR Projects	AID Funds	Share of Total AID Funds	U.S. University Matching Contributions	U.S. University Matching as % of Matchable AID Funds (1)
	($)	(%)	($)	(%)
U.S. University	572,948	81.5	179,752	31.4
Host Country	130,456	18.5	--- (2)	---
Total	703,404	100.0	179,752	31.4

(1) Matchable AID Funds, $572,948.
(2) The Host Country has been making matching contributions, but they are not required and are thus not budgeted.

Table 7. UW/UCR Project Budgets for Obligated Funds (7/1/85 - 4/27/89)

Institution/Project	AID Funds ($)	U.S. University Matching Contributions ($)
Sampling Catch Project		
UW	225,507	72,107
UCR	49,196	---
UDelaware	60,973	16,824
Total Project	335,676	88,931
Age/Size Modeling Project		
UW	206,324	59,483
UCR	28,233	---
Total Project	234,557	59,483
Age/Size Relationships Project		
UW	116,359	17,594
UCR	16,933	---
Total Project	133,292	17,594
Hydroacoustics		
UW	134,841	26,514
UCR	22,337	---
Total Project	157,178	26,514

Total UMCEES/UCR Projects	AID Funds	Share of Total AID Funds	U.S. University Matching Contributions	U.S. University Matching as % of Matchable AID Funds (1)
	($)	(%)	($)	(%)
U.S. University	774,004	86.4	192,522	24.9
Host Country	116,699	13.6	--- (2)	---
Total	860,703	100.0	192,522	24.9

(1) Matchable AID Funds, $774,004.
(2) The Host Country has been making matching contributions, but they are not required and are thus not budgeted.

Table 8. URI/UP Project Budgets for Obligated Funds (7/1/85 - 4/27/89)

Institution/Project	AID Funds ($)	U.S. University Matching Contributions ($)
Empirical Analyses and Modeling Project		
URI	246,472	65,455
UPVCF	34,725	---
ICLARM	5,500	---
Thailand and Indonesia	5,450	---
Total Project	292,147	65,455
Multispecies Field Studies Project		
URI	478,540	127,497
UPMSI	90,816	---
ICLARM	4,500	---
Total Project	573,856	127,497

Total UMCEES/UCR Projects	AID Funds	Share of Total AID Funds	U.S. University Matching Contributions	U.S. University Matching as % of Matchable AID Funds (1)
	($)	(%)	($)	(%)
U.S. University	725,012	83.7	192,952	26.6
Host Country	140,991	16.3	--- (2)	---
Total	866,003	100.0	192,952	26.6

(1) Matchable AID Funds, $725,012.
(2) The Host Country has been making matching contributions, but they are not required and are thus not budgeted.

B. Expenditures

The financial situation has been so constrained that the CRSP entities have been spending all of the obligated funds by AID and have been depending on extra matching contributions from the participating U.S. and host country institutions to keep the efforts moving along. Estimated expenditures of AID funds over the three years to June 30, 1985, amount to $2,312,000. This has been supplemented by U.S. university matching contributions of about $645 900, or 39.5 percent of the matchable AID funds, which is substantially above the required 25 percent matching contribution. When host country contributions to the CRSP research efforts are added in, the total CRSP expenditures over the three years amount to $3,126,200. This total is 35.2 percent above the total AID funding and 49.7 percent above the matchable AID funds. During this period of financial constraint, the U.S. and host country institutions have shown their commitment to the CRSP research agenda by almost doubling their required financial obligations to the CRSP program.

Approximately 83.4 percent of the total AID funds have been spent in the United States, with the remaining 16.6 percent being spent in the host countries. Within the programmatic expenditures alone (excluding the Management Entity expenditures), however, the host countries have received 19.6 percent of the AID funds. Expenditures in the host countries during the first three years of the CRSP have been greater than those budgeted under the MOU's--19.6 percent of actual spending as compared to 16.0 percent of budgeted funds for programmatic purposes--primarily because URI devoted approximately an additional $20,000 per year to operational expenses of the field programs being conducted in the Philippines. (Beyond this, however, the URI projects are supporting Dr. John McManus as an on-site scientist in the Philippines. If the expenses of the on-site scientist were included in the URI host country expenditures, the URI host country expenses would be about 50 percent of the total URI/UP total spending.) The commitment by the host countries to the CRSP is revealed by the following. While the CRSP has spent an estimated $384,900 in AID funds in the host countries over the past three years, the host countries have contributed an additional $167,600 to the research program, or an additional 43.5 percent of the AID funds spent by the CRSP in the host countries.

Programmatic expenses have accounted for 84.7 percent of the total AID funds spent over the three years, with the Management Entity spending the remaining 15.3 percent. While the Management Entity is not required to contribute matching funds to the operation of the CRSP, the University of Maryland-College Park has indeed been making matching contributions, amounting to $48,000 over the past three years, or almost seven percent of the U.S. university matching contributions.

Tables 9-12 below highlight the relevant expenditure data by project and institution, by line item, and by source of funds. In addition, the unexpended balances of AID obligated funds are indicated.

