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FISHERIES STOCK ASSESSMENT

Title XII Collaborative Research Support Program

A Search for New Methods in Fisheries Stock Assessment

Program Overview

July 1, 1985 - June 30, 1990

FSA CRSP
Management Office
1109 Symons Hall
The University of Maryland
College Park, MD 20742

SUMMARY

Title XII Collaborative Research Support Program
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Program Overview

Rationale

Small scale fisheries are an important source of food and employment in many coastal regions of the world, and represent a significant source of protein for domestic consumption in developing countries. Fisheries stock assessment techniques employed by third world 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.

Goals and Objectives

The five-year USAID-funded Fisheries Stock Assessment CRSP will develop stock assessment methodologies for use by fisheries managers in developing countries. Specific objectives for this project include the following:

- o Production of a stock assessment handbook for fishery managers in tropical countries - a manual that will provide a guide for optimal fishery stock assessment and management.
- o Testing of existing methodology for stock assessment as it applies to tropical fisheries.
- o Development of new methodologies for stock assessment in tropical developing countries.
- o Development and testing of multispecies fishery assessment models.

Participating Institutions

The Fisheries Stock Assessment CRSP research program is managed by the University of Maryland-College Park. The research is being performed by the University of Maryland-Center for Environmental and Estuarine Studies, the University of Washington, the University of Rhode Island, and two host country institutions: the Universities of Costa Rica and the Philippines. Other participating institutions include the Universities of Delaware and Miami and the International Center for Living Aquatic Resources Management.

Intended Impact

Research projects at participating institutions will be coordinated toward the achievement of overall project objectives. Ultimately, results of this research will be applied to improve fishery management practices so that maximum benefits may be derived from fisheries resources in tropical developing countries.

TITLE XII COLLABORATIVE RESEARCH SUPPORT PROGRAM

A SEARCH FOR NEW METHODS IN FISHERIES STOCK ASSESSMENT

A PROGRAM OVERVIEW

July 1, 1985 - June 30, 1990

Program Rationale

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 40-50 percent of their protein consumption. In recent years 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, sometimes contributing to severe social problems. 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 application of standard approaches to fisheries management has not materially extended stock assessment knowledge in recent years. New methods of fisheries stock assessment are

needed. The five-year USAID-funded Title XII Fisheries Stock Assessment Collaborative Research Support Program (CRSP) is designed to improve fisheries stock assessment methodology, to provide stock assessment advice to fishery managers who operate under diverse conditions, and to train U.S. and host country scientists. This research project is particularly concerned with improving stock assessment methodology in small-scale single and multiple species tropical fisheries.

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 present make prediction and management difficult and sometimes counter-intuitive. 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 upon firm biological, field, and capture data. This 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 will extend fisheries stock assessment knowledge, methodologies and techniques to contribute to the development of effective management techniques for tropical small-scale fisheries. In addition to improving fisheries management in the developing countries, the research will contribute to improving fishing yields in the tropical and semi-tropical

environments along the coasts of Hawaii, southern California, and the Gulf of Mexico, as well as in the U.S. territories in the South Pacific and the Caribbean Basin. Improved stock assessment and management techniques will be applicable to other U.S. artisanal fisheries. Improved scientific understanding of fish ecology and viable management practices of multispecies fisheries will further the development of temperate fisheries sciences 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.

Goals and Objectives

The Fisheries Stock Assessment CRSP will develop stock assessment methodologies for use by fisheries managers in developing countries. Specific objectives for this project include the following:

- o Production of a stock assessment handbook for fishery managers in tropical countries - a manual that will provide a guide for optimal fishery stock assessment and management.
- o Testing of existing methodology for stock assessment as it applies to tropical fisheries.
- o Development of new methodologies for stock assessment in tropical developing countries.
- o Development and testing of multispecies fishery assessment models.

In the process of carrying out this research program, the CRSP will provide extensive training to U.S. and host country scientists and researchers, along with strengthening the host country fisheries research institutions in both Costa Rica and the Philippines. Specific efforts will be made to contribute to the development of a Latin America regional stock assessment research and training center in Costa Rica.

Participating Institutions

The Fisheries Stock Assessment CRSP research program will be managed by the University of Maryland-College Park. The research will be performed by the University of Maryland-Center for Environmental and Estuarine Studies, the University of Washington, the University of Rhode Island, and two host country institutions: the Universities of Costa Rica and the Philippines. Costa Rica will be the prime host country for the Universities of Maryland and Washington, and the Philippines will serve as primary host country for the University of Rhode Island. Additional research collaboration is being provided by the Universities of Delaware and Miami in Costa Rica and by the International Center for Living Aquatic Resources Management in the Philippines.

