Indian Ocean Tuna Commission
Commission des Thons de l'Océan Indien

Report of the *ad hoc* IOTC Working Party on Methods

Sète, France 23-27 April, 2001

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EXECUTIVE SUMMARY

The meeting of the *ad hoc* Working Party on Methods (WPM) was held in Sète, France, from 23 to 27 April 2001, involving 12 participants from seven countries or organisations.

The meeting had as its main objectives to discuss methodological aspects relevant to the activities of the species Working Parties. The discussions were centred on problems affecting directly the assessment of bigeye tuna, the main priority for the Working Party on Tropical Tunas which will be convened shortly.

The WPM noted that, until the on-going work on the estimation of indices of abundance from the purse-seine fishery is completed, any CPUE-based analyses of yellowfin or bigeye tuna would have to rely primarily on data from the longline fleet. The Working Party agreed that most of the CPUE analyses would have to be based on the data from the Japanese fleet as Korean data were not considered reliable and some data from Taiwan, China were not available to the Secretariat. The Working Party recommended that a number of additional analyses be carried out that could improve the index of abundance based on these data.

After taking into account the quality of the data available and the history of exploitation of bigeye tuna, the WPM considered that the preferred methodological approach for the assessment of this resource in the near future should be one that could reflect well the effects of changes in selectivity pattern that took place in this fishery. As the size composition of the catch is not well known even for recent years, the WPM also recognized the need for giving priority to approaches based on production modelling. Age-structured production models were cited as an example of a method that would probably represent adequately the effect of selectivity changes. The WPM also recommended carrying out further simulation testing, both for this method and for other potentially useful approaches.

The Working Party also acknowledged the benefits of integrating the standardization of the CPUE with the assessment model and recommended that further work be done in this area, although it would not be possible to carry such work before the next WPTT meeting.

1. OPENING OF THE MEETING AND ADOPTION OF THE AGENDA

The Meeting of the *ad hoc* Working Party on Methods (WPM) opened on 23 April 2001 in Sète, France by the Chairman of the Scientific Committee, Renaud Pianet, from IRD, France, who welcomed the participants (see List of Participants in Appendix I). Alejandro Anganuzzi, from the IOTC Secretariat, was elected as Convenor for this meeting. The Agenda for the Meeting was adopted as listed in Appendix II. The documents available for discussion are listed in Appendix III.

The WPM decided to focus its attention on methodological approaches applicable to the analysis of the data available for bigeye tuna, recognizing the priorities assigned to it by the Scientific Committee and also that the Working Party on Tropical Tunas will give precedence to assessing the status of this species. However, it noted that the methodological problems encountered in the assessment of this species will be equally relevant to the assessment of the other tunas, for which limited data are also available.

The WPM recognized that the methodological approaches that might be recommended are closely related to the characteristics and availability of the data for the stock in question. It was therefore decided to summarize the features of the main datasets available for the assessment of bigeye tuna.

2. REVIEW OF CATCH-AND-EFFORT DATA AVAILABLE FOR MAIN LONGLINE FISHERIES

Issues of data quality

Catch-and-effort data are available from a number of coastal and distant-water fisheries in the Indian Ocean. The WPM agreed to concentrate its review of the data series from the main distant-water nations, Japan, Korea and Taiwan, China, which have the longest time series and widest spatial coverage.

Japan

The coverage of the logbook information is about 80 % for most of the time series and has reached 95 % in recent years. Concerns were raised about the reduction in the fraction of the catch sampled for size data in recent years. Although the collection of size data is mandatory for the Japanese distant-water longline tuna fisheries, the number of fish measured has been decreasing recently as most of the size data has been collected on high-school longline training vessels rather than in commercial fishing operations. Furthermore, the operations of these training vessels in the Indian Ocean have been reduced in recent years. The WPM noted these trends with concern and observed that the performance of methods that depend on this type of data would improve if sample sizes for commercial longliners were increased. These data would also provide better information on targeting strategies for different sizes of fish.

Two sources of data are now available for the estimation of average weight: size sampling and the extended logbook information which, since 1994, includes both the number of fish caught and the total catch in weight in each set, from which an estimate of average weight per set can be derived.

The current size data are reported to IOTC in 10x20-degree area aggregates because of the small sample sizes. Although it is possible to link the original size data to their corresponding catch data at the time of the operation, it would be a time-consuming operation to establish this link.

In 1994, Japan started to collect information on the materials used in the line (nylon or other materials). Furthermore, since 1997, Japan has collected data on the length of the float line, branch line and the length in meters between branches. This information could be important for future standardization procedures. However, other information that might also be useful, such as use of line thrower, the speed at which the line is set or time of the set is not currently available, except for operations of training vessels.

Unconfirmed reports from on-board observers suggest that the number of hooks actually deployed during commercial operations might be less than reported by the vessel. This would result in an over-estimation of the current effort and would be especially problematic if this over-reporting has shown a trend in recent years. It was recommended that, if possible, the extent of this problem might be assessed by comparing observer data on the actual number of hooks set (e.g.: from the existing observer programmes in the BIOT and in Australia) with the data provided by the skipper for the same operations.

Taiwan, China

The WPM noted that logbook coverage for the Taiwanese large-scale longline fleet has always been some 10-15 % lower than that for Japanese vessels. A comparison of the total catch reported in the nominal catch (NC) database with the catch reported in the catch-and-effort (CE) database suggests that the logbook data have been raised to processed weight (rather than total weight) for the period 1972-1993. However, for some years and species, the ratio between the two catch estimates is unexpectedly high. The reason for these anomalies has to be explored. Taiwan, China has collected data on the number of hooks between floats since 1995. Unfortunately, no such information exists for earlier years.

No size-frequency data are available after 1988 for this fleet. The WPM recommended that the Secretariat continue its efforts to recover this information, but also noted that Taiwan, China has reported CE data both in weight and numbers, which allows some estimation of the distribution of average weight in the catch.

Korea

The WPM noted that there is no knowledge about the current or past coverage of logbook data. It also expressed serious concerns about the quality of the 5x5-degree CE data or the NC data reported, as a simple comparison shows that the catches reported in the CE data exceed those in the NC data. It was suggested that this problem might originate in data processing. In addition, sample sizes have been very low for size-frequency data and were not provided with the minimum required level of detail.

The WPM recommended that the Secretariat continue its efforts to contact Korean authorities in order to better assess the problems and recommended that this information not be used until the quality issues are better understood.

Spatio-temporal patterns and targeting practices

The distribution of average annual fishing effort for three recent periods (1975-1984; 1985-1994 and 1995-1999), shown in Figure 1, illustrate the main differences in the spatial distribution of effort for the fleets. The patterns in the three panels show an increase in the overall effort, especially in the Taiwanese fleet, which covers most of the area of distribution of the tropical tunas. Japanese fishing effort, concentrated in the southern area in the first period considered, has shifted to the area of the Mozambique Channel in the most recent period. The total fishing effort of Taiwan, China has increased greatly since the late 1980s and early 1990s, primarily in the tropical areas.

