BLUEFIN TUNA RESEARCH PROGRAM PLANNING MEETING

(ICCAT Secretariat, 15-16 May 2003)

SUMMARY

At its November 2002 meeting, the Commission recommended that a Working Group, comprised of scientists and managers, be established to evaluate all available biological information relevant to the issue of stock structure and mixing, and to develop operational options for implementing alternative approaches for managing mixed populations of Atlantic bluefin tuna, considering scientific information on the biology of bluefin tuna, historical data on fisheries, and the feasibility of alternative scenarios [Ref. 02-11]. In anticipation of that meeting, the SCRS Chairman requested a meeting 15-16 May 2003 in Madrid with bluefin tuna scientific advisors to discuss the development of a large-scale ICCAT bluefin tuna research proposal. The report of this meeting was considered a starting point by the SCRS for a research plan.

RÉSUMÉ

A sa réunion de novembre 2002, la Commission a recommandé qu'un Groupe de travail composé de scientifiques et de gestionnaires soit établi afin d'évaluer toute l'information biologique disponible sur la structure et le mélange des stocks, et d'élaborer des options opérationnelles visant à mettre en place des approches alternatives de gestion des populations mixtes de thon rouge de l'Atlantique, en tenant compte de l'information scientifique sur la biologie du thon rouge, des données historiques sur les pêcheries et de la faisabilité d'autres scénarios [Réf. 02-11]. Avant cette réunion, le Président du SCRS a sollicité la tenue d'une réunion les 15 et 16 mai 2003 à Madrid rassemblant des conseillers scientifiques sur le thon rouge afin de discuter de l'élaboration d'une proposition de programme de recherche ICCAT de grande envergure sur le thon rouge. Le SCRS a estimé que le rapport de cette réunion servirait de point de départ au programme de recherche

RESUMEN

En su reunión de noviembre de 2002, la Comisión recomendó que se estableciese un Grupo de Trabajo, formado por científicos y gestores, para evaluar toda la información biológica disponible relacionada con cuestiones de estructura y mezcla del stock, y para desarrollar opciones operativas para implementar enfoques alternativos para la ordenación de las poblaciones mezcladas del atún rojo del Atlántico, considerando la información científica sobre biología del atún rojo, los datos históricos de las pesquerías y la viabilidad de escenarios alternativos [Ref. 02-11]. Como adelanto de dicha reunión, el presidente del SCRS convocó una reunión del 15 al 16 de mayo de 2003, en Madrid, con los asesores científicos del atún rojo para debatir el desarrollo de una propuesta de ICCAT para la investigación a gran escala sobre el atún rojo. El SCRS consideró el informe de dicha reunión como el punto de partida para un plan de investigación.

KEYWORDS

Bluefin tuna, Biological sampling, Stock identification, Environmental factors, Operational models

1 Opening of meeting

The meeting was opened and chaired on 15 May by the Bluefin Tuna Rapporteur, Dr. Joseph Powers, in the absence of the SCRS Chairman, who was delayed by one day. The remainder of the meeting was chaired by the SCRS Chairman, Dr. Joao Pereira. The Agenda and List of Participants are attached as **Appendices 1 and 2.**

The Commission at its 2002 Meeting in Bilbao called for a *Working Group to Develop Integrated and Coordinated Atlantic Bluefin Tuna Management Strategies* (Rec. 02-11; **Appendix 3**) to meet in 2003. The Working Group, comprised of scientists and managers, is be established to evaluate all available biological information relevant to the issue of stock structure and mixing, and to develop operational options for implementing alternative approaches for managing mixed populations of Atlantic bluefin tuna, considering scientific information on the biology of bluefin tuna, historical data on fisheries, and the feasibility of alternative scenarios. In anticipation of this meeting, the SCRS Chairman requested this meeting with bluefin tuna scientific advisors (BFT Rapporteurs, and BYP Coordinators present and past) to discuss the development of an ICCAT research proposal for a large-scale Bluefin Tuna Research Program, to be fully discussed at the SCRS Meeting in 2003. This program is envisioned to enhance and replace the current Bluefin Year Program (BYP). This is a report to Head Scientists and SCRS Officers of the outcome of this meeting and the start the formal consultative process.

2 Objective

The objective of this meeting is to initiate the development of a research proposal to identify clear lines of research on bluefin tuna both to improve future assessments and to address management issues.

3 Proposal for a large-scale ICCAT Bluefin Tuna Research Program

While the following proposal addresses the *research* requirements for improved bluefin tuna management, the Commission should recognize that success will largely be determined by the extent to which Contracting Parties fulfill their required responsibilities for collecting and reporting basic catch and effort data.

The SCRS has addressed the movement and mixing of bluefin tuna in the Atlantic and Mediterranean for many years through the National Scientists' research contribution on conventional and electronic tagging, genetic and micro-constituent analyses, examination and comparison of growth and reproductive parameters, conducting larval surveys and modeling of alternative mixing and movement scenarios. Additionally, National Scientists have contributed to the understanding of bluefin dynamics through their monitoring of traditional fisheries statistics of catch, catch-at-size, effort and the examination of catch-per-unit-effort data. However, much remains to be learned, as illustrated by the suite of research recommendations made in recent bluefin research and assessment meetings (**Appendix 4**). There is continued commitment for ICCAT's National Scientists to contribute to these research goals in a substantial way. Here it is proposed to establish an enhanced bluefin tuna research program within ICCAT to support and coordinate both on-going and new research.

Following are general topics on research strategies for addressing the objectives including how this research fits within long-term research goals for bluefin tuna.

3.1 Basic data

3.1.1 Catch inputs to stock assessment models

Reliable information is needed on total catch and size composition by fleet and area. The considerable uncertainty about the eastern bluefin tuna catches has become greater due to a probable increase in the level of unreported catches following the imposition of quotas, and the development of bluefin tuna farming (see 3.1.2). The routine collection of these statistics and making them available to ICCAT is normally the responsibility of fisheries administrations. An enhanced research program should be able to identify fleets/areas for which improved data collection is crucial to bring to the attention of the Commission and the national fisheries administrations (related projects: 3.1.2- Bluefin farming; 3.1.3- Inventory of Fisheries; 3.1.4- Substitutions; 4.4 - Modeling).

Quantitative estimates of the uncertainty of the catch and catch-at-size data need to be obtained by scientists. To do this, scientists need to analyze the statistical properties of the procedures used by administrations to estimate the basic data (see above). It is also important to better understand if the size data are representative: What fraction of the catch of a given fleet is measured? How many fleets are actually sampled?

