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EVALUATING TUNA MANAGEMENT IN THE EASTERN PACIFIC OCEAN

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ABSTRACT

We answer four questions about tuna management in the eastern Pacific Ocean: What are the management objectives? Are they reasonable? Can we determine whether they have been achieved? Have they been achieved? There are explicit, overarching management objectives including keeping populations at levels that will permit maximum sustainable yields, consideration of the precautionary approach, and consideration of ecosystem consequences, but although reasonable, these objectives are vague from a stock-assessment perspective. Objectives of individual participants are unlikely to be the same and collectively make achieving the overarching objectives more difficult. For data-rich stocks, we can determine whether the yield-based objectives have been achieved, but even these results have alternative interpretations. Unfortunately, when data are limited, the management objectives cannot be evaluated. In the eastern Pacific, species differ in achievement of objectives. Yield-based objectives are probably being achieved for yellowfin tuna—yields may increase if effort is reallocated among fishing methods—whereas for bigeye tuna, biomass levels are falling below that necessary for maximum sustainable yield. For skipjack, although the population level is healthy, restrictions designed to protect bigeye and yellowfin tuna prevent fishermen from achieving maximum sustainable yield. By-catch of other species in the tuna fisheries is a management concern.

The status and management of large pelagic fish populations worldwide is causing concern (Pauly et al., 1998; Jackson et al., 2001; Baum et al., 2003; Myers and Worm, 2003). On the basis of a meta-analysis, Myers and Worm (2003) estimated that biomass of large predatory fish today is only about 10% of preindustrial levels, but their work is highly controversial, and they have been charged with selective use of data and use of inappropriate assumptions (Walters, 2003; Hampton et al., 2005; Polacheck, in press). Similar criticism has been directed at the other studies (e.g., by Burgess et al., 2005). Despite the controversy, evaluation of the management of large pelagics is important; it will identify areas of improvements and allow a continued sustainable and beneficial use of the resource. Here, we discuss an approach to evaluating management of tuna stocks and apply it to the stocks in the eastern Pacific Ocean (EPO).

To evaluate management of tunas, we address four questions: What are the management objectives? Are they reasonable? Can we determine whether they have been achieved? Have they been achieved? The final question is discussed only in the specific case of the management of tunas in the EPO. We answer these questions from our perspective as stock assessment scientists, so economic and social issues, although important, are given only cursory treatment.

The Tuna Fisheries in the EPO

Tuna are fished in the EPO by vessels of many nations and by various fishing methods (Table 1). The majority of catch is taken by longlines—used by Japan (Okamoto and Bayliff, 2003), the Republic of Korea, Chinese Taipei, and the Peoples Republic

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Table 1. Characteristics of major fishing methods for tunas in the eastern Pacific Ocean.

Fishing method	Tuna catch	By-catch	Countries	Current management measures
Longline	Large bigeye and yellowfin tunas, albacore tuna	Billfish, sharks, turtles, seabirds	Japan, Republic of Korea, Chinese Taipei, Peoples Republic of China	Catch limits for bigeye tuna
Purse seine, floating objects	Skipjack tuna, small bigeye, and yellowfin tunas	Various species	Central and South American nations, European Union	Temporal closure
Purse seine, free-swimming schools	Skipjack, small to medium yellowfin tuna	Various species	Central and South American nations; European Union	Temporal closure
Purse seine, dolphin-associated	Large yellowfin tuna	Dolphins	Mexico and Venezuela	Temporal closure

Table 2. Average annual estimated by-catch (1993–2003) by Class-6 (≥ 364 mt) purse-seine vessels in the eastern Pacific Ocean by set type. Average number of sets by classes 1–5 are given for comparison. Data compiled from IATTC (2004a, b, c). See Olson and Watters (2003) for a finer breakdown of species and limited by-catch data for the longline fisheries. Units for tuna catches are in metric tons; those for other species are numbers of individuals.