In previous analyses, a sudden increase of the bigeye tuna CPUE obtained from the Japanese longline data was noted in 1977 and 1978 in the Indian Ocean. Document WPM-01-01 explores two hypotheses to explain such an increase: 1) concentration of fishing effort had occurred in a relatively small region in the Indian Ocean with high CPUE, and 2) in 1977 and 1978, a very large recruitment took place in the bigeye stock that was exploited by the longline fishery. Analysis of the geographical distribution of effort and CPUE and of the distribution of size specific CPUE did not lend support to the first hypothesis. Sample length-frequencies in tropical area do not show signs of a strong year class in this Ocean, suggesting also that there is no support for the second hypothesis. Another possible explanation considered was based on the introduction of the deep longline as a new fishing technique. However, the jump in CPUE over this period is also observed in other Asian longline CPUE data for bigeye in the Indian Ocean and in the Japanese longline CPUE for bigeye in two other oceans (Pacific and Atlantic) and the CPUE for yellowfin in the Indian and Pacific Oceans. However, the timing of the introduction of deep longlining does not correspond with the increase in CPUE in all these cases. Another possibility suggested, but not fully explored, is that a large change in oceanographic conditions (regime shift) occurred around 1976 at a global scale.

Results from examining the monthly effort, CPUE and area fished trends (Tables 1 and 2) were also presented during the meeting. These tables suggest that there was a substantial change in the area and temporal pattern of longline effort between 1976 and 1977. When catch rates are examined for only the five-degree squares that were fished within a month in 1977, the large increase observed in the CPUE between 1976 and 1977 is diminished (Figure 4). This suggests that a least part of the observed large increase in the CPUE between these two years may be due to changes in the spatial/temporal operations of the fleet. This highlights the importance of using appropriate spatial/temporal strata when developing standardized CPUE indices and of testing and incorporating (when appropriate) year/area/season interaction terms. The results also suggest that such interactions may be occurring at relatively fine spatial/temporal scales. This can confound the interpretation of the extent to which changes in CPUE indices represent changes in abundance or fishing patterns, since the areas fished at these finer scales of resolution can vary considerably between years.

In the ensuing discussion, it was noted that there are a number of alternative interpretations for this apparent anomaly, including the rapid introduction of new technological devices such as GPS, powerful echo sounders, etc. It is also possible that several factors were acting simultaneously to produce the anomaly. However, at this stage, the WPM felt that the possible explanatory factors were difficult to identify, and recommended to continue the work on this problem.

An extensive discussion was centred on the targeting practices of fishermen, in particular, as to whether large bigeye tuna were targeted specifically due to their high commercial value. To clarify this issue, further analyses were conducted during the meeting on the relationship between concentrations of effort and bigeye CPUE, calculated separately for large and small sized fish (Figure 3). The results of these analyses suggest that there is a negative relationship between CPUE for small bigeye tuna and CPUE for large bigeye tuna and that the CPUE for small bigeye tuna is larger than the CPUE for large bigeye tuna. The Working Party also noted that the figures in document WPM-01-01 indicate that there are areas and times where catches of small or large fish predominate. The WPM suggested that these differences could be useful in determining areas for the calculation of indices for different size categories. These results seem to indicate that a large CPUE for a particular species or size may not be an indicator of targeting.

The appropriateness of using the species composition of the catch in order to allocate targeting was discussed. It was noted that, in the case of yellowfin and bigeye tuna, this procedure could lead to misleading results, as fishermen could be targeting large (and more valuable) bigeye tuna in areas where the catch of yellowfin tuna exceeds the catch of bigeye. On the basis of species composition of the catch, effort from such areas would be erroneously classified as targeting yellowfin tuna. An additional problem with this approach is that, if the distribution of the target species contracts as a consequence of its exploitation, more areas would be erroneously classified as showing predominant targeting to the other species. The WPM agreed that the number of hooks between floats might still be more effective in tackling the problem of targeting and further recommended that future analyses by done on set-by-set data.

3. Discussion on the main assumption of CPUE standardization

In document WPM-01-05 a method is proposed to compare statistical models for CPUE standardization through the use of information criteria such as Akaike's Information Criterion (AIC). Recent standardization of CPUE data have been performed by generalized linear models (GLM). The estimation of the parameters of a GLM has usually been performed by modelling the CPUE, assuming a log-normal error distribution, or by modelling catch and assuming a Poisson error distribution. The analysis of CPUE trend and standard residuals have often been carried out in order to verify which whether the lognormal or Poisson model is better. However, no statistical comparison of those two models seems to have been performed so far. The AIC method is applicable to almost all GLM models dealing with CPUE standardization.

The WPM suggested that, although this newly developed method is appreciated, standard residual analyses are still needed in order to select the most appropriate error structure in the GLM model, as the procedure suggested is based only on a comparison of the likelihoods of the model. It was also noted that small differences in the AIC criterion often indicate that there is almost no difference between the ability of similar models to fit the data.

4. Standardization of longline CPUE indices

GLM

The factors used in past analyses for standardizing nominal hooking rates of the industrial tuna longline fisheries of yellowfin and bigeye tuna in the Indian Ocean are discussed in document WPM-01-03. Based on this review, the authors recommend a list of factors for inclusion in future standardization work.

The WPM recommended being very cautious when using regime-shift related factors in standardizing CPUE as the environmental changes associated with regime shifts could actually affect abundance of the resource rather than its catchability. Therefore, standardizing by a regime shift would remove information about the abundance of the population from the index. On the other hand, in a different methodological approach, variables associated with a regime shift could be used in the definition of the habitat in which the species of interest could be found. In this type of analyses, the average density could be estimated as a function of the habitat index and then integrated over the observed values of the habitat index.

An extensive discussion followed regarding the handling of the interaction terms involving year effects in the usual GLM. It was recommended that such interactions should not be ignored, but incorporated if they are shown to be significant. In those cases, special care has to be taken when defining the index of abundance, since it becomes necessary to integrate over the range of the variable interacting with year. For example, if year-area interactions are shown to be significant, an adequate index could be based on the average of the predicted values for each area, weighted by the size of the area.

The inclusion of country as a factor in the GLM was discussed. The WPM suggested using the Japanese data alone at this stage, as there are some problems with Korean and Chinese (Taiwanese) longline data (see previous discussion under section 2). However, it was also noted that the spatial coverage of the Japanese longline fisheries has been contracting in the 1990s, while that of the fleet from Taiwan, China has been expanding. Therefore, there might be some advantages (related to the increase in sample sizes and coverage) in conducting the GLM analyses after pooling data for the various fleets, once the problems with the Korean and Taiwanese datasets are resolved.

Other potentially important factors were discussed, i.e., losses from predators (cetaceans and sharks) and the evolution of technical devices such as the widespread use of GPS. The WPM suggested considering these factors in the future, as and when sufficient data become available.