Biometric relationships (*e.g.*, length-weight) are often critical for the accurate estimation of total catch in weight. Scientists need to develop (or validate, as the case may be) relationships to be used for different fleets/areas.

3.1.2 Statistical uncertainties related to bluefin tuna farming

The inputs to and outputs from farming (fattening) operations are not always well documented and/or reported, for a variety of reasons. Fishery administrations should be responsible for developing reporting mechanisms that allow for a full accounting of these activities.

However, current practices are such that is technically difficult to accurately measure the number, biomass and size structure of the fish that are transferred directly from purse seines to cages. Scientists need to develop cost-effective methods to estimate inputs to farming; these may involve modern acoustic and visual techniques (see also SCRS/2003/020, *Report of the First Meeting of the Ad Hoc GFCM/ICCAT Working Group on Sustainable Tuna Farming/Fattening Practices in the Mediterranean*). The BYP has supported some research on this topic, but increased levels of research support are needed to more fully address this issue.

3.1.3 Inventory of fisheries

There are few fisheries for which complete information is available on catch, size structure, effort, fishing areas/times, etc. These fisheries tend to be the ones upon which much of the assessment work is based, while the more poorly known ones end up being lumped together. Scientists should develop a complete inventory of fisheries (fleets/areas) that catch Atlantic bluefin tuna. Such an inventory would be important to characterize the fisheries that are currently operating in the Atlantic and Mediterranean. The inventory would also allow for a study of the historical changes and development of fishing operations and gear technology, which is essential to understand time trends in catchability. The inventory would also be important in the development of Operational Models (Item 3.4) and in any analysis of the overall quality of data used in the assessments (*e.g.*, Items 3.1.1 and 3.1.4).

3.1.4 Substitution of size data

The last BFT stock assessment stressed the large quantity of substitutions of size data and the lack of information about its consequences on the quality of the catch-at-age matrix. A group of scientists together with the ICCAT Secretariat should check this, which is fundamentally necessary for future assessments. The work of this group will be facilitated by the information obtained in the item 3.1.3. (Inventory of fisheries). Level of substitutions should be identified by gear and area.

3.1.5 Ageing of the catches

The catch-at-age matrix is constructed by applying age slicing to length distributions of catches. This method employs two growth curves, one for each stock, that were estimated a long time ago (more than ten years). These two growth curves need to be revised and a standardized methodology should be followed for both of them, since the West Atlantic growth curve is based on tagging data and the East Atlantic and Mediterranean is based on spines. The differences in growth between stocks should be checked to determine if differences are due to the methodology applied. These differences have implications in the mixing models, that must be solved.

For direct aging, the most promising hard structures are spines and vertebra. A bluefin ageing network should be established to try to standardize the technique since both methodologies present difficulties and differences in interpreting ages. Also a validation of the technique is needed by other methods as length frequency analyses, strong cohorts and release-recapture data. Coordination is crucial since the different migratory behaviour of adult and juveniles means that the different age-classes are vulnerable to exploitation by many different gears and countries. This coordination includes ageing workshops, interchange of hard parts, and verification among/between laboratories. The BYP has supported initiating such coordination, but the available funding for this activity will be insufficient to fully address this issue, unless there are substantial contributions from National Scientists.

The investigation of innovative growth models, that integrate within the same framework, information from commercial catch, tagging and hard parts should be explored.

Farming tuna provides an opportunity for the development of this research item, since experiments are currently on-going in bluefin tuna reared in floating cages.

3.1.6 Effort and CPUE series: tuning indices

There are very few long-term series of data because of the influence of introduced management measures and changes in fishing technology and strategy. These have stopped series or interrupted them. There is also very little information from the Mediterranean, were the main catches come from.

Is essential to apply the same methodology to standardize the abundance indices, since coefficients of variation, and their subsequent influence on the virtual population analysis (VPA), depend on the standardization procedure. Also a better understanding of the influence of calibrating indices in the assessment is required.

A quality control should be established to check within and between series. For that purpose a methodology for splitting the plus group indices into ages is needed, since most of them are estimated for groups of ages.

Fishery independent indices, such as larval and aerial surveys, should be encouraged. More integrated approaches using airplanes, vessels, and electronic tagging may make monitoring more efficient, particularly for juveniles. Experimental designs and pilot surveys should be developed leading to juvenile relative abundance monitoring programs. A discussion is needed to reduce the source of errors. Aerial surveys have been seen to be a better way of estimating abundance for juveniles than for adults.

3.1.7 Reproductive biology

It is recommended to continue with the studies on sex-ratio, maturity, fecundity, and spawning duration emphasized under BYP, but at an elevated level to put some light on the differences in these biological parameters between East and West stocks. These differences have implications in the mixing models, that must be solved.

Studies on reproductive biology and development of maturity schedules using biochemical assay techniques, gonad-somatic indices and gonad samples for histological studies.

Farming tuna provides an opportunity for the development of this research item, since experiments on reproduction in captivity are currently on-going.

3.1.8 Mortality

Natural mortality for bluefin tuna is poorly estimated. Further, there are differences in the assumed values for the eastern and western stocks, and the bases for these values should be confronted. Scientists should also investigate the possibility of using tagging data to estimate natural mortality (perhaps by age) or to use integrated assessment models that incorporate auxiliary information on tagging data.

In stock assessment, the values of natural mortality and selectivity/availability-at-age are closely correlated. In Atlantic bluefin tuna assessments, this problem is exacerbated by the use of a relatively large "plus group" in which all fish age 10 and older are treated as having the same vulnerability to fishing and the same natural mortality. Scientists should use tagging data and other empirical information (*e.g.*, from experimental fishing) to better understand the dynamics of the “plus group.”

3.2 Stock structure

Issues associated with spawning site fidelity, migration paths, and mixing are amongst the most important of the uncertainties in the assessment and management of Atlantic bluefin tuna. Repeatedly there are recommendations to move from an opportunistic to a broad-scale design-based research program. However, lack of a coordinated research plan-of-attack has prevented achieving this goal. Studies should follow a specific experimental design to maximize information output and to compliment the data requirements of models.

3.2.1 Tagging. A broad-scale tagging experiment that takes into account age or size of bluefin tuna should be conducted in order to obtain basic knowledge about stock structure. This tagging program would utilize both electronic (pop-up and implantable types) and conventional tags, though with more emphasis on electronic tags. However, since both types of tagging have advantages and disadvantages, the design of experiments should take this into account. The experimental design for this tagging should be developed and specify where, when and how many tags are released for what duration, etc. Additionally, there is still scientific debate about the algorithms by which locations are computed. Progress on this topic is being made elsewhere, but should be followed closely by this enhanced bluefin tuna research program.

