INTER-AMERICAN TROPICAL TUNA COMMISSION

WORKING GROUP ON STOCK ASSESSMENT

5TH MEETING

REVIEW OF 2003 STOCK ASSESSMENTS

La Jolla, California (USA)
May 11-13, 2004

CHAIRMAN'S REPORT

Chairman: Dr. Robin Allen

AGENDA

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2.	The fishery in 2003	
3.	Sampling of catches for species composition	
4.	Review of 2003 management measures	SAR-5-06
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6.	Review of stock assessments:	
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		SAR-5-05 BET A
	iii. Skipjack	SAR-5-05 SKJ
	iv. Swordfish	SAR-5-05 SWO
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7.	Status of stocks of tuna and billfish in the EPO	SAR-5-07
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The 5th Meeting of the Working Group on Stock Assessments was held in La Jolla, California, USA, on May 11-13, 2004. The attendees are listed in Appendix A.

1. Welcome, introductions, consideration of agenda

The meeting was called to order on May 11, 2004, by the Chairman, Dr. Allen, Director of the IATTC, who thanked the attendees for coming to the meeting, and then asked them to introduce themselves. After a brief discussion, the provisional agenda was approved, with minor changes.

2. The fishery in 2003

Mr. Everett reviewed the information on the fishery for tunas in the eastern Pacific Ocean (EPO) in 2003 (first part of Document SAR-05-07). This document is to be the primary source of data and scientific information presented to the Commission for its consideration of the effects of the fishery and of any conservation measures. The sections on yellowfin, bigeye, skipjack, and swordfish are summaries of this year's assessments. The remaining sections are mostly updates of information and assessments previously reported.

Discussion centered on the nature of new longline catch estimates, on suggestions to improve tables and figures, and on the usefulness of quarterly plots to better show seasonal patterns.

3. Sampling of catches for species composition

Mr. Tomlinson presented updated information on a system for sampling surface-caught tunas in the EPO, which was initiated in 2000. Briefly, the fish in a well of a purse-seine or pole-and-line vessel are selected for sampling only if all the fish in the well were caught during the same month, in the same type of set (floating-object, unassociated school, or dolphin), and in the same sampling area. These data are then categorized by fishery. The discussion focused on the nature of catch estimates provided by the industry, especially regarding bigeye, yellowfin, and skipjack tuna, where year-to-year variation is apparent. In some cases it could be attributable to management measures. There were also questions about the level of sampling and about the numbers of Pacific bluefin tuna measured.

Ms. Suter reviewed results of a study on the comparison of estimates from vessel logbooks, scientific observers, unloading records, and length-frequency and species composition sampling data. The study indicated that bigeye catches are underestimated by logbooks, observers, and unloading weights. Participants noted that the problem of misidentification of bigeye is the same in other parts of the world, and that the best solution to it is the system of sampling of catches for species composition developed by the IATTC staff.

4. Review of 2003 management measures

Dr. Harley presented an analysis of the December 2003 purse-seine closure in an equatorial area of the EPO (SAR-05-06). Estimations based on the analysis of recent catch and effort data show that the catch in December was the highest in record, and that the reduction in catch attributable to the closure was negligible, due to both reallocation of effort to other areas, and to the short duration and small area of the restriction. During the discussion it was suggested that length-frequency data be also examined for evaluation of closure effects. It was also pointed out that boundary effects and compliance problems may also play a role in the effectiveness of the closure. It was suggested that the effect of the tuna discard provisions of the 2003 Consolidated Resolution on Bycatch should be analyzed in the same way.

5. Review *Report of meeting on reference points*

Dr. Maunder reviewed the report of the workshop on reference points for tunas and billfishes, held in La Jolla, California, USA, October 27-29 2003 (Appendix B). The meeting followed a recommendation of the 4th meeting of the Working Group on Stock Assessments. The group examined management objectives and the use of reference points at other organizations, and also multi-species and ecosystem reference points. General and Commission-specific recommendations were made on limit and target reference points. The future importance of developing a predetermined set of strategies or control rules that include stock status feedback and the role of long-term oceanographic factors were discussed.

Dr. Harley reviewed the importance of the assumed steepness of the spawner-recruitment relationship. The base case assessments for yellowfin, bigeye, and skipjack assume that recruitment is independent of spawner abundance, but more pessimistic scenarios (*i.e.* greater reductions in fishing mortality) develop when a spawner-recruitment relationship is assumed. The importance of choosing management strategies robust to this and to other model uncertainties was pointed out.

6. Review of stock assessments

The assessments of yellowfin, bigeye, and skipjack were performed with A-SCALA (*Age-Structured Statistical Catch-at-Length Analysis*).

6.1. Yellowfin

Dr. Maunder reviewed the yellowfin assessment presented in Document SAR-5-05 YFT. The stock assessment for yellowfin is similar to that of 2003. The base case assessment indicates that the stock size has declined from a high point in 2001 to about 80% of the level corresponding to the average maximum sustained yield (AMSY). The fishing mortality rate in recent years (2001-2002) has been less than that required to produce the AMSY, however the fleet capacity continued to grow. The base case assessment did not include a stock-recruitment relationship; if that were incorporated (the alternative assessment), the current estimated stock size would be only 60% of the AMSY level, and the fishing mortality rate would be greater than that corresponding to the AMSY. The forecast recovery of the spawning stock to above the AMSY level depends on future recruitment being at average levels.

Regardless of the recruitment, the total catch and stock size could be increased if the average size of the yellowfin in the catch were increased. The longline fishery produces the largest-sized fish, but takes less than 5% of the catch. The purse-seine fishery takes fish of less than the critical size (although there are marked differences in size of yellowfin taken in different set types). The catch from other fisheries is negligible.

The discussion included the consideration of the effects of the environment, specifically of regime shifts on recruitment. Model area selection and stock structure were also discussed. It was suggested, as a way of communicating changes, updates and technical details in the model, that tables similar to those previously published be updated.

6.2. Bigeye

Dr. Harley reviewed the bigeye assessment presented in Document SAR-5-05 BET. The 2004 results are similar to those of previous assessments, and consistent with the previous stock projections. Longline catches are a large part of the total bigeye catch, and at the time of the assessment all longline catch and effort data for 2003 were not available and fishing effort was assumed to be the same as that for 2002. Species composition sampling of the purse-seine catches of the past four years shows that the estimated purse-seine catches that are greater than reported unloadings. Accordingly, sensitivity analyses included alternative versions of the basic input data.

The trends of last year's assessment have continued. Recent recruitment has been poor, and the stock is declining. The large recruitment from 1995-1997 which provided large purse-seine catches in 2000 and improved longline catches in 2001 is now passing out of the longline fishery. The stock is now below the AMSY level. While there is no evidence of a relationship between stock size and recruitment, the stock will reach levels lower than any of previous years. The base case assessment estimates that the fishing mortality rate corresponding to the AMSY is 38% less than the fishing mortality rate during 2001-2002, and the alternatives considered suggested reductions ranging from 20% to 62%. Taking account of the restrictions in 2001 and 2002 and the continuing growth of fleets, catches should be reduced by 50%.

The discussion centered on the effects of the environment on stock dynamics, the uncertainty associated with lack of recent longline information, and trends in fishing power and catchability in recent years.