Table 9. Estimated Expenditures By Line Item, Years 1 - 3
(7/1/85 - 6/30/88)

Purpose/Line Item	Expenditures ($)
Programmatic Expenditures	
Personnel	740,500
Supplies/Expenses	142,800
Travel	101,900
Equipment	37,300
U.S. Subcontracts	171,400
Host Country Subcontracts	324,300
Other In-Country Expenditures	60,600
Indirect Costs	381,100
Total Costs (AID)	1,959,900
U.S. Univ. Match	597,900
Total Programmatic (AID + Match)	2,557,800
Management Entity Expenditures	
Personnel	164,900
Supplies/Expenses	44,600
Travel	45,500
Equipment	3,400
Indirect Costs	94,400
Total Costs (AID)	352,800
U.S. Univ. Match	48,000
Total Management Entity (AID + Match)	401,800
Total Expenditures (AID Funds)	2,312,700
Total Expenditures (U.S. Univ. Matching Funds)	645,900
Total Expenditures (AID Funds + U.S. Univ. Match)	2,958,600

Table 10. Estimated Expenditures By Source and By Entity, Years 1 - 3 (7/1/85 - 6/30/88)

Institution	AID Funds Expended By U.S. Univ. ($)	AID Funds Expended By Host Country ($)	Matching Contributions U.S. Univ. ($)	Matching Contributions Host Country ($)	Total Expenditures U.S. Origin ($)	Total Expenditures Total ($)
UMCEES/UCR	465,100	104,600	211,600	61,600	781,300	842,900
UW/UCR	603,400	91,700	180,300	52,200	875,400	927,600
URI/UP	506,500	188,600(1)	206,000	53,800	901,100	954,900
ME (UMCP)	352,800	---	48,000	---	400,800	400,800
Total	1,927,800	384,900	645,900(3)	167,600	2,958,600	3,126,200

(1) URI In-Host-Country expenditures were in excess of that formally budgeted in the Memoranda of Understanding by $60,600, as extra funds were channelled through the URI on-site field scientist to support operational expenses of the field studies.

Table 11. Distribution of Estimated Expenditures By Source and By Entity, Years 1 - 3 (7/1/85 - 6/30/88)

Institution	Percent of AID Funds U.S. Univ. (%)	Percent of AID Funds Host Country (%)	Matching Contributions As Percent of Matchable AID Funds U.S. Univ. (%)	Matching Contributions As Percent of Matchable AID Funds Host Country (%)	Matching Contributions As Percent of Matchable AID Funds Total (%)	Percent of Total Expenditures U.S. Origin (%)
UMCEES/UCR	81.6	18.4	45.5	13.2	58.7	92.7
UW/UCR	86.8	13.2	29.9	8.6	38.5	94.4
URI/UP	72.9	27.1	36.3	9.5	45.8	94.4
Mgmt. Entity	100.0	0.0	---	---	---	100.0
Total CRSP	83.4	16.6(1)	39.5(2)	10.2	49.7(2)	94.6

(1) While In-Host-Country expenditures were only 16.6 percent of the total AID funds expended, they amounted to 19.6 percent of the programmatically-oriented AID funds, i.e., excluding Management Entity expenditures.
(2) U.S. University Matching Contributions, $645,900, were 39.5 percent of matchable AID funds, $1,635,600, substantially above the 25 percent matching requirement and above the budgeted match of about 27.2 percent. When the Host Country Matching Contributions are added in, the total matching contributions amount to $813,500, which is an extra 35.2 percent over the AID contribution of $2,312,700 and 49.7 percent above the matchable AID funds of $1,635,600.

Table 12. Project Budgets: Obligated Funds, Estimated Expenditures, and Unexpended Balances, 6/30/88

Institution/Project	AID Funds: Obligated Funds (7/1/85-4/27/89) ($)	AID Funds: Estimated Expenditures (7/1/85-6/30/88) ($)	AID Funds: Estimated Unexpended Balances (6/30/88) ($)
Programmatic Budgets			
UMCEES/UCR			
Multiple Species Fisheries Research Project	430,828	351,200	79,628
Economics and Probabilistic Extensions Project	272,576	218,500	54,067
UW/UCR			
Sampling Catch Project	335,676	266,000	69,676
Age/Size Modeling Project	234,557	193,100	41,457
Age/Size Relationships Project	133,292	112,000	21,292
Hydroacoustics Project	157,178	124,000	33,178
URI/UP			
Empirical Analyses and Modeling Project	292,147	222,800	69,347
Multispecies Field Studies Project	573,856	472,300	101,556
Total Programmatic Budgets	2,430,110	1,959,900	470,210
Management Entity Budget (UMCP)	464,890	352,800	112,090
Total CRSP Budget	2,895,000	2,312,700	582,300

C. Financial Plan

Below is a detailed review of the financial plan for the CRSP for years four and five of the current grant and for a three year extension of the CRSP research program.

The CRSP is currently operating with the AID funding of $704,000 per year, and as outlined in the budget section above, monies are obligated through April 27, 1989. At a recent CRSP Technical Committee and Board meeting, held at the University of Maryland-College Park on March 31, 1988, a review of the financial situation led to the conclusion that the CRSP badly needs to increase its rate of expenditure, expecially in the next year or two. Field studies, data collection, and training efforts conducted in the host countries are essential if the modeling and data analysis are to yield their desired results. The Board and the Program Director agreed to make every effort to accelerate the funding and spending rate of the CRSP in the coming period, the accelerated spending being crucial to the timely success of the research program. Accordingly, the planning budgets for years four and five of the current grant incorporate a spending rate of $894,000 and $898,600, respectively. This is approximately a 27 percent increase in the current AID funding rate of $704,000.

A substantial share of the requested increase in funding will be devoted to host country activities. With the additional funds, the host country expenses are budgeted to increase to about 24 percent of total programmatically-oriented AID funds in year four, and to about 25 percent in year five, as compared to the 19.6 percent experienced during the first three years of the grant.

It should be noted that even with the accelerated funding in years four and five, the total AID contribution to the CRSP by the end of the initial five years will amount to only $4.1 million, or only 82 percent of the initial $5 million grant. If the funding is not accelerated, but remains at $704,000 per year for the next two years, the total AID funds expended by the CRSP will amount to only $3.72 million, or only 74.4 percent of the funds allocated in the initial grant document.