Program Description

The Fisheries Stock Assessment CRSP has been established to develop new methods in fisheries stock assessment. The research program is composed of the following eight interrelated projects:

- Multiple Species Fisheries Research
- Economic and Probabilistic Extensions of Standard Fishery Models
- Age and Size Dependent/Independent Modeling
- Sampling Catch and Abundance
- Age and Size Relationships and Consequences of Errors
- Shallow-Water Hydroacoustics
- Empirical Analyses and Modeling
- Multispecies Field Studies

Research projects at participating institutions will be coordinated toward the achievement of overall project objectives.

This research will be applied to improve fishery management practices so that maximum benefits may be derived from fisheries resources in tropical developing countries. The results of these projects will be incorporated into a stock assessment manual that will be usable by the local fisheries manager. Ideally, a fishery manager who has enough information to categorize the characteristics of a fishery will be able to select the stock assessment techniques in the manual which are most appropriate and most effective for managing such a fishery.

Each of the eight research projects is briefly described below.

MULTIPLE SPECIES FISHERIES RESEARCH

Principal U.S. Institution: University of Maryland-Center for Environmental and Estuarine Studies

Principal Host Country Institution: University of Costa Rica, Centro Investigacion en Ciencias del Mar y Limnologia

Other Participating U.S. Institutions: University of Miami
University of Maryland-College Park

Project Rationale

Although predictive understanding of marine fish populations is increasing, little is understood about biological community structure in general or about species interactions within the community. This is a critical problem in tropical small-scale fisheries where many species are fished simultaneously or where effort switches among species throughout the year.

Project Objective

The objective of this project is to develop an investigatory strategy that will lead to a better understanding of multiple species fisheries and how they relate to community and population dynamics. Emphasis is placed on designing the components of a decision support system, incorporating some expert system features, to study the population dynamics and management of tropical and subtropical multispecies fisheries.

Project Description

Addressing fishery/fish ecology problems requires a systematic and analytic study of what is known with respect to this

complex system. The research plan for accomplishing this involves both exploring the bounds of what can be learned about complex systems and systematically evaluating the current fisheries system to try to achieve a better understanding of the way the system works. This approach is expected to contribute to advancing stock assessment theory, particularly as it relates to variability in fish stocks, recruitment, natural mortality and multiple species interactions.

The project will design and develop a unique, canonical, fishery management system, which will be applicable to both small and large fisheries in single and multiple species contexts. The decision support system/expert system will explicitly link together sampling, optimization, and simulation techniques which are sometimes implemented independently. The linkages are developed from recent advances in artificial intelligence, primarily expert or consultation systems techniques.

The first task of this research project is to investigate system complexity. This will include an analysis of simple and complex ecosystems, systems architecture, problem definition and formulation of analytic approaches for these studies. Operations research methods will be employed, including artificial intelligence, expert systems and decision support systems, as well as the more conventional repertoire of management science techniques. An initial task will be to survey the wide range of applications of operations research to fisheries management, resulting in detailed synthesis and categorization of approaches. Based upon this first task, promising directions for further

research will be identified and evaluated mid-way through the project. Following a thorough evaluation process, several of these approaches will then be pursued during the remainder of the project.

ECONOMIC AND PROBABILISTIC EXTENSIONS OF STANDARD FISHING MODELS

Principal U.S. Institutions: University of Maryland-Center for Environmental and Estuarine Studies

Principal Host Country Institution: University of Costa Rica, Centro Investigacion en Ciencias del Mar y Limnologia

Other Participating U.S. Institutions: University of Delaware

Project Rationale

Standard fishery models are often criticized because they do not take into account important management questions that relate to the future state of exploited stocks. These questions often involve aspects of the multiple species nature of fisheries, the stochastic properties of fisheries, and the relationship of economic value to the catch size or the species composition.

Project Objective

The objective of this study is to extend standard fisheries models to increase their utility to managers of tropical small-scale fisheries.

Project Description

Emphasis will be placed on developing feasible techniques that have minimal information requirements. The multiple species nature of fisheries will be addressed by examining variability in recruitment and species interaction in terms of parameter definition and estimation. The stochastic properties of fisheries will be approached through the study of the empirical probabilities of

recruitment and production function. In developing economic extensions of currently available models, the utility of these models for small-scale fishery stock assessment will be evaluated. Where these models fail to be beneficial, new methodologies for providing useful bioeconomic information will be developed using a decision theoretic model.