Dr. Harley presented, in addition, preliminary results of a Pacific-wide bigeye assessment model in which the EPO is considered a subregion. In general, biomass trends and mortality results are consistent with the EPO assessment. The discussion considered the usefulness of releasing tagged bigeye through out a wider area than has been achieved so far.

Dr. Harley reviewed also the results of a study on the possible utility of catch limits for individual vessels for reduction of bigeye mortality (Document SAR-5-05 BET A). The study shows that 11 to 15 vessels take 50% of the bigeye catch, so that setting individual vessel limits of about 350 t (unloading weight or about 500 t with scientific sampling) would reduce fishing mortality on bigeye, without major losses in skipjack catch. The group discussed the approach, and found it a useful new tool in the conservation of bigeye. Participants suggested, however, that it be considered together with traditional conservation measures, such as area and time closures. There were comments on the accuracy of bigeye data, on the possibility of some vessel captains having the ability of avoiding setting on bigeye-dominated schools, and on the research on sonar, webbing hanging beneath fish-aggregating devices (FADs), and area and time strata that shows promise on bigeye mortality reduction. Implementation problems were also addressed.

Dr. Deriso presented preliminary results of archival and conventional tagging research conducted by the staff. A total of 10336 fish have been tagged during 2000-2003 in the areas where the purse-seine fishery operates, and 38.5% tags have been returned. Length-frequency distribution of released bigeye is also similar to that of fish caught by purse-seine gear. Only 8 recoveries have been from longline vessels, and only 6 (out of 3,980) have been recovered west of 140°W, while 50% of 2003 recaptures were within 100 nm of the release location. The high recovery rate was the focus of the discussion. It was pointed out that this exploitation rate is roughly the same as that resulting from the assessment and that it may be indicative of high catchability of bigeye while they are associated with FADs.

6.3. Skipjack

Dr. Maunder reviewed the skipjack assessment presented in Document SAR-5-05 SKJ. The assessment is still considered uncertain because 1) it is not known whether catch per day of fishing for purse-seine fisheries is proportional to abundance, 2) it is possible that there is a population of large skipjack that is not currently available to the fisheries, and 3) stock structure in relation to the fish in the western and central Pacific is uncertain. However, results from sensitivity analyses for this assessment are more consistent than those of previous years.

The recruitment of skipjack tuna to the fisheries in the EPO is highly variable. Fishing mortality is estimated to be about the same or less than the natural mortality. These levels of fishing mortality are supported by estimates from tagging data. Biomass fluctuates in response to variations in both recruitment and exploitation. Estimates of absolute biomass are moderately sensitive to weights given to the information about abundance in the catch and effort data for the floating-object fisheries and the monotonic selectivity assumption, but the trends in biomass are not.

The analysis indicates that a group of relatively strong cohorts (but not as strong as those of 1998) entered the fishery in 2002-2003 and that these cohorts increased the biomass and catches during 2003. There is an indication the most recent recruitments have been about average, which may lead to lower biomasses and catches. However, these recruitment estimates are based on limited information, and are therefore very uncertain.

There is considerable variation in spawning biomass ratio (ratio of the spawning biomass to that for the unfished stock; SBR) for skipjack tuna in the EPO. In 2003 the SBR was at a high level (about 0.61). Estimates based on AMSY and yield per recruit indicate that maximum yields are achievable with infinite fishing mortality because the critical weight is less than the average weight at recruitment to the fishery. However, this is uncertain because of uncertainties in the estimates of natural mortality and growth.

Estimates of SBR are not sensitive to weights given to the information about abundance in the catch and effort data for the floating-object fisheries and the monotonic selectivity assumption.

The discussion centered on the effects of the environment on recruitment and biomass (apparently stronger than the effect of fishing), on the increases in fishing power, and catchability. It was noted that the expansion of the area exploited has lead to increased estimated recruitment.

6.4. Swordfish

Dr. Hinton reviewed the swordfish assessment presented in Document SAR-5-05 SWO. Preliminary research indicates no large genetic exchange between the Hawaiian region and the EPO. The research is expected to be complete shortly. There may be two stocks of swordfish in the EPO. If this is the case, one is centered in the southeastern Pacific Ocean, and the other is centered off California and Baja California. However, there may be movement of a northwestern Pacific stock of swordfish into the EPO at various times.

Production modeling indicates that the CPUE of swordfish, although they have declined and then increased recently, are still greater than the CPUE that correspond to the AMSY. This conclusion is tentative, due particularly to the current uncertainty regarding stock structure.

The discussion centered on the need to continue, and improve, monitoring of recent high catches which may eventually lead to measurable declines in stock size. The possibility that small fish were selectively not measured during the 1970s and 1980s was raised. Length frequency data in relation to recent CPUE increases, and information on stock structure that will be available soon were also discussed.

6.5. Forward projections

Document SAR-05-05 PRO, on the technical details of including parameter uncertainty in forward projections of models such as A-SCALA, was made available to meeting participants. There was no discussion of this document.

7. Status of stocks of tunas and billfishes in the EPO

Dr. Allen introduced the second part of Document SAR-05-07, on the status of other tunas and billfishes in the EPO, and ecosystem considerations. He indicated that assessments for 2003 are similar to those of previous years, and that the staff would have no management recommendations for species other than yellowfin and bigeye. Participants made general suggestions on improvements to the document, including plots of historical catches, total catch used in the stock assessment by gear and year, and maps on linear scales for the major species. Specific suggestions were made to include catch by flag in the swordfish sections, and to update the North Pacific albacore section with information from a report recently available on the status of that species.

Dr. Olson presented recent research on ecosystem studies in the EPO. He emphasized new information on marine mammals, sea turtles, and research in progress, particularly on ecosystem trophic structure and tuna movement, studying the accumulation of C and N isotopes in predators. The discussion included a suggestion to show trends in mortality for the last ten years in tables for sea turtles (numbers and species) and other species such as sharks (by species/groups and weight). Partial information on longline bycatch and the possible inclusion of recreational fisheries as predators in the model were also discussed.

8. Targets for fleet capacity

Dr. Arenas reviewed a document on the target size for the tuna fleet in the EPO (Documento SAR-05-08). He explained that the Permanent Working Group on Fleet Capacity had requested that the Working Group on Stock Assessment consider the issue of a target fleet size. In the case of the purse-seine fleet, this consisted of a review of the figure of 158,000 m^3 of well volume considered in several resolutions of the Commission and in the *Plan for Regional Management of Fishing Capacity*. In the case of the longline fleet, it involved the consideration of factors for the development of such a target. The document concluded that the 158,000 m^3 figure seems appropriated for the purse-seine fleet from the point of view of optimizing the purse-seine fishery for yellowfin tuna. Given management tradeoffs and characteristics of factors affecting the various tuna fisheries, and considering the potential increase of fishing power of fleets, the optimal size for both components of the tuna fleet will continue to be a moving target.

The discussion centered on the complexity of the issue, especially considering the mix of gears, species, and set types in the EPO. There were differing views on the role of vessel efficiency in the EPO regarding the question of capacity, a consideration of whether carrying capacity or number of sets offered the best way of controlling fleet capacity for purse-seine; and whether number of hooks or number of vessels offered a suitable way to control the capacity of the longline fleet. The group discussed the overall conclusions of the document SAR-05-08, and recommended that it be revised and presented to the Commission at its annual meeting in June 2004, seeking guidance on management considerations for both fleets in the EPO. The group considered the approach outlined in the document a useful new tool for the management of fleet capacity in the EPO, and that the management of fishing capacity is essential to make more effective and acceptable regulatory measures, as the present problem is an over excess of fishing capacity for the size of the tuna resources available. The group also pointed out that any indices discussed (*e.g.* carrying capacity, well volume, or number of hooks) may not reflect true fishing capacity, as fishing efficiency is always improving.