The possibility was discussed of carrying out a long-term project to obtain information on other factors affecting the nominal CPUE. The main factors identified are ability of the fishing master, the evolution of the technical devices for tuna longline fisheries and information on predation of hooked fish. Although the fishing master's ability is an important factor, only captains' names have been recorded in the current Japanese logbook. Thus, it was suggested to collect data on the identity of the fishing masters as well in the future if possible. Collection of the information of the predation of hooked fish is now on-going, and could be utilized in future GLM analyses if required.

It was noted that the effect of bathymetry as a GLM factor (an approach illustrated in document WPM-01-02) could be captured by an appropriate definition of sub-areas. However, it was recognised that further work on this subject might improve the definition of spatial strata for different stocks.

Application of the CPUE index estimation based on catch in weight (as opposed to numbers) was discussed. Such an index would be more appropriate to fit a production model that represents the dynamics of biomass rather than of number of fish. The WPM recommended that work towards developing such indices be undertaken as soon as possible. It also recognized that, given that there is no discernible trend in the average weight of the bigeye tuna caught by Japanese longline, both indices might show a very similar trend.

Other approaches (GAM, regression trees, etc)

Some preliminary analyses based on regression tree models applied to the Japanese longline data, conducted by the Secretariat and discussed during the meeting, suggest that this class of models could be a valuable tool in identifying potential interaction terms to be included in the GLM. For example, potentially significant three-way interactions would appear in the tree model as a sequence of splits involving different levels of the same three variables. The analyses used the proportion of bigeye tuna relative to the catch of bigeye and yellowfin tunas to account for targeting. However, as was mentioned earlier, this variable might not adequately reflect the intended target species and it was recommended that it should not be used in the future.

It was agreed that the optimum size of the regression trees needs to be carefully evaluated by cross-validation studies before deciding on the final tree size. The WPM recognized the value of these alternative approaches and recommended further developing the exploratory approach presented in order to assist in the GLM model selection process.

An example of the application of generalized additive models (GAM) in document WPM-01-Inf.5, based on data for yellowfin tuna in the Atlantic Ocean for two fishing fleets, shows how to identify non-linear relationships between various hydrological factors and age-structured CPUE. Catchability effects are distinguished from effects of tuna environmental preferences in the CPUE variability. With respect to catchability, an important non-linear effect of local fishing effort was identified for each fleet. This effect was interpreted as resulting from the local high exploitation rate of adult yellowfin tuna and from fishing tactics (vessels cooperating/spying). The environmental preferences obtained facilitate the interpretation of the hierarchical spatial distribution and age-dependent movements of the yellowfin population. It was shown that, on a large spatio-temporal scale (the whole ocean), low salinity is a good predictor of yellowfin habitat. Juveniles are mainly distributed in low salinity waters (<35g·kg-1) when adult extend their range to 36g·kg-1 waters. On a meso-scale, annual transatlantic reproductive displacements of the adult population are probably driven by temperature and salinity gradients to warm and low salinity places which are favourable for juveniles. North-South seasonal movements of the population are clearly related to warm-water seasonal oscillations. On a small scale, ocean thermal stability and gradients of sea surface temperature are important physical factors controlling concentrations of yellowfin tuna.

The WPM recognized that the application of GAM could help in better modelling the non-linear responses of the dependent variable and in providing a method for estimation of missing data in certain time and area strata. However, it also noted that the effectiveness of the application of the model would depend on the coverage of the data. For example, if data are not available from areas with low density, the model could indicate unreasonable extrapolations at the limits of the range. Other approaches, such as geostatistical analyses or analyses based on some measure of potential habitat, could yield better results, depending on the data.

The possibility of applying this method to data from the Indian Ocean was discussed. A potential problem noted was that the oceanographic data available for the Indian Ocean would not be as complete as for the Atlantic Ocean.

5. REVIEW OF AVAILABLE PURSE-SEINE CATCH-AND-EFFORT DATA

Issues of data quality, spatial distribution and targeting

The quality of the data from purse-seine fisheries (composed mainly of vessels of European origin) is considered to be generally good, although some problems have arisen in recent years affecting the estimates of the species and size composition of the catch in the EU purse-seine fishery. However, the main issues lie in the rapid development of a fishery in association with floating objects, in particular Fish Aggregating Devices (FADs), since the early 1990s. The development of this fishery brought about two important consequences. First, it changed significantly the pattern of fishing mortality at age, as fish in association with floating objects are significantly smaller than longline-caught fish. Second, it challenged the interpretation of traditional measures of fishing effort (such as search time or fishing time) as a quantity directly related to the fishing mortality. The extensive use of FADs has resulted in a change of fleet behaviour, since vessels are less engaged in search-related activities than in a fishery targeting free-swimming schools and assisted by supply vessels in deploying and inspecting FADs. This suggests that a measure of effort that incorporates the total number of FADs deployed (unfortunately, these data are not available) would be better related to fishing mortality than the traditional measures.

In addition, there have been significant technological improvements in recent years in this fleet that have not been properly documented. Several of these problems are being addressed in the context of EU project called “Efficacité des Senneurs THoniers et Efforts Réels” (ESTHER). A meeting of scientists involved in this project has been scheduled for early June and its results are expected to be reported at the next WPTT meeting.

Progress in the standardization of Purse-seine CPUE indices

The WPM was briefed on the progress of research oriented towards obtaining an index of abundance based on data from the purse-seine fishery, reported in WPTT-00-04 during the last WPTT meeting. The Spanish purse seine fleet has operated in a wide area of the Indian Ocean since 1984. A logbook system provides detailed information of catches (set by set) and effort. Together with this information, an intensive work of interview during four years (1994-1997) has provided data on the technical equipment. These data have been used to obtain standardized catch per unit effort (CPUE) indices of abundance for yellowfin caught in free-swimming schools from the Indian Ocean, using a GLM approach. The results from this work should still be considered as preliminary.

The WPM encouraged the scientists involved to continue their efforts, recognizing the need for an index of abundance for the purse-seine fishery that could reflect the abundance of the younger fish.

6. PRODUCTION MODELLING

As recommended by the Scientific Committee, the WPM discussed possible variants of production models to be applied to the Indian Ocean data. This recommendation was based on the lack of consistent size data for tropical tunas in the Indian Ocean, in particular for important components of the longline catches. This will likely continue to be the case in the near future, until other sources of data (e.g.: tagging data) are available.

The Scientific Committee specifically requested the WPM to look at possible ways of combining the estimation of the parameters of a production model and those parameters related to the CPUE standardization. One such procedure was presented in document WPM-01-Inf.4 in which catchability parameters are related to external factors through linear or non-linear functions. The parameters are then estimated using a maximum-likelihood procedure in which there are separate components of the likelihood function for the population-dynamics parameters and the catchability-related parameters. The author illustrated the procedure with a Pella and Tomlinson model as the dynamics model applied to a simulated data set. The performance of the integrated approach in the simulated scenarios is compared with that of a model fitted to an effort series standardized externally with a GLM procedure. The results show that the integrated approach shows more precise and less biased estimates of the parameters of interest.

