Workshop to Further Develop, Test and Apply a Method for the Estimation of Tuna Fishing Capacity from Stock Assessment-Related Information

La Jolla, California, USA
14-16 May 2007

1. Opening

On behalf of the Food and Agriculture Organization of the United Nations (FAO) and its Project on the Management of Tuna Fishing Capacity, Dr. Jacek Majkowski, the Coordinator of the project and the Convenor of the Workshop, opened the Workshop to Further Develop, Test and Apply a Method for the Estimation of Tuna Fishing Capacity from Stock Assessment-Related Information. He welcomed the participants, thanking them for their attendance at the Workshop and expressing gratitude to the countries, institutions and persons who contributed to its organization.

In particular, he pointed out that:

- Through the FAO Project, the government of Japan has provided funds for the organization of the Workshop,
- The Inter-American Tropical Tuna Commission (IATTC) has kindly offered to host it,
- The subject of the Workshop is a method developed by Dr. Victor Restrepo of the International Commission for the Conservation of Atlantic Tunas (ICCAT) that he presented at the Methodological Workshop on the Management of Tuna Fishing Capacity (La Jolla, California, USA, 8-12 May 2006) and
- Dr. Haritz Arrizabalaga of AZTI-Tecnalia/Marine Research carried out various analyses, using the new method, which are described in his paper presented at the Workshop of 14-15 May 2007.

2. Introduction of Participants

Dr. Majkowski introduced Dr. Robin Allen, Director of the Inter-American Tropical Tuna Commission (IATTC), who would serve as Chairman of the Workshop.
Dr. Allen asked the participants of the Workshop to introduce themselves. The participants are listed in Appendix I.

3. Adoption of the Provisional Agenda

The Provisional Agenda of the Workshop (Appendix II) was adopted without any changes.

4. Logistic arrangements for the Workshop

Dr. Allen summarized the various logistic arrangements for the Workshop.

Dr. Majkowski suggested the following participants as Rapporteurs.

Agenda Items 1 to 5 – Jacek Majkowski
Agenda Item 6 – Robin Allen
Agenda Item 7 – Mark Maunder and Iago Mosqueira
Agenda Item 8 – Mark Maunder
Agenda Item 9 – SungKwon Soh
Agenda Items 10 and 11 – Yukio Takeuchi
Agenda Items 12 and 13 – Jacek Majkowski
Overall coordination – Haritz Arrizabalaga and Jacek Majkowski

5. FAO`s Activities on the Management of Tuna Fishing Capacity: Progress Report

Dr. Majkowski outlined the activities of the FAO's Project on the Management of Tuna Fishing Capacity, emphasizing those of direct relevance to the Workshop. He pointed out that the Project, which was financed by the government of Japan, commenced its activities in the second half of 2002. To foster the collaboration of the regional fisheries management organizations (RFMOs) concerned with tunas and other institutions involved in tuna fishing and fisheries research and management, the Project established an external Technical Advisory Committee (TAC) composed of experts affiliated with these institutions.

At the first meeting of the TAC, held in Rome, Italy, on 26-28 March 2003, the objectives were to:

- review methods for the estimation of fishing capacity and their data requirements,
- determine the applicability of these methods for tuna fisheries and
- finalise the proposal for the studies to be carried out by the Project.

The subjects of these studies were:

- tuna resources and fisheries,
- quantification of tuna fishing capacity,
- demand for tuna raw materials and products and their prices and
- management of tuna fisheries, particularly through controlling fishing capacity.

At the second meeting of the TAC, held in Madrid, Spain, on 15-18 March 2004, the objectives were to:

- review the outcome of the studies implemented by the Project and
- make recommendations on tuna fishing capacity management and future activities of the Project.

The participants in the second meeting of TAC also prepared a statement, which was presented at the Technical Consultation to Review Progress and Promote the Full Implementation of the International Plan of Action (IPOA) to Prevent, Deter and Eliminate IUU [Illegal, Unreported and Unregulated] Fishing and the IPOA for the Management of Fishing Capacity. (Rome, Italy, 24-29 June 2004). The papers resulting from the studies were published as the 336-page FAO Fisheries Proceedings No. 2 (Second Meeting of the Technical Advisory Committee of the FAO Project "Management of Tuna Fishing Capacity: Conservation and Socio-Economics", Madrid, Spain, 15-18 March 2004).