3.2.2 Biological markers. There are several other methods to analyze stock structure in addition to the tagging experiments described above. Those include micro-constituent analysis of otolith, parasites, morphometry and genetic studies. These studies require the types of biological specimens that have been the target of much of the recent BYP. Among those, micro-constituent analysis has provided promising preliminary results to identify the origin of fish. Therefore, while not to deter the progress of other methods, renewed emphasis should be placed on the micro-constituent analysis.

3.2.3 Spawning sites. Although two geographically separated major spawning areas are recognized, there might be other significant spawning areas unknown to date, possibly in the eastern Mediterranean and central North Atlantic. Therefore, research on spawning tuna and larvae in known spawning areas and in these other areas is recommended.

3.2.4 Spatial distribution of fish and fisheries. Information obtained through the research program recommended above and detailed space-time information of bluefin fisheries should be collated so that this information is fed into the mixing models or used to improve the modeling.

3.3 Environmental variability

In all of the Species Groups, including bluefin tuna, as well as in the Sub-Committee on the Environment, it has been recommended that the influence of environmental variability be further investigated, both over the short- and long-term. Initially this involves procurement, implementation and management of complex oceanographic databases. In this proposed research program it is recommended that the influence of environmental and climatic factors/changes be investigated on the following:

3.3.1 Spawning/reproduction. In previous spawning surveys, the distribution of spawning has been related to environmental factors. This relationship has also been used in a predictive way in exploratory surveys to attempt to locate new spawning grounds (with limited success). However, further research is required to better understand and more fully describe the influence of the environment on both spawning and reproduction.

3.3.2 Larvae and recruitment. By further studying and modelling the relationship between bluefin tuna and their environment, the requirements for successful spawning and reproduction can be better understood, and thus the consequence of fluctuations in the environment on recruitment and growth and on the subsequent stock size and estimates of management target points.

3.3.3 Catches or CPUEs (distribution of bluefin tuna). Already some of the CPUEs used in stock assessments use environmental factors and/or oceanographic data in the process of standardization. Further development can be made by incorporating behavioural and/or physiological data from electronic tags and information on the environment (*e.g.*, temperature, light levels at depth) into the standardization models. By using spatial oceanographic databases overlaid with archival tagging data, for example, the habitat and distribution of bluefin can be further investigated.

3.3.4 Abundance of forage species. The forage species of bluefin tuna are also influenced by the environment. By better understanding these relationships, the abundance and distribution of forage species in combination with the environmental conditions can be used to explain the feeding concentrations and migrations of bluefin tuna. This in turn can be used to improve CPUE and assessment models, including the ecosystem approach to fisheries.

3.4 Models

Models of Atlantic bluefin tuna have been developed and used for assessments for many years. However, for certain kinds of models the complexity of the modeling approach is more sophisticated than the basic input data

warrant. Additionally, management issues related to movement of bluefin and the amount and kind of mixing of bluefin between areas may require that models of different scopes be implemented. Therefore, there are several different kinds of models that need to be developed to address these requirements.

3.4.1 Models of underlying biological and fishery dynamics

One step in the process of building understanding of bluefin dynamics is the development of *Operational Models*, *i.e.*, models of biological, ecological and fisheries "reality" which may be used to test assessment and management procedures. In particular these models should consider hypotheses on age-specific migration patterns and the reasons for these patterns; incorporate spatial strata; include alternative hypotheses on reproductive scenarios; address the kind and extent of data collection that has occurred (or might occur in the future); and the spatial and temporal pattern of exploitation by the fisheries.

There will be more than one plausible hypothesis on how bluefin dynamics work, *e.g.*, how fish move, the sparseness of catch data and other factors. These should be constructed carefully to assure that tests of assessment models or management scenarios would be meaningful. Operational Modeling is an approach that has been undertaken by the scientific committee of the Commission for the Conservation of Southern Bluefin Tuna (progress reports published on www.ccsbt.org). Similar efforts need to be developed for the Atlantic. National scientists may initiate these activities. However, ultimately the SCRS should provide guidance on how these models are developed.

3.4.2 Assessment models

There are many alternative assessment models that exist and have been utilized for bluefin tuna assessment. However, the complexity of some models does not conform to the scale of the data being collected. For example, VPAs require complete catch-at-age data for all relevant fisheries strata. These data do not exist for many sectors; therefore, a process of substitution is used which may not be appropriate for all sectors. Additionally, there are a number of ways in which movement and mixing might be incorporated into assessment models (*e.g.*, diffusion versus overlap models). Each of these modeling approaches should be evaluated against the scale of the data that is being collected and that is likely to be collected in the future. In particular, more simple modeling approaches should be examined for use when data are sparse (or non-existent).

The assessment modeling approaches should be evaluated as to their usefulness, *even when it is known that data are less than ideal*. Can the models be developed recognizing the compromises and tradeoffs between biological reality and statistical precision? The assessment models should be tested against the Operational Models as a means of evaluating their robustness and practicability. Additionally, diagnostic indicators need to be developed to characterize how well the assessments are performing in terms of statistical fitting criteria, likely bias and other factors.

National Scientists may initiate these activities. However, ultimately the SCRS should provide guidance on how these models are developed.

3.4.3 Management procedures and scenarios

The SCRS's working group meeting on Bluefin Tuna Mixing held in 2001 recommended that spatial strata be developed for assessment and management which encompass the "Regional Concentrations Approach" and possibly other approaches, as well. These approaches could then be tested against various management and harvest scenarios and mechanisms for their utility and robustness. There is a need for the development of alternatives for management structures. The SCRS should be developing those alternatives, then evaluating their performance of those in relationship to the underlying Operational Models and Assessment Models. The implication is that criteria for performance need to be developed. For example, in our current modeling of management scenarios, the typical performance measures are trajectories in biomass, recruitment, fishing mortality rate and catch. However, there may be other criteria that may be useful to managers (*e.g.*, stability of catch from one year to the next). Alternative harvest and management approaches need to be designed; they need to be tested against the operational and assessment models; and they need to be evaluated relative to management and fishery performance criteria.

Again, national scientists may initiate these activities. However, ultimately the SCRS should provide guidance on how these models are developed.

3.5 Costing, leadership and timeframe

It is recommended that in order to achieve the goals of the proposed research, a Scientific Coordinator should be hired to coordinate, initiate and report on the required research. While this Scientific Coordinator would work with an Advisory Committee established by the SCRS Chairman, he/she would be empowered to make decisions to implement the research developed under the guidelines of the proposal and the guidance of the Committee, as required. Therefore this Scientific Coordinator should be an experienced scientist with considerable experience in planning and undertaking fisheries research.