Following the crucial period of the next two years in the CRSP research program, the Management Entity is requesting that AID fund the CRSP at the annual rate of $845,000 for the three year extension, from July 1, 1990 to June 30, 1993. While this represents a 20 percent increase over the current funding of $704,000 per year, the request is intended to seek continuity in the real spending rate, net of inflation. In the expectation that the federal fiscal situation may be better under control by the early 1990's, the CRSP representatives feel that the request for $845,000 per year is a modest one. Furthermore, in years six through eight, the host country spending is budgeted to take an increasing share of the AID funds, 22.2 percent, reflecting the desire by all participants to increase the host country training and research dissemination efforts.

If the funding is accelerated in years four and five and if the modest monetary increases in CRSP funding are achieved in years six through eight, then by the end of the eight years of the CRSP, AID will have contributed approximately $6.64 million to the development of new methodologies for fisheries stock assessment and management. U.S. university matching

contributions are budgeted to add another $1.2 million, although excess U.S. university matching (now running about 60 percent greater than budgeted) and host country matching (now adding an additional 5.4 percent to the total CRSP funding) will probably mean that the total CRSP research program will run considerably in excess of $8 million, approaching $8.5 million over the eight years.

Throughout the five year projections, the Management Entity expenses are planned to remain at about 16.9 percent of the total AID funds. The U.S. university matching contributions continue to be budgeted at above 27 percent over the next five years, with the projected budgeted U.S. university matching contribution amounting to about 27.5 percent over the entire eight years ending in June 30, 1993.

Table 13 below is a detailed financial plan by institution, by project, by source of funds, and by detailed line item, for years four through eight of the CRSP.

Table 13. Institutional and Project Budgets By Line Item, Years 4 - 8 (7/1/88 - 6/30/93)
($ 000)

	Estimated Expenditures Yrs. 1-3	Yr. 4	Yr. 5	Total Exp. Yrs. 1-5	Yr. 6	Yr. 7	Yrs. 8	Total Exp. Yrs. 6-8	Total Exp. Yrs. 1-8
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Programmatic Expenses									
UMCEES/UCR									
Multiple Species Fisheries Research									
Personnel	132.6	47.6	47.6	227.8	51.6	51.6	51.6	154.8	382.6
S&E	4.2	1.7	1.7	7.6	1.9	1.9	1.9	5.7	13.3
Travel	11.8	3.1	3.1	18.0	3.9	3.9	3.9	11.7	29.7
Equipment	.8	0.0	0.0	.8	0.0	0.0	0.0	0.0	.8
U.S. Subcontracts, MI.	91.3	35.0	35.0	161.3	21.1	21.1	21.1	63.3	224.6
HC Subcontracts, UCR	52.3	25.5	25.5	103.3	18.6	18.6	18.6	55.8	159.1
Indirect Costs	58.2	20.4	20.4	99.0	22.4	22.4	22.4	67.2	166.2
Total Costs	351.2	133.3	133.3	617.8	119.5	119.5	119.5	358.5	976.3
*Budgeted Match	99.1	26.9	26.9	152.9	24.3	24.3	24.3	72.9	225.8
UMCEES/UCR									
Economic & Probabilistic Extensions of Standard Fisheries Models									
Personnel	78.2	26.5	34.5	139.2	33.1	42.5	34.8	110.4	249.6
S&E	3.1	.5	.8	4.4	.8	.8	.8	2.4	6.8
Travel	12.0	3.1	3.1	18.2	3.5	3.5	3.5	10.5	28.7
Equipment	7.3	0.0	0.0	7.3	0.0	0.0	0.0	0.0	7.3
U.S. Subcontracts, DE.	27.9	8.3	0.0	36.2	0.0	0.0	0.0	0.0	36.2
HC Subcontracts, UCR	52.3	25.5	25.5	103.3	23.0	23.0	23.0	69.0	172.3
Indirect Costs	37.7	11.8	11.8	61.3	14.3	14.3	14.3	42.9	104.2
Total Costs	218.5	75.7	75.7	369.9	74.7	84.1	76.4	235.2	605.1
*Budgeted Match	51.2	14.3	14.3	79.8	18.9	18.9	18.9	56.7	136.5
UMCEES/UCR TOTAL									
U.S. University	465.1	158.0	158.0	781.1	152.6	162.0	154.3	468.9	1250.0
Host Country	104.6	51.0	51.0	206.6	41.6	41.6	41.6	124.8	331.4
Total UMCEES/UCR	569.7	209.0	209.0	987.7	194.2	203.6	195.9	593.7	1581.4
*Total Budgeted Match	150.3	41.2	41.2	232.7	43.2	43.2	43.2	129.6	362.3

Table 13. Institutional and Project Budgets By Line Item, Years 4 - 8 (7/1/88 - 6/30/93)
($ 000)