9. Review of the resolution on data provision and technical aspects of data

Dr. Hinton reviewed the *Resolution on Data Provision* of June 2003 (Resolution C-03-05). He described the category, level and resolution of data requested and pointed out some of the technical issues and practical problems associated with data collection efforts.

The discussion centered on how to improve data collection for small longliners, on current international definitions for these vessels, on whether the exception for these vessels in paragraph 5a of the resolution should be revised, on the use of VMS within the data provision context, and on the risks associated with requesting detailed data at the expense of accuracy.

The Working Group considered that data collection on catch and effort is a first priority, and was concerned about uncertainty associated with estimates of longline total catch, and particularly that some important longline total catch data were revised and became available only very recently, after the assessments were carried out.

Some participants raised a practical concern regarding the timing for providing longline catch and effort (and length) data, because provision of this information may be delayed by one more year due to fishery practices, and suggested that this issue could be considered in the resolution.

10. Recommendations

Dr. Allen reviewed the staff conservation recommendations for 2005. In general, the working group agreed with the recommendations made by the staff, and agreed that this is an appropriate way to convey scientific results to the Commission, and several comments and suggestions were made. The staff incorporated most of these to the revised *Staff Conservation Recommendations* attached in Appendix C. During the discussion, some specific comments were made, in particular concerning conservation recommendations affecting bigeye.

It was noted that the bigeye assessment is more complete than the previous assessment, and that the conclusion of decreased spawning biomass is robust. Regarding the inclusion in the model of longline data that became available only very recently, Dr. Allen pointed out that preliminary sensitivity work carried out by Dr. Harley with the new data indicated that the bigeye assessment results will probably not change.

The group considered that the separate request for total nominal catch data by species for the entire EPO on an annual basis should be made and strictly implemented by the staff and national offices.

Assessments and implementation of regulations depend on this information and it is the responsibility of cooperating parties to provide it.

Some participants believed that the recommendation that bigeye longline catches be reduced to the level of 2000 should not be made until the data to evaluate the effect of the 2003 conservation resolution becomes available, and that if necessary, this recommendation could then be revised. Others were concerned that the measures proposed for longline gear were less stringent than those for purse-seine gear. Some participants believed that the longline fishery should also be closed for two months. In this regard, the development of control rules or management procedures was proposed, while some problems associated with implementation were considered.

The group recommended that research on selectivity in the skipjack fishery (to avoid catching bigeye) be carried out, and that tagging of bigeye in a larger area in the central Pacific is important and should be carried out.

Given the impacts of environmental variables and of long-term trends on the dynamics of most of the tuna species under consideration, a recommendation was made on the importance of incorporating further oceanographic studies and interdisciplinary research into the work of the Commission.

11. Other business

Dr. Miyabe from the National Research Institute of Far Seas Fisheries of Japan presented an update on the CPUE of the Japanese longline fishery in the EPO. In particular, these data showed a large decline in CPUE for the Japanese fleet in 2003, consistent with the assessment results.

The group agreed with the staff proposal to examine the standardization of CPUE in the purse-seine fishery, especially the fishery on floating objects, by convening a workshop during September or October. The group was informed also that a technical meeting on the formal incorporation of tagging data into the stock assessments is being planned for September or October next year. The group endorsed the proposal to hold a meeting of data correspondents to examine the developments of the tuna fisheries in each area, to be convened before the stock assessment group meeting. The group also endorsed a proposal to ask governments about a suitable level of public domain data on the IATTC website.

12. Meeting report

The draft meeting report was discussed and generally agreed by the group. Most comments and suggestions were incorporated into this final report.

13. Adjournment

The meeting was adjourned at 5:30 pm on 13 May.

Appendix A.

INTER-AMERICAN TROPICAL TUNA COMMISSION
COMISION INTERAMERICANA DEL ATUN TROPICAL

SCIENTIFIC WORKING GROUP -- GRUPO DE TRABAJO CIENTÍFICO

5th MEETING- 4ª REUNION

May 11-13, 2004 – 11-13 de mayo de 2004
La Jolla, California, USA

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Appendix B.

INTER-AMERICAN TROPICAL TUNA COMMISSION

WORKSHOP ON REFERENCE POINTS FOR TUNAS AND BILLFISHES

La Jolla, California (USA)
27-29 October 2003

REPORT

Compiled by Mark N. Maunder

AGENDA

1. Introduction
2. Reports on management objectives and use of reference points
   - 2.1 Inter-American Tropical Tuna Commission (IATTC, Allen and Maunder)
   - 2.2 International Commission for the Conservation of Atlantic Tunas (ICCAT, Restrepo)
   - 2.3 Secretariat of the Pacific Community (SPC, Hampton)
   - 2.4 U.S. National Marine Fisheries Service (NMFS)
     1. Pacific Islands Fisheries Science Center (PIFSC, Kleiber)
     2. Southwest Fisheries Science Center (SWFSC, Crone)
     3. Southeast Fisheries Science Center (SEFSC, Ortiz)
3. Multi-species and ecosystem reference points (Hall and Maunder)
4. Research
   - 4.1. Management strategy evaluation for Spanish mackerel (Hoyle)
   - 4.2. Application of spawning biomass per recruit (SBPR) proxies and effects of mis-specifying fishing mortality that produces maximum sustainable yield (F_{MSY}) for yellowfin and bigeye tuna in the eastern Pacific Ocean (EPO, Harley and Maunder)
   - 4.3. Stochastic management strategy evaluation for tuna (Hoyle, Maunder, and Harley)
   - 4.4. Uncertainty in reference points (Conser)
   - 4.5. Critical weight as a reference point (Maunder)
5. Discussion of reference points
6. Recommendations

APPENDIX

1. Participants

1. Introduction

The IATTC holds an annual mid-year technical workshop on a topic that is of significant importance to the stock assessment of tunas and billfish in the eastern Pacific Ocean (EPO). The topic of the meeting arises from research needs identified in the annual scientific review. In the previous year, the technical workshop addressed the diagnostic requirements for highly-parameterized models such as those used for assessing tunas in the EPO and western-central Pacific Ocean (WCPO) by the IATTC and SPC, respectively. The results of this meeting were used for the assessments of bigeye and yellowfin tuna in the EPO during 2003.

The IATTC has developed several reference points over the last few years, and presents these in its annual Stock Assessment Reports. Reference points are also used by most agencies involved in the management and assessment of tunas and billfishes. However, reference points are less well developed for tunas and billfishes than for many other species. In addition, management of world fisheries is trending toward a greater use of reference points. Therefore, it was decided at the IATTC stock assessment review meeting that a mid-year technical workshop on reference points for tunas and billfishes would be of benefit to the assessment and management of these species.