In the discussion, it was suggested that the increased precision is likely to be the result of taking into account the full covariance structure of the parameters related to the CPUE standardization. By contrast, the traditional approach ignores the possible correlation structure of those parameters. The WPM recognized the technical advantages of this approach and recommended that future work should seek to integrate CPUE standardization into the estimation procedure for the assessment model.

Considering the particular case of the bigeye tuna, the WPM discussed extensively the possible production modelling approaches that could be used, taking into account the limitations of the data and the characteristics of the time series available. Past applications of different variants of production models to data from the bigeye tuna resource were reviewed in the document WPM-01-06. The authors review several studies that used either a Schaefer model with a non-equilibrium estimation procedure (as implemented in the program ASPIC) or an age-structured production model (ASPM), noting that very different results were obtained depending on the model assumptions.

Another possible approach is implemented by PROCEAN (described in the document WPM-01-07), which is based on a multi-fleet, non-equilibrium Pella and Tomlinson model which includes both observation error and process error on carrying capacity and catchability for each fleet. The process error for catchabilities combines a random-walk error structure which allows for slow trends in fishing power and a robust error structure which allows for high frequency random variability of catchability. PROCEAN is designed in a Bayesian context which allows for using priors on r, K and the biomass at the beginning of the time period.

Another application of a Pella-Tomlinson model in a Bayesian framework was presented in document WPM-01-08. The approach illustrated is motivated is by the observation that most tuna fisheries are characterized by a “one way trip”: a continuous increase of fishing effort which does not provide enough contrast in the data to correctly estimate the production model parameters. One way of dealing with this situation, which corresponds to the one shown by the bigeye tuna fishery in the Indian Ocean, is to carry out the assessment in a Bayesian framework. In this approach, prior distributions are chosen for the parameters of the production models as being uninformative or, more appropriately, on the basis of external knowledge from similar species in other oceans. The document illustrates one way of obtaining informative priors for the parameters of a Pella-Tomlinson model, based on simulations of an age-structure production model.

The WPM noted that the trend of bigeye tuna CPUE is inconsistent with the expected trend under the assumptions of a production model. This fact explains in part the difficulties encountered in past analyses using Schaefer or Pella-Tomlinson models. In particular, the WPM noted that, while the catches increase rapidly in the early 1990s both in the longline fishery and in the purse-seine fishery which targets younger fish, the CPUE maintained the same rate of decline as in previous years. Therefore, it will be very difficult to find a combination of reasonable parameter values that would adequately represent this pattern using traditional estimating procedures. Therefore, the WPM recognized that it might be necessary to rely on a Bayesian approach to obtain more stable parameter estimates. In discussing guidelines about how to proceed in developing appropriate prior distributions for the relevant parameters, the WPM recommended that the Secretariat compile information on biological characteristics and assumptions on bigeye tuna from other oceans prior to the next WPTT meeting. It also suggested that consideration be given to the question of developing joint priors for parameters that are usually correlated.

The WPM further noted that the change in age-specific fishing mortalities brought about by the development of the FAD-associated fishery in the purse-seine fishery violates the assumption of a constant selectivity pattern, and agreed that the model to be used should be able to effectively represent the effects of this change in selectivity. Age-structured production models (ASPM) were mentioned as a class of models that would meet that criterion. However, the WPM also recognized that it is possible that other methods such as PROCEAN might represent the changes in productivity as changes in the intrinsic rate of growth or changes in carrying capacity. Some preliminary simulations were carried out during the meeting to evaluate how PROCEAN would represent such changes. The results were inconclusive and it was recommended that further simulation studies be conducted prior to the next WPTT to better assess the performance of PROCEAN under this specific circumstance. It was also recommended that parallel simulation-based evaluations be carried out on an age-structured production model to compare the response of both methods.

The WPM also recommended that results be presented, including various reference points beyond the traditional MSY that could provide a more comprehensive evaluation of the assessment.

7. DEFINITION OF A SIMULATION-BASED APPROACH TO ASSIST IN EVALUATING THE PERFORMANCE OF METHODS

The WPM recognized that there was a need to better understand the performance and properties of the methods used to standardized CPUE indices and stock assessment methods in general. In particularly, there is a need to understand their robustness in the face of violations of the underlying assumptions that are encountered in assessments of Indian Ocean tuna stocks. The most appropriate way identified for doing this was through simulation testing in which an operating model is created to represent plausible alternative hypotheses for the actual underlying population dynamics and the processes which generate fishery and related data. The data generated from such an operating model can then be analyzed with various methods to compare their performance since the “true” value of the parameters is known. In conducting such an evaluation, it is critical, where there is uncertainty about the dynamics of the process and the data collection, that a sufficiently wide range of assumptions and parameter values reflecting the underlying uncertainty are considered. In other words, the operating model can not simply be a perfect reflection of the assumptions in the assessment modelling. It was noted that this approach for testing and developing methods (including management procedures) is becoming common and is being used in a large number of regional fishery organizations.

The Working Party recommended that an operating model be constructed for the above purpose. It identified the following features that should be included in the development of such a model:

* The model should be age, size, time and space-structured.
* It should allow for multiple fleets with different and variable selectivity.
* It should allow for testing trends and variability in catchability, including effects due to targeting.
* It should allow for the distribution of fishing effort and catchability to change spatially and temporally.
* The spatial structure should be sufficient to allow testing for effects due to concentration of effort and density-dependent population responses in habitat use, but it does not necessarily need to be a highly realistic representation of the Indian Ocean.
* The spatial component should allow for movement between areas that contains both a random and directed components. This may need to vary with age and season to account for spawning behaviour, etc.
* The model should allow for flexibility in modelling of growth. It should allow for both density-dependent and size-based models to be incorporated. However, this is not seen as an initial high priority and the initial modelling of growth would be done using a standard VBG formulation.
* Recruitment should be flexibly modelled to include a range of possible stock recruitment relationships with a random component. It should also allow for a range of different hypotheses for how recruitment is spatially distributed, including the possibility of localized stock/recruitment relationships.
* The observational data produced by the model needs to include realistic levels of variability and potential biases.

The development of the operating model should be seen as an evolving process, with initial priority being given to those features that have been identified as most problematic in Indian Ocean Tuna assessments (e.g. multiple fleets with different selectivities and different temporal effort trends; non-random and localized concentration of fishing effort). The computer implementation of the model should be designed in an object-oriented framework to allow increasing complexity to be added progressively. Development of the model should be done taking into account, and in coordination with, similar developments that are occurring in ICCAT and other regional fishery organizations. In this regard, a paper was circulated on the development of simulation framework to evaluate management strategies for Atlantic tuna. The meeting noted the framework being proposed contained many of the features noted above and might provide a useful framework for the development of an operating model for Indian Ocean tunas. However, this framework did not contain any spatial structure, which the working party considered to be essential.

Given the uncertainties about the performance of the current assessment models when fitted to the available data, the utilization of the operating model approach was considered to be a high priority. Development of the operating model should be included within the on-going work plan.

An important component in the development and application of the operating model will be the conditioning of the model (i.e. selecting combination of parameter estimates that that are consistent with existing observational data). This will require identifying the sets of observational data that should be used in this conditioning process.