	Floating-object	Free-swimming	Dolphin-associated
Average number of sets, class 6	4,459	4,882	9,367
Average number of sets, classes 1–5	850	5,698	9
Retained yellowfin tuna	32,615	83,509	174,668
Retained skipjack	110,749	4,4502	2,586
Retained bigeye tuna	37,604	2,588	28
Discarded yellowfin tuna	3,995	943	1,170
Discarded skipjack tuna	17,570	2,332	635
Discarded bigeye tuna	2,973	23	0
Dorado, *Coryphaena hippurus* Linnaeus, 1758	523,537	10,349	328
Wahoo, *Acanthocybium solandri* (Cuvier, 1832)	259,240	1,067	378
Rainbow runner, *Elagatis bipinnulata* (Quoy & Gaimard, 1825), and yellowtail, *Seriola lalandi* Valenciennes, 1833	101,921	18,298	1,206
Sharks	37,011	6,957	3,930
Rays	239	3,250	796
Billfishes	1,921	1,107	946
Other large fishes	16,525	20,091	26
Trigger fishes and filefishes	719,287	5,102	3,453
Other small fishes	664,047	58,424	26,558
Frigate and bullet tunas (*Auxis* spp.)	1,284	235	41
Turtles, mainly olive ridley, *Lepidochelys olivacea* (Eschscholtz, 1829)	77	34	16
Dolphins	3	10	2,398

of China—and purse seines (used by other nations). These vessels catch yellowfin, *Thunnus albacares* (Bonnaterre, 1788), bigeye, *Thunnus obesus* (Lowe, 1839), and skipjack, *Katsuwonus pelamis* (Linnaeus, 1758), tunas and several other species of lesser commercial importance (IATTC, 2000). The purse-seine method can be divided into three set types, that on tunas associated with floating objects, that on tunas associated with dolphins, and that on free-swimming schools of tunas. Importantly, more than one species are often caught in the same set. Fisheries for tunas capture a variety of by-catch (Hall, 1998; see Table 2). The dolphin-associated sets encircle dolphins but usually release all of them.

The Inter-American Tropical Tuna Commission (IATTC) is responsible for management of tropical tunas and tuna-like species in the EPO. It also has significant responsibilities for the implementation of the International Dolphin Conservation Program and provides the secretariat for that program. Stock assessments for the main tropical tuna (yellowfin, bigeye, and skipjack) are based on an age-structured statistical catch-at-length analysis (A-SCALA) that combines multiple sources of information (Maunder and Watters, 2003) and are published by the IATTC (e.g., Harley and Maunder, 2005; Maunder and Harley, 2005a,b); stock status appears in the annual "Fishery Status Reports." These reports and information about other IATTC activities are available on the IATTC website (www.iattc.org). The IATTC, in collaboration with member countries, runs a comprehensive observer program that collects a range of data, including information about the catch of the target and bycatch species. Management controls include, among other things, capacity limits on fish-carrying capacity, catch limits, and spatial and temporal restrictions designed to reduce fishing mortality.

The IATTC collaborates with other organizations in the assessment of and research on tunas and related species in the EPO and other oceans. For example, it collaborates with the Secretariat of the Pacific Community, the National Marine Fisheries Service, and the National Research Institute of Far Seas Fisheries to produce a Pacific-wide assessment for bigeye tuna (Hampton et al., 2003).

What Are the Management Objectives?

Several regional fisheries management organizations have been established for the management of tuna stocks around the world, both within and outside of 200-mi Exclusive Economic Zones, both within individual countries and by international organizations. Several international conventions, such as the 1982 United Nations Convention on the Law of the Sea and the 1995 UN Fish Stocks Agreement, are followed by many of these regional organizations. The report of the October 2003 IATTC Workshop on Reference Points for Tunas and Billfishes (http://iattc.org/Meetings2003ENG.htm) summarizes the management objectives of the tuna-related regional organizations and the U.S. National Marine Fisheries Service, and much of the following is taken from that report.

Maintaining tuna stocks at levels that permit maximum sustainable yield (MSY) is the main objective stated in the conventions of most international organizations. This objective is often modified by other factors. For example, the 1949 ICCAT convention specifies as one of its objectives "the maintenance of the populations ... at levels which will permit the maximum sustainable catch and which will ensure the effective exploitation of these fishes in a manner consistent with this catch," and the key guidance from the recent Western and Central Pacific Fisheries Convention is the objective to "...maintain or restore stocks at levels capable of producing maximum sustainable yield, as qualified by relevant environmental and economic factors..."