The meeting was organized to provide an opportunity for both presentations and discussions. The presentations were divided into 1) those describing the objectives of organizations and their use of reference points, and 2) those describing research on reference points. In addition, there were presentations on multi-species and ecosystem reference points and management strategy evaluation. A large amount of time was devoted to discussions. The final section of the meeting was used to develop recommendations for reference points for tunas and billfishes in general and specifically for the IATTC.

2. Reports on management objectives and use of reference points

2.1. Inter-American Tropical Tuna Commission (IATTC, R. Allen and M. Maunder)

The 1949 Convention of the IATTC provides the formal management objective for the Commission, which is to keep the populations of fish at levels that will provide the maximum sustainable catch. The species specifically mentioned in the Convention are yellowfin, skipjack, baitfishes, "and other kinds of fish taken by tuna fishing vessels." It is understood that both natural factors and human activities affect the abundance of fish populations.

While this is not a full ecosystem approach, it is a long way beyond what might have been thought of as a mid-twentieth century single-species approach to fisheries management. The management goal ("to keep the populations of fishes covered by this Convention at those levels of abundance which will permit the maximum sustained catch") can be used to define a reference point, which could be seen as either a limit or a target reference point.

While the 1949 Convention provides the formal objectives, the new "Antigua Convention" gives a current perspective on the thinking of the member countries. The management objectives of the Antigua Convention are more specific than those the 1949 Convention, but do not contradict the earlier ones, so it is appropriate to take account of its provisions in thinking about reference points. The Antigua Convention preserves the general objective of maintaining populations of harvested species at levels that can produce the maximum sustainable yield (MSY).

Some of the key new points are:

- Application of the precautionary approach;
- A different objective for species belonging to the same ecosystem;
- A specific reference to measures to prevent excess fishing capacity.

The IATTC considers several reference points and related quantities in its annual Stock Assessment

Reports. Reference points are generally more developed for the main tuna species (yellowfin and bigeye), but are also presented for several species of billfish.

Spawning biomass ratio (SBR) is the ratio of the spawning biomass to the average spawning biomass in the absence of fishing. This quantity is compared to the SBR required to produce the maximum sustainable yield (SBR_{MSY}). SBR is also a quantity that is presented in future projections. The estimates of SBR and its relation to SBR_{MSY} have changed among the assessments due to changes in values used for growth, steepness of the stock-recruitment relationship, fecundity, and values of the age-specific fishing mortality rate.

MSY is calculated based on the current age-specific fishing mortality. It is also calculated using the age-specific fishing mortality based on a single fishery, allowing the comparison of the efficiency of each fishing method in respect to maximum yields. The associated SBR is also presented. MSY and SBR are also calculated for two different productivity regimes for yellowfin tuna.

Plots of the biomass trajectory are compared to plots of the biomass that would have been expected if no fishing had occurred. These plots show the depletion level, while taking into consideration the time trajectory of recruitment, and may be more informative than comparisons to equilibrium unexploited biomass, as used in SBR.

The critical age is a theoretical concept that maximizes the yield from a cohort that would result from removing all the individuals at a single age. The weight corresponding to critical age is compared to the average weight in the total catch and the average weight in each fishery, as predicted by the stock assessment model. The weight corresponding to the critical age may provide information on the status of the stock and the efficiency of the different fishing methods with respect to maximizing yields.

The lifetime reproductive potential for each age class is calculated to give an indication of the effect of each fishing method on the spawning potential of the population. The calculation is based on both a marginal change in numbers and a marginal change in weight to reflect the difference a fish of each age contributes to the catch due to differences in weight.

MSY_{ref} which is an approximation of the global MSY, is calculated as the highest sustainable yield when capturing only fish at a single age. It is calculated to illustrate the potential yields from the stock and to provide a measure of the efficiency of each fishing method with respect to maximizing yield. SBR_{ref} is the SBR associated with MSY_{ref}.

Retrospective analysis is used to show that estimates of current SBR are highly uncertain. Sensitivity analyses, particularly to the steepness of the stock-recruitment relationship, are used to show the sensitivity of the reference points and indicators.

2.2. International Commission for the Conservation of Atlantic Tunas (ICCAT, V. Restrepo)

The 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." Thus, the implicit target is a biomass around the biomass corresponding to MSY (B_{MSY}) and/or the fishing mortality corresponding to MSY (F_{MSY}). In practice, ICCAT has mandated rebuilding plans for several overfished stocks; in these cases, the target has been to reach B_{MSY} by a given year with a probability of 50% or greater.

ICCAT assessment working groups thus attempt to estimate B_{MSY}- and F_{MSY}-related benchmarks (or proxies) with a variety of methods. More attention is paid to ratio statistics (*e.g.* B_t/B_{MSY}, where B_t is the biomass at time t), than to absolute quantities. Traditional production models are used primarily, followed by a variety of age-structured analyses. In terms of expressing uncertainty in these estimates, common statistical procedures, such as bootstrapping, are used. However, a variety of results may be taken into consideration together when communicating uncertainty to the Commission.

The guidelines for limits and targets in the 1995 UN Fish Stocks Agreement are potentially in conflict with ICCAT's implicit F_{MSY} target. ICCAT scientists have recommended that management control rules that define both limits and targets be identified and evaluated for various stocks. It has been recommended that the specification of alternatives be made jointly by scientists and managers and that the evaluations be carried out with simulation studies.

2.3. Secretariat of the Pacific Community (SPC, J. Hampton)

The Western and Central Pacific Fisheries Convention requires the use of reference points in developing scientific advice and the precautionary approach for designing and implementing management measures. Key guidance from the 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 …". This indicates that MSY-based reference points – B_{MSY} and F_{MSY} – will be strongly featured in future management advice to the WCPF Commission. The adoption of the precautionary approach will possibly mean that target reference points will be set such that there is a reasonably small probability of the limit reference point being exceeded. In addition to the above, the Convention also requires that "… members of the Commission shall … ensure long-term sustainability of highly migratory fish stocks in the Convention Area and promote the objective of their optimum utilization." This implies that there will be a need to at least monitor variables such as yield per recruit and average weight in relation to critical weight, so that advice with respect to optimum utilization can be provided.

In recent years, stock assessments conducted by the SPC Oceanic Fisheries Programme have attempted to incorporate some of these ideas in advance of the Commission coming into effect. The assessments use the MULTIFAN-CL approach, and integrate Beverton and Holt stock-recruitment parameter estimation and yield estimation into the model. MSY and associated *B*- and *F*-based reference points are estimated conditioned on assumptions regarding stock-recruitment steepness and the overall age-specific selectivity of the combined fisheries. Confidence intervals for the ratios of B_{current} to B_{MSY} and F_{current} to F_{MSY} are estimated using both likelihood profile and normal approximation.

2.4. U.S. National Marine Fisheries Service (NMFS)

2.4.1. Pacific Islands Fisheries Science Center (PIFSC, P. Kleiber)

The management objectives of the U.S. National Marine Fisheries Service (NMFS) in the Pacific islands region are governed, as in other regions, by the the 1996 version of the Magnuson-Stevens Fishery Conservation and Management Act (M-SFCMA), with modifications in accordance with the Endangered Species Act and the Marine Mammal Protection Act. The overarching objective defined by the M-SFCMA is to manage fishery resources "for the greatest benefit of the Nation." Specific exhortations are embodied in "National Standards 1" (NS1) of the M-SFCMA. These include achieving an "optimum yield" on a "continuing basis" while preventing overfishing and keeping resource stocks out of an overfished state.