	Estimated Expenditures Yrs. 1-3	Yr. 4	Yr. 5	Total Exp. Yrs. 1-5	Yr. 6	Yr. 7	Yrs. 8	Total Exp. Yrs. 6-8	Total Exp. Yrs. 1-8
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Programmatic Expenses									
UW/UCR Sampling Catch									
Personnel	103.1	44.5	52.2	199.8					199.8
S&E	19.8	4.0	9.2	33.0					33.0
Travel	4.7	4.1	3.0	11.8					11.8
Equipment	6.9	0.0	0.0	6.9					6.9
U.S. Subcontracts, DE.	52.2	12.0	0.0	64.2					64.2
HC Subcontracts, UCR	37.3	26.3	29.9	93.5					93.5
Indirect Costs	42.0	19.2	15.8	77.0					77.0
Total Costs	266.0	110.1	110.1	486.2					486.2
*Budgeted Match	71.7	20.6	20.3	112.6					112.6
UW/UCR Age/Size Modeling									
Personnel	97.0	36.7	36.7	170.4					170.4
S&E	11.8	3.0	2.0	16.8					16.8
Travel	8.8	2.0	2.0	12.8					12.8
Equipment	4.9	0.0	0.0	4.9					4.9
U.S. Subcontracts	0.0	0.0	0.0	0.0					0.0
HC Subcontracts, UCR	22.6	19.6	21.5	63.7					63.7
Indirect Costs	48.0	16.5	16.6	81.1					81.1
Total Costs	193.1	77.8	78.8	349.7					349.7
*Budgeted Match	50.5	14.6	14.3	79.4					79.4
UW/UCR Age Determination									
Personnel	55.2	21.5	21.7	98.4					98.4
S&E	5.1	2.4	2.7	10.2					10.2
Travel	5.8	1.0	1.0	7.8					7.8
Equipment	4.3	0.0	0.0	4.3					4.3
U.S. Subcontracts	0.0	0.0	0.0	0.0					0.0
HC Subcontracts, UCR	14.0	3.5	4.6	22.1					22.1
Indirect Costs	27.6	9.4	9.5	46.5					46.5
Total Costs	112.0	37.8	39.5	189.3					189.3
*Budgeted Match	12.9	8.6	8.7	30.2					30.2

Table 13. Institutional and Project Budgets By Line Item, Years 4 - 8 (7/1/88 - 6/30/93)
($ 000)

	Estimated Expenditures Yrs. 1-3	Yr. 4	Yr. 5	Total Exp. Yrs. 1-5	Yr. 6	Yr. 7	Yrs. 8	Total Exp. Yrs. 6-8	Total Exp. Yrs. 1-8
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Programmatic Expenses									
UW/UCR Hydroacoustics									
Personnel	59.3	21.5	21.2	102.0					102.0
S&E	11.4	3.4	3.6	18.4					18.4
Travel	7.7	2.0	2.0	11.7					11.7
Equipment	0.0	0.0	0.0	0.0					0.0
U.S. Subcontracts	0.0	0.0	0.0	0.0					0.0
HC Subcontracts, UCR	17.8	5.2	6.9	29.9					29.9
Indirect Costs	27.8	8.4	8.7	44.9					44.9
Total Costs	124.0	40.5	42.4	206.9					206.9
*Budgeted Match	19.4	8.8	8.9	37.1					37.1
UW/UCR Assessment Sampling & Modeling									
Personnel					64.6	67.1	67.4	199.1	199.1
S&E					5.0	6.0	6.0	17.0	17.0
Travel					3.5	4.5	2.0	10.0	10.0
Equipment					2.5	2.5	1.0	6.0	6.0
U.S. Subcontracts					0.0	0.0	0.0	0.0	0.0
HC Subcontracts, UCR					26.6	26.6	26.6	79.8	79.8
Indirect Costs					33.9	35.9	34.2	104.0	104.0
Total Costs					136.1	142.6	137.2	415.9	415.9
*Match Contribution					27.0	28.5	27.1	82.6	82.6
UW/UCR Recruitment & Productivity									
Personnel					53.8	54.4	54.9	163.1	163.1
S&E					2.0	4.0	4.0	10.0	10.0
Travel					3.0	4.0	2.0	9.0	9.0
Equipment					2.5	2.5	1.0	6.0	6.0
U.S. Subcontracts					0.0	0.0	0.0	0.0	0.0
HC Subcontracts, UCR					21.8	21.8	21.8	65.4	65.4
Indirect Costs					28.2	29.9	28.5	86.6	86.6
Total Costs					111.3	116.6	112.2	340.1	340.1
*Budgeted Match					22.4	23.7	22.6	68.7	68.7
UW/UCR TOTAL									
U.S. University	603.4	211.6	207.9	1022.9	199.0	210.8	201.0	610.8	1633.7
Host Country	91.7	54.6	62.9	209.2	48.4	48.4	48.4	145.2	354.4
Total UW/UCR	695.1	266.2	270.8	1232.1	247.4	259.2	249.4	756.0	1988.1
*Total Budgeted Match	154.5	52.6	52.2	259.3	49.4	52.2	49.7	151.3	410.6

Table 13. Institutional and Project Budgets By Line Item, Years 4 - 8 (7/1/88 - 6/30/93)
($ 000)