As a follow up to the second Meeting of TAC, the Project organized the Methodological Workshop on the Management of Tuna Fishing Capacity, which was hosted by the IATTC in La Jolla, California, USA, on 8-12 May 2006. The Workshop was organized by the Project in collaboration with and with financial and in-kind support of (1) most tuna agencies and programs, (2) some other international and national fisheries institutions, including those of the tuna fishing industry and (3) some universities. These included:

- the Forum Fisheries Agency, the IATTC, ICCAT, the Indian Ocean Tuna Commission, the Secretariat of the Pacific Community,
- the Japan Federation of Tuna Fishermen's Association, the U.S. National Marine Fisheries Service, the National Research Institute of Far Seas Fisheries of Japan, the World Tuna Purse-Seine Organization,
- the College of William and Mary and the University of California, San Diego.

The objectives of the workshop were:

- to develop methods for the estimation of tuna fishing capacity from stock assessment-related information,
- to determine the feasibility of (1) routinely collecting input data for performing Data Envelopment Analysis (DEA) and (2) performing industry surveys of tuna fishing capacity utilization,
- to relate DEA estimates of fishing capacity utilization to traditional estimates of fishing capacity,
- to review the factors affecting fishing capacity (such as the numbers of vessels and their physical characteristics) that could be regulated by fisheries authorities,
- to review the existing measures for managing tuna fishing capacity, and possibly to identify additional options for such measures in the context of the outcome of addressing the above-mentioned objectives,
- to prepare a statement of the participants in the Workshop and
- to formulate recommendations of the Workshop to the FAO Project on the Management of Tuna Fishing Capacity, FAO and the other institutions participating in the Workshop.

The method mentioned in the first objective of the previous Workshop was developed, but not tested and applied comprehensively to tuna stocks on a global scale. For that reason, the present Workshop was held.

The papers from the previous workshop and its Report have been edited, and will be published as an FAO Fisheries Proceedings. The Statement of the previous Workshop was presented to the Meeting of tuna RFMOs and their members, which was held in Kobe, Japan, in January 2007.

6. Meeting of Tuna Regional Fisheries Organizations and their Members (Kobe, Japan, 22-26 January 2007): Developments Related to the Management of Tuna Fishing Capacity

Dr. Allen reported on the discussions on tuna fishing capacity at the meeting of tuna RFMOs and their members. Fleet capacity was discussed under the agenda item concerning specific actions to improve the functions of each RFMO, including coordination and collaboration among the RFMOs. The results of the 2006 Methodological Workshop on Fishing Capacity were presented, together with a statement from a related IATTC Workshop on Regional Economic Cooperation in the Pacific Fishery for Tropical Tunas. The course of actions agreed by the Kobe Meeting included the following actions on tuna fishing capacity.

- Development, where appropriate, and application of equitable and transparent criteria and procedures for allocation of fishing opportunities or level of fishing effort, including provisions to allow for new entrants.
- Controls, including fishing capacity reduction as appropriate, to ensure that actual total catch, fishing effort and capacity are commensurate with available fishing opportunities in order to ensure sustainability of tuna stocks while allowing legitimate fishery development of developing coastal states, particularly small island developing states and territories.

7. Estimation of Tuna Fishing Capacity from Stock Assessment-Related Information

a) Outline of the Method

In a paper presented at the Methodological Workshop on the Management of Tuna Fishing Capacity, held in La Jolla, California, USA, on 8-12 May 2006. Restrepo (in press) presented a method for the estimation of fishing capacity on tuna fisheries based on estimates of fishing mortality obtained from stock assessments. In contrast to economic methods of capacity estimation (Kirkley and Squires, 1999), this method does not require disaggregated data and uses information readily available for most tuna stocks.

In brief, an algorithm connects consecutive peaks, defined here as values larger than the two nearest ones, of fishing mortality by quarter and on a fishery-by-fishery basis. These are then used to infer the output capacity (in tons) for each fishery. Information

on age-specific selectivity and trends in fishing efficiency is also incorporated. The original document presented an application of the method to Atlantic bigeye tuna.

The author highlighted the simplicity of the approach, but also recognized the lack of a sound theoretical basis and the multiple methodological choices available for its implementation. For example, a Generalized Additive Modeling approach was suggested in an appendix, and a piece-wise regression between peaks was suggested as an alternative to the peak analysis conducted.