8. OTHER MATTERS

Methodological issues concerning the assessment of swordfish

A summary of the current problems encountered in the assessment of the status of the swordfish were presented in document WPM-01-09. The WPM noted that many of the methodological issues involved are similar to those discussed in relation to bigeye tuna and most of the recommendations are directly applicable.

Methodological issues involved in providing advice on optimal fishing capacity

Under this agenda item, the methodological issues involved in providing advice on optimal fishing capacity were briefly discussed. The WPM noted that this was a difficult problem for a number of reasons. Any estimate of overall fishing capacity needs to be able to be able to be able to estimate the relative effects of different vessels and gear on the stock (e.g. to estimate relative fishing power or what the fishing mortality rate for a specific combination of vessel types and number would generate). The information required to generate reliable estimates of vessel-specific fishing power are not available. The Working Party also noted that fishing power often changes markedly over time, with an increasing trend and, as such, fishing capacity, if measured in terms of number of vessels, will not be a static quantity. In addition, the Working Party noted that different combination of number and types of vessels can have comparable effects on the stock (in terms of the effect of their removals on the dynamics of the stock). As such, when a variety of vessel types and sizes exist in a fishery, there is no unique combination of vessels that would yield “optimal” performance in terms of normal stock assessment performance criteria (e.g. MSY, F_{msy}, risk statistic). Other criteria (often economic and social) come into consideration. Other data and method that are outside the scope of the normal fishery assessment work are required to undertake evaluations against such criteria.

Development of new methods in other agencies

A brief report of a new assessment model (FASST) being developed in ICCAT was presented (WPM-01-Inf.2 and WPM-01-Inf.3). This model is size and age based and also includes spatial structure. The WPM noted that the model contains several interesting and potentially useful features not incorporated into most stock assessment models. As such, comparative results on the performance of this model when completed will be of interest. However, the data requirements for such a model were beyond what was currently available for Indian Ocean Tuna.

9. CONCLUSIONS AND RECOMMENDATIONS

The WPM, noting that its primary mandate is to assist the work of the species Working Parties and, noting that the priority for the next WPTT is to assess the status of the bigeye tuna, agreed to focus on issues directly relevant to this stock. However, it also noted that most of the issues reviewed are also relevant to the work in progress in other stocks.

Concerning the work to be done on bigeye tuna in preparation for the next meeting of the WPTT, the Working Party agreed to the following recommendations:

CPUE issues

The Working Party noted that any CPUE-based analyses of yellowfin or bigeye tuna would have to rely primarily on data from longline fleet until the on-going work on the estimation of indices of abundance from the purse-seine fishery is completed.

Of the three longline fisheries that have been operating over a wide area and for a long period of time (Japan, Korea and Taiwan, China), the Working Party agreed that most of the CPUE analyses would have to be based on the data from the Japanese fleet. The use of Taiwanese data in estimating an index of abundance is problematic because of the low logbook coverage, the lack of data to account effectively for targeting practices and the some inconsistencies in the data. The Working Party also recommends that the data from Korean longliners not be used until the important inconsistencies noted have been resolved.

The Working Party recommended that a number of additional analyses be carried out to take into account:

* If interactions between year effects and other factors are shown to be significant, the index of abundance should incorporate them, using an appropriate weighting scheme (e.g. an area-weighted scheme if year-area interactions are significant).
* Indices for two size categories should be developed.
* Indices should be presented reflecting catch both in weight and numbers.
* The effects of alternative spatial stratification that would better reflect areas with similar fishing practices or ecological characteristics should be explored.

The Working Party also acknowledged the benefits of integrating the standardization of the CPUE with the assessment model and recommended that further work be done in this area, although it will not be possible to carry such work before the next WPTT meeting.

Production modelling

The Working Party agreed that, considering the large changes in age-specific fishing mortality in recent years for bigeye tuna, priority should be given to those models that would adequately represent the effects of those changes in selectivity. At this time, age-structured production models seem to be the best approach. Based on the results of the preliminary simulations, it is possible that other model formulations, such as PROCEAN, might adequately reflect the effects of changes in selectivity, although more extensive simulations were recommended to better assess their robustness.

The Working Party noted that, in any case, due to the lack of contrast in the history of the fishery, it would be necessary to carry out the estimation of the parameters in a Bayesian framework. Therefore, it recommended that information that could assist in the determination of priors (such as information from similar stocks in other oceans) be made available at the next WPTT meeting. It also recommends that, in setting these priors, consideration be given to assign joint priors to reduce the weight of unlikely parameter combinations.

Recommendations for future work

The Working Party agreed on the need of developing an operating model that could be used both for understanding the properties of methods for analyses and to explore possible mechanisms behind some of the features observed in the data. It also agreed that work on this subject should begin as soon as possible, as this is a long-term project that would require continuity and that would benefit from similar experiences in other organizations. However, its benefits would extend to all species Working Parties.

APPENDIX I. LIST OF PARTICIPANTS

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APPENDIX II. AGENDA OF THE MEETING.

1. *Adoption of the Agenda*
2. *Review of Catch-And-Effort Data Available for Main Longline Fisheries*
   - 2.1. *Issues Of Data Quality*
   - 2.2. *Spatio-Temporal Patterns And Targeting Practices*
3. *Discussion on the Main Assumption of CPUE Standardization*
4. *Standardization of Longline CPUE Indices*
   - 4.1. *GLM*
   - 4.2. *Other Approaches (GAM, Regression Trees, Etc)*
5. *Review of Available Purse-Seine Catch-And-Effort Data*
   - 5.1. *Issues of Data Quality*
   - 5.2. *Progress in Standardization of Purse-seine CPUE Indices*
6. *Production Modelling*
7. *Definition of a Simulation-Based Approach to Assist in Evaluating the Performance of Methods*
8. *Other Matters*
   - 8.1. *Methodological Issues Concerning The Assessment Of Swordfish*
   - 8.2. *Methodological Issues Involved In Providing Advice On Optimal Fishing Capacity*
   - 8.3. *Development Of New Methods In Other Agencies*
9. *Conclusions And Recommendations*