	Estimated Expenditures Yrs. 1-3	Yr. 4	Yr. 5	Total Exp. Yrs. 1-5	Yr. 6	Yr. 7	Yrs. 8	Total Exp. Yrs. 6-8	Total Exp. Yrs. 1-8
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Programmatic Expenses									
URI/UPVCF									
Empirical Analyses and Modeling									
Personnel	83.7	64.7	66.1	214.5	48.9	52.2	51.0	152.1	366.6
S&E (U.S.)	18.9	11.0	9.9	39.8	7.1	9.0	9.1	25.2	65.0
S&E (Host Country)	0.0	0.0	0.0	0.0	4.5	8.1	0.0	12.6	12.6
Travel	26.2	5.5	3.8	35.5	6.0	6.5	5.0	17.5	53.0
Equipment	8.5	.5	0.0	9.0	3.6	.5	0.0	4.1	13.1
U.S. Subcontracts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HC Subcontracts	36.9	18.5	18.5	73.9	13.2	13.2	13.2	39.6	113.5
Indirect Costs	48.6	32.5	32.9	114.0	26.5	28.5	26.9	81.9	195.9
Total Costs	222.8	132.7	131.2	486.7	109.8	118.0	105.2	333.0	819.7
*Budgeted Match	41.5	28.7	24.4	94.6	26.3	28.3	30.4	85.0	179.6
URI/UPMSI									
Multispecies Field Studies									
Personnel	131.4	41.0	43.7	216.1	47.0	50.5	54.3	151.8	367.9
S&E (U.S.)	48.5	7.0	8.0	63.5	8.2	7.2	11.5	26.9	90.4
S&E (Host Country)	60.6	33.5	32.0	126.1	38.5	39.5	32.8	110.8	236.9
Travel	44.9	5.0	3.5	53.4	5.5	6.0	5.0	16.5	69.9
Equipment	4.6	0.0	0.0	4.6	1.5	0.0	0.0	1.5	6.1
U.S. Subcontracts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HC Subcontracts	91.1	17.5	17.5	126.1	12.0	12.0	12.0	36.0	162.1
Indirect Costs	91.2	21.9	22.7	135.8	25.2	26.3	28.9	80.4	216.2
Total Costs	472.3	125.9	127.4	725.6	137.9	141.5	144.5	423.9	1149.5
*Budgeted Match	103.5	28.7	24.4	156.6	26.3	28.3	30.4	85.0	241.6
URI/UP TOTAL									
U.S. University	506.5	189.1	190.6	886.2	179.5	186.7	191.7	557.9	1444.1
Host Country	188.6	69.5	68.0	326.1	68.2	72.8	58.0	199.0	525.1
Total URI/UP	695.1	258.6	258.6	1212.3	247.7	259.5	249.7	756.9	1969.2
*Budgeted Match	145.0	57.4	48.8	251.2	52.6	56.6	60.8	170.0	421.2

Table 13. Institutional and Project Budgets By Line Item, Years 4 - 8 (7/1/88 - 6/30/93)
($ 000)

	Estimated Expenditures Yrs. 1-3	Yr. 4	Yr. 5	Total Exp. Yrs. 1-5	Yr. 6	Yr. 7	Yrs. 8	Total Exp. Yrs. 6-8	Total Exp. Yrs. 1-8
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total Programmatic Expenses									
Personnel	740.5	304.0	323.7	1368.2	299.0	318.3	314.0	931.3	2299.5
S&E	103.0	33.0	37.9	193.7	25.0	28.9	33.3	87.2	280.9
Travel	117.2	25.8	21.5	169.2	25.4	28.4	21.4	75.2	244.4
Equipment	30.4	.5	0.0	37.8	10.1	5.5	2.0	17.6	55.4
U.S. Subcontracts	171.4	55.3	35.0	261.7	21.1	21.1	21.1	63.3	325.0
Host Country Expenses	384.9	175.1	181.9	741.9	158.2	162.8	148.0	469.0	1210.9
Indirect Costs	381.1	140.1	138.4	659.6	150.5	157.3	155.2	463.0	1122.6
Total Costs	1959.9	733.8	738.4	3432.1	689.3	722.3	695.0	2106.6	5538.7
*Budgeted Match	449.8	151.2	142.2	743.2	145.2	152.0	153.7	450.9	1194.1
Management Entity Expenses									
Personnel	164.9	56.9	59.5	281.3	54.7	57.5	60.4	172.6	453.9
S&E	44.6	16.0	28.6	89.2	14.1	14.4	24.6	53.1	142.3
Travel	45.5	39.9	24.7	110.1	42.0	15.5	21.7	79.2	189.3
Equipment	3.4	0.0	0.0	3.4	0.0	0.0	0.0	0.0	3.4
Indirect Costs	94.4	47.4	47.4	189.2	44.9	35.3	43.3	123.5	312.7
Total Costs	352.8	160.2	160.2	673.2	155.7	122.7	150.0	428.4	1101.6
*Off-Budget, Match	48.0	16.5	16.5	81.0	16.5	16.5	16.5	49.5	130.5
TOTAL U.S. UNIVERSITY	1575.0	558.7	556.5	2690.2	531.1	559.5	547.0	1637.6	4327.8
TOTAL HOST COUNTRY EXPENSES	384.9	175.1	181.9	741.9	158.2	162.8	148.0	469.0	1210.9
TOTAL PROGRAMMATIC EXPENSES	1959.9	733.8	738.4	3432.1	689.3	722.3	695.0	2106.6	5538.7
TOTAL MANAGEMENT ENTITY	352.8	160.2	160.2	673.2	155.7	122.7	150.0	428.4	1101.6
TOTAL AID FUNDING	2312.7	894.0	898.6	4105.3	845.0	845.0	845.0	2535.0	6640.3
TOTAL BUDGETED MATCH	449.8	151.2	142.2	743.2	145.2	152.0	153.7	450.9	1194.1
TOTAL AID + BUDGETED MATCH	2762.5	1045.2	1040.8	4848.5	990.2	997.0	998.7	2985.9	7834.4

IX. Project Overviews: Participating Institutions and Research Personnel

This final section presents the overviews of the several CRSP projects, highlighting the participating institutions and research personnel. The following summarizes the status of the CRSP research personnel which are listed by name and associated project and institution in the project overviews:

Table 14. CRSP Research Personnel

Research Position	United States	Host Country	Total
Scientists and Researchers	14	22	36
Research Assistants	14	11	25
Total	28	33	61

The 61 CRSP researchers tabulated above in Table 14 represent those contractually linked to CRSP efforts, and thus represent only a partial list of all those collaborating in the CRSP activities. The CRSP is an research network encompassing the efforts of many individuals and institutions, many of whom receive no compensation for their contributions to the CRSP. Many additional contributors are mentioned in Sections III-V earlier in this report. Furthermore, the 61 include only the current list of CRSP participants. Several researchers and research assistants have made short-term contributions to the CRSP efforts in the past. In addition, there are some administrative and technical support personnel (e.g., an ultralight aircraft mechanic and instructor on the URI/UP team) who are not included with the research personnel listed. It should be noted that only one individual, the URI on-site scientist at UP, is working full-time on the CRSP. Most of the scientists and researchers are receiving compensation for one or more months per year, and most of the research assistants are engaged on partial to half-time assistantships.