To comply with requirements of the NS1, NMFS created a set of guidelines to help refine under various circumstances the concepts of optimum yield, overfishing, and overfished state and to define rules for examining the situation of a fish stock with respect to those concepts and to rules for management action whenever the situation needs to be changed. Unfortunately, NS1, and the guidelines in particular, have not fit well with the nature, particularly the international nature, of the pelagic fishes and fisheries in the Pacific Island region, with the result that the Western Pacific Regional Fishery Management Council (WPRFMC) has found it difficult to promulgate rules that pass muster with the guidelines. Eventually, the WPRFMC adopted the approach behind the rules already approved for the U.S. east coast pelagic fisheries, which are also embedded in an international situation. The new preferred rules for the Pacific Island region have now been accepted.

Meanwhile, it appears that other regions have also had difficulty in conforming to the guidelines, and in February 2003 NMFS proposed a new set of NS1 guidelines to ameliorate some of the problems. The new guidelines are controversial, and have not yet been formally adopted. Predictably, non government organizations (NGOs) argue that the guidelines should, if anything, promulgate stricter rules, while industry argues for guidelines producing more relaxed rules.

Research on reference points and control rules has not been conducted by the WPRFMC or PIFSC. However, outside the hurly-burly and contention of determining acceptable reference point rules and guidelines thereto, PIFSC scientists have been collaborating with other regional and international institutions in the Pacific to conduct stock assessments and develop stock assessment methodologies. This, after all, is where information on status of fish and fisheries is gleaned from fishery and other data, regardless of whether that status information is then viewed through the prism of reference point rules. This work is not without controversy either, but it deals with more fundamental, or more cogent, questions such as whether there has been a true trend in recruitment or "regime shift" with possible implications for the long-term sustainability of current harvest levels.

2.4.2. Southwest Fisheries Science Center (SWFSC, P. Crone)

The Pacific Fishery Management Council (PFMC) serves as one of eight regional fishery Councils of the NMFS. The PFMC's jurisdiction is largely the Exclusive Economic Zone off the west coast of the continental United States. Each Council is mandated by law to adhere generally to stipulations of the M-SFCMA and, in particular, to technical guidance documented in NS1 of the legislative act. In general, management approaches are founded on MSY theory and application and, more recently, the concept of "optimum yield" (OY), which are folded into formal Fishery Management Plans (FMPs). Optimum exploitation strategies inherently consider "precautionary" principles and essentially, define target levels more conservative than those recommended in MSY-based approaches, *e.g.*, 0.75(F_{MSY}).

Species managed under the auspices of the PFMC fall generally under four broad assemblage classifications, namely coastal pelagic stocks (*e.g.*, sardine, mackerel, squid, *etc.*), highly-migratory stocks (*e.g.*, tunas, billfishes, sharks, *etc.*), groundfish stocks (*e.g.*, rockfishes, flatfishes, *etc.*), and salmon stocks (*e.g.*, Pacific Northwest and coastal California salmon populations). The biological reference points (BRPs) and harvest control rules (HCRs) for two of these species groups were discussed: coastal pelagic stocks (Pacific sardine); and highly-migratory stocks (North Pacific albacore).

For Pacific sardine, a unique HCR has been established that incorporates various BRPs, including an exploitation fraction based on an oceanographic parameter (sea-surface temperature, T) that is related to F_{MSY}, and to estimates for current stock size (B_t), minimum biomass threshold (*Cutoff*), and distribution of the stock in U.S. waters (*U.S. Distribution*). The general form of the HCR follows:

$$\textit{Harvest Guideline}_{t+1} = (B_t - \textit{Cutoff}\,) \bullet \textit{Fraction} \bullet \textit{U.S. Distribution},$$

where estimable parameters include B_t and *Fraction*, and *Cutoff* (150,000 mt) and *U.S. Distribution* (87% of stock found in U.S. waters) are fixed variables. B_t is determined by conducting a quantitative (peer-reviewed) assessment and *Fraction*, which serves as a proxy for F_{MSY}, is estimated as follows;

$$F_{MSY} \equiv \textit{Fraction} = 67.4558 - 8.1901(T) + 0.2486(T^2)$$

All highly-migratory species, including North Pacific albacore, are managed according to the "default" MSY Control Rule, as outlined in the M-SFCMA. The MSY Control Rule is quite general, and defines current conditions (stock size and fishing mortality) relative to "target" (B_{MSY} and F_{MSY}) and "limit" (minimum stock size threshold and maximum fishing mortality threshold) reference points. Finally, an extension of the above Control Rule, referred to as the OY Control Rule, is also incorporated in the highly-migratory species FMP, which essentially defines more conservative fishing mortality rates for "vulnerable" (low-productivity) species, such as sharks.

2.4.3. Southeast Fisheries Science Center (SEFSC, M. Ortiz)

For highly-migratory species (HMS) in the Atlantic, the United States manages all of its fisheries for tunas and billfishes following the specifications of the M-SFCMA under the implementations and agreements of ICCAT, of which the United States is a contracting party. Two FMPs apply for highly-migratory species, the Atlantic tuna, swordfish, and sharks FMP and the billfish FMP. The two fundamental objectives of these FMPs are to halt or prevent overfishing and to rebuild overfished fish stocks to ensure the long-term sustainability of the stocks. The FMPs require that reference points for fishing mortality rate (*F*) and for biomass are defined for each stock. These reference points will be used for determining the status of the stock(s). The FMPs defined the control rules of limit reference points for *F* and biomass of each stock that will identify when overfishing is occurring and/or when the stock is overfished. The Minimum Stock Size Threshold (MSST) defines a limit biomass for which biomass levels below will be considered as an overfished stock. The maximum fishing mortality threshold (MFMT) defines the fishing rate above which the stock will be classified as in an overfishing condition. FMPs for both tunas and billfish defined F_{MSY} and corresponding fraction of B_{MSY} as the MFMT and MSST, respectively, for all species under management, with exception of Atlantic bluefin tuna, for which biomass is defined in terms of spawning stock biomass. These FMPs defined MSST fractions as a function of natural mortality rates (*M* – in fact a scalar equal to the annual mortality rate); thus MSST = $B_{limit} = (1-M)B_{MSY}$ when $M < 0.5$ and MSST = $B_{limit} = 0.5\ B_{MSY}$ when $M \geq 0.5$. For the current assessments of tunas and billfish species, only Atlantic yellowfin tuna assessments use *M* value(s) greater of 0.5.

Following these definitions, tuna and billfish stocks are considered "healthy" when the ratios of current B/B_{MSY} is greater than MSST, F/F_{MSY} is less than MFMT, and the stock is NOT in the rebuilding phase. Consistently, the stocks are considered "not healthy" when biomass falls below MSST, in which case *F* must be reduced to a level below F_{MSY} (MFMT) in order to rebuild the stock. When *F* goes above MFMT, overfishing is occurring and must be stopped immediately. It is important to note that for Atlantic tunas and swordfish managed internationally by ICCAT, F_{MSY} is considered as a target reference point, not a limit.