<u>Presentation:</u> "Thoughts on capacity and its estimation", prepared by Victor Restrepo.

A presentation based on that prepared by Dr. Restrepo for ICCAT's Working Group on Methods (Madrid, Spain, 19-23 March 2007) was given by Dr. Arrizabalaga. The main points of the method were covered, and the calculation procedure was explained in detail (Figure 1).

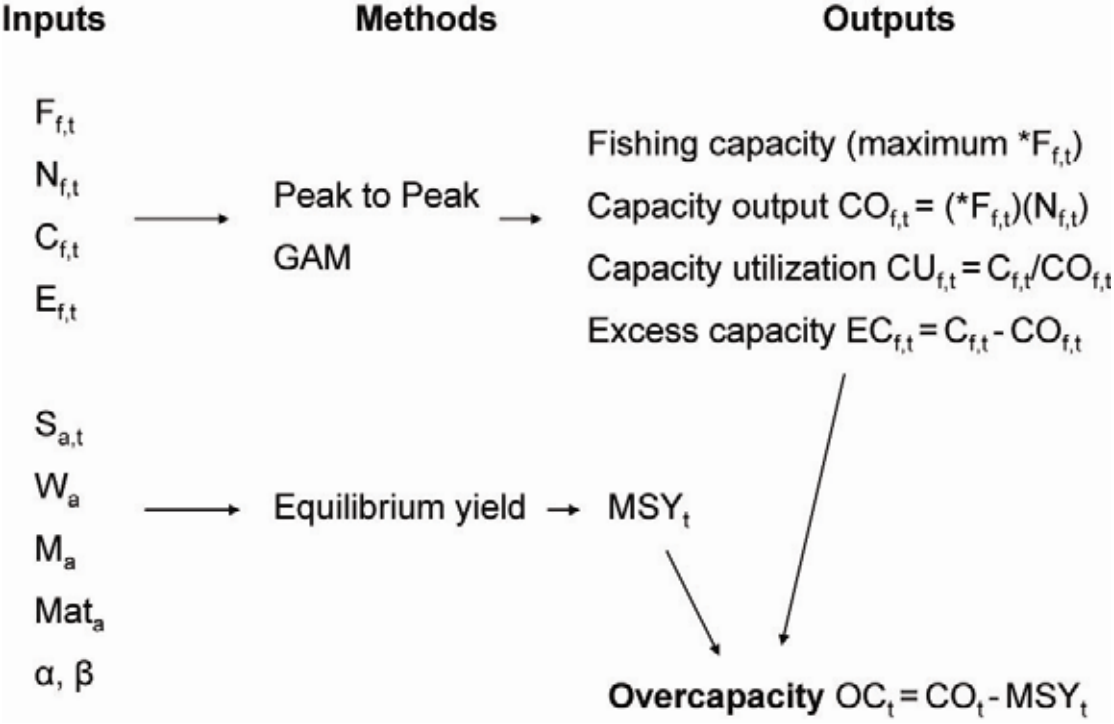

Figure 1: Schematic of the calculations in the method. F, fishing mortality; N, exploitable biomass; C, catch; E, effort; S, selectivity; W, weights at age; M, natural mortality; Mat, maturity; α and β, parameters of the Beverton and Holt stock-recruitment relationship; GAM, general additive model; MSY, maximum sustainable yield. Subscripts $_{f,\ t}$ and $_a$ stand for fishery, time and age, respectively.

Discussion

A general discussion on the merits and possible shortcomings of the method brought out some issues that might warrant further investigation. Both methods assume that

peak *F*s are measured without error. It was pointed out that the influence of the quality of the estimates of *F* on the results obtained is an important consideration.

Although the method incorporates yearly values of maximum sustainable yield (MSY), in the examples presented these vary only due to changes in selectivity. It might be necessary to incorporate changes in the ecosystem, such as the regime shifts observed in the past in the eastern Pacific Ocean, that would switch the system to a different MSY level.

The impact of management measures, such as closures, on *F* must be considered carefully. If fishing effort, and hence fishing mortality, are restricted through management measures, the analysis would likely interpret it as a decrease in fishing capacity. If, in fact, there has been no reduction in fishing capacity, a possible solution would be to adjust the values of *F* for the effect of management regulations, for the appropriate period of time, before fitting the model.