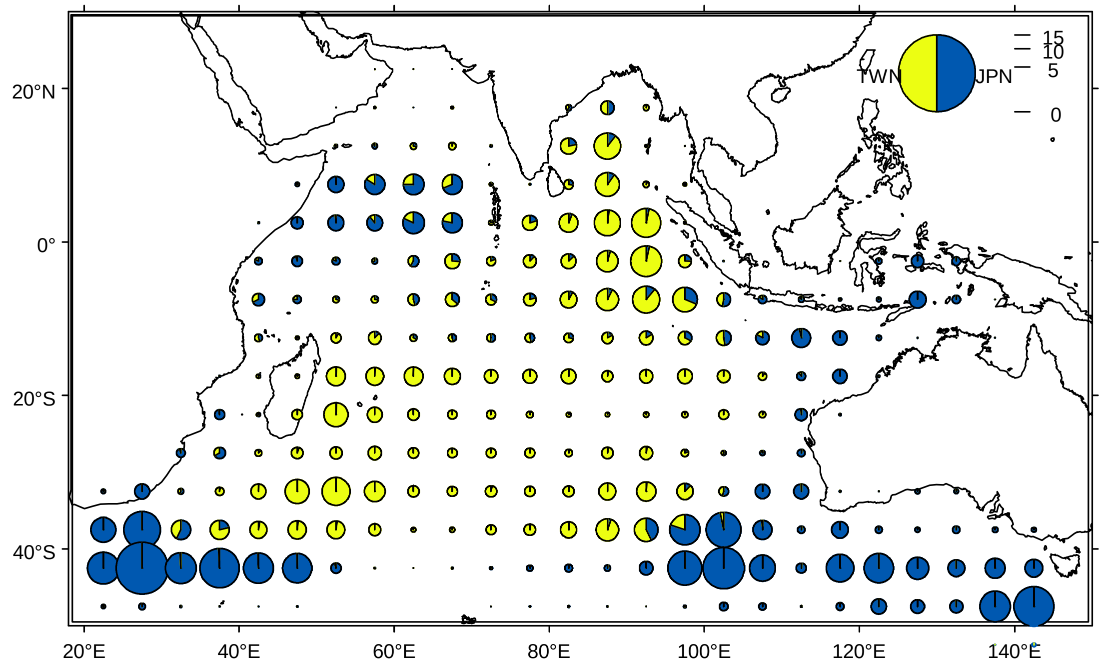
APPENDIX III. LIST OF DOCUMENTS AVAILABLE TO THE MEETING.

WPM-01-01	Interpretation of high catch rates of bigeye tuna in 1977 and 1978 observed in the Japanese longline fishery in the Indian Ocean. *Okamoto, H., N. Miyabe and D. Inagake*
WPM-01-02	Study of bathymetry effects on the nominal hooking rates of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) exploited by the Japanese tuna longline fisheries in the Indian Ocean. *Nishida, T., M. Mohri, K. Itoh and J. Nakagome*
WPM-01-03	Consideration of factors affecting nominal hooking rates of the industrial tuna longline fisheries of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) in the Indian Ocean by *Nishida, T. and H. Shono*
WPM-01-04	Review on CPUE standardisation of the industrial longline tuna fisheries and production model analyses for yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) resources in the Indian by *Nishida, T.*
WPM-01-05	Comparison of statistical models for CPUE standardisation by information criteria - Poisson model vs. Log -normal model. *Shono, H.*
WPM-01-06	Review of the production model analysis of bigeye tuna (*Thunnus obesus*) in the Indian Ocean. *Matsumoto, T. and H. Shono*
WPM-01-07	PROCEAN: a production catch/effort analysis framework to estimate catchability trends and fishery dynamics in a Bayesian context. *Maury, O.*
WPM-01-08	Priors for the shape and productivity parameters of a Bayesian Pella - Tomlinson model. *Maunder. M.N.*
WPM-01-09	Problems in swordfish stock assessment in the Indian Ocean. *Yokawa K.*
WPM-01-Inf.1	Atlas of the Japanese industrial tuna longline fisheries of yellowfin tuna (*Thunnus albacares*) and bigeye tuna in the Indian Ocean by *Nishida T. and K. Itoh*
WPM-01-Inf.2	FASST : a fully age- size and space- time structured statistical model for the assessment of tuna populations. by *Maury, O., and V. Restrepo*
WPM-01-Inf.3	Summary of the discussions held at the first informal meeting for the design of an atlantic bigeye tuna statistical model (FASST : Fully Age - Size - Space – Time structured model) by *IOTC*
WPM-01-Inf.4	A general framework for integrating the standardisation of catch per unit of effort into stock assessment models, *Maunder, M.N.*
WPM-01-Inf.5	Hierarchical interpretation of nonlinear relationships linking yellowfin tuna (*Thunnus albacares*) distribution to the environment in the Atlantic Ocean. by *Maury, O., D. Gascuel, F. Marsac, A. Fonteneau and A-L de Rosa*
WPTT-00-04	Standardized Catch Rates For Yellowfin (Thunnus a*lbacares*) From The Spanish Purse Seine Fleet (1984-1995). *Soto, M., Morón, J. And Pallarés, P.*

Appendix IV. Figures and Tables

Figure 1. *Spatial distribution of the fishing effort for three periods for the fleets of Japan and Taiwan, China.*

Average effort (in millions of hooks) in 1975-1984 for the fleets of Japan and Taiwan,China



Average effort (in millions of hooks) in 1985-1994 for the fleets of Japan and Taiwan,China

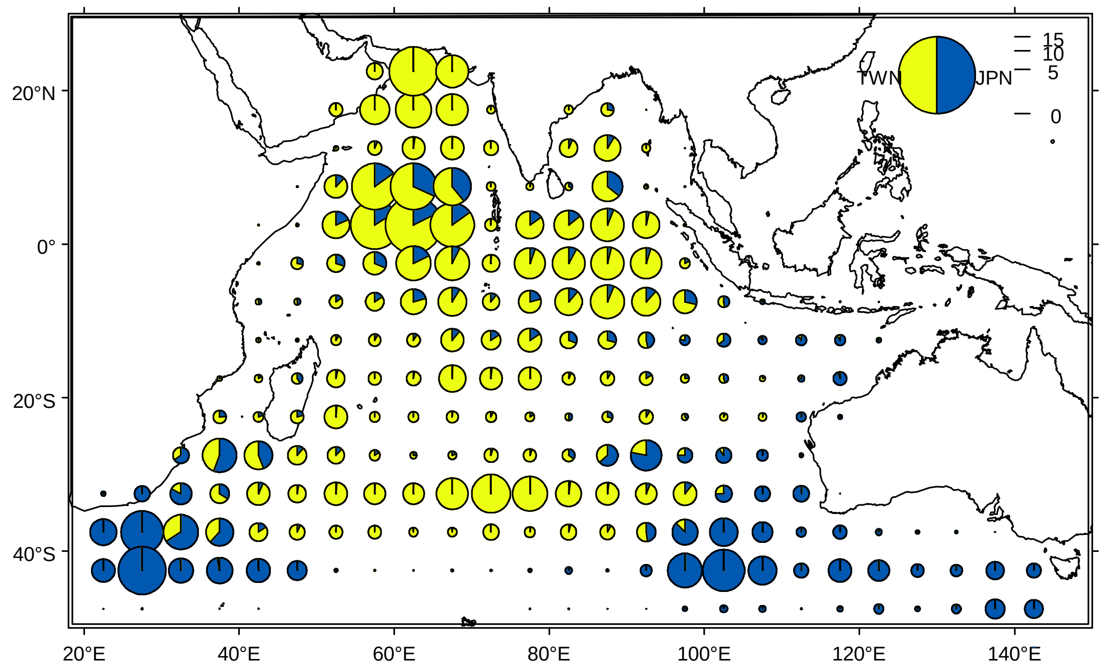


Figure 1 (cont) *Spatial distribution of the fishing effort for three periods for the fleets of Japan and Taiwan,China.*