In addition, National Scientists should continue to conduct research and provide samples as in the past for the BYP.

Table 1 provides cost estimates, anticipated leadership roles and research timeframes for the proposed enhanced bluefin tuna research program. It is envisioned that this enhanced program be undertaken for more than 4 years (in addition to the set-up period), with an estimated annual budget of about 2 million Euros. If this program is launched, then it is expected that it could only be funded through extra-budgetary contributions to the Commission. However, the success of this program also depends on considerable contributions from National Laboratories. The assistance from the current East and West BYP coordinators continues to be important, and has been taken into account in the budget (**Table 1**). The most important contribution of the proposed enhanced research program is, in fact, the role of coordination of on-going research.

4 Consultative process and follow-up

The following steps in the consultative process were agreed to:

- Send this report as adopted at the 15-16 May meeting to the group of bluefin scientific advisors initially identified by the Chairman of the SCRS to consult on this topic. In addition to the participants in Appendix 2, this includes J.-M. Fromentin (BFT-E Rapporteur) and G. Scott (BYP-W Coordinator). **31 May 2003** is the deadline for comments to be sent to the Secretariat.
- During the first week of June this proposal (including any revisions agreed upon by the advisory group) will be sent to Head Scientists and Rapporteurs for their comments in order to improve the proposal for discussions at the SCRS. Instructions should request that Head Scientists consult their National Scientists, as appropriate, and Head Scientists should consolidate any comments into a single response to the SCRS Chairman (by way of the Secretariat). The deadline for these comments is **15 July 2003**.
- Head Scientists will also be informed that this proposal will be discussed and further developed at a 2-day meeting in the week prior to the SCRS. At that time, Head Scientists should be prepared to provide a summary of current research activities and requirements for their country.
- The proposal will be presented to the SCRS Plenary by the SCRS Chairman and fully debated and discussed at that time.
- If agreed upon and adopted by the SCRS, the proposal as agreed upon by the SCRS, will then be presented to the Commission.

5 Closing

The Report was adopted by the participants, and the consultative process and follow-up agreed upon.

Dr. Pereira thanked the participants for their hard work. He again apologized for the one-day delay in his arrival, and especially thanked Dr. J. Powers for chairing the meeting in his absence.

The meeting was adjourned at 1600 h on 16 May 2003.

Table 1. Cost estimates, anticipated leadership roles and research timeframes for the proposed enhanced bluefin tuna research program.

Item	Anticipated leadership	Research timeframe	Cost estimate (Euros)			
			Set-up year	Year 1	Annual costs thereafter	Total
COORDINATION						
Hiring of Scientific Coordinator [1]	Secretariat/SCRS	On-going	150,000	150,000	150,000	
Travel and scientific coordination [2]	Coordinator	On-going	60,000	60,000	40,000	
Data Management (10%)			40,000	161,500	148,500	
RESEARCH						
1. Basic data						
Catch Inputs to Stock Assessment Models	Coordinator and BFT Rapporteurs	Tri-annually	--	50,000	50,000	
Statistical Uncertainties Related to BFT Farming	Coordinator and Scientist	2 years	--	100,000	100,000	
Inventory of Fisheries	Coordinator, National Scientists	1 year	--	In-kind	In-kind	
Substitution of size data	Coordinator, Secretariat	1 year		30,000		
Ageing of the catches	Coordinator, National Scientists	Multi-year	100,000	20,000	20,000	
Effort and CPUE series; Tuning indices -development methods manual -experimental design for co-ord surveys	Coordinator and Chairman of Methods WG, National Scientists	1 year (2^{nd})	--	20,000		
Reproductive biology -coordination meetings among labs -invest in new techniques -continue traditional sampling	Coordinator & National Scientists	Multi-year	--	100,000	100,000	
Mortality	Coordinator & National Scientists	Multi-year	--	In-kind	In-kind	
2. Stock structure						
Tagging -workshop -coordination, purchase tags, tagging technician, charter costs, sample purchase, data analyses	Coordinator & National Scientists	At least two years of tagging	50,000	1,000,000	1,000,000	

[1] Inludes salary and benefits.
[2] Includes considerable East Atlantic coordination to collect samples: about 20% of one person's time as an in-kind contribution, plus 10,000 Euros for travel for this advisor.

Item	Anticipated leadership	Research timeframe	Cost estimate (Euros)			
			Set-up year	Year 1	Annual costs thereafter	Total
Biological markers -coordination meetings among labs -invest in new techniques -continue traditional sampling	Coordinator & National Scientists	Multi-year	--	100,000	100,000	
Spawning sites -coordination	Coordinator & National Scientists	Multi-year	--	20,000	20,000	
Spatial distribution of fish and fisheries.	Coordinator & National Scientists	Multi-year	--	20,000	20,000	
3. Environmental variability -Procurement, implementation and management of large oceanographic databases	Coordinator, Environment WG, Contract	2 years	--	75,000	75,000	
Spawning/reproduction.						
Larvae and recruitment.						
Catches or CPUEs						
Abundance of forage species.						
4. Models						
Models of underlying biological and fishery dynamics -hardware and contracts	Coordinator, National scientists and BFT Rapporteurs	3 years	120,000	90,000	30,000	
Assessment Models	Coordinator, National scientists and BFT Rapporteurs	3 years	15,000	105,000	60,000	
Management Procedures and Scenarios	Coordinator, National scientists and BFT Rapporteurs	3 years	15,000	75,000	90,000	
Total			**550,000**	**2, 176,500**	**2,003,500**	

Appendix 1

Agenda

1. Opening of meeting
2. Objectives
3. Proposal for a large-scale ICCAT Bluefin Tuna Research Program
4. Consultative process and follow-up
5. Closing

Appendix 2

List of Participants

CONTRACTING PARTIES

SCRS Chairman

Pereira, Joao Gil
Universidade dos Açores, Dep. de Oceanografia e Pescas 9900 - Horta, Açores, PORTUGAL
Tel: +351 292 200 431; Fax: +351 292 200 411; E-Mail:pereira@notes.horta.uac.pt

EUROPEAN COMMUNITY

de la Serna Ernst, Jose Miguel
Ministerio de Ciencia y Tecnología (MCYT), Instituto Español de Oceanografía, Apartado 285/ Puerto Pesquero s/n 29640 - Fuengirola, Málaga ESPAÑA
Tel: +34 952 476 955; Fax: +34 952 463 808; E-Mail:delaserna@ma.ieo.es

Rodríguez-Marin, Enrique
Ministerio de Ciencia y Tecnología (MCYT), Instituto Español de Oceanografía, Promontorio de San Martín, s/n 39004 Santander ESPAÑA
Tel: +34 942 29 10 60; Fax: +34 942 27 50 72; E-Mail:rodriguez.marin@st.ieo.es