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

Existing data and contextual information will be collected to support the initial modeling phase. Then, formal modeling efforts will be initiated. As a model is developed and tested, and as new data needs are discovered and areas in which inadequate data exist are exposed, data collection methods will be modified. These activities will continue through the life of the CRSP and will be developed in a collaborative mode by Costa Rican and United States researchers.

AGE AND SIZE DEPENDENT/INDEPENDENT MODELING

Principal U.S. Institution: University of Washington, School of Fisheries and Center for Quantitative Science

Principal Host Country Institution: University of Costa Rica, Centro Investigacion en Ciencias del Mar y Limnologia

Project Rationale

Management models are normally an integral part of fisheries management. Existing management models as applied in tropical fisheries, however, are much less successful than the same models applied to temperate zone fisheries. This is often said to be caused by the multispecies nature of tropical fisheries. The analyses proposed rest upon recognition that multispecies management modeling is still primitive and that, even in tropical environments, more progress may be made by judicious use of single species models. Another common explanation for the failure of management/assessment models in tropical fisheries centers on the reported quasi-continuous spawning of fish. These difficulties can be overcome to some extent by the appropriate choice of models, but guidelines on what can be accomplished, and at what cost in terms of data requirements, need to be formulated.

Project Objective

This project will first examine traditional single species fisheries models for their applicability to tropical small-scale fisheries. The aspects of the model that are useful will be combined with new formulations based explicitly on the biological

and harvest realities. Further, the research will develop a general framework, methodology, and validation techniques for understanding and predicting the abundance and growth of selected fish and invertebrate stocks in tropical environments.

Project Description

The project will examine single species models currently used for management and assessment for their applicability to tropical environments. The traditional single species management models have something to offer because they are the substance of existing fisheries management, which is most familiar, and because of the comparative value they bring. These models are of two types -- those where age or size is explicitly represented and those where it is implicitly present. The group of models where age, size, or growth is explicitly involved contain most of the new ideas, concepts and theories today, and thus even in temperate fisheries has only begun to receive extensive application. Within this group are models that require large amounts of detailed data and those which are readily applied without costly data collection. Usually, however, those requiring large amounts of data provide higher quality predictions. The trade-offs between costs of collecting a large amount of data and the potential costs of less refined management information will be evaluated. Trade-offs of one type of model for another will be evaluated.

The most straight forward and inexpensive models of the explicit type are those that use size rather than age. Some use has already been made of these to investigate recruitment and

spawning behavior in tropical waters. These models raise possibilities for new conceptual developments with associated mathematical and statistical analyses. Models that explicitly involve age or size can be discrete or continuous, and can deal with quasi-continuous spawning problems. Initial modeling efforts will be based on an age specific cohort model in current use which will provide a standard against which to judge new and currently known length-specific models.

Field experiments will 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 project 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 or in the harvest regime, such as gill net mesh size, changes in effort, etc.

Criteria will be developed for making value judgements about the optimal model to apply, from the simple to the biologically complex, and clear ways of predicting the costs of collecting the corresponding appropriate data will be developed and made accessible for LDC applications.

The interactive nature of the modeling between the biology, the mathematics, and the computers will continue over the duration of the project, requiring scientists from Costa Rica to come

to the University of Washington for collaborative work and training. Gradually, scientists from Costa Rica will take over the use of the management models.

SAMPLING CATCH AND ABUNDANCE

Principal U.S. Institution: University of Washington, School of Fisheries and Center for Quantitative Science

Principal Host Country Institution: University of Costa Rica, Centro Investigacion en Ciencias del Mar y Limnologia

Other Participating U.S. Institutions: University of Delaware

Project Rationale

Catch and effort information is critical in stock assessments for estimating fishing mortality and variations in abundance, as well as for providing management advice. The vast number of fishermen in small-scale fisheries and the difficulties associated in contacting them make it especially difficult to collect this information. Standard sampling designs usually will not provide the level of precision necessary for management. Therefore, new designs taking into account the realities of artisanal fisheries need to be developed. Furthermore, the concepts of decision theory need to be investigated as a means of utilizing whatever information can be collected.