The precautionary approach (FAO, 2001) also appears as part of fisheries management plans and has been widely adopted by several fisheries bodies (e.g., the Convention on the Conservation of Antarctic Marine Living Resources, the International Commission for the Conservation of Atlantic Tunas, the International Council for the Exploration of the Sea, the International Pacific Halibut Commission, the International Whaling Commission). For example, the 1998 Guidelines for National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act in part 600 state, "In general, Councils should adopt a precautionary approach to specification of OY [optimal yield]," but the terminology used is often so broad that management bodies differ in the interpretation and implementation of this approach.

The species specifically mentioned in the IATTC Convention are yellowfin, skipjack, baitfishes, "and other kinds of fish taken by tuna fishing vessels." Both natural factors and human activities are understood to affect the abundance of fish populations. Although this is not a full ecosystem approach, it is far beyond what might have been thought of as a mid-20th-century single-species approach to fisheries management. The management goal can be used to define a reference point, which could be seen as either a limit or a target. The newer "Antigua Convention" (http://

www.iattc.org), which has not yet entered into force, preserves the general objective of maintaining populations of harvested species at levels that can produce the maximum sustainable yield, but three new key points have been introduced: application of the precautionary approach, different objective for species belonging to the same ecosystem, and a specific reference to measures designed to prevent excess fishing capacity.

The objectives held by individual countries are not written into the conventions and probably change over time. These objectives are not documented and can be determined only by examination of actions, so we will not consider them further but will instead focus on the objectives of the management bodies. In conclusion, yes, explicit overarching management objectives exist, but from a stock-assessment perspective they are often vague.

Are the Management Objectives Reasonable?

In general, management objectives for tuna stocks in the EPO and elsewhere are quite vague. Maximizing yield as modified by other factors, while taking into consideration the precautionary approach, allows considerable flexibility in interpreting them. MSY, modifying factors, and the precautionary approach are all reasonable, but specific interpretations may not be. From the points of view of most management bodies, an overarching objective is required that addresses the needs of most resource users. Despite their problems, MSY-related management objectives are often those that best fill this requirement. We comment below on some of the aspects of MSY management objectives that should be considered.

The main concept running through the conventions of the international tuna organizations is MSY. MSY has numerous problems (e.g., it depends on uncertain biological processes, it differs for different fishing methods, it ignores economics, and maximizing yield of all species independently in a mixed-species fishery is impossible) and many critics (e.g., Larkin, 1977), but maximizing the yield from a fishery, or maintaining the biomass at a level that could support maximum yields, is not an unreasonable overarching goal. Of course, maximizing yield would not be desirable if doing so caused more harm than good. For example, if maximizing the yield of the target species causes the population of a more vulnerable by-catch species to collapse, then a trade-off between yield and maintaining the by-catch species must be considered. This trade-off is encapsulated in the management objectives through modifying factors (e.g., economic or social) and the precautionary approach.

One of the major criticisms of MSY is that many fisheries catch more than one species and that MSY cannot be achieved for all species simultaneously. For example, attempts to maximize the sustainable yield for skipjack tuna in the EPO has reduced the yields of bigeye tuna (Harley et al., 2005). An alternative to single-species MSY is multispecies MSY (i.e., maximization of the combined catch of all species). In the EPO, stock assessments and management advice are usually provided on a single-species basis. Reduction in fishing effort is recommended on the basis of assessment of the species being overexploited. For example, reduced fishing on floating objects has been recommended as a way to lower the fishing mortality of bigeye tuna. In this case the yield-management objective for one stock (skipjack tuna) is not achieved because it would cause sustainability concerns about another.

