

## Tuna Research in the 1980's<sup>1,2</sup>

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Tuna-research requirements are changing. Past research was oriented toward classic population dynamics models. More recent research has tended to be oriented toward rectifying deficiencies in the classic models. Future research will need to focus on decision-theoretic models, especially probabilistic aspects of problems relating to: 1) homogeneity of stocks and fishery grounds, 2) growth, 3) natural mortality, 4) fishing mortality, 5) variable spawning-time age-independent models, 6) recruitment, 7) economics, 8) the relation between tunas and the oceanic environment, 9) integration, and 10) asking the right questions.

La demande en recherches thonnières évolue. Celles-ci étaient auparavant orientées vers les modèles classiques de dynamique des populations. Les recherches plus récentes tendent à corriger les lacunes des modèles classiques. Celles de l'avenir devront être axées sur les modèles théoriques de décision, en particulier sur les aspects probabilistes des problèmes concernant: 1) homonégénéité des stocks et lieux de pêche, 2) croissance, 3) mortalité naturelle, 4) mortalité par pêche, 5) modèles indépendents de l'âge et d'une époque variable de ponte, 6) recrutement, 7) considérations économiques, 8) relation entre thonidés et milieu océanique, 9) intégration, et 10) formulation des questions pertinentes.

La investigación sobre túnidos está evolucionando. En el pasado, se orientaba hacia modelos clásicos de dinámica de poblaciones. Recientemente tiende a buscar la rectificación de las deficiencias en los modelos clásicos. En el futuro tendrá que concentrarse sobre modelos teóricos de decisión, en especial sobre aspectos probabilísticos de los problemas relacionados con: 1) homogeneidad de stocks y caladeros, 2) crecimiento, 3) mortalidad natural, 4) mortalidad por pesca, 5) modelos independientes de la edad y de la variabilidad de la época de desove, 6) reclutamiento, 7) aspectos económicos, 8) la relación entre los túnidos y el medio ambiente oceánico, 9) integración y, 10) planteamiento de las cuestiones pertinentes.

### 1. Introduction

Improved tuna management, a goal of fishermen, fish-processors, and public-sector representatives requires a better conceptual understanding of tuna abundance, distribution, and fishing mortality and careful attention to the quality of fishery statistics. These are key topics in tuna research. In my talk this morning, I should like to consider how tuna research might be improved, not so much with regard to specific research details, but rather with regard to new directions required by extended jurisdictions, stabilization of tuna landings, and increased costs. To develop a perspective on this topic it is important to appreciate the nature of changing requirements for research. These changing requirements might be understood best by placing the question of scientific advice for managers in a historical perspective, before considering the development of new approaches to tuna research, and problems of specific importance.

### 2. Historical Perspective and Changing Requirements

Changing requirements for scientific advice for fishery management may be deduced from the classification scheme in Table 1. Past approaches were "relatively precise" involving well-defined models such as yield-per-recruit and stock-and-recruitment. Contemporary approaches while retaining concepts such as yield-per-recruit and stock-and-recruitment have tended to relate to concepts such as "optimum yield" and "ecosystem management"

which are difficult to define. Future activities need to be more responsive to management and directed toward dual goals of a) establishing conditions under which management can thrive and b) generating analyses that provide decision makers with information on the consequences of their decisions.

Transitions among the past, contemporary, and future approaches are discussed in terms of 1) the fifties and early sixties; 2) the early 1970's; and 3) the late 1970's.

#### 2.1 THE FIFTIES AND EARLY SIXTIES

In the 1950's fishery-management activity concerned itself with setting over-all quotas for catch and minimum-sizes or ages of fish in the catch.

The development of the production model and the yield-per-recruit model led to seemingly easy quantification of the effects of fishing. In addition, various forms of the stock-and-recruitment models became increasingly popular, but data often exhibited considerable variability and the models were not particularly useful for prediction, particularly of stock collapses. An intense interest in environmental varia-

<sup>1</sup> One of two keynote addresses at the conference on the International Skipjack Year Program.

<sup>2</sup> Parts of this address were drawn from "An Agenda for Tuna Research in the 1980's" by B.J. Rothschild, ms.

Table 1. Past, contemporary and future approaches to giving advice to managers.