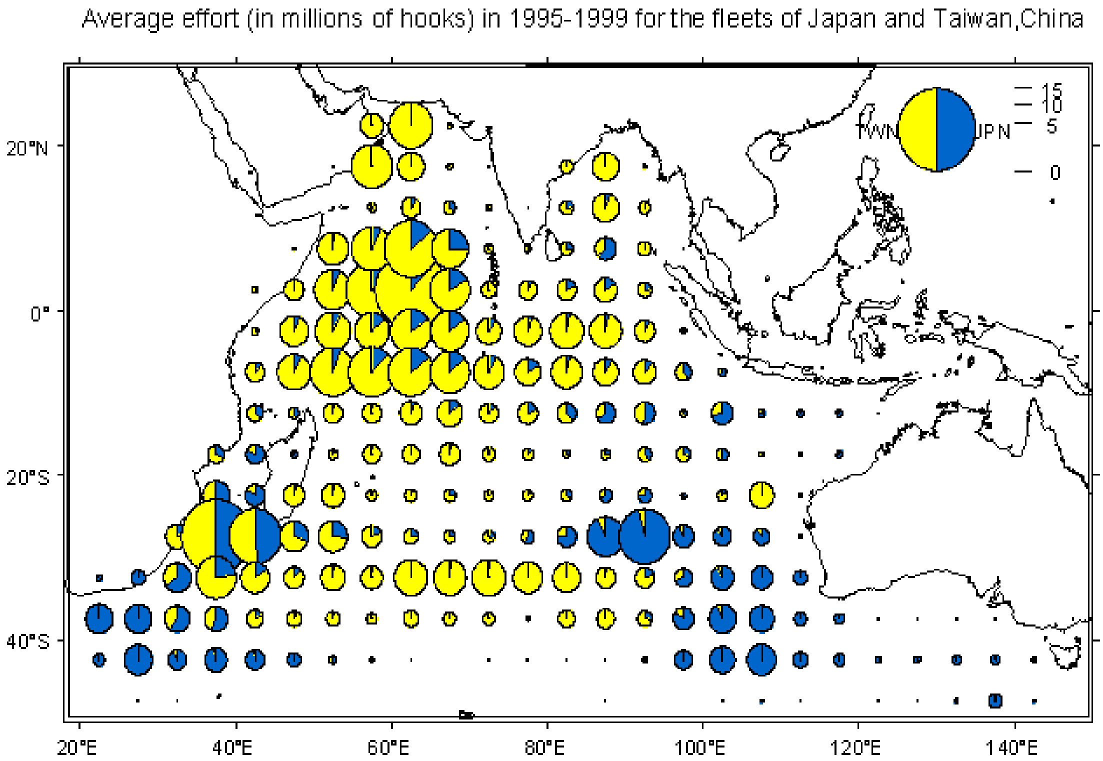


Figure 2. *Relationship between yield and effort for the longline fishery.*

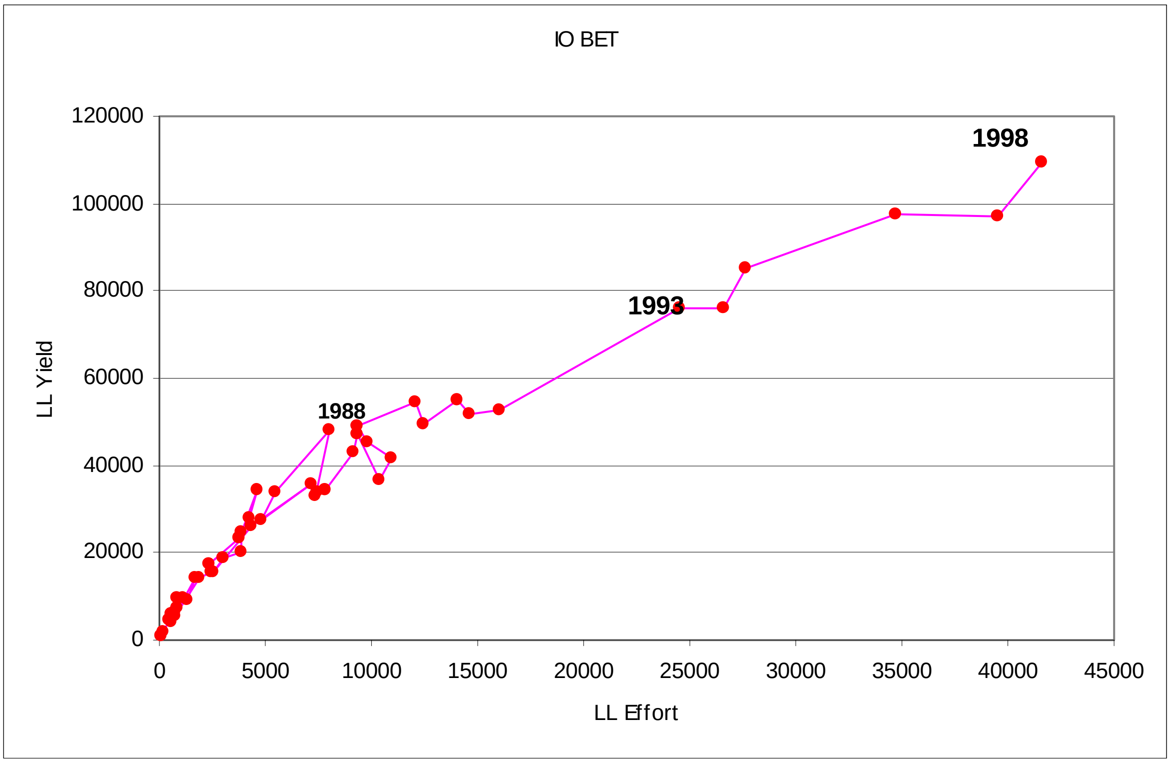


Figure 3. *Relationship between log(CPUE) of BET and number of hooks (panels on the left) and between log(CPUE) for two different fish size categories: S (smaller than 50kg) and L(larger or equal to 50 kg)*