MSY is typically defined on the basis of a given age-specific fishing mortality. For any given fishery this mortality is achieved through gear selectivity (or age-specific availability). In a multigear fishery it results from a combination of the selectivity of each gear and the relative efforts allotted to gears; different gears may produce different levels of MSY (Maunder, 2002). If fishing for yellowfin tuna in the EPO involved only a single gear, the MSY would be higher for fisheries on dolphin-associated fish than for those on free-swimming schools. A further complication is that the allocation of effort to different gears may change over time, changing MSY and the related quantities. For example, reducing longline effort and increasing purse-seine effort on floating objects has increased the relative fishing mortality for small bigeye, in turn reducing MSY. The other MSY-related quantities also change. For example, the biomass of yellowfin that would support MSY is much greater for the longline fisheries than for the floating-object fisheries (Maunder, 2002). In conclusion, the general overarching management objectives appear to be reasonable if taken collectively, but their interpretation can be problematic.

Can We Determine Whether the Management Objectives Have Been Achieved?

When the management objective is maintenance of a biomass that will produce MSY (B_{MSY}), the problem appears to be well defined, and most modern stock assessments can be used to determine MSY-related quantities. If the current biomass (B_{cur}) is below B_{MSY}, the stock is overfished. A related management measure is based on the fishing mortality associated with achieving MSY (F_{MSY}). If the current fishing mortality is above F_{MSY}, overfishing is occurring and is particularly undesirable if the stock is also overfished. Both of these situations indicate that the stock is not well managed with respect to the MSY management goal. Evaluation of these criteria requires estimation of both the reference (e.g., B_{MSY}) and the indicator (e.g., B_{cur}) quantities. Unfortunately, uncertainty in the definition and estimation of these quantities is often considerable. It is often greatest for estimates of B_{cur}/B_{MSY} in the most recent time period, which is, unfortunately, the period of most interest.

Uncertainty in the estimation of the reference and indicator quantities can be due to uncertainty in parameter estimates (parameter uncertainty) or in model assumptions (structural uncertainty). Much of this uncertainty is usually not considered in the normal statistical sense because structural uncertainty is usually not taken into consideration, and many uncertain parameters (e.g., natural mortality and steepness of the stock-recruitment relationship) are fixed in the model. This is the reason for the widespread use of analyses of sensitivity to parameter values and model structure. For example, the estimates of the ratio of B_{MSY} to the average unexploited biomass (B_0) for yellowfin tuna in the EPO have varied from 0.23 to 0.44 in recent years because of changes in assumptions about growth and fecundity. Also, B_{MSY}/B_0 for bigeye tuna in the EPO is estimated to be 0.21 without a stock-recruitment relationship and 0.30 with a moderate stock-recruitment relationship (a Beverton-Holt stock-recruitment relationship with a steepness of 0.75; Maunder and Hoyle, 2006). MSY-related quantities also depend on forms of density dependence other than the stock-recruitment relationship that are usually not included in the analysis (e.g., density-dependent growth or natural mortality).

Some quantities are more robust to parameter or structural uncertainty than others. For example, estimates of MSY are often more reliable than those of B_{cur}/B_{MSY} in production models when the shape of the production function is uncertain (Maunder, 2003), but ratios (e.g., B_{cur}/B_{MSY}) are often more robust than absolute values (e.g., B_t) either because uncertain quantities are used in both the numerator and denominator and the uncertainty is therefore cancelled out to some degree, or because the data provide information about the ratio (Punt et al., 2001). Hampton et al. (2004) suggest that estimates of ratios of the current status to their corresponding MSY values are much more precise than the components, and this suggestion has been confirmed in simulation studies (Labelle, 2005). Hampton et al. (2004) suggest that the estimation of MSY-related quantities should be integrated into the stock assessment model so that estimates of uncertainty take into consideration the correlation between the estimates of current status and the MSY-related quantity.

MSY, from age-structured models, is conditioned on the age-specific fishing-mortality pattern (selectivity) and can change over time as the selectivity of the gear or the allocation of effort among different gears changes (Maunder, 2002). Therefore, a decision must be made about which age-specific fishing-mortality pattern should be used to estimate the MSY-related quantities. An obvious choice would be that of the most recent year, but unfortunately, it is often very imprecise, so some average of mortality rates for previous years is better. Substantial changes in the allocation of effort among years would add additional uncertainty to the analysis.