PAST (Relatively Precise)	MORE OR LESS CONTEMPORARY (Difficult to Define)	FUTURE (Responsive to Mgmt.)
<ul style="list-style-type: none"> <li>• Yield-per-recruit</li> <li>• Stock and recruitment setting —</li> <li>• Production including MSY</li> </ul>	<ul style="list-style-type: none"> <li>• Optimum yield</li> <li>• Ecosystem management</li> <li>• Extensive ill-defined data requirements</li> <li>• Multiple species</li> <li>• Preventing stock collapse</li> <li>• Effort limitation</li> <li>• Health of ecosystem and stress</li> <li>• Rehabilitation</li> <li>• Even more environmental correlations</li> </ul>	<p>A. Socio-economic</p> <p>considering conditions necessary for management</p> <p>B. Quantitative technical analysis to support decision making under A. These include consideration in a decision theoretic framework:</p> <ul style="list-style-type: none"> <li>— states of nature</li> <li>— alternative actions</li> <li>— metrics of performance</li> <li>— discount rates</li> <li>— utility</li> <li>— hypotheses on population dynamics and economics</li> <li>— planning horizons</li> </ul>

bles resulted in the development of various environmental correlations, generally of little value for prediction. Economic analyses of fishing were initiated with the development of simple fixed-price cost and revenue curves, and the notion that limiting entry into a fishery would serve to maximize economic rent.

In sum, management in the 1950's was relatively simple, the models were not complex; they developed simple equations from simple assumptions. Complex issues of interspecific interaction and the dynamic behavior of fish populations were avoided, but there seemed to be relatively few problems at least when compared to the contemporary fishery management scene.

## 2.2 THE EARLY 1970's

The computer era came into being in the early 1970's. Before computers were generally available to fisheries scientists, only a dozen years ago, computations which are now routine and take a few minutes, if that, of computer time, were virtually impossible to undertake on a routine basis. In addition, computers led to easy generalization of simple population-dynamics models, such as the generalization of pro-

duction models and the development of yield isopleths with age or size-specific fishing mortality.

Much of the work concentrated on computation. Because of this, collection of basic biological data suffered and even though models were more general and more flexible, they added little incremental understanding to the workings of the fish/fishery system. In brief, the mathematical generalizations did little to improve the conceptual basis of fishery dynamics.

## 2.3 THE LATE 1970's

By the late 1970's, the limitation of the simple models and their generalizations was recognized and managers and observers of the fishery management scene, with new optimism and management authority enhanced by extended jurisdiction attempted to be responsive to increasing necessity for management. But there were many complications. Fishing intensity increased on many of the stocks and this and the changed allocation schemes resulting from the application of management measures required stricter and more detailed regulation, often causing a politicization of the scientific process. (We saw this with Atlantic bluefin tuna, for example). As part of this politicization, Fishery Science became captured by clichés such as "optimum yield", "ecosystem management", "multiple-species management", "prevention of stock collapse", "health-of the ecosystem" and "environmental rehabilitation", just to name a few. It was not uncommon, indeed, for the public in many parts of the world to think of each major body of water in terms of its "health" and whether or not it was "dying".

The notions of the 1970's such as optimum yield and ecosystem management were difficult to put into practice because they were ill-defined, despite the well-directed idealism and good intentions of their proponents. The era of intense environmental concern served to broaden the questions asked about stock dynamics. Still little was added to understanding the fish/fishery system.

## 2.4 THE FUTURE

Thus we enter into the 1980's armed with the hindsight that the mathematical approaches were too specialized, the computer approaches lacked empirical and conceptual validation, and that the environmental approaches were too poorly defined to be operationally useful.

The historical perspective that evolves from these hindights is that the approaches of the 1950's,

1960's and 1970's had limited utility, because they did not develop information central to the needs of decision makers — the administrators and managers responsible for making public-sector decisions on fishery-resource management.

In contrast, it is now becoming increasingly clear in the 1980's that the fishery-research community will need to be more responsive to the needs of managers. To begin this process it is essential for administrators and scientists to have a common view of the nature of the fishery management problem. This common view needs to consider both management institutions and information required for management (see Rothschild 1983). The institutional question referring to the political, legal, social and economic settings for management is important because it defines in broad terms what managers can and cannot do (e.g. open access vs. limited entry). The information question is important because for any particular institutional setting, the quality and quantity of information often sets bounds on the effectiveness of the management process. In addition, the quality and quantity of management-relevant information can influence society to change the fundamental nature of the management process from a less desirable institutional setting to a more desirable institutional setting.