The possible impact of fleets switching between stocks on the estimates of capacity based on fishing mortality was discussed. For example, fleets moving between the western and central Pacific and eastern Pacific areas would decrease fishing pressure on one of the stocks, this change being reflected in estimates of fishing mortality and fishing capacity. However, the effective fishing capacity may remain at the previous level, as those fleets may be permitted to return to the initial stock.

b) Application and Testing of the Method

***Presentation*: "Methods to estimate fishing capacity using stock assessment information. Sensitivity tests and application to Pacific, Atlantic and Indian Ocean tuna stocks" by Haritz Arrizabalaga**

An example of implementation of the method outlined above was presented by Dr. Arrizabalaga. Capacity analyses were carried out for seven stocks (Atlantic bigeye, eastern Pacific bigeye, western and central Pacific bigeye, Indian Ocean bigeye, western and central Pacific yellowfin, eastern Pacific yellowfin and western and central Pacific skipjack).

Sensitivity analyses were also conducted to assess the impact on the estimates of capacity of the level of aggregation of the input data and of the variability on the estimates of fishing mortality allowed in the Multifan-CL model fits. For the first case, three levels of time-gear aggregation on an assessment of Atlantic bigeye conducted using Multifan-CL were considered:

- Fourteen fisheries were considered in quarterly time steps, as in the original assessment.
- The data were aggregated around three fisheries, purse seine, longline and others, and by semester.
- All fisheries were combined into a single fishery, and the data were considered in yearly time steps.

The effect of the given variability in estimates of fishing mortality in Multifan-CL was investigated by redoing the Atlantic bigeye assessment with three levels of variability (measured as $p = 1/(2*CV^2)$):

- The original values of p = 5, 10 and 20
- A high *F* variability scenario with p = 1, 2 and 3
- A low *F* variability scenario with p = 20, 40 and 80

The main conclusions of this exercise were related to both the method itself and the results obtained for the stocks analyzed. Values estimated using the peak-to-peak method were usually greater than those obtained with general additive modeling (GAM). This is not unexpected, as the peak-to-peak method tends to provide values as high as the greatest values obtained, while GAM provides a smooth time series that is later raised to the maximum values observed.

Periods during which the peak-to-peak method estimated overcapacity were apparent in almost all the stocks. A common trend in time was apparent for most stocks too, reaching maximum values during the late 1990s or early 2000s. For most of the stocks analyzed, there was overcapacity during some years. An increase in overcapacity along the time series was due to both an increase in capacity output and a decrease in MSY due to changes in selectivity.

The sensitivity analyses conducted showed the importance of assumptions in the stock assessment, especially those affecting the estimation of MSY. Comparison of the effect of data aggregation appeared to indicate that as the input data are aggregated, overcapacity is estimated to be less than with disaggregated data.

The relationship between effort and capacity output was not clearly evident for most stocks, which limits the ability to determine appropriate effort levels from capacity analyses. The relationship between estimated capacity output and effort for all fisheries in the bigeye tuna stock of the western and central Pacific Ocean is shown in Figure 2.