Another source of uncertainty is that MSY and related quantities will change as the productivity of the stock changes from one regime to another. In this case the quantities can be estimated for each regime or averaged over all regimes. In the yellowfin tuna population in the EPO this characteristic has caused problems in defining B_{MSY} and MSY. If only the most recent, more productive regime is used, the estimate of the MSY is higher, but the ratio of the current biomass to B_{MSY} is lower (Maunder and Harley, 2005a).

Several very different methods can be used to estimate the status of the stock (Quinn, 2003). Most modern stock assessments use statistical age-structured population-dynamics models fit to multiple types of data (e.g., catch-at-age, catch per unit of effort (CPUE), survey indices of abundance; Fournier et al., 1998; Hampton and Fournier, 2001; Butterworth et al., 2003; Maunder and Watters, 2003), as does assessment of the tuna stocks in the EPO (Maunder and Watters, 2003). These assessment methods can also be used to describe the uncertainty in the estimated status of the stock. These integrated age-structured models are in some ways superior to the traditional surplus-production models because they can better represent the system being analyzed (Maunder, 2003). For example, the use of surplus-production models to assess the yellowfin population in the EPO (Pella and Tomlinson, 1969) was discontinued because they were unable to represent the change in effort distribution between fishing on dolphin-associated schools and fishing on free-swimming schools and the regime change in productivity (Tomlinson, 2001). In addition, surplus-production models are limited in the data they can use. For example, such a model for the bigeye tuna stock in the EPO would not predict the recent decline in biomass because it would not include the information about the recent poor recruitment contained in the catch-at-length data from the purse-seine floating-object fishery.

Because long series of usable data are available for so few fisheries, evaluation of the performance of stock-assessment models is difficult. One method is retrospective analysis, which compares results from analyses that ignore the most recent data to an analysis that uses all the data. This method is based on the assumption that using all the data gives accurate results, however, and it is used mainly to evaluate estimates of abundance and recruitment, rather than management strategies. Simulation analysis can be used for more comprehensive testing, but it is based on incomplete knowledge of the system. Several comprehensive simulation studies have been performed (e.g., National Research Council, 1998). A recent series evaluating assessment methods for tunas (J. Ianelli, U.S. National Marine Fishery Service, pers. comm.; Kolody et al., 2004; Sibert, 2004; Labelle, 2005) showed that in information-rich scenarios the current assessment methods perform reasonably well, but estimation of age-specific natural mortality and bias in CPUE data were identified as major factors that degraded results. These recent simulation analyses have indicated that the Fox (1975) production model performs better than integrated age-structured models (Kolody et al., 2004; Sibert, 2004), but the relatively good performance of the Fox model may be due to use of integrated age-structured models that did not attempt to estimate the relative precision of the different CPUE data sets and the effective sample size of the catch-at-age (or length) data.

Our discussion so far has focused on estimating biological parameters and the MSY-related quantities. None of the economic and social aspects have been considered. These bring another level of complexity and uncertainty into the assessment of the management objectives. Social and economic aspects could be integrated into the stock-assessment models, but very little work, using modern stock assessment methods, has been done on this topic.

In conclusion, in studies with substantial amounts of information, we can determine whether the overarching management objectives have been achieved for the major species, but even these results can have alternative interpretations and are sensitive to assumptions about important model parameters, such as natural mortality and the stock-recruitment relationship. Unfortunately, when data are limited, as is the case for many by-catch species, the management objectives cannot be evaluated.

