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Report of the bigeye tuna modelling workshop

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Introduction

The Pelagic Fisheries Research Program of the University of Hawaii is funding a one-year project on the application of a length-based, age-structured model, MULTIFAN-CL (Fournier et al. 1998), to the Pacific-wide stock assessment of bigeye tuna. The project is collaborative, involving scientists from the Secretatiat of the Pacific Community (SPC), the Inter-American Tropical Tuna Commission (IATTC) and the National Research Institute of Far Seas Fisheries (NRIFSF). David Fournier (Otter Research Ltd.) is a consultant to the project. The objective of the project is to analyse available bigeye tuna catch, effort, length frequency and tagging data to determine the suitability of the MULTIFAN-CL model for Pacific-wide bigeye tuna stock assessment.

A planning meeting for the project was held on 14 June 1999. All SCTB12 paritcipants were invited to participate in this meeting (Annex 1). The objectives of the meeting were to discuss the main concepts of the modeling approach to be used, to review progress in assembling the necessary data, to decide on the temporal and spatial stratification of the model and the definition of fisheries, to discuss possible structural hypotheses that might be incorporated into the model, to review the type of model output required, and to decide how the initial tasks would be allocated among the collaborators.

Overview of MULTIFAN-CL

David Fournier gave an overview of the concepts of MULTIFAN-CL. The model is fundamentally age-structured, but uses length frequency data to estimate the age composition of catches as an integrated component of the model. The software is written in C++, which allows the use of complex data structures and object-oriented programming. This enables additional structure to be relatively easily incorporated into the model. The use of automatic differentiation allows for efficient estimation of parameters. Various aspects of the model were discussed, using examples from the recent yellowfin tuna analaysis (Hampton and Fournier 1999).

Status of the bigeye database

SPC is coordinating the compilation of data to be analysed. The data are being compiled on FoxPro databases and query programs being developed to enable efficient generation of data files for analysis. The database and query software will be provided to other collaborators on completion. The current status of data holdings was reviewed as follows:

Catch data

Most of the catch and effort data to be analysed has now been assembled. It was agreed that the analysis would cover the period 1952-1998. NRIFSF will provide 5 degree-square-month data for 1952-1998 to SPC for inclusion in the project database. Preliminary estimates of 1998 longline catches would be used until the final data become available later in 1999.

Problems in estimating bigeye tuna purse seine catches were discussed. In the Eastern Pacific Ocean (EPO), yellowfin and bigeye tuna catches are separated using species composition samples collected by port sampling of catches from 13 “market measurement” areas. The EPO purse seine catch estimates are the best that can be produced from the available data. For the EPO, catches have thus far been compiled by weight, whereas the model input requires catches in number of fish. The IATTC will investigate the conversion of EPO catch weights to numbers. In the Western and Central Pacific Ocean (WCPO), purse seine catches by US vessels have been sampled for species and size composition since 1988. NRIFSF has been sampling catches of Japanese purse seiners since 1994. The SPC and its member countries have been collecting species and size composition samples from purse seiners by both port sampling and scientific observers since 1994. The SPC is currently undertaking a study to determine the optimal use of the existing sampling data to estimate bigeye catches. It is anticipated that best estimates of bigeye catches for WCPO purse seiners will be available by August 1999.

Catches of bigeye tuna by the domesitic fisheries in the Philippines and Indonesia are likely to be significant and need to be included in the model. SPC has generated estimates based on limited sampling data – it is unlikely that further information to estimate these historical catches will become available.

While there are uncertainties in some components of the catch data, it was agreed that we should proceed with compiling best estimates based on the available information. If necessary, alternative databases reflecting the range of catch uncertainty could be developed, but for the purpose of this project, it is best to proceed with using the best estimates to investigate the potential of the MULTIFAN-CL approach to stock assessment.

Effort data

It was agreed that estimates of "effective" effort would be used for the longline fishery. Such estimates have been derived for bigeye tuna by Bigelow et al. (1999). The estimates are based on the numbers of longline hooks deemed to have fished in bigeye habitat, which is defined by temperature preferences and dissolved oxygen tolerance. Changes in the depth distribution of longline gear in relation to bigeye habitat, and interannual variation in the vertical distribution of bigeye habitat since 1980 are accounted for. The use of other standardized longline effort series (e.g., by general linear models) may also be investigated.

Purse seine fisheries will be classified according to set type. Effort will be based on days fished and searched, and for the WCPO will be apportioned to various set types based on the set proportions. In the EPO, it will not be possible to distinguish FAD and log sets (at least in the time available for this project), but the different types of set tend to occur in different areas so an area-based classification should be possible.

Pole-and-line effort will also be based on days fished and searched, but without classification by school association (information which is not generally available).

No effort data are available for the Philippines and Indonesian domestic fisheries – this will be treated as missing data by the model.

Length frequency data

Length frequency data are required for all fisheries defined in the model. Data have been compiled for purse seine, and non-Japanese pole-and-line and longline fleets in the WCPO. Similarly, data have been compiled for the EPO purse seine and pole-and-line (baitboat) fleets for 1980 onwards. Pre-1980 data for the EPO fisheries will soon be forthcoming. NRIFSF will compile and provide data for Japanese longline and pole-and-line fleets for inclusion in the database in the near future.