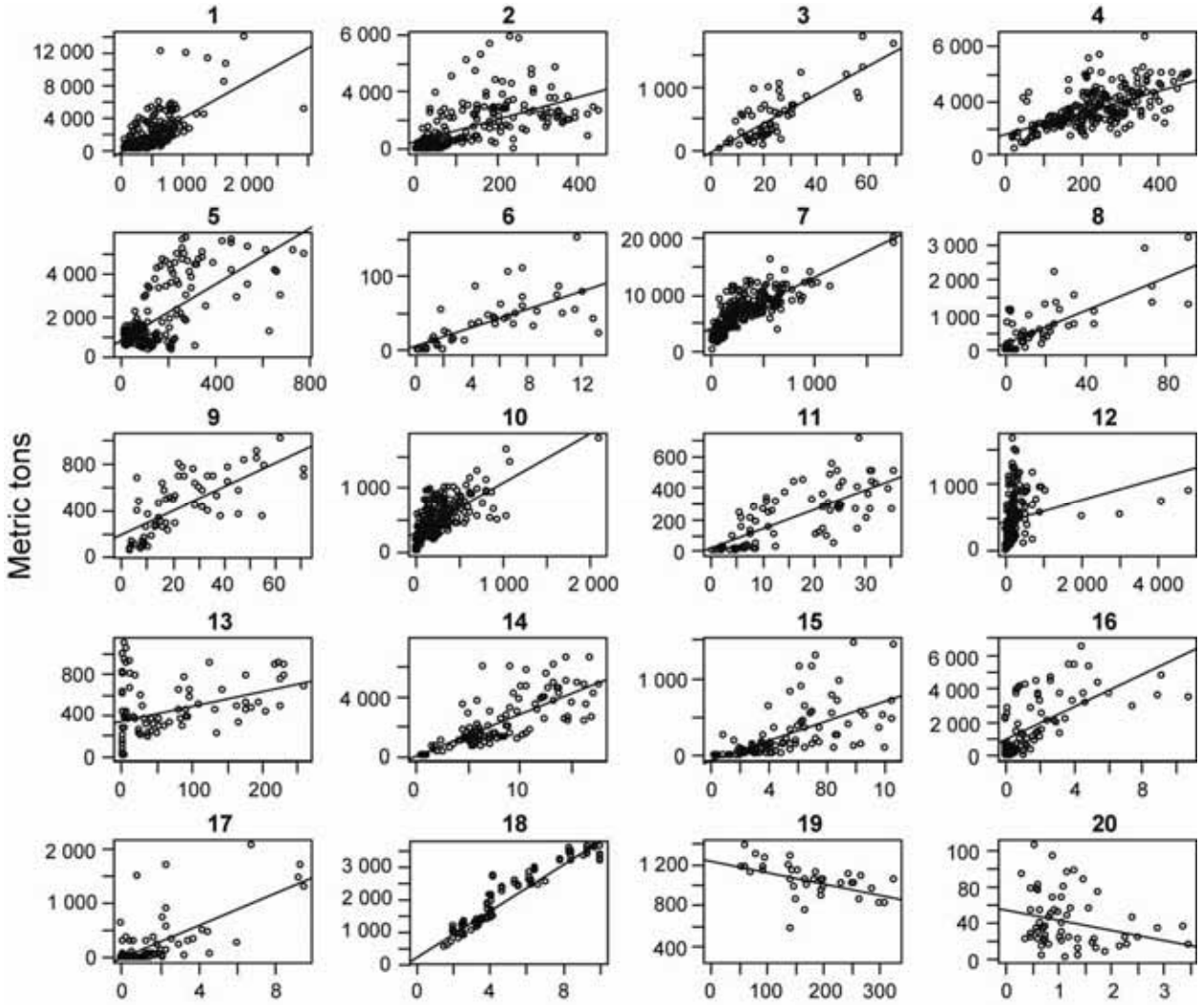

Figure 2: Western and central Pacific bigeye tuna. Relationship between estimated capacity output (Y axis) and fishing effort (X axis), by fishery (number at the top of each panel).

c) General Discussion

The difference in the estimates of capacity obtained at the beginning and the end of each time series was noted. The GAM and peak-to-peak methods estimate different values at the start and end of the series, as a GAM is able to interpolate along the whole series, while the implementation of the peak-to-peak method used the observed *F* values as measures of fishing capacity before the first and after the last peak.

The sensitivity analyses carried out appear to indicate that overcapacity estimates are quite sensitive to the way fishing mortality is estimated in the various stock assessment methods, as the inverse relationship between fishing mortality and biomass estimates affects the MSY-related calculations. Assessments carried out using Multifan-CL seem to be especially affected, which could be related to the way fishing mortality is modeled in this model. The coefficient of variation in the fishing

mortality estimation is modified, but variability in length frequencies is not, so their relative importance is effectively being altered.

The results for the most recent year obtained for bigeye tuna of the western and central Pacific Ocean were negatively affected by having only some of the longline data. A previous comment on the need to account for known changes in the environment modifying the value of MSY was highlighted by the estimates of capacity for eastern Pacific bigeye. Overcapacity was estimated to be very great in 2000, following abnormally strong recruitment. Similarly, the trends in capacity presented for eastern Pacific yellowfin tuna are not completely consistent with current knowledge of both fishery and stock, which motivated the use of dynamic MSY, as described below.

Variations in the estimated capacity may be caused by variations in fishing mortality due to the imperfect ability of fleets to obtain the same results with their effort.