Management and Assessment of the EPO Tuna Fisheries

The management objectives for tropical tunas in the EPO, as indicated by the Antigua Convention, are to keep stocks at levels able to produce MSY, while the precautionary approach and the ecosystem are considered, and to limit fleet size. Yellowfin tuna is estimated to be below but close to levels that would produce MSY, but yields could be increased if fishing effort were reallocated from sets on floating objects and free-swimming schools to sets on dolphin-associated fish (Maunder and Harley, 2005a). The stock assessment for yellowfin is more reliable than those for skipjack and bigeye, but uncertainties arise because of possible trends in catchability, limited information about the age-specific natural mortality, and steepness of the stock-recruitment relationship. Additional uncertainty is due to regime shifts in productivity that influence MSY and related quantities. Management is based on restricting effort to reduce fishing mortality. Keeping fishing mortality close to a level that would produce MSY is probably the most appropriate approach, given the uncertainty in absolute quantities. The fisheries directed at yellowfin tuna influence the ecosystem through by-catch of noncommercial species, but most focus is on the by-catch of dolphins, for which, despite considerable uncertainty about the status of the populations (e.g., Hoyle and Maunder, 2004; Gerrodette and Forcada, 2005), the danger of extinction seems small.

The status of skipjack tuna is much more uncertain, but most information indicates that the population is healthy and highly variable from year to year because of variation in recruitment (Maunder and Harley, 2005b). The rates of age-specific natural mortality and growth and the steepness of the stock recruitment-relationship are uncertain. As with yellowfin, because of the large interannual variation in abundance and uncertainty in the stock assessment, management controlling fishing effort is probably the most appropriate. Much of the catch of skipjack is taken by the floating-object fishery, which has expanded substantially since 1993. The methods used are evolving rapidly and must be carefully monitored. By-catch in the floating-object fishery is high, and reducing it is a priority for the IATTC.

The assessment for bigeye tuna is more uncertain than that for yellowfin partly because of lack of information about young individuals before 1993 (Harley and Maunder, 2005; Harley et al., 2005), but the bigeye tuna population is almost certainly highly overexploited and overfished. The fishery has contributed to the decline of the population, although part of the decline can be attributed to a series of poor recruitments, in turn attributed to environmental conditions. The stock-assessment results have been supported by predictions of low longline catch rates, which have been realized in recent years. One of the major problems with managing the bigeye tuna fishery is that about half of the current catch is from the floating-object fishery, for which the majority of the catch is skipjack tuna. Any reduction in the floating-object fishing effort would decrease the catch of skipjack. Development of methods for catching skipjack tuna in the floating-object fishery without catching bigeye tuna is the top priority for IATTC research.

The 2003 stock assessment revealed the need for substantial management action for bigeye tuna in the EPO (Table 3), but previous assessments had indicated declines in future biomass due to a series of low recruitments, so restrictions were placed on the catch of small bigeye in 2001, and a similar recommendation was made for 2002. Substantial management recommendations for conservation of bigeye tuna, based on MSY-related management quantities estimated from the stock assessment, were made in 2003, but the IATTC decided on less restrictive management action. The 2004 stock assessment indicated the need for even more restrictive management action, but the IATTC again decided on less restrictive action. The results of the bigeye tuna stock assessment suggest that the management measures adopted were insufficient to produce the desired management objectives (Table 3).

The Way Forward

Because of uncertainties in the stock assessments for tunas (e.g., about age-specific natural mortality, steepness of the stock-recruitment relationship, regime shifts, and assumptions of proportionality between stock size and CPUE), development of management strategies and assessment methods that are robust to the multiple problems and bias might be beneficial. Current research in fisheries has focused on the use of management strategy evaluation (MSE) as a fish-stock management tool (De Oliveira et al., 1998). For example, this approach is being developed for southern bluefin tuna (Haist et al., 2002). MSE involves using simulation analysis to evaluate several

Table 3. Stock assessment advice, management recommendations, management actions, and resulting change in fishing mortality for the bigeye tuna fisheries in the EPO. The change in fishing mortality from the comparison year is based on Maunder and Hoyle (2006) and calculated from the average age-specific fishing mortality weighted by the abundance at age.