Several key scientists were dropped from the program early on, as the budget reductions began to have impact on the research efforts. Making substantial contributions to the CRSP in its early phases were Drs. Houde and Assad from the University of Maryland. In addition there were five U.S. research assistants who were unable to continue on CRSP activities due to budget reductions. Mainly, however, the budget reductions had their greatest impact by making it impossible to expand the research effort and associated personnel to the initially planned levels. And the financial constraints have particularly limited the CRSP contribution the training of host country personnel, since one of the principal mechanism for financing that training is by providing graduate research assistantships host country representatives studying for advanced degrees at the U.S. universities.

The dozen institutions in five countries listed in the following project overviews, similarly, represent only those formally linked to the CRSP. The list of institutions cooperating with the CRSP in one capacity or another is constantly growing as the research program matures.

Project Overview

Project Name: MULTIPLE SPECIES FISHERIES RESEARCH

Host Country: Costa Rica

Host Country Lead Institution: The University of Costa Rica (UCR-CIMAR)

Host Country Principal Investigator: Dr. Manuel M. Murillo (UCR-CIMAR)

Other Participating Host Country Institutions: Ministry of Agriculture

Host Country Associate Investigators: Dr. Jose Gracia (UCR)
Dr. Joseph Varilly (UCR)
Jorge Campos (UCR)
Eduardo Madrigal (Ministry of Agriculture)
J. C. Briceno (UCR)

United States Lead Institution: The University of Maryland-Center for Environmental and Estuarine Studies (UMCEES)

United States Principal Investigator: Dr. Brian J. Rothschild (UMCEES)

Other Participating U.S. Institutions: The University of Maryland-College Park-College of Business and Management (UMCP-CBM)
The University of Miami (UMiami)

United States Associate Investigators: Dr. Bruce Golden (UMCP-CBM)
Dr. William Fox (UMiami)

United States Research Assistants: Cluney Stagg (UMCEES)
Gerard DiNardo (UMCEES)
Doug Levy (UMCP-CBM)
Hiren Trivedi (UMCP-CBM)
Jerald S. Ault (UMiami)
David Die (UMiami)
Victor Restrepo (UMiami)
Steven G. Smith (UMCEES)

Research Locations: UMCEES, UMCP-CBM, UMiami, and UCR

Project Objective: To develop a better understanding of how multiple species fisheries influence the ecology and population dynamics of fish communities. Continued emphasis is placed on designing the components of CANOFISH, a decision support system with expert system features (DSS/ES), to study the population dynamics and management of small-scale multiple species fisheries.

Project Overview

Project Name: ECONOMIC AND PROBABILISTIC EXTENSIONS OF STANDARD FISHERY MODELS

Host Country: Costa Rica

Host Country Lead Institution: The University of Costa Rica (UCR-CIMAR)

Host Country Principal Investigator: Dr. Manuel M. Murillo (UCR-CIMAR)

Other Participating Host Country Institutions: Ministry of Agriculture

Host Country Associate Investigators: Dr. Edison de Faria (UCR)
Jorge Campos (UCR)
Dr. Edwin Castro (UCR)
Dr. Ricardo Estrada (UCR)
Eduardo Madrigal (Ministry of Agriculture)

United States Lead Institution: The University of Maryland-Center for Environmental and Estuarine Studies (UMCEES)

United States Principal Investigator: Dr. Brian J. Rothschild (UMCEES)

Other Participating U.S. Institutions: The University of Maryland-College Park-College of Business and Management (UMCP-CBM)
University of Delaware (UDelaware) (Through year 4 only)

United States Associate Investigator: Dr. Lee Anderson (UDelaware)

United States Research Assistants: Cluney Stagg (UMCEES)
Chris Rogers (UDelaware)
Yang Gru (UDelaware)
Steven G. Smith (UMCEES)

Research Locations: UMCEES, UMCP-CBM, UDelaware, and UCR

Project Objective: To modify standard fisheries models to increase their utility to managers of small-scale fisheries.

Project Overview

Project Name: SAMPLING CATCH AND ABUNDANCE

Host Country: Costa Rica

Host Country Lead Institution: University of Costa Rica (UCR-CIMAR)

Host Country Principal Investigator: Dr. Manuel M. Murillo (UCR-CIMAR)

Other Participating Host Country Institutions: Ministry of Agriculture

Host Country Associate Investigations: Juan Chavarria (UCR-CIMAR)
Eduardo Madrigal (Ministry of Agriculture)

United States Lead Institution: The University of Washington (UW)

United States Principle Investigator: Dr. Vincent F. Gallucci (UW)

Other Participating U.S. Institutions: The University of Delaware (UDelaware) (Through year 4 only)

United States Associate Investigators: Dr. Loveday Conquest (UW)
Dr. Lee Anderson (UDelaware)
Dr. Robert Donnelly (UW)

United States Research Associate: Robert Burr (UW)

United States Research Assistants: Shi Quan Liao (UW)
Jose Orensanz (UW)
Christopher Rogers (UDelaware)

Research Locations: UCR, UDelaware, and UW

Project Objectives:

To develop statistical sampling methodology for the assessment of tropical fish stocks exploited via artisanal fisheries. Artisanal fish catches have been sampled at the ports of landing as well as on the "vessels at sea." These activities will continue, in conjunction with analyses of the acquired data. New sampling methodology will be tried in light of the analyses. Sampling in the field independent of the artisanal fishing activity has started and will continue. This latter sampling will be conducted both independently of, and in conjunction with hydroacoustic estimates of abundance. New developments in sampling methodology will continue to be sought in order to improve stock assessment accuracy and efficiency. Sampling/assessment techniques will be integrated into a decision support system to assist tropical multispecies fisheries managers plan, execute and evaluate stock assessment sampling studies. An economics component (under Dr. Anderson) will continue to evaluate the utility of current stock and recruitment models for small-scale fisheries stock assessment and will develop new methodologies and economic extensions of these models to provide useful bioeconomic information.