Tagging data

Tagging data are crucial for estimating movement and mortality rates. Unfortunately, tagging data for Pacific bigeye tuna are not extensive compared with other tropical tunas. The SPC tagged ~10,000 bigeye in the early 1990s, from which >1,000 returns have been received up to seven years after release. A small amount of bigeye tagging is believed to have occurred in the EPO, and IATTC will compile these data for possible inclusion in the analysis. Also, NRIFSF has routinely tagged tuna, a small proportion being bigeye tuna, in the North Pacific, and these data will also be compiled for possible inclusion. The University of Hawaii is currently undertaking bigeye and yellowfin tagging in the EEZ around Hawaii. The possible inclusion of pre-1999 data from this project will also be investigated.

Data stratification for bigeye analysis

Time

A quarterly time period was used in the yellowfin tuna MULTIFAN-CL analysis, and this stratification seemed to be sufficient to extract useful information on growth from the length frequency samples. A quarterly stratification also allows seasonal phenomena to be incorporated into the model. It was agreed that a quarterly time period would also be used initially in the bigeye analysis.

Sub-regions

Ideally, the definition of sub-regions should be sufficient to capture heterogeneity in the spatial distribution of recruitment (in particular). On the other hand, the number of regions needs to be kept small in order to minimize the number of movement parameters to be estimated, particularly given the limited tagging data that are available. Other factors that are important are the distribution of the fisheries and particular fishing grounds, and management considerations that might dictate that stock assessment advice be area specific. After considering a variety of information, it was decided that two alternative area stratifications would be adopted – a three-area configuration and a six-area configuration (Figure 1). Independent analyses would be conducted under each configuration and the results compared.

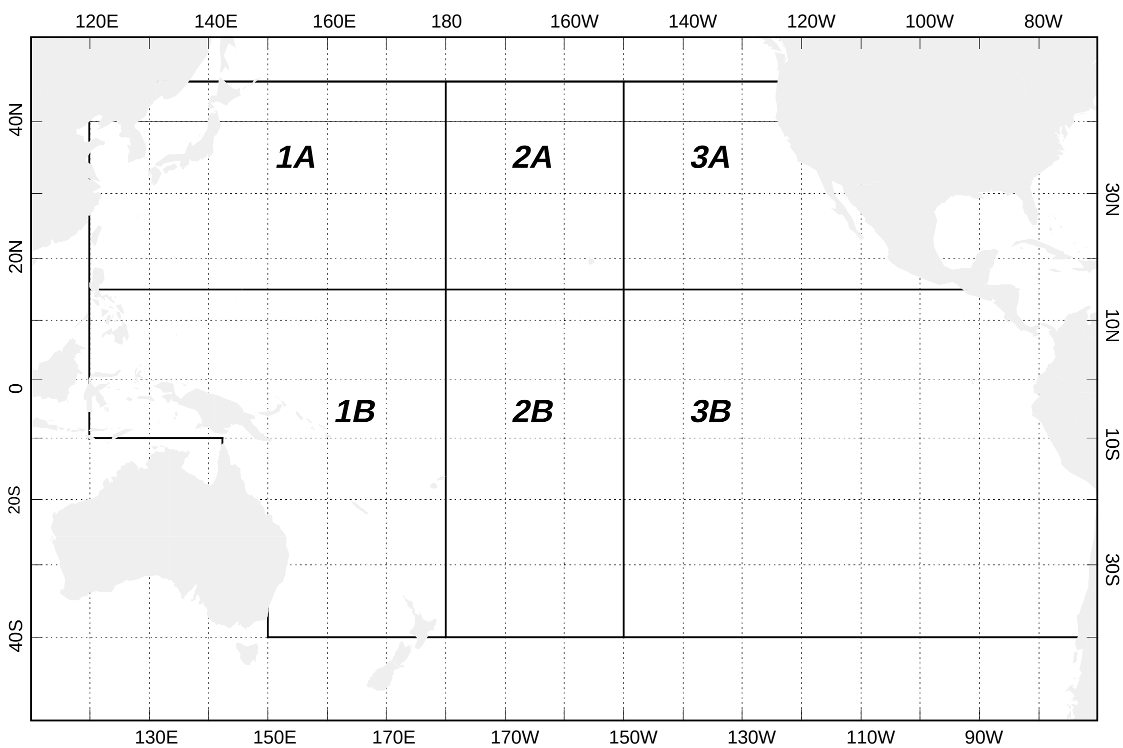

Figure 1. Proposed area stratification for bigeye tuna analysis. The three-area configuration will combine areas 1A/1B, 2A/2B and 3A/3B.

Fisheries

The individual fisheries to be defined in the model are shown in the table below. Note that it may be possible to effectively combine some of these fisheries by setting their catchability and selectivity parameters to be common, subject to initial fits of the model to the data.