Year of assessment	Stock assessment conclusion	IATTC staff recommendation (includes actions for all species)	Conservation measures adopted	Effect on bigeye fishing mortality
2000	Assuming a moderate spawner-recruitment relationship, fishing mortality should be kept at 1999 levels	No recommendation for bigeye; catch quota for yellowfin	3-mo closure of the floating-object fishery	Fishing mortality increased 57% from 1999 levels
2001	Assuming a moderate spawner-recruitment relationship, fishing mortality should be reduced (10%) from 2000 levels	Limitation of fishing effort to current levels	Closure of floating-object fishery if catches of small bigeye reach 1999 levels, but not before November 2001; no closure occurred	Fishing mortality increased 4% from 2000 levels
2002	Assuming a moderate spawner-recruitment relationship, fishing mortality should be kept at 2001 levels	Closure of the floating-object fishery if small bigeye catches reach 1999 levels; complete EPO closure for December 2002	Complete closure of the EPO for December 2002	Fishing mortality increased 59% from 2001 levels
2003	Fishing mortality must be reduced substantially (20%–50%) from levels observed in 2000 and 2001	Complete EPO closure for 2 mo, plus 2-mo closure of an area of high bigeye catches; reduction of longline catches to 2000 levels	Closure of a smaller region (than proposed) for December 2003; longline catches reduced to 2001 levels	Fishing mortality increased 33% from 2000–2001 levels
2004	Fishing mortality must be reduced substantially (30%–60%) from levels observed in 2001 and 2002	Complete EPO closure for 2 mo, plus either a 6-mo closure of an area of high bigeye catches or a 6-mo closure of an area for floating-object sets or 500-mt individual vessel catch limits; reduction of longline catches to 2000 levels	Complete closure of the EPO for 6 wks (agreed upon in October 2003); longline catches reduced to 2001 levels.	Fishing mortality decreased 10% from 2001–2002 levels

comprehensive management strategies under different possible states of nature to define a strategy that is robust and provides desirable outcomes. The comprehensive management strategy includes definition of the data to be collected, how they are analyzed, and the management action based on the results.

MSE has recently been applied to tunas and billfishes. Punt et al. (2001) used it to investigate strategies that use data-based indicators for the broadbill swordfish (*Xiphias gladius* Linnaeus, 1758) off eastern Australia. Kell et al. (2003) used MSE to investigate the performance of MSY management-based strategies, using current assessment procedures for Atlantic tuna stocks. Haist et al. (2002) have developed MSE for southern bluefin tuna.

We consider MSE a good candidate for management of tunas in the EPO because it explicitly considers uncertainties and can be used to evaluate multiple management objectives that may be held by the different interest groups. We suggest that a comprehensive MSE for the EPO would have to consider the three tuna species, the three purse-seining methods, and the longline fishery, as well as by-catch species, such as dolphins. Spatial structure and consideration of links with the western and central Pacific Ocean may also be important, although including them would make the analysis much more complex.

Summary

"Are pelagic fisheries managed well?" is a difficult question to answer. The management objectives described in international conventions are generally vague and may not represent the objectives of the individual countries, so realized management actions may not follow the overarching management objectives. The overall idea of the management objectives may be appropriate, but specific interpretations and implementations may not be. The performances of stock assessments differ, depending on the data available and the management quantities being estimated. Also, very little information is available about many of the ecosystem components that may be affected by the fisheries. Both well and poorly managed fisheries exist. In some cases (e.g., southern bluefin tuna), stocks managed poorly in the past, whose current biomass is low, are now being rebuilt under improved management, but the management objectives are to allow harvesting while the population rebuilds. Pelagic fisheries are probably managed better than some claim and worse than others claim. For example, recent claims about the poor state of tuna stocks (Myers and Worm, 2003) were based on flawed methods of analysis that used only a small portion of the available data (Walters, 2003; Hampton et al., 2005; Polacheck, in press). Determining whether these differences in opinion are due to different management objectives, different interpretations of the results, uncertainty in the assessments, or different scientific opinion about methodology and assumptions can be difficult.

We recommend that MSE be considered for use in the EPO tuna fisheries. In addition to explicitly addressing uncertainty and management objectives, MSE will focus discussions on the important components of management. Its use will therefore increase the probability of reasonable, well-defined management objectives and development of methods for determining whether they have been achieved. Formal agreement to the use of management strategies will increase the likelihood that management will be based on science rather than politics, and use of MSE will, we hope, result in achievement of the management objectives.

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