JAPAN

Suzuki, Ziro
National Research Institute of Far Seas Fisheries, 5-7-1 Shimizu-Orido Shizuoka-City,Shizuoka 424-8633
Tel: +81 543 36 60 41; Fax: +81 543 35 96 42; E-Mail:zsuzuki@fra.affrc.go.jp

UNITED STATES

Powers, Joseph E.
NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive Miami, Florida 33149-1099
Tel: +1 305 361 4295; Fax: +1 305 361 4219; E-Mail:joseph.powers@noaa.gov

ICCAT SECRETARIAT

Julie Porter
Victor Restrepo

Appendix 3

Recommendation by ICCAT to Establish a Working Group to Develop Integrated and Coordinated Atlantic Bluefin Tuna Management Strategies [02-11]

RECALLING that the current boundary between eastern and western management areas was established for the purpose of managing spatially distinct fishing grounds and spawning areas;

RECOGNIZING that one of the elements of uncertainty surrounding the assessment relates to the boundary between the eastern and western management areas for bluefin tuna that may impact negatively on the effectiveness of management actions throughout the Atlantic and Mediterranean;

BEARING IN MIND that evidence on mixing of the bluefin tuna of uncertain origin (eastern or western) is a key source of uncertainty to enable more precise assessments to be made, and it could reduce, to some unknown extent, the effectiveness of ICCAT management measures;

NOTING that the 2001 ICCAT Workshop on Bluefin Tuna Mixing (SCRS/01/020) concluded that "it is unlikely that any management unit boundary between the Western and Eastern Atlantic will be effective in separating bluefin tuna of Gulf of Mexico (Western Atlantic) and Mediterranean Sea (Eastern Atlantic) origin, into non-overlapping populations", and that the Standing Committee on Research and Statistics (SCRS) in 2002 stated that "the Committee lacked a quantitative basis for recommending a change in the management area boundary or the implications of the change;"

FURTHER RECALLING that the SCRS Response in 2002 to the Commission on Bluefin Tuna Mixing recommended research to better quantify the origin of fish, mixing and its implications in the central Atlantic;

RECOGNIZING, however, that much of the relevant research is being conducted in diverse locations, and there is a need to synthesize all available information within a unified framework.

THE INTERNATIONAL COMMISSION FOR THE CONSERVATION
OF ATLANTIC TUNAS (ICCAT) RECOMMENDS THAT:

1. A Working Group, comprised of scientists and managers, shall be established to evaluate all available biological information relevant to the issue of stock structure and mixing, and to develop operational options for implementing alternative approaches for managing mixed populations of Atlantic bluefin tuna including but not limited to those developed by SCRS;

2. In developing options, the Working Group shall consider scientific information on the biology of bluefin tuna, historical data on fisheries, and the feasibility of alternative scenarios;

3. The Working Group shall meet no later than November 2003 and as necessary thereafter, and report to the Commission at its meeting in 2004.

Appendix 4

Bluefin Tuna Research Recommendations

In order to facilitate discussions on the development of a proposal for a large-scale Bluefin Tuna Research Program, bluefin tuna recommendations from the last few years have been consolidated and arranged by subject (**Table 1**). Broadly, the priorities for research fall out into 4 major categories:

1) Basic data. In order to improve stock assessments, there is a serious and fundamental need for an improvement in the basic data (catch, effort, CPUE, size samples, studies on ageing, growth, maturity, fecundity, etc.). A number of mechanisms have been suggested to accomplish this.

2) Stock structure. Issues associated with spawning site fidelity, migration paths, and mixing are amongst the most important of the uncertainties in the assessment and management of Atlantic bluefin tuna. Repeatedly there are recommendations to move from an opportunistic, to a broad-scale design based research program. Studies should follow a specific experimental design to maximize information output, and to compliment the data requirements of models.

3) Environmental variability. In all of the Species Groups, including bluefin tuna, as well as in the Sub-Committee on the Environment, it has been recommended that the influence of environmental variability be further investigated, both over the short- and long-term.

4) Models. The short-comings of the models in use are related primarily to a lack of appropriate data inputs. It could be said that the models are far more sophisticated and complex than the current data warrant. Therefore the suite of recommendations regarding models simply reflect the paucity of basic data and biological information (1 and 2 above).

Table 1. ICCAT bluefin tuna recommendations.[3]

STATISTICS

Provisioning of data
General

1) Irrespective of what management structure may be adopted by the Commission, the Workshop emphasized the need to maintain and improve, when appropriate, the collection and reporting of basic fishery statistics and of data for basic studies of fishery biology. This includes catches, effort, size samples, studies on growth, maturity, fecundity, etc. This is of particular concern for the fisheries in the east Atlantic and Mediterranean. The need for basic fishery information is also of concern because of IUU catches. *(Mixing Report 2001)*

2) The Group continues to recommend that the Commission ensure that the ICCAT Secretariat be provided with reliable data on catch, effort, size in the format requested, and on as fine a scale as possible. These obligations are considered a minimum standard as they are clearly stated in the ICCAT Convention, FAO's Code of Conduct for Responsible Fisheries, as well as the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks. *(BFT 2000, BFT 2002)*

3) The Group recommended that logbooks or other reporting systems providing equivalent detailed information be completed for all commercial and recreational fisheries. At present, some fisheries do not have requirements for such data collection systems, and there is a paucity of information on these fisheries. *(BFT 2000)*

4) The Group recognizes the improvements facilitated by the project FAO-COPEMED in statistics and research in the Mediterranean and recommends the continuation of these activities in the future. *(BFT 2002)*

5) The work of the Secretariat in assembling the catch and catch-at-size information with very limited time was well appreciated by the Group. It was further noted that if time permits, it would be helpful in the future to also receive these inputs disaggregated by fleet and area. Such an approach would assist in the discussion of stock and mixing issues. *(BFT 2002)*

Farming/fattening

6) Currently, there are difficulties in estimating bluefin tuna catches. Although data on farming operations are not directly related to ICCAT's mandate to collect statistics from capture fisheries, the reporting of such data to ICCAT would allow for

[3] Sources: 2000 Detailed Report for Western Bluefin Tuna (SCRS/2000/024)
2001 Report of the ICCAT Workshop on Bluefin Mixing (SCRS/2001/020)
2002 Report of the 6th GFCM-ICCAT Meeting on Stocks of Large Pelagic Fishes in the Mediterranean (SCRS/2002/10)
2002 Report of the Atlantic bluefin tuna stock assessment session (SCRS/2002/12)
2002 Bluefin Year Program: Progress achieved through 2002 and future perspectives (SCRS/2002/16)

more complete catch estimates. It is recommended that data on bluefin farming (inputs and outputs to fattening operations) be reported to ICCAT. *(GFCM 2002)*