Project Overview

Project Name: AGE-SIZE DEPENDENT/INDEPENDENT MODELING

Host Country: Costa Rica

Host Country Lead Institution: The University of Costa Rica (UCR-CIMAR)

Host Country Principal Investigator: Dr. Manuel M. Murillo (UCR-CIMAR)

Other Participating Host Country Institutions: None

Host Country Associate Investigators: Dr. Joseph Varilly (UCR-CIMAR)

United States Lead Institution: The University of Washington (UW)

United States Principal Investigator: Dr. Vincent F. Gallucci (UW)

Other Participating U.S. Institutions: None

United States Research Assistants: Han-Lin Lai (UW)
Jose Orensanz (UW)
Robert Burr (UW)

Research Locations: UCR and UW

Project Objectives:

To develop the framework, methodology and validation techniques for understanding and predicting the abundance and growth of selected fish and invertebrate stocks. Existing models will be examined and improved, once developed. Data from field experiments will be used to estimate parameters for models which are a basis for predicting productivity. Field experiments seek to estimate: 1) age/size distributions of stocks per species, 2) age/size specific rates of mortality, 3) fecundity, and 4) growth. The theoretical framework and software written for this component will integrate these estimates with data from other projects, to allow fishery managers to follow the status of an exploited fish stock and to predict the consequences of changes in a stock's environment (such as gill net mesh size, changes in effort, and shifts in alternative gears)

Project Overview

Project Name: AGE AND SIZE RELATIONSHIPS AND CONSEQUENCES OF ERRORS

Host Country: Costa Rica

Host Country Lead Institution: The University of Costa Rica (UCR-CIMAR)

Host Country Principal Investigator: Dr. Manuel M. Murillo (UCR-CIMAR)

Other Participating Host Country Institutions: None

Host Country Associate Investigator: Jorge Campos (UCR-CIMAR)

United States Lead Institution: The University of Washington (UW)

United States Principal Investigator: Dr. Vincent F. Gallucci (UW)

Other Participating U.S. Institutions: None

United States Associate Investigators: Dr. Han-Lin Lai (UW)

United States Research Assistants: None

Research Locations: UCR and UW

Project Objective:

1) To develop age determination methodology for tropical fish and invertebrates. 2) To develop an age-size relationship for the corvina-like species in the Gulf of Nicoya to construct age-size keys and thus to draw inferences about recruitment, growth, and mortality. 3) To develop an age determination laboratory at UCR that may later serve regional fishery agencies in Latin America. 4) To validate age determination techniques

Project Overview

Project Name: SHALLOW-WATER HYDROACOUSTICS

Host Country Lead Institution: The University of Costa Rica (UCR-CIMAR)

Host Country Principal Investigator: Dr. Manuel M. Murillo (UCR-CIMAR)

Other Participating Host Country Institutions: Ministry of Agriculture

Host Country Associate Investigator: Jorge Campos (UCR-CIMAR)

United States Lead Institution: The University of Washington (UW)

United States Principal Investigator: Dr. Richard E. Thorne (UW)

Other Participating U.S. Institutions: None

United States Research Assistants: John Hedgepeth

Research Locations: UCR and UW

Project Objectives:

To develop hydroacoustic fish assessment techniques for shallow-water, multispecies, environments such as the Gulf of Nicoya, Costa Rica. There are four aspects: 1) Determine the distribution, abundance and behavior of the corvina-like fishes, evaluating variables such as tidal, diel, location, seasonal and annual. Measurements will be taken on abundance, vertical distribution, and velocity of fish, as well as salinity and water currents. Dual stationary transducers will be used, one mounted at a slant angle on the bottom, the other deployed at the surface and mounted at 90 degrees. 2) Determine the effectiveness of artificial reefs in attracting fish. The same deployment techniques as above are used at three locations (on an artificial reef, adjacent to a reef, and a control). 3) Determine the efficiency of locally fished gill nets and other direct capture techniques. 4) Introduce the results of hydroacoustic estimation as auxiliary input for artisanal fisheries catch and stock assessment analysis.

Project Overview

Project Name: EMPIRICAL ANALYSES AND MODELING

Host Country: Philippines

Host Country Lead Institution:
College of Fisheries, The University of the Philippines in the Visayas (UPVCF)

Other Participating Host Country Institutions:
International Center for Living Aquatic Resources Management (ICLARM)
Bureau of Fisheries and Aquatic Resources (BFAR)
Marine Science Institute, The University of the Philippines (UPMSI)

Host Country Principal Investigator: Dr. Efren Ed. C. Flores (UPVCF)

Host Country Associate Investigators:
Dr. Daniel Pauly, Senior Scientist (ICLARM)
Dr. Sonia S. Formacion, Senior Scientist (UPVCF)
Prof. Geronimo T. Silvestre, M.S., Scientist (UPVCF)
Prof. Nygiel B. Armada, M.S., Scientist, (UPVCF)
Prof. Glenn D. Aguilar, M.S., Scientist, (UPVCF)
Mr. Victor C. Sambilay, Research Assistant, (UPVCF)
Ms. Joanna M. Rongo, Research Assistant, (UPVCF)