In addition to limit or control rules, the FMP also defined target reference points for which the fishery ought to aim in the long term. When a fishery is "healthy", managers will try to set *F* so that it produces the optimum yield (OY), resulting in a stock size of B_{OY}. OY is the yield from a fishery that will provide the greatest overall benefit to the nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems. F_{OY} is the F_{MSY} from the fishery, as reduced by any relevant social, economic, or ecological factors. Since F_{OY} cannot exceed F_{MSY}, then B_{OY} (the equilibrium or average *B* associated with F_{OY}) must be equal to or greater than B_{MSY}.

When a stock is defined as "not healthy" the FMP specifies a rebuilding plan. For tunas and billfish, only rebuilding plans that specify a constant-catch scenario are considered.

NMFS will depend on the results of the stock assessment and fishery evaluation (SAFE) report for determining the status of the stock and will follow the framework procedure before changing any management measure. Stocks under a rebuilding phase also have specific biomass and fishing rate targets. Both FMPs have defined the biomass rebuilding target as B_{MSY}. For highly-migratory species, rebuilding management alternatives follow the recommendations and programs defined by the Scientific Committee on Research and Statistics of ICCAT. The FMPs also stated that a level of acceptable probability (certainty) must be set to establish targets and to determine the level of confidence that can be placed in the recovery estimates to ensure that stocks are rebuilding. Any management action under consideration for stocks of highly-migratory species should have at least a 50-percent probability of the desired effect.

3. Multi-species and ecosystem reference points (M. Hall and M. Maunder)

Many fisheries management agencies and researchers are now focusing on fishing effects on multiple species and the environment. Development of multi-species or ecosystem reference points might be appropriate for providing advice to managers about the impacts of a fishery on the ecosystem. There are several types of reference points including 1) single-species reference points applied to multiple species (*e.g.* all species have to be above $S/S_0 = 0.2$, where *S* is the current spawning biomass and S_0 is the spawning biomass in the absence of fishing), 2) reference points based on combining species (*e.g.* sum of yield from all species = MSY), or 3) ecosystem reference points based on emergent properties (*e.g.* average trophic level).

There has been much less research carried out into the development of multi-species and ecosystem reference points compared to single-species reference points. Numerous problems must still be resolved. For example, ecosystems change naturally with the environment, fisheries may cover multiple ecosystems, how many species should be considered, which species should be considered (keystone species, indicator species), availability of data for unharvested species, should there be upper limits of abundance for some species, and are the measures species-insensitive. Reference points are only part of management, and management measures that reduce ecosystem effects must be developed (*e.g.* what harvest levels should be implemented, and what mitigation measures could be implemented).

4. Research

4.1. Management strategy evaluation of Queensland Spanish mackerel (S. Hoyle)

In management strategy evaluation, the consequences of alternative management strategies are predicted in terms relevant to the decision makers. This manifestation of decision analysis has four essential components: management objectives, performance criteria, management options, and a method for predicting the performance of the options. Decision makers must be directly involved in specifying performance criteria and management options.

The process was illustrated, using the example of the Queensland east coast Spanish mackerel fishery. Key advantages of using this approach, coupled with a Bayesian operating model, include: 1) the approach reports in terms relevant to the decision-maker, so the results are likely to be used; 2) it assesses the management system as a whole, integrating across uncertainty, which increases the accuracy of predictions; 3) performance criteria provide a common currency to assess management alternatives. Performance criteria are better expressed in terms of 'real' objectives (*e.g.* average yield, profit, risk of biomass below critical level) than in derived or surrogate objectives (*e.g.* proximity to B_{MSY}), since these are more likely to be understood and used by decision makers.

4.2. Application of spawning biomass per recruit (SBPR) proxies and effects of mis-specifying F_{MSY} for yellowfin and bigeye tuna in the eastern Pacific Ocean (S. Harley and M. Maunder)

In age-structured models many factors contribute to the estimated F_{MSY} and associated MSY and biomass of spawners at MSY (S_{MSY}), *e.g.*, the assumed spawner-recruitment curve and age-specific mortality, maturity, and selectivity. Using data from assessments of bigeye and yellowfin tuna in the EPO, we show that F_{MSY} is sensitive to the steepness (the fraction of virgin recruitment that is produced if the spawning stock size is reduced to 20% of its unexploited level, and it controls how quickly recruitment decreases when the spawning stock size is reduced) of a Beverton-Holt spawner-recruitment curve. Unfortunately, it is difficult to estimate steepness, so there is a good chance that our assumed values are incorrect.

To evaluate the possible consequences of mis-specifying steepness we used simple equilibrium equations for an age-structured model. We estimated the F_{MSY} associated with a given value for steepness and applied that fishing mortality to a population for which the true steepness was different from that assumed. For both bigeye and yellowfin we found that assuming that steepness is 1.0 (as currently assumed) will result in considerable losses in yields and reductions in spawner abundance well below S_{MSY} if the true steepness is less than 1.0. We found that assuming a steepness of around 0.6-0.7 resulted in a fishing mortality that provided yields only slightly less than MSY if true steepness was in the range of 0.5-1.0. This fishing mortality was equivalent to a spawning biomass per recruit (SBPR) of 0.4-0.5. Assuming a steepness of 0.6-0.7 or using a proxy of SBPR = 0.45 will likely result in the maximization of expected yield, given our uncertainty as to the shape of the spawner-recruitment curve.

4.3. Stochastic management strategy evaluation for tuna (S. Hoyle, M. Maunder, and S. Harley)

A stochastic operating model developed for the yellowfin tuna fishery of the EPO was used to carry out management strategy evaluation, with the aim of demonstrating aspects of the process for discussion. Performance criteria based on the management objective of MSY were defined as average yield / MSY (*Y/MSY*), final-year biomass / B_{MSY} (B/B_{MSY}), and the risk of spawning biomass going below 20% of the virgin stock size (S_{min}<20%S_0). Management options were based on alternative assumed values of steepness, $h_{assumed}$, with harvest rate set according to the NFMS Magnuson-Stevens technical guidelines under $h_{assumed}$. The performance of the management strategies was evaluated at a range of values of steepness in the operating model. The model included annual assessment of available biomass with 30% normally-distributed error, implementation error (normal) of 10% in setting harvest rate, and annual lognormal variation in recruitment of 60%. Other parameter values were set at the maximum likelihood estimates from the 2003 yellowfin tuna assessment. Assuming a steepness of 0.6 gave similar *Y/MSY* and better B/B_{MSY}, and S_{min}<20%S_0 than higher values. Steepness of 0.4 gave higher B/B_{MSY} and lower S_{min}<20%S_0 again, but at some cost in *Y/MSY*. The model was also applied to bigeye, starting at the current estimated biomass and projecting forward 5 years.

4.4. Uncertainty in reference points (R. Conser)

The use of biological reference points as a formal basis for management of fish populations has become commonplace in the world's oceans. Fishing mortality rate (*F*)-based reference points (*e.g.* $F_{20\%}$, $F_{40\%}$, $F_{0.1}$, F_{MAX}, *etc.*) are most commonly used, but biomass-based reference points have received increased interest in recent years. However, for most tuna stocks-including North Pacific albacore (*Thunnus alalunga*)-no agreed-upon biological reference point has been adopted as a formal part of the fisheries management process. With international management of tuna stocks in the western and central Pacific Ocean approaching, it is likely that consideration of appropriate biological reference points will receive renewed interest.