7) The Group continues to be especially concerned with the lack of ability to accurately track catches, catch at size, origin of catches and fishing effort expended on fish that are farmed in cages. The Group recommends that efforts be made to implement the suggestions for improvement made by the Sixth GFCM-ICCAT meeting (SCRS/2002/010), such as observers on board and on cages, extension and modification of the BSTD to live fish, modification of logbooks to report details on fish transferred to cages. *(BFT 2002)*

8) Research to provide more accurate methods on calculating the total weight and size composition at capture of cultured fish. *(BYP 2002)*

Data quality control

9) The substitutions of size data used for the calculation of the catch at size tables need to be revised for the years prior to 1998. The quality of the size data (sample size) submitted should also be verified, since cases of high levels of extrapolation have been identified. Furthermore, the procedure used for ageing of the catches (slicing) should be checked. Therefore, it is recommended that a data exploratory meeting for the East and Mediterranean bluefin tuna be held before the next stock assessment. *(BFT 2002)*

10) The Group recommended that efforts be made to provide estimates of uncertainty (*e.g.*, coefficients of variation) for statistics (*e.g.*, landings, discarded catch, other forms of fishery-induced mortality) which are estimated from sampling surveys. *(BFT 2000)*

Fishing gears

11) Various Mediterranean countries use drift nets to catch tunas and tuna-like species. An increase in the use of these gears by some countries was noted during the meeting of the Group. In some cases, the experts have not presented information regarding the fishery, description of fishing gear, catches, or any other useful information for the assessment and management of the fisheries. The Group recommends that in order to facilitate the standardization of data with regard to the various gears included in the "drift net" category, detailed catch and operational information about the fishery be submitted by those countries which have not already done so. *(GFCM 2002)*

12) Precise data on catch, effort and size of the new fishing gears that will replace the drift net fishery in the Gulf of Biscay (PS and pelagic trawling) should be collected and analyzed in order to investigate the impact on the eastern bluefin tuna stock. *(BFT 2002)*

Discards

13) The Group recommended that further attention be paid to the collection of data on discards and their subsequent estimation so that the effect of discarding can be fully included in the stock assessment. The quality of the information is enhanced by Observer Programs. Observer sampling should be sufficient to quantify discarding in all months and areas and to avoid the need for pooling across time or area strata thought to be important to constructing estimates. Studies should be conducted to improve estimation of discards and to identify methods that would reduce discard mortality. Studies should also be conducted to estimate the subsequent mortality of bluefin discarded alive. *(BFT 2000)*

RESEARCH

Biological

14) The Group endorsed the recent recommendations of the GFCM/ICCAT Ad Hoc Working Group (COM-SCRS/2000/025). In particular, the Group supported the recommendation for an inter-sessional meeting to review and integrate research results as they relate to biological mechanisms and how they should be best addressed in stock assessments (including the implications of possibly different growth rates). Participation should include scientists from the east and West Atlantic and Mediterranean, as well as global experts. There is a strong need to move from an opportunistic to a broad-scale design based program. The need for dialogue between scientists and managers was also highlighted as these new research results point to the need to rethink both assessment and management approaches. *(BFT 2000)*

Stock structure

15) Issues associated with spawning site fidelity, migration paths, and mixing are amongst the most important of the uncertainties in the assessment and management of Atlantic bluefin tuna. Specific areas of research that could significantly advance our knowledge in this area are given below: *(BFT 2000, 2002)*

> a. The Secretariat should bring the ICCAT Tagging Data Base up to date. All Parties, Entities or Fishing Entities should be encouraged to submit mark-recapture information in a timely manner. Investigators using electronic tags

should be encouraged to submit at least all release and end-point data to ICCAT, in particular date, location and size/weight at release and recapture.

b. ICCAT should consider scheduling a special planning session on tag deployment to coordinate with the developers of mixing models special experiments designed to provide data deemed necessary for producing meaningful model results.

c. National scientists should be encouraged to resolve some of the biological uncertainties that have been of major concern in the past, including:

i. The development of new area specific growth curves using recent data for the West, the eastern Atlantic, the central Atlantic and the eastern and western Mediterranean.

ii. Age at maturity ogives for these same areas.

iii. Model age-specific natural mortality rates in VPAs and standardize among all areas if indicated.

d. National scientists should be encouraged to continue genetic and chemical studies that may resolve some stock mixing issues. In particular, more precise marks are needed to quantify mixing rates in the areas identified by the Group.

16) In addition to the need for improvement in basic catch statistics, the Group continues to endorse the research directed at spawning site fidelity, migration paths and mixing. Therefore it is recommended to reinforce tagging activities, especially by archival and pop-up tags, as well as studies on the microchemistry of both juvenile and adult fish in the eastern Atlantic and Mediterranean. *(BFT 2002)*

17) It is clear that the priorities of the scientists who study bluefin tuna on both sides of the Atlantic are related to an improvement in knowledge on the stock structure. The three most important activities are the studies on genetics, reproduction and tagging. Several programs or activities concerning subjects of interest for the Bluefin Program should be initiated or continued in 2003 *(BYP 2002)*

- *Tagging*

18) It would be ideal to greatly increase the number of archival tags (implantable and pop-up) on fish of all sizes throughout the Atlantic and Mediterranean in such a way so as to obtain a complete picture of bluefin movement and residence patterns. Lacking unlimited budgets, however, it is necessary to focus on smaller experiments targeted at testing specific hypotheses (for example, tagging large fish during the spawning months in the known spawning areas in order to test for spawning site fidelity). *(Mixing Report 2001)*

19) In the short term, the Commission may want to monitor closely the fisheries in the Central Atlantic area and their impact on the stocks. In such case, VMS equipment could be useful from a surveillance point of view and the Commission may wish to increase the VMS requirements for this area. In addition, it would be useful to conduct pop-up archival tagging in this area in order to examine the dispersal of these tuna concentrations. *(Mixing Report 2001)*

20) Much of our current perception of bluefin mixing in the Atlantic comes from fish that were tagged off the North American coast. It is important to increase efforts to tag and recover information from bluefin throughout the Atlantic, especially in the Central Atlantic and Mediterranean, in order to obtain a better understanding of bluefin mixing. As recommended by the BYP, this tagging should follow a specific experimental design to maximize information output. *(Mixing Report 2001)*