Other Participating Country Institutions:
Research Institute for Marine Fisheries of the Agency for Agricultural Research and Development, Republic of Indonesia (Dr. Nurzali Naamin, Director)
Division of Marine Fisheries of the Department of Fisheries, Thailand (Boonlert Phasuk, Director)

United States Lead Institution: The University of Rhode Island

United States Principal Investigator: Dr. Saul B. Saila (URI)

Other Participating U. S. Institutions: None

United States Associate Investigators:
Dr. Janet McLeavey, Scientist (URI)
Dr. John W. McManus, On-Site URI Scientist, Philippines
Dr. Conrad Recksiek, Scientist (URI)

United States Research Assistants:
Mr. Karim Erzini, M.S., Research Assistant II (URI)

Research Locations: UPVCF and URI

Project Objective:
To use existing fisheries data to contribute to the development of mathematical models and computer programs which address the relationship among harvest, fishing effort, species composition, and stability of tropical fish stocks. A major emphasis is on the analysis and prediction of catch composition.

Project Overview

Project Name: MULTISPECIES FIELD STUDIES

Host Country: Philippines

Host Country Lead Institution:
Marine Science Institute, The University of the Philippines (UPMSI)

Host Country Principal Investigator: Dr. Edgardo D. Gomez (UPMSI)

Other Participating Host Country Institutions:
International Center for Living Aquatic Resources Management (ICLARM),
Bureau of Fisheries and Aquatic Resources (BFAR), and
College of Fisheries, The University of the Philippines in the Visayas (UPVCF)

Host Country Associate Investigators:
Dr. Daniel Pauly, Senior Scientist (ICLARM)
Mr. Wilfredo L. Campos, M.S., Research Associate (UPMSI)
Ms. Annabelle G.C. del Norte, M.S., Senior Research Assistant (UPMSI)
Mr. Philip A. Roa, Senior Scientific Programmer (UPMSI)
Mr. Ruben C. Garcia, Senior Scientific Engineer (UPMSI)
Mr. Cleto L. Manola, Research Assistant (UPMSI)
Ms. Clarissa C. Arida, Research Assistant (UPMSI)
Ms. Mary Janeth P. Poot, Research Assistant (UPMSI)
Ms. Gemma Cecilia P. Yalung, Research Assistant (UPMSI)
Mr. Rodolfo Reyes Jr., Research Assistant (UPMSI)
Mr. Jerome P. Cabansag, Research Assistant (UPMSI)
Mr. Miguel P. Miguel, Research Aide (UPMSI)
Mr. Jesse Cabansag, Research Aide (UPMSI)

Also members of the U.S. AID/ASEAN Coastal Resources Management Project (CRMP) and the U.S. AID/Philippines Rainfed Resources Project are working collaboratively with the CRSP.

United States Lead Institution: The University of Rhode Island (URI)

United States Principal Investigator: Dr. Saul B. Saila (URI)

Other Participating U.S. Institutions: None

United States Associate Investigators:
Dr. John W. McManus, On-Site URI Scientist, Philippines
Dr. Conrad W. Reckseik, Scientist (URI)
Dr. Janet A. McLeavey, Senior Scientist (URI)

Research Locations: UP and URI

Project Objectives

1. To produce at end of the five-year CRSP one or more chapters in a book of methods for multispecies stock assessment, a summary of existing

methods for assessing and managing shallow water (principally coral reef) multispecies fisheries, in conjunction with methods tested and developed by our own research team.

2. To assess the impact of fishing pressure relative to other factors influencing the abundances and distributions of fish species across a heterogeneous coral reef system and the variations in a community structure over a three-year period.

3. To obtain general information as to the relationship between the catch composition yielded by each of several important small-scale fishing gears and the composition of the fish community being exploited.

4. To assess the relationship between catch composition, standing stock, and fishery production in a variety of shallow water fish habitats.

5. To determine to what extent the catch composition and fishery production of a coastline can be predicted from habitat information obtained from satellite imagery, aerial photographs from low-cost aircraft, chart information, bathymetry, and environmental parameters obtained from site sampling.

6. To disseminate this information to countries involved in multispecies fisheries management, including the United States and developing countries.

7. To develop within the host country collaborating institution the capability to continue independently to investigate and to refine the assessment and management approaches which are developed within the CRSP.

It should be noted that the personnel involved and the objectives of each project will undergo some alteration over the coming five years. Modifications in project objectives will be in accordance with the Objectives and Work Plans outlined in Sections III-V above. The most significant change in the projects will involve the reorganization of the UW projects.

Beginning in year six, the UW projects will be reorganized into two rather than the current four projects. A new Management and Stock Assessemnt Sampling Project will have the following objectives: The specification of a fishery management plan (FMP) for the Gulf of Nicoya, involving the use of CASA, length cohort analysis, bioeconomics, and effort regulation. Definition of new and appropriate criteria for biological reference points such as F(0.1), F(msy), etc., as criteria for setting harvest levels. A new Recruitment and Productivity Project will have the following objectives: Evaluation of the productivity and growth rates of selected species, especially on how rates are affected by environment and the prospect of developing an index of year-class strength. Investigation of the recruitment and fecundity processes and the relationships to growth and recruitment overfishing. The two new projects will involve the same personnel as are involved in the current four projects, but research priorities and funding allocations among components will be adjusted. Both new projects anticipate some interface with the University of the Philippines for testing of results developed in Costa Rica and for sharing CRSP research developments.