Traditionally, the choice of a biological reference point has been a tradeoff between taking maximum yield from a stock while ensuring its long-term sustainability. In most cases, simple models (*e.g.* spawning biomass per recruit - SBPR) are used to calculate the point estimate of an agreed-upon, *F*-based reference point for comparison with the point estimate of recent *F* from a stock assessment model. Considerable uncertainty is common in both of these point estimates, but it is usually ignored in the process of judging whether recent *F* exceeds an established *F*-based reference point.

Using North Pacific albacore as an example, methods for formally incorporating the stochastic aspects of reference point estimation, recent *F* estimation, and population projections are illustrated. Results indicate that some reference points are more difficult to estimate than others (*i.e.* the precision of the estimates can vary considerably). Consequently, in addition to the traditional tradeoffs used for selecting reference points (*i.e.* yield *vs*. sustainability), consideration of the precision of the estimates may be warranted as well.

4.5. Critical weight as a reference point (M. Maunder)

The IATTC has been presenting critical weight in its Stock Assessment Reports for several years. The critical weight, which is the weight corresponding to critical age, is compared to the average weight in the total catch and the average weight in each fishery, as predicted by the stock assessment model. The critical age is a theoretical concept that maximizes the yield from a cohort by removing all the individuals at a single age. The weight corresponding to the critical age may provide information on the status of the stock and the efficiency of the different fishing methods with respect to maximizing yields. Analyses were carried out to determine the appropriateness of critical weight as a reference point for fisheries management.

Analyses for different values of the steepness of the stock-recruitment relationship, natural mortality, growth rate, and age at maturity showed that the ratio of average weight in the catch at maximum sustainable yield (MSY) to critical weight was relatively insensitive and around 0.8. However, this ratio is very sensitive to the selectivity curve.

Fishing at a level that produces an average weight that is 80% of the critical weight, gives yields close to MSY and is relatively insensitive to the selectivity (age at first vulnerability in knife-edge selectivity) and is robust to small mis-specification in natural mortality or the growth rate. Critical weight did not appear to be a good indicator of stock status.

Eighty percent of critical weight may be a useful reference point for low-information species. Calculation of critical weight requires only estimates of natural mortality and growth rate by age. Evaluation of the stock based on critical weight requires only the measurement of average weight. There are several possible problems with using critical weight as a reference point, including difficulty in estimating the natural mortality rate, and sensitivity of average weight to recruitment fluctuations.

5. Discussions

Numerous discussions among the participants were held after each presentation and in the special sessions at the end of the meeting. In general, these discussions led to the recommendations listed in Section 6. Some of the discussion topics included: which years to use when calculating reference points, dynamic versus equilibrium reference points, presentations of reference points as ratios of indicators to the reference points to include uncertainty, what selectivity to use when creating reference points, reference points for local areas, how to relate fishing method effects on reference points, tradeoff between catchability estimates and recruitment estimates, the relationship between target and limit reference points, difficulties in determining ecosystem reference points, multi-species versus ecosystem reference points, whether B_{MSY} should be a target or a limit, sustainable overfishing, and adoption of the recommendations of the Marine Stewardship Council as a guide for reference points.

One concept that was discussed and needs definition is virgin biomass. This could mean pristine conditions prior to any fishing, conditions at time zero of the data set, or the estimate of current conditions if no fishing had taken place. A similar definition is needed for S_0: is this the spawning biomass at time zero or for zero effort?

6. Recommendations

6.1. General

Several limit reference points, particularly those that are based on probability of exceeding the limit, were recommended for further investigation; for example:

- X probability of the current spawning biomass (S_{cur}) being below $S_{F=FMSY}$
- X probability that current S is above S_{min} where S_{min} is the lower y% confidence limit of $S_{F=FMSY}$
- p($S_{cur} > S_{X\%}$) = Y
- $S_{X\%}$ *e.g.* $S_{20\%}$

Several target reference points were recommended for further investigation; for example:

- S_{MSY}
- No biomass target

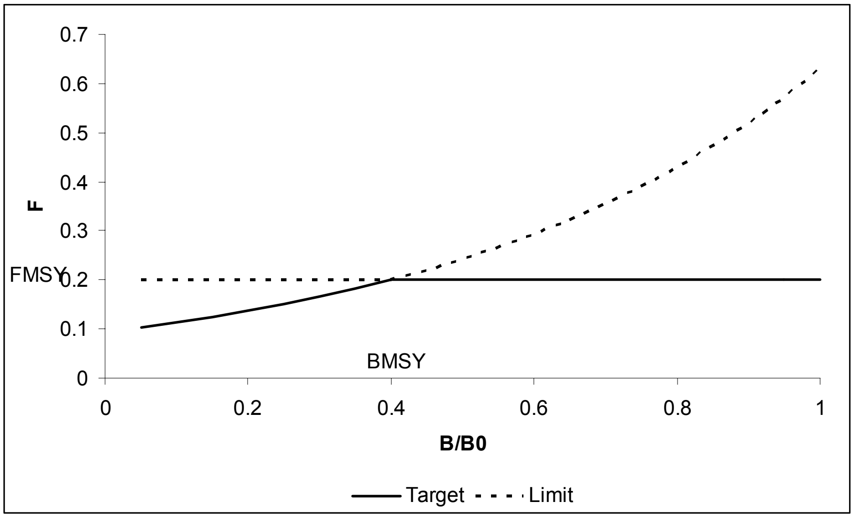
It was recommended that the quantities should be based on current age-specific relative F and that target and limit reference points that are regime-specific or robust to regime changes should be investigated.

Several quantities were recommended as indicators; for example:

- $CPUE/CPUE_{MSY}$ (empirical, model, or equilibrium based)
- C/MSY
- Calculation of the impact of each fishery (by region if possible)

- Depletion estimates based on the fished versus unexploited spawning biomass trajectories (by fishery)

It was recommended that a general framework based on an *F* reference line be investigated. This reference line determines the target as F_{MSY} if spawning biomass is above S_{MSY} and the *F* that would allow the stock to be at S_{MSY} in one generation if the spawning biomass is below S_{MSY} (see Figure). The limit would be F_{MSY} if the spawning biomass is below S_{MSY} and the *F* that would allow the stock to be at S_{MSY} in one generation if the spawning biomass is above $S_{MSY.}$ Other forms of the reference line may also be appropriate.



Several recommendations were made regarding the estimation of reference points. Robust reference points or proxies should be determined through simulations, both equilibrium and dynamic. The sensitivity of reference points to assumptions and the estimation uncertainty should be evaluated and communicated. Reference points should be compared to those of similar species. Methods should be developed to detect regime shifts and determine the responses of stocks to regime shifts. The computational requirements for determining reference points should be characterized.

Simulations of the performance and properties of alternative strategies, *e.g*., control rules based around target and limit reference points, should be carried out.

6.2. IATTC-specific

The reference points and associated quantities presented by the IATTC in its Stock Assessment Reports were evaluated and appropriate changes were recommended.

a. Confidence intervals should be calculated for SBR/SBR_{MSY} (= S/S_{MSY}).

b. The presentation of MSY and associated quantities by fishery should be grouped by fishing method.

c. The no-fishing plots should start from a unexploited condition, and include the stock-recruitment relationship, as appropriate.

d. Fishery-impact graphs similar to those used by the SPC should be presented.

e. The weight should be included on the x-axis of the critical weight plots.

f. The average weight at MSY using the fishery with the highest MSY should be included on the average weight plot.

g. The selectivity of the different fishing methods should be included on the MSY_{ref} plots.