21) The Committee endorse the concept of the proposed program of investigation into satellite tagging of bluefin in the Mediterranean and eastern Atlantic. Recommendation to conduct research to better quantify the origin of fish, mixing and its implications for assessment and management of bluefin fisheries. Increased effort on electronic tagging, especially in the Mediterranean, is strongly encouraged and cooperation between scientists/organizations of coastal countries, with technical collaboration by scientists from the west involved in these research applications is required for success of this research. *(BYP 2002)*

22) Modeling excercises indicate the need for better information on age-specific movements. This requirement could guide the design of future studies of movement and migration. *(BFT 2002)*

23) Interested scientists should collaborate together with ICCAT to raise awareness about tagging programs with the objective of improving reporting rates. *(GFCM 2002)*

24) The Group recommended a fuller exploration of the tagging database to generate testable hypotheses about migration paths by age and area of origin. More formal and statistically rigorous incorporation of tagging data (*e.g.*, SCRS/2000/098) into assessment models should be further explored. *(BFT 2000)*

- *Genetics and microconstituent analyses*

25) The group agreed that microconstituent analyses have very good potential in terms of parameterizing some of the "overlap" models discussed earlier if they provide reliable classification keys for the origin of fish. Research aimed at further refinement and testing of this tool should receive high priority. *(Mixing Report 2001)*

26) Stock structure (micro constituents and genetics) sampling. Exchanges of samples between both sides of the Atlantic, and subsequent analyses in relation to programs on bluefin stock structure and biology. *(BYP 2002)*

- *Spawning sites*

27) The Committee endorsed the proposed research sampling of larvae and spawning-sized tuna and the oceanographic conditions in and around the Balearic Islands and in the Central North Atlantic. After 2 years of field sampling there is a need to review and revise, as necessary, sampling plans associated with these studies. *(BFT and BYP 2002)*

28) The Group recommended that a comprehensive review of information on larval bluefin samples be undertaken. *(BFT 2000-Res 6)*

Biological parameters

29) It is recommended to update biological parameters and do new studies on growth, maturity, fecundity and other biological information in order to be able to use it in the next assessment and put some light in the differences in these biological parameters between east and West stocks. *(BFT 2002)*

30) Studies on reproductive biology and development of maturity schedules using biochemical assay techniques, gonad-somatic indices and gonad samples for histologic studies. *(BYP 2002)*

31) It is recommended that a bluefin ageing network of people who have worked on age determination of bluefin be initiated. The aim of the network will be to compare and evaluate various ageing methods for various ages and from different seasons in order to develop a standardized protocol for age determination in bluefin. *(BYP 2002)*

Tuning Indices

Basic data

32) The Group also noted that a standard for reporting CPUE series should be adopted by authors. A document providing a detailed description of the standardized CPUE indices should be prepared periodically, including a narrative of the history and development of the index, management measures that have affected the index, details of the statistical treatment and other relevant considerations. In addition, the annual updates of CPUE should contain, as a minimum, graphical presentation of the spatial distribution of the fishery, the age range that the index relates to, and tabulation of the number of catch records used in each index year. *(BFT 2002)*

33) The collection of fishery-independent data on bluefin abundance via larval and aerial surveys should be continued in order to develop long-term fishery-independent indices for stock assessment. *(BFT 2000, BFT 2002, GFCM 2002)*

34) The Group noted that most of the indices of abundance calculated for the various Atlantic bluefin fisheries indicated time-area effects that might be explained in part by environmental variability. Causes for this variability may include short- and long-term, small- and large-scale changes in the ocean climate and/or changes in the availability of prey species over a similar time and area scale. The Group recommended research to document the fishery and oceanographic history for the areas in which fisheries for Atlantic bluefin be conducted. Such research might include the compilation of an oceanic climatological series for the area, and information related to the abundance of forage species as, such as squid, herring, sardines, mackerel, butterfish, sand eel, and other species. The expectation is that where such data series exist, they might be used when standardizing the abundance indexes for Atlantic bluefin tuna. Further, if these data series prove of sufficient extent in time and area, they also may be used to investigate reasons for the apparent major historical shifts in areas of abundance for Atlantic bluefin that have occurred over the past five decades. *(BFT 2000-Res 11)*

35) It is recommended that the standardization of the CPUE index by age for the Spanish traps be further investigated. *(BFT 2002)*

36) The Chinese Taipei CPUE series should be reviewed in order to be able to use it in the next assessments and also the possibility of a joint analysis with Japanese series for a combined index. *(BFT 2002)*

CPUE models

37) The Group was concerned about applying the various methodologies used to standardize the CPUE indices. The effects of these standardizations on the assessment modeling should be investigated before the next stock assessment. *(BFTE 2002)*

38) The CVs from the GLMM CPUE standardization could be biased lower ignoring the spatial correlation. Then the CVs inputted in to the VPA are smaller than they should be. This could probably explain the lack-of-fit in VPA model. Further analysis should be done on this issue. *(BFTE 2002)*

39) When reviewing the utility of CPUE series for possible inclusion in the population model, the Group recognized that there is a need for the Methods Working Group to review methods for developing, standardizing, and evaluating the usefulness of CPUE series as indices of abundance. In particular, consideration needs to be given to the terms to be treated as random effects in approaches that use such methodology, and diagnostics that could be used to check that the assumption of randomness is reasonable. *(BFT 2002)*

40) In analyses dealing with zero catches in CPUE data, a common procedure is to add a constant of about 10% of the average value to all of the CPUE data and take the natural logarithm of the result (*e.g.*, SCRS/2002/103; SCRS/2002/108; SCRS/2002/109). Other more recent methods have applied mixed probability models to model the data that included a binomial model to model the presence or absence of catch (*e.g.*, whether fishing in the presence of bluefin tuna) and some other density function such as lognormal, Poisson, negative binomial to model the catches when fishing in the presence of bluefin tuna (*e.g.*, SCRS/2002/089). Formal attention to decisions over the use of these various density functions, *e.g.*, lognormal, Poisson, and negative binomial, for positive observations requires further in-depth attention. Abundance indices and CVs can potentially be sensitive to the method applied, and comparisons of the potential biases in the methodologies require further in-depth examination. Other more explicit approaches to modeling the probability of positive observations and the positive observations have also been suggested (SCRS/2001/043). Further analysis to compare the statistical properties of these various approaches is required to develop recommendations about how to deal with zero catches in CPUE data. *(BFT 2002)*