Project Objective

This project will undertake a comprehensive field study for sampling tropical small-scale fisheries. Appropriate existing data and the information collected in this and other Fisheries Stock Assessment CRSP projects will be used to design a monitoring program which will provide host country scientists with the kinds of catch and effort data needed to manage the fisheries.

Project Description

The field study for sampling tropical small-scale fisheries has two components. The first component is a dockside sampling program to address: (1) the selection and statistical weighting of ports and vessels to be sampled, (2) the temporal distribution of sampling, (3) the selection of samples from the catch (animals), (4) specification of sampling rates, (5) the derivation of a system to estimate the cost, precision, and accuracy of the sampling program a priori, and (6) the investigation of several different sampling methods to estimate catch and effort from large stretches of coastline. The second component in field sampling will help determine what is available to be caught in contrast to what the fisheries are catching.

These two components will be used as the basis for developing new sampling designs and a decision theoretic framework to enable a manager to deal with low quality sample data. Such data in combination with experience with the fishery will facilitate management decision making. The principles of decision theory will provide a new context in which to view situations where a management plan contains elements that are the "best guess."

The methodology being developed will allow for improvements in sampling designs using Bayesian and decision theoretic techniques. Statistical analyses and computations will have aspects of an expert system software package for transfer to Costa Rica. An economics component of this project will evaluate the utility of current stock and recruitment models for small-scale fisheries

stock assessment and develop economic extensions of these models to provide essential bioeconomic information.

The sampling programs will begin in year one and continue over the life of the project. Costa Rican personnel will visit the University of Washington for training, and the entire program will eventually be taken over by host country statisticians and scientists.

AGE AND SIZE RELATIONSHIPS AND CONSEQUENCES OF ERRORS

Principal U.S. Institution: University of Washington, School of Fisheries and Center for Quantitative Science

Principal Host Country Institutions: University of Costa Rica, Centro Investigacion en Ciencias del Mar y Limnologia

Project Rationale

Age determination of tropical fish is a difficult and imprecise process because growth typically does not follow the regular seasonal patterns that characterize fish growth in temperate zones. The degree to which assessment biologists in the developing countries will be able to make use of relationships that exist between age and mortality rates depends upon their ability to reliably age fish in their region. The inability to consistently separate the mature from the less fecund ages contributes to an inability to recognize overfishing before it is in an advanced condition. The results of an increased capability to age fish and to relate age and the distribution of length will be integrated with the age explicit modeling in the Age and Size Dependent/Independent Modeling Project.

Project Objective

This project will develop methods of ageing tropical fish species based on new techniques, as well as on the extrapolation of techniques used in temperate zones. The project will develop age and size relationships for various species to construct age-

size keys to draw inferences about recruitment, growth, and mortality. Efforts will contribute to the development of an age determination laboratory at the University of Costa Rica that may later serve regional fishery agencies in Central and Latin America.

Project Description

This study will focus on the following approach to ageing tropical fish species: (1) Techniques currently used in the temperate zone will be explored for their applicability to tropical species. (2) New methods of age determination will be sought and validated. (3) Indirect methods of estimating age and size specific natural mortality coefficients from age and size composition data will be explored.

Age and size relationships will be developed for the corvina-like species in the Costa Rican Gulf of Nicoya to construct age-size keys for drawing inferences about recruitment, growth, and mortality.

During the first part of the investigation, research will focus on Costa Rica. During the final phases of the project, opportunities to test methodologies in the Philippines will be explored.

SHALLOW-WATER HYDROACOUSTICS

Principal U.S. Institution: University of Washington, School of Fisheries and Center for Quantitative Science

Principal Host Country Institutions: University of Costa Rica, Centro Investigacion en Ciencias del Mar y Limnologia

Project Rationale

The stock assessment information necessary to manage a commercial fishery can be obtained by two general approaches. One approach is to rely on analysis of catch and effort statistics from the commercial fishery itself; the other is through direct measurement by means of hydroacoustics or direct capture gear. Hydroacoustics has the highest sampling power and the lowest cost of all direct population assessment techniques. It is usually employed in conjunction with direct capture techniques (trawls, nets, traps) for species identification. However, hydroacoustics techniques are not well developed for shallow-water or multispecies environments.

Project Objective

This project will develop methods of rapidly assessing the population size of fish stocks in shallow-water multispecies environments based on hydroacoustic (echo location) techniques.