Computing dynamic MSY based on F_{MSY} and biomass estimates (Dr. Mark Maunder)

An alternative calculation of MSY, taking into consideration yearly changes in stock abundance due to recruitment and environmental factors, was presented for yellowfin tuna in the eastern Pacific Ocean. MSY is estimated by modeling the population over the historical period, while applying F_{MSY} to recruitment and other parameters taken from the stock assessment. It was suggested that an alternative approach would be to take biomass estimates themselves from the stock assessment for each year and multiply that quantity by F_{MSY}. When MSY is considered to vary according to stock productivity, a different picture of the relationship between catch and capacity emerges.

The estimates of capacity output are shown in Figure 3.

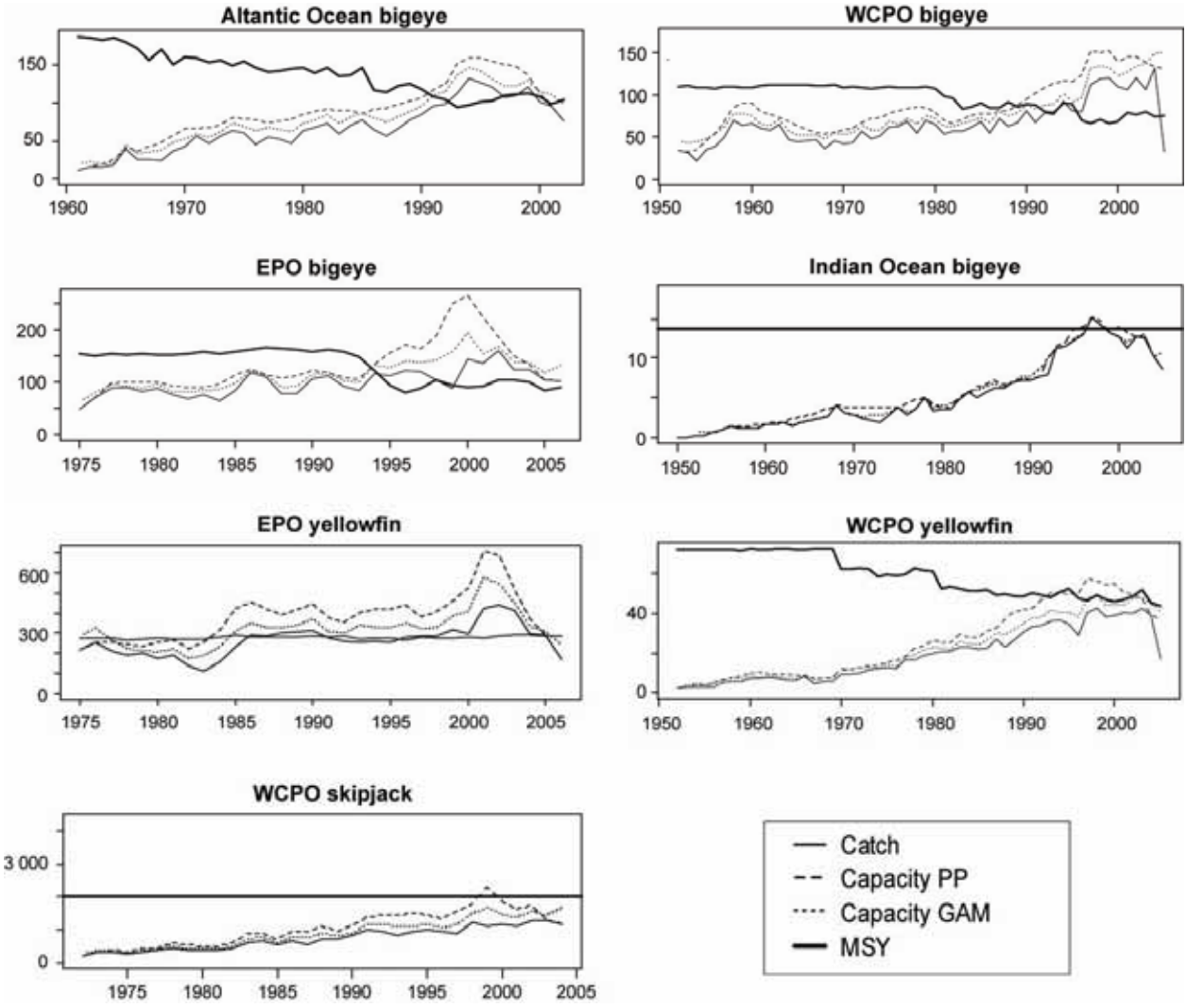

Figure 3: Estimates of capacity output, with the Peak to Peak (PP) and general additive model (GAM) methods for all stocks considered in the paper. MSY = maximum sustainable yield; WCPO = western and central Pacific Ocean; EPO = eastern Pacific Ocean.