Appendix.

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WORKING GROUP ON STOCK ASSESSMENTS

5TH MEETING

LA JOLLA, CALIFORNIA (USA)
11-13 MAY 2004

STAFF CONSERVATION RECOMMENDATIONS FOR 2005

1. YELLOWFIN TUNA

The stock assessment for yellowfin (Document IATTC-72-04, Section B) is similar to that of 2003. The base case assessment indicates that the stock size has declined from a high point in 2001 to about 80% of the level that would provide the average maximum sustained yield (AMSY). The fishing mortality rate in recent years (2001-2002) has been less than that required to produce the AMSY, but the fleet capacity continued to grow. The base case assessment did not include a stock-recruitment relationship; if that were incorporated (the alternative assessment), the current estimated stock size would be only 60% of the AMSY level, and the fishing mortality rate would be greater than the rate corresponding to the AMSY. The forecast recovery of the spawning stock to above the AMSY level depends on future recruitment being at average levels.

Regardless of the recruitment, the total catch and stock size could be increased if the average size of the yellowfin in the catch were increased. The longline fishery produces the largest-sized fish, but takes less than 5% of the catch. The purse-seine fishery takes fish of less than the critical size (although there are marked differences in size of yellowfin taken in different set types.) The catch from other fisheries is negligible.

The base case assessment estimates that fishing mortality rate corresponding to the AMSY is 12% more than the fishing mortality rate during 2001-2002. The closures affecting yellowfin during 2001-2002 reduced the time available for fishing to 87% of the year. Between the end of 2001 and of the end of 2003 the capacity at sea increased by 18%. On the basis of this assessment the purse-seine fishery in 2005 should be restricted for 17% of the year, or the equivalent of two months.

The recommendation assumes that the fleet capacity will not continue to grow; if it does, greater reductions would be necessary to keep the fishing mortality rate corresponding to the AMSY.

The alternative assessment, which includes a stock-recruitment relationship, starts with an estimate of fishing mortality that is 20% greater than that corresponding to the AMSY. The same considerations concerning previous closures and growth of the fleet apply, and suggest the need for a longer closure.

1.1. Recommendations

1. Close the purse-seine fishery in the eastern Pacific Ocean for two months in 2005.

2. BIGEYE TUNA

The 2004 results are similar to those of previous assessments (Document IATTC-72-04, Section D), and consistent with the previous stock projections. Longline catches are a large part of the total bigeye catch, and at the time of the assessment all longline catch and effort data for 2003 were not available, so fishing effort was assumed to be the same as that for 2002. Species composition sampling of the purse-seine catches during the past four years produces estimates of the purse-seine catches greater than reported unloadings. Accordingly, sensitivity analyses included alternative versions of the basic input data.

The trends reported last year have continued. Recent recruitment has been poor, and the stock is declining. The large recruitment from 1995-1997 which provided large purse-seine catches in 2000 and improved longline catches in 2001 is now passing out of the longline fishery. The stock is now below the

AMSY level. While there is no evidence of a relationship between stock size and recruitment, the stock will reach lower levels than have been seen. The base case assessment estimates that fishing mortality rate corresponding to the AMSY is 38% less than the fishing mortality rate during 2001-2002, and the alternatives considered suggested reductions ranging from 20% to 62%. Taking account of the restrictions in 2001 and 2002 and the continuing growth of fleets, catches should be reduced by 50%.

The reduction in bigeye catches should be greater than that achievable by the two-month closure to purse-seine fishing proposed for conservation of yellowfin in 2005. Over the past four years the Commission has adopted several different measures to restrict bigeye catches.

2000: Resolution C-00-02 imposed a three-month closure for purse-seine fishing on floating objects.

2001: Resolution C-01-06 imposed a closure for sets on floating objects if a catch limit was reached. This closure was not triggered.

In view of the significant compliance problems resulting from the difficulty in defining sets on floating objects, the Commission contemplated other measures.

2002: Resolution C-02-04 imposed a one-month closure on all purse-seine fishing in the eastern Pacific Ocean (EPO). This compromise between the requirements for conservation of yellowfin and bigeye tuna, which involved a greater restriction on yellowfin and lesser one on bigeye than the assessment suggested, was thought to be useful because of the simplicity of implementing a total closure.

In 2003, the staff's conservation recommendations contemplated much more severe measures for bigeye than for yellowfin. Thus, for the purse-seine fishery a two-month closure was proposed for the entire EPO, affecting both species, with an additional closure of a certain area that would affect mainly bigeye. The 2003 resolution (C-03-12) imposed a closure of an area of the EPO in December 2003 and a six-week closure of the entire EPO in July and August 2004 for the purse-seine fishery, and restricted longline catches to 2001 levels.

The staff's evaluation of the limited closure in 2003 indicatesd that the area was too small to have any effect on purse-seine catches of bigeye.

On several occasions the staff has expressed the view that changes in fishing practices might allow the catches of bigeye to be reduced without reducing the catches of skipjack to the same extent.

Purse-seine sets on floating objects take primarily skipjack, and closures to conserve bigeye may reduce skipjack catches unnecessarily. In recent years, 15 vessels have taken 50% of the purse-seine catch of bigeye, suggesting that it is possible to reduce catches of bigeye in sets on floating objects. Individual vessel catch limits for bigeye tuna should be considered as a way of allowing purse-seine vessels to continue fishing for skipjack while reducing catches of bigeye. This type of restriction would not affect most of the vessels that primarily catch skipjack.

Given the very low projected levels of spawning stock size, the catches of both large and small fish should be reduced. Between 2000 and 2001, longline catches increased by nearly 50%, from about 45,000 to about 63,000 t. Measures should be taken to restrict the total longline catch to the level of 2000. Longline fisheries may adjust gear configurations and areas of operation to decrease the catch of bigeye tuna.

2.1. Recommendations

The following recommendations (1-3) are for measures to be applied in 2005, in keeping with paragraph 9 of Resolution C-03-12 (*Resolution on the conservation of tuna in the EPO*, October 2003). However, on the basis of the assessments and new information presented at this meeting, the staff recommends that the Commission also consider additional conservation measures for bigeye in 2004.

1. Close the purse-seine fishery in the eastern Pacific Ocean for two months.

2. Reduce longline catches of bigeye in the eastern Pacific Ocean to the levels of 2000.
3. The three alternative options proposed below, in addition to recommendation 1 above, are intended to reduce the purse-seine fishing effort on bigeye in 2005 by 50%:
    a) Close the purse-seine fishery for six months in the area between 8°N and 10°S west of 95°W; this closure would not occur simultaneously with the two-month closure of the entire EPO recommended in (1) above, or
    b) Close the purse-seine fishery on floating objects for six months in the area west of 95°W; this closure would not occur simultaneously with the twomonth closure of the entire EPO recommended in (1) above, or
    c) Limit the total annual catch of bigeye by each purse-seine vessel that is required to carry an observer to 500 metric tons, estimated either by the observer or, at the request of the captain, by scientific sampling of the vessel's catch conducted by IATTC staff at the time of unloading. If this latter option is chosen, the vessel would be responsible for the costs of the sampling.

3. OTHER SPECIES

There are no recommendations for management of fisheries for other species.