Project Description

Comparisons of population abundance estimates will be made between hydroacoustic techniques and (1) assessment techniques traditionally used by scientists in the collaborating countries,

(2) other direct capture techniques appropriate for particular environments, and (3) the actual artisanal catch. The first step is to work with the scientists of the collaborating host country to demonstrate the hydroacoustic techniques and compare results with extant assessment methods. This will be followed by experimentation with additional techniques that have been successful in shallow-water environments. Finally, since a considerable portion of the overall CRSP program will deal with catch data of the artisanal fisheries themselves, this project will work closely with other projects in the research program to compare the hydroacoustic observations with the corresponding fishery data.

The results of hydroacoutsic estimation will be introduced as auxiliary input for artisanal fisheries catch and assessment analysis.

Efforts in the first four years will include exploratory field studies and comparisons with other fishery data in Costa Rica. The models developed in the Costa Rican situation will be tested in the Philippines in the final phases of the project.

EMPIRICAL ANALYSES AND MODELING

Principal U.S. Institution: University of Rhode Island, Graduate School of Oceanography and School of Resource Development

Principal Host Country Institution: University of the Philippines, College of Fisheries, Visayas

Other Participating Host Country Institutions: International Center for Living Aquatic Resources Management and Bureau of Fisheries and Aquatic Resources

Project Rationale

A very important and as yet poorly understood problem in tropical fishery stock assessment involves a determination of the quantitative relationships among yields, effort and species composition for multispecies fisheries.

Project Objective

The objective of the Empirical Analysis and Modeling Project is to contribute to the development of relatively simple stock assessment models and computer programs which address relationships among yield, fishing effort, species composition, and stability, and which can be effectively tested and evaluated.

Project Description

The methodology for this project consists of a strategy for analyzing distribution patterns (in time and space) of demersal fish assemblages in the Sunda Shelf region of Southeast Asia. The results of the distribution analysis will be correlated with

environmental and fisheries data in an effort to develop alternate multispecies assessment techniques and to provide an understanding of the basic causal mechanisms for changes in relative species composition. A simple predictive model for this mixed species fishery will be developed, as will a complementary package of user-friendly fisheries programs to aid in the analysis of tropical multispecies fisheries. These models will be based on existing and ongoing demersal fisheries surveys in the Philippines, Thailand, Malaysia, and Indonesia.

The first stage of this project will consist of gathering and entering existing survey data on microcomputer diskettes and formulating a data management system. Stage two will be devoted to running classification and ordination analyses. In stage three, the environmental data base will be developed and tested for associations with species groups. During the final phases of the project, practical operating empirical models will be developed, field testing of the models will be conducted, user-friendly microcomputer programs to facilitate the use of the models will be developed, and the transfer of technology will take place.

MULTISPECIES FIELD STUDIES

Principal U.S. Institution: University of Rhode Island, Graduate School of Oceanography and School of Resource Development

Principal Host Country Institution: University of the Philippines, Marine Science Institute, Diliman

Other Participating Host Country Institutions: International Center for Living and Aquatic Resources Management and Bureau of Fisheries and Aquatic Resources

Project Rationale

Because coralline areas are highly productive and often easily accessible fishing grounds, they are especially critical to small-scale fisheries, single-person boat operators, and food-gatherers. Hence, these areas provide a protein source for a large segment of the population for which no realistic alternative sources exist. The need to understand the population dynamics of fish in both coralline and non-coralline shoreline areas is critical because of the importance of the fisheries to developing country coastal regions throughout the world.

Project Objectives

The two general objectives of this field project are (1) to develop and validate techniques for the estimation of fishery productivity in reef and shore-line fisheries, and (2) to apply the resultant methodology to the estimation of fishery potential within the study area.

Project Description

Several approaches to attaining these objectives will be taken. Visual assessments will be made to determine the composition and variability of the fish communities. In addition fish trapping will be undertaken to supplement existing information on the fish community and to assess the limitation of trap sampling and harvesting, as well as that of gill net and beach seine sampling for non-reef shore-line fishery analysis.

Specialized techniques will be developed to tag reef and non-reef fishes with a view toward establishing home ranges, and growth, mortality and recruitment parameters. Protocols for establishing long-term monitoring and sampling sites will be established. Attempts will be made to assess recruitment dynamics through field experiments.

Efforts will be made to develop objective methods for effectively reducing some of the complexities of multispecies fisheries data to permit further analysis and interpretation.

The validation of visual, trap and shoreline sampling techniques will be done during the first year. During the remaining four years, community monitoring of reef and non-reef areas will take place.

MANAGEMENT STRUCTURE

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