d) Conclusions

- The workshop recognized the usefulness of this method as a strategic tool to identify problems in estimating capacity and trends in capacity over time, especially in settings in which both fishing mortality and stock abundance fluctuate significantly.
- A useful addition to this method for management purposes would be to simulate the population consequences of application of the estimated fishing capacities to the stock. Increases in capacity following the estimations obtained here would have an impact on the abundance, and thus on the corresponding ability of the fleet to exert its fishing capacity on the stock in the following year.

Methodological

- Calculations should be extended to include MSY variability due to environmental factors, changes in productivity and variability in recruitment, in addition to changes in selectivity.
- Although general methods for calculating capacity such as this one allow for direct comparison of results among stocks and regions, *ad-hoc* methods adapted to the local characteristics of both fishery and stock might provide more practical estimates on which to base management. As the theoretical basis for a method for estimating maximum fishing mortality is not clear, it might prove difficult to justify its adoption.
- One of the methods employed, the peak-to-peak method, appears to underestimate capacity at the start and the end of the series unless peaks are present on the first and last values. The GAM-based method does not suffer from this limitation, as splines are able to interpolate along the whole time series. However, the choice of smoothing splines is mostly arbitrary.
- Fisheries assessment techniques are capable of calculating desired target fleet sizes. For example, with stable gear mixes and average recruitment, F_{MSY} can be estimated and compared to actual *F(t),* which itself can be related over longer periods of time with levels of fishing effort as measured by days at sea, which, in turn, can be related to fleet size.
- Fishing mortality may be a more appropriate measure of capacity than catch. For example, if the fishery is operating at FMSY and the population size is above the biomass corresponding to MSY (BMSY), the fishery would be designated as at overcapacity, even though the number of vessels may be appropriate to produce the average MSY when the population is at BMSY. The population may be above BMSY because the stock has historically been only lightly exploited or because of increases in productivity (see above).
- Conversely, fishing an overfished stock at FMSY will produce estimated negative overcapacity (using the average MSY).

Interpretation

- Estimates of capacity may be biased upward because the catch may be restricted by the carrying capacity of the fleet and travel time, rather than by the ability of the fleet to find the fish.
- Interpretation of peak values in fishing mortality should include consideration of a range of possible factors. The method assumes that peaks represent instances of full use of the fleet capacity. An alternative view, for example, could explain those peaks as changes in catchability due to environmental or technological factors.
- External information on stock and fishery dynamics that might help explain peaks in fishing mortality should be used. Management measures, changes in fleet dynamics or other biological and technological factors might be behind

some of the observed peaks in fishing mortality, and should not be interpreted only as changes in capacity.

- The difference between potential and practical capacity should be fully explored. Estimates of overcapacity in years during which the catches were extremely high appear to indicate that the method provides an indication of maximum capacity that cannot always be achieved even under the best conditions.
- The methods of estimation of excess capacity reviewed during the meeting all guarantee that the results will indicate excess capacity every year and for every species. Furthermore, if the fishery is managed in what some might consider appropriately by fishing the stock at $F_{MSY}\ (t)$ the annual catch would match dynamic MSY_t, defined as $\sim B_t * F_{MSY,t}$, and thereby guarantee that the estimates will indicate that overcapacity exists. Yellowfin tuna in the eastern Pacific Ocean is a case in point.
- The quantities "excess capacity" and "over-capacity" (defined as capacity output minus catch and capacity output divided by MSY, respectively) may not represent the estimates desired by fisheries management. Instead fisheries managers may be more interested in obtaining practical levels of fleet size that would allow the fleet to operate under normal conditions year-round without need for further management constraints, except in some circumstances (*e.g.* the need to reduce the catches of bigeye tuna in sets made on tunas associated with floating objects).

8. Proposals forFurther Application and Testing of the Method

It was noted that certain tuna RFMOs may be interested in additional applications of the method, using updated stock assessment data. In this case, the issues summarized in the General Discussion, Conclusions and Recommendations section should be taken into consideration.