Fishery number	Type of fishery	Regions	Number of fisheries
1-6	DWFN/offshore longline (JP, KR, TW)	All	6
7-10	EPO purse seine (FAD/log sets)	3B (classified by combinations of the 7 IATTC market measurement areas)	4
11	EPO FAD/log set discards	3B	1
12	EPO dolphin/school sets (incl. discards)	3B	1
13	EPO pole & line (baitboat)	3B	1
14-15	WCPO purse seine (log sets)	1B, 2B	2
16-17	WCPO purse seine (FAD sets)	1B, 2B	2
18-19	WCPO purse seine discards	1B, 2B	2
20-22	WCPO purse seine misc. sets	1A, 1B, 2B	3
23-26	WCPO pole & line	1A, 1B, 2A, 2B	4
27	Hawaii handline	2A	1
28	Philippines ringnet	1B	1
29	Philippines handline	1B	1
30	Indonesia miscellaneous	1B	1

Model structure for bigeye analysis

The meeting discussed many different structural hypotheses that might be tested. These are briefly summarized below. Not all will necessarily be appropriate for Pacific bigeye tuna, and some others may be proposed as the work proceeds.

Recruitment and number of age classes

An appropriate assumption for the periodicity of recruitment and number of age classes will need to be identified early on in the project. Initially, we will test 2 recruitments per year and 14 six-monthly age classes against 4 recruitments per year and 28 quarterly age classes. Alternative hypotheses regarding the spatial distribution of recruitment will also need to be tested. Two alternatives would be an even distribution across regions and a distribution giving relatively larger recruitment in areas 1 and 3. The ability of the model to estimate recruitment for each region independent of the other areas, and the possibility of parameterizing recruitment in terms of seasonal variation, should be also be investigated.

Initial population

In the yellowfin analysis, a static initial population age structure was assumed, i.e. the initial population age structure was generated from the estimated total mortality over the initial period of the analysis (5 years was used for yellowfin). For bigeye, we intend to begin the analysis in 1952, when exploitation was relatively light. Under these circumstances, it would be reasonable to generate the initial age structure from the estimated natural mortality rates only.

Growth

As in the yellowfin analysis, it will be necessary to test alternative growth parameterizations. Bigeye have some similarities to yellowfin in their growth patterns, so a similar growth model (i.e. von Bertalanffy for adults and independent mean lengths at age for juveniles) may be appropriate. It may also be possible to test for environmental effects and inter-area differences in growth.

Natural mortality

Preliminary analyses of tagging data indicate that it will be important to allow natural mortality to be age-dependent. Age-dependent *M* has been a feature of previous applications of MULTIFAN-CL to tuna data sets.

Catchability

Catchability may be allowed to vary seasonally and over time. For some fisheries, e.g. the DWFN longline fisheries, it may be possible to set a common catchability and assume it to be constant over time (because of prior standardization and estimation of "effective" effort). This tends to stabilize some important aspects of the model.

Selectivity

Selectivity coefficients are age-based but with smoothing applied such that age classes with highly overlapping length distributions will have similar selectivity coefficients. Other constraints may be applied to selectivity, e.g. that longline selectivity is non-decreasing with age class.

Movement

Given the paucity of tagging data available for bigeye, the ability of the model to estimate complex movement patterns will almost certainly be severely limited. In fact, it may be necessary to use a range of fixed movement coefficients between some areas to test the impact of different stock mixing assumptions on model results. It may be possible to allow estimated or assumed movement to be age-dependent to reflex changing movement behaviour with age.

Tagged population pooling

It is useful to pool the modeled tag populations over the different tag release groups after a certain number of periods at liberty. This improves computational efficiency while maximizing the information extracted from the tag return data. In the yellowfin analysis, tags were pooled after 10 quarters – a similar procedure will be adopted for bigeye, possibly with a longer initial unpooled period to reflect the greater longevity of bigeye.

Tag reporting

There is independent information on tag reporting for some fisheries, but not for others. For fisheries that recaptured considerable numbers of tags, it may be possible to estimate reporting rates using the model. For other fisheries, it will probably be necessary to fix the reporting rates at reasonable assumed values.

Model output format

Graphical summaries of results

Good graphical summaries of the model results greatly assist the efficient assessment of model performance. A Java package has been developed to display the results of fits to the length frequency data, and similar is required to rapidly view other aspects of the model results and fits to other components of the data.

Example risk analysis using a limit reference point

Some example applications of the use of limit reference points will be built into the software. This might take the form of specifying a LRP in terms of a percentage of maximum observed or virgin adult biomass, and estimating the probability that the current adult biomass is beneath that level. Other types of reference points, e.g. fishing mortality based, could also be incorporated.

Conclusion

Allocation of tasks

A detailed allocation of tasks was not undertaken. This will be finalized by correspondence. The initial priority is to finalize the compilation of data. Also, the IATTC and NRIFSF collaborators will familiarize themselves with the model by analyzing sets of simulated data (to be produced using a simulator in the final stages of development).

Next meeting

It was agreed that it would be desirable for the project collaborators to meet in early 2000 to review results to date and to plan the final assault of the project. Hawaii may be a convenient location for such a meeting.

References

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