The linkage between the institutional setting and the quality of management information thus lies at the heart of improving the management process. A study of the management-process improvement requires a theoretical basis for identifying the kinds of research most appropriate to management and the information requirements that would support such research. Because this management process is essentially a decision-making process, decision analysis can provide this basis. In other words, decision analysis provides the fundamental model for linking management institutions and the research function of information development.

Details on the general structure of decisions analysis is beyond the scope of this talk but the development of more modern fisheries management questions can be inferred from the study of even a simple decision-analysis "tree" such as that in Figure 1. Examples are, a) what is the probability of a good year class or poor year class, b) what is the probability that any particular research strategy will predict or detect a good versus a poor year class and c) how valuable is a correct as opposed to incorrect decision on year class strength?

What is important about the decision-analysis approach is that we can specify not only the decisions that can be made, but their value as well. We can also see that while the traditional analysis of stock and recruitment, yield per recruit, and production models

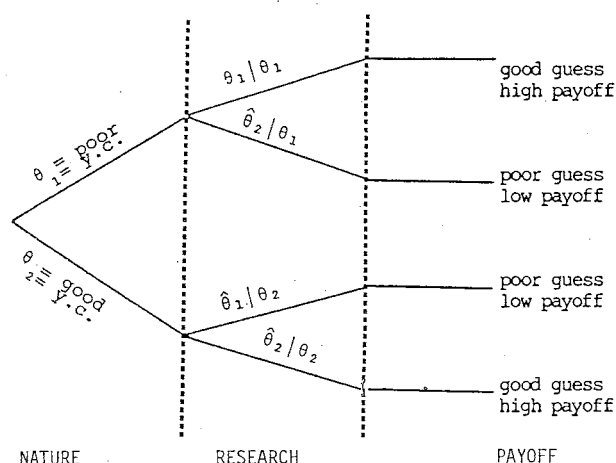


Figure 1. Structure of a decision-analysis problem using a simple hypothetical decision tree segmented into actions by nature ( $\theta$ ); decisions emanating from research ( $\hat{\theta}_i|\theta_j$ ); and payoffs. To utilize a decision theoretic approach information is required on States of Nature  $\theta$ ; alternative management actions; metrics for measuring performance; discount rates; measures of utility; hypotheses on how the system works; and a planning horizon (see Rothschild and Heimbuch 1983).

remain valid, new information is needed on a) *probability of various events* (such as levels of production of the probabilities of particular yield-per-recruit isopleths), b) *economic consequences of various decisions*, and c) *specification of actual management alternatives*.

### 3. The Development of New Approaches to Tuna Research

The decision model thus sets the framework for examining research questions. It is important to note that new approaches may mean simply changes in emphasis or direction, as well as the development of completely new ideas.

As I see it, the tuna research in the 1980's will be focused on management, that is the set of decisions made by the public sector. It will be oriented toward making more efficient use of the stocks that we already fish, and it will be oriented toward finding new stocks and new methodologies for fishing.

The more efficient uses will come from a more finely tuned analysis of stock dynamics and management; that is analyses which concentrate on variability rather than averages so that management decisions can relate and possibly take advantage of temporal-spatial stock variability. Attainment of more finely-tuned management will require reexamination of the entire production process. This may sound like a simple or casual observation, but it is not.

This is because what is required is not simply a reanalysis of the factors of production — growth,

mortality and recruitment, but rather an examination of these factors in the context of decision analysis. This will necessarily involve examining *growth*, *mortality*, and *recruitment* in the context of their probability distributions, as well as considering the economic value generated by various research approaches. Considering the reevaluation of the contextual basis of traditional techniques in a decision-theory setting can improve information supplied to managers, reduce risk, and therefore increase the imputed value of the resources.

An important consideration in estimates of biological parameters in tuna stocks and placing these estimates in the context of decision theory is the fact that tuna stocks are distributed over vast areas of the ocean and any single estimate of production is an average over this large area. Since it is unlikely that fish move infinitely fast or that the fishery always takes representative sample of the stocks, then any spatial shift in the character of the stock or the velocities of fish in the stock will result in estimates which are based upon a varying and unknown averaging processes. This averaging process both contributes to and masks variability in estimates. This variability which may be either increased or masked needs to be identified if the components of tuna-biomass production are to be understood. This observation provides a context for specific research problems.

#### 4. Specific Research Problems

In order to improve information for management, I can envision consideration of ten elements important to developing contemporary tuna research strategy.