Two alternative approaches to the estimation of tuna fishing capacity were recommended for further investigation. The first approach uses F/F_{MSY} as a practical indication of the level of overcapacity, rather than considering it in the context of economic definitions. Regression of F against explanatory factors (*e.g.* total vessel tonnage and stock biomass) could be used to identify appropriate ways to restrict capacity.

The second approach is a method that uses vessel-specific estimates of fishing mortality, rather than estimates aggregated by fishery.

9. Plans for Publications

There was agreement that the work presented by Dr. Arrizabalaga and discussions at the Workshop provided insight into the Dr. Restrepo's method and into problems

associated with estimating fishing capacity in general. Two outlets for publication were suggested. The first was FAO Fisheries Proceedings (Report of the Workshop, plus the paper by Dr Arrizabalaga, with a brief description of the events in the fishery that may have affected the estimates of overcapacity). The second was a primary publication in a peer-reviewed journal such as the Fishery Bulletin or Marine Policy, which would outline the problems of determining capacity.

10. General Discussion, Conclusions and Recommendations

The Workshop identified the various difficulties and problems with using the methods considered to estimate fishing mortality. They are probably applicable to the DEA methods, but the lack of expertise at this Workshop did not allow the participants to fully consider them.

The future of the TAC of the FAO Project on the Management of Tuna Fishing Capacity was discussed. In addition to its advisory role for the FAO Project, the Workshop recognized the usefulness of the TAC as a forum for the tuna RFMOs and the tuna fishing industry

- to consider the technical issues involved and
- to consult and coordinate the research related to the management of tuna fishing capacity.

Therefore, the Workshop recommended that before the termination of the FAO Project on the Management of Tuna Fishing Capacity, FAO in consultation with the TAC, consider the transformation of the TAC into a Technical Coordination Committee (TCC) that would continue provide such a forum after the termination of the FAO Project.

The Workshop recommended also that FAO secure funds for meetings of the TCC, for technical work on the management of tuna fishing capacity and for work required to complete the publications described in section 9.

11. Any Other Matters

No other matters were considered by the participants in the Workshop.

12. Adoption of the Report

The Report of the Workshop was adopted on 16 May 2007.

13. Adjournment of the Workshop

Dr. Majkowski, Convenor of the Workshop, thanked:

- The IATTC for hosting the Workshop,
- Dr. Allen for chairing the Workshop,

- Dr. Arrizabalaga for his presentation,
- The rapporteurs for drafting the report,
- All the participants in the Workshop for their technical input to the Workshop and
- Ms. Mónica Galván and Ms. Cynthia Sacco for secretarial and other assistance.

14. References

Anon. 2007. Report of the Methodological Workshop on the Management of Tuna Fishing Capacity: Stock Status, Data Envelopment Analysis, Industry Surveys and Management Options. *In* W.H. Bayliff and J. Majkowski, eds. *FAO Fish. Proceedings* No. 8: 1-13, Rome.

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Restrepo V.R. 2007. Estimates of large-scale purse-seine, baitboat and longline fishing capacity in the Atlantic Ocean: an analysis based on a stock assessment of bigeye tuna. *In* W.H. Bayliff and J. Majkowski, eds. Report of the Methodological Workshop on the Management of Tuna Fishing Capacity: Stock Status, Data Envelopment Analysis, Industry Surveys and Management Options, *FAO Fish. Proceedings* No. 8: 51-62, Rome.

Appendix I

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Appendix II

Agenda

14 May 2007 (Monday), 9.30 a.m.

1. Opening
2. Introduction of Participants
3. Adoption of the Provisional Agenda
4. Logistic Arrangements for the Workshop
5. FAO's Activities on the Management of Tuna Fishing Capacity: Progress Report
6. Meeting of Tuna Regional Fisheries Organizations and their Members (Kobe, Japan, 22-26 January 2007): Developments Related to the Management of Tuna Fishing Capacity
7. **Estimation of Tuna Fishing Capacity from Stock Assessment-Related Information**
   a) Outline of Method
   b) Application and Testing of the Method
   c) General Discussion
   d) Conclusions

15 May 2007 (Tuesday), 9.00 a.m.

7. **Estimation of Tuna Fishing Capacity from Stock Assessment-Related Information (*continued*)**
8. Proposals for Further Application and Testing of the Method
9. Plans for Publications
10. General Discussion, Conclusions and Recommendations
11. Any Other Matters

16 May 2007 (Wednesday), 1.00 p.m.

12. Adoption of the Report
13. Adjournment of the Workshop