41) Further attention is required to develop, test and identify clear interpretations of other potential diagnostics for the goodness of fit of stock assessment models to data. Methods to quantitatively evaluate the residual plots to check whether the distribution assumptions are valid are required. An additional diagnostic that should be investigated is the use of bootstrap confidence intervals about the predicted CPUE data. In theory, the proportion of outliers should be not be much larger than (1-0.95) if 95% confidence intervals were to be applied. The p-values of each CPUE data point could be calculated from such bootstrap output. If a parametric bootstrap approach is applied, such confidence intervals and p-values could be computed analytically without bootstrapping. *(BFT 2002)*

42) Further in-depth attention is required to the issue of how to proceed and modify the stock assessment methodology applied if statistical diagnostics suggest discrepancies in statistical model assumptions. When CPUE series are found to have pronounced serial autocorrelation in model fit residuals, some formal protocols need to be developed for how to deal with these situations. For example, if a few different CPUE series show systematic trends in the residuals, should they be removed from the base case stock assessment or left in? Additionally, if it is found that the data are over-dispersed with respect to the assumed likelihood function of the data, what should be done? For example, should a different likelihood function be applied that allows for more dispersion in the data or if this is not possible, should a larger residual variance be input until the null hypothesis of no over dispersion can no longer be rejected? *(BFT 2002)*

Assessment Methods

43) The Group recommended that a clearer process be established for evaluation of and agreement to new methods to be used in the Bluefin Tuna Stock Assessment Group. *(BFT 2000)*

Alternate assessment approaches

-Mixing models

44) The fishery-dependent recovery of implantable archival tags in recent years suggest much higher mixing rates between east and west than does the historical conventional tagging data. This discrepancy should be investigated with the aid of models (*e.g.*, SCRS/00/98). *(Mixing Report 2001)*

45) Two modeling papers described potential mixing between east and west components and impacts on the populations using age disaggregated and age specific approaches. While both papers described results that were qualitatively similar and that were consistent with the expectations of Group participants, it was agreed the papers and other future modeling work could potentially identify areas of sensitivity where more data were required. For example, one paper pointed to the need for better information on age-specific movements. This requirement could guide the design of future studies of movement and migration. *(BFT 2002)*

46) The Group noted the progress that has been made with the VPA Two Box software with appreciation. The thorough documentation was also well received. The Group did, however, recommend that the Chi-square discrepancy statistic in VPA Two Box be revised. *(BFT 2002)*

47) The evaluation of the effects of some management measures and mixing scenarios discussed during the meeting was not possible using the VPA 2 box model (*i.e.*, mixing of the population in area 3 only). More detailed modeling frameworks which could simulate a greater range of mixing scenarios would enable a better understanding of the dynamics of the

population and of the measures that could be effective for the management of the bluefin tuna fisheries. The adoption of a more detailed modeling framework could also add flexibility in the simulation of the population and enable a better utilization of the available information. Thus, it is recommended that multi-area models be developed and added to the ICCAT catalogue. *(BFT 2002)*

48) Current and proposed research is aimed at developing more realistic and data-appropriate estimation models (*e.g.*, robust statistically based models, and mixing models). It is proposed to use these models in the future to aid in experimental design and to provide management advice. Before this is done, it is important that their estimation properties are fully understood. In particular, it is crucial to understand how they perform when their underlying assumptions are violated. Quantitative testing of estimation models is best done using simulation methods where reality is modeled using an independent and more complex model structure, termed an "operating model." A new generation of models is needed for this purpose. They should not be limited in scope by the availability of data or other constraints that are needed in estimation models. In the long term, such models could be used to evaluate management strategies. *(BFT 2002)*

-Other

49) Some further evaluation of diagnostics that can be used for stock assessment model selection and evaluation of the goodness of fit of stock assessment models to CPUE data are required. AIC model selection criteria have been applied in the 2000 and 2002 assessments of western bluefin tuna. While this is a commonly accepted approach for model selection, some different formulations of it have been suggested, *e.g.*, SCRS/2000/024 and SCRS/2002/086. In the 2002 western assessment, some concerns were raised over the comparability of AIC as defined in the VPA Two Box manual when the likelihood was changed from equal variance (no GLM CVs included in the likelihood function) to deviance scaling and additional variance approaches in which GLM CVs were included in the likelihood function. More thorough deliberation needs to be devoted to consideration of the use of AIC and other criteria in model selection to inform future assessments that might be using these diagnostics. *(BFT 2002)*

50) The Group recommended that alternate assessment approaches, such as CATCHEM (SCRS/00/100) that allow for errors in the catch at age, be further developed for more extensive use at meetings in the near future. This has broad implications (not just for assessment results) in the way data are reported by national scientists and retained by ICCAT and this should be addressed (*e.g.*, the actual size frequency observations used to estimate the catch at size for the various fleets). *(BFT 2000)*

51) The Group recommended that existing assessment software be modified to account for changes in the age and size composition of the plus group as stock abundance changes, where this has not already been done. *(BFT 2000)*

F-ratio

52) The Group recommended that the impact of specifications regarding the F_{10}/F_9 ratio be further investigated to better understand which of the input data are most influential on estimation of this ratio. This in turn should improve estimation procedures involving this ratio. The Group recommended that data be collected on items that will allow better estimates of the F on older ages, such as direct ageing, separate indices of abundance for older ages or the plus group, and/or tagging experiments designed for this purpose. *(BFT 2002)*

Stock-recruitment

53) The specifications for the two line stock recruitment relationships are currently estimated qualitatively by inspection of the data. There is a need to develop more quantitative methods for this specification. The Group suggested that the level of spawning stock size at which recruitment begins to decline in the 2-line relationship might better be based on a level of spawning stock size (for example the lower x^{th} percentile of the spawning stock size estimates) rather than on a range of years. Such an approach would seem more likely to be robust to differences in stock trajectories among bootstrap replicates. It is also recommended that future versions of the projection software should include the ability to fit the 2-line stock-recruitment relationship, and a diagnostic related to the fraction of simulations in which the generation of the recruitments for the last three years had to be replicated, as the recruitments drawn initially could not support the known catches taken from the cohorts concerned. *(BFT 2002)*

Recovery program

54) The structure of the population model used to monitor the progress of the recovery program could be improved on. In particular, future research should focus on developing statistically-based models that are robust to bias and variability of the estimates of F ratios, estimate absolute abundance of large fish (or at least bounds on these estimates), and are robust to mis-reporting of catch and to mis-ageing of the catch. *(BFT 2002)*

55) The Group raised concerns over the potential bias in the uncorrected median (50^{th} percentile) results reported for the projections. If such a bias exists, it means that the results presented, including the probability of rebuilding to target levels by the 2018, may be optimistic to an unknown degree. It is important that this issue of potential upward bias be investigated for the next assessment. *(BFT 2000)*