1. *Homogeneity of stocks and fishery grounds*: Studies need to be developed on the affect of fish movement and distribution on estimates of population-dynamics parameters. The study of homogeneity with respect to growth mortality and recruitment in tuna stocks is one of the critical prerequisites to understanding the affects of fishing on tuna stocks.

2. *Growth*: Growth is usually taken to be a simple function of age. It is further generally assumed that growth is constant over all years and all population levels. While biomass dynamics might not be always sensitive to average growth, sensitivity to variability in growth may be an important factor to attain optimum harvest strategies. Therefore, management strategies need to be examined to determine whether growth variability, if it exists, is important and if it is, how it can be measured. This is not a particularly simple task since it is likely that before variability in growth can be understood, it will first be necessary to investigate the linkage of growth with the evidently extensive spawning period characteristic of many

tuna populations. This suggests more intensive studies on not only growth but time of spawning as well.

3. *Natural mortality*: Natural mortality is one of the more difficult parameters to estimate. In addition, in tunas, it is difficult to conceptualize the mechanisms of mortality in the sense that mortality rate of large tuna may owe more to senescence than to predation, in contrast to fishes that do not attain a large ultimate size. Natural mortality is in a sense interchangeable with growth in affecting yield; therefore our understanding of natural mortality may be a weak link in our understanding of population dynamics theory. It is unlikely that conventional estimators of natural mortality can be improved, but what can be studied are conceptual models on natural mortality particularly involving the extent of predation on large tunas and senescence.

4. *Fishing mortality*: Although fishing mortality might be estimated by fishery-independent means it is still necessary to appreciate the extent to which the operation of the fleet is capable of inducing fishing mortality. This is important because the fleet is the major variable controlled by management and future management is likely to require advance information on the likely time-space distribution of fishing mortality. This will require the development of synthetic models of fishing mortality in which conventional linear model analysis of fishing power is combined with operations-research studies on the time dependent behavior of the fleet to forecast fishing mortality.

5. *Variable spawning-time age-independent models*: A considerable body of theory is based upon knowing the age of the fish. The age of most tunas is difficult to determine and the problem is made even more complicated because of frequent spawning. Therefore, it might be useful to develop yield-per-recruit models and stock-and-recruitment models which do not depend on specific knowledge of age or spawning time. As a first step the sensitivity of existing models to age and spawning time information needs to be explored.

6. *Recruitment*: Variability in recruitment for most tuna species is generally less than in most fish stocks. Is this variability homogenously low or does it result from an averaging process over the spatial-temporal distributions of tuna spawning? Because the variability is low, perhaps it is not important, an assertion which could be tested by use of various decision-theoretic models.

7. *Economics*: If information for managers is placed in a decision-theoretic setting, then it is necessary to obtain information on the values or payoffs associated with various decisions.

8. *The relation between tunas and the oceanic environment:* There are numerous correlations between the distribution and abundance of tunas and the oceanic environment, but to what extent can these correlations be used as predictions? It is clear that one of the problems in developing predictions is the long sequence of events between the apparent cause, and the effect of interest (e.g. if we attempted to account for the chain: wind strength → primary production and drift → successful hatching → larval nutrition → larval predation → recruitment simply by examining the linkage between wind strength and recruitment). In order to reduce the extensive dimensionality of the problem it will be necessary to study much shorter causal chains (e.g. the study of larval tuna nutrition).

9. *Integration:* All management results in an allocation. It is a goal of society to have a "good" allocation. A theoretical framework is needed to evaluate the quality of allocations and the sensitivities of allocations to modifications in either the objectives or the constraints of allocation. Allocation models which are well known in the literature would, therefore, be useful to evaluate the "goodness" of various allocation schemes; to provide advice on the sensitivity of an

optimal allocation to changes in values or constraints; to serve as guidance toward appropriate data to collect for management purposes; and to serve as an *integrative force* for assembly of concepts and information on tuna stocks and tuna fisheries. Emphasis needs to be continually placed upon the notion that studies on allocations are not intended to replace the political allocation process. Rather, they are intended to provide guidance to those charged with the responsibility to allocate.

10. *Asking the right questions:* Fisheries research, as any research, can move in either profitable or unprofitable directions. To minimize the latter, it is necessary to continually monitor and review its status and to consider whether the right questions are indeed being addressed. Various forums on strategic questions in tuna research need to be nurtured and new ones created where necessary.

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