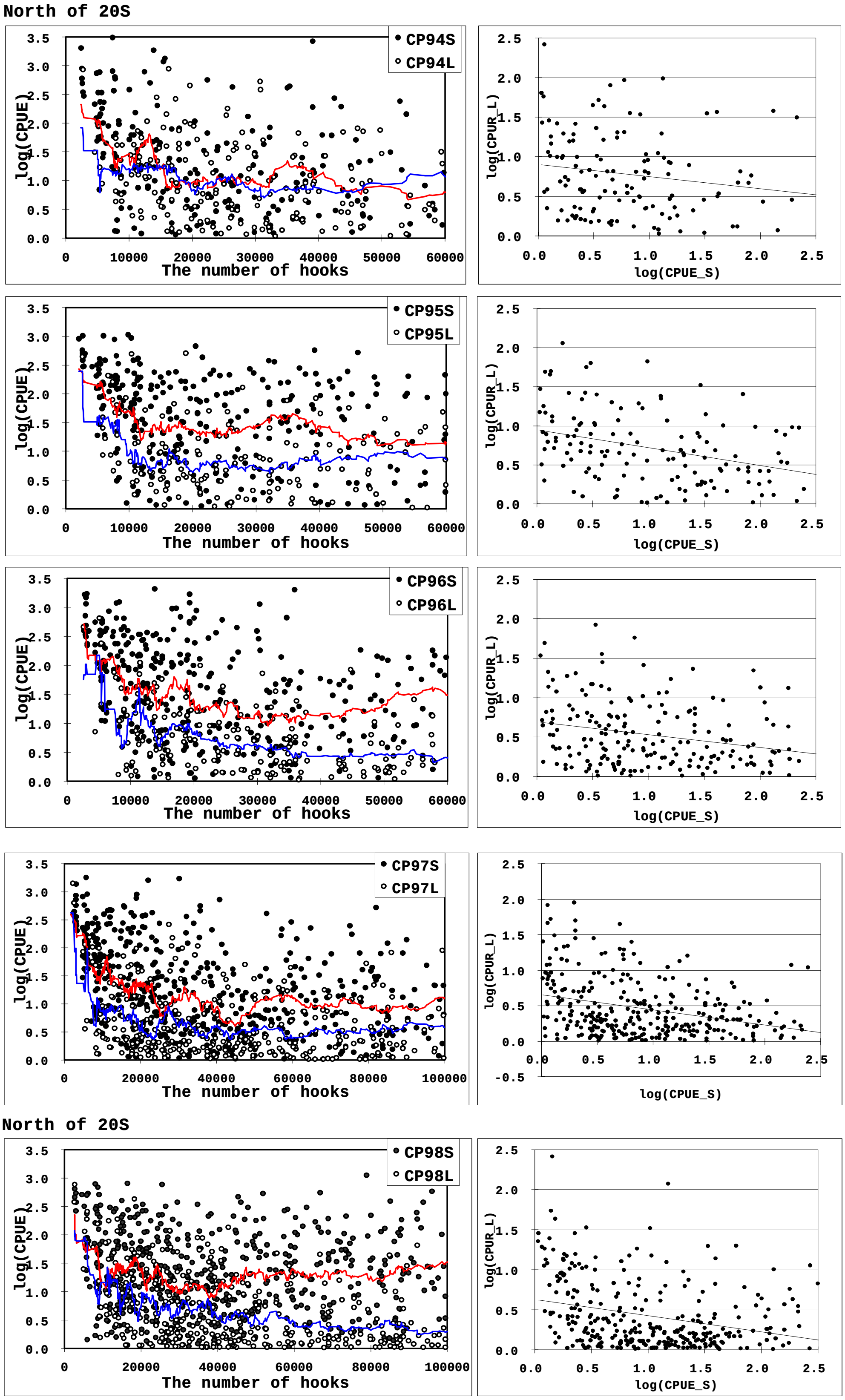


***Table 1**. Totals for the Japanese longline fishery by year and month, data including only squares north of 20 degrees south and with at least 10,000 hooks of fishing effort.*

***Table 1a.** Total number of hooks (in millions).*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	2.06	2.02	2.06	1.96	2.05	1.63	1.27	1.21	1.34	1.40	1.07	0.78
76	1.06	1.02	1.23	0.91	0.93	0.57	0.22	0.36	0.47	0.48	0.22	0.12
77	0.17	0.38	0.45	0.41	0.36	0.38	0.49	0.56	0.53	0.71	0.81	0.79
78	1.75	2.44	2.36	1.68	1.28	1.16	1.48	1.08	0.70	0.81	1.07	0.95
79	1.17	1.26	1.20	0.62	0.61	0.51	0.35	0.43	0.52	0.91	0.94	0.85
80	1.25	1.36	1.35	1.29	0.89	0.52	0.49	0.46	0.56	1.03	1.09	1.08
81	1.68	2.19	1.81	1.13	0.73	0.42	0.36	0.50	1.00	1.50	1.59	1.67
82	2.21	2.59	2.05	1.27	0.93	1.00	1.07	1.23	1.75	2.11	2.60	3.24
83	3.57	5.00	4.92	2.37	2.19	1.73	1.44	1.54	1.66	2.02	2.13	2.24
84	2.87	3.55	2.28	1.50	1.22	1.24	1.27	1.34	2.08	3.58	3.18	2.76
85	3.66	4.74	3.92	2.12	1.83	1.45	1.56	1.60	2.65	3.66	3.40	2.87
86	4.87	6.17	4.64	2.00	1.39	1.01	0.99	0.93	0.90	1.66	1.81	2.30
87	4.47	4.82	4.52	1.81	1.48	0.57	0.44	0.39	0.63	1.15	2.21	2.28
88	3.51	4.90	3.58	1.33	1.07	0.63	0.49	0.47	0.75	1.21	1.89	1.88
89	2.33	2.79	2.41	1.31	0.89	0.45	0.24	0.21	0.28	0.41	0.71	1.07
90	2.64	2.72	1.85	0.85	0.57	0.39	0.24	0.30	0.64	0.96	1.59	2.08
91	3.01	2.75	1.59	0.63	0.41	0.13	0.34	0.39	0.51	0.76	0.64	0.94
92	1.59	1.23	0.64	0.54	0.43	0.34	0.24	0.35	0.35	0.54	0.78	0.80
93	1.38	1.01	0.47	0.55	0.66	0.36	0.37	0.34	0.52	0.83	1.08	1.23
94	1.78	1.47	0.97	0.98	0.94	0.46	0.40	0.63	0.55	0.91	1.49	1.76
95	2.03	1.60	1.27	0.91	0.78	0.60	0.35	0.49	0.57	1.24	1.52	2.03
96	2.19	2.01	1.62	1.39	1.03	0.74	0.49	0.80	1.36	2.06	2.69	2.96
97	4.25	4.25	2.79	2.43	2.13	1.64	1.15	1.18	1.55	2.15	4.25	5.40
98	6.73	4.93	3.81	3.14	2.53	1.64	1.40	1.18	0.97	1.22	1.61	1.77

***Table 1b:** Average CPUE of bigeye tuna (in number of fish /1000 hooks).*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	6.45	5.83	4.82	5.22	7.61	6.25	5.39	5.79	5.19	4.70	5.20	4.27
76	4.40	3.74	2.96	6.03	8.98	7.97	7.82	12.06	7.46	7.00	6.28	9.38
77	15.52	13.44	10.44	8.80	14.11	16.31	13.40	17.16	19.78	9.43	11.23	12.34
78	14.73	13.29	12.59	14.63	12.84	12.29	13.84	13.50	9.82	9.13	12.03	12.99
79	11.31	7.93	7.87	10.55	12.19	11.62	7.71	8.00	8.78	9.56	11.46	10.17
80	8.62	5.70	5.41	8.72	12.99	11.75	9.23	10.05	8.61	8.99	10.59	12.73
81	7.97	7.07	5.55	9.98	13.26	17.09	8.05	12.38	9.99	8.11	11.53	9.76
82	8.24	7.92	9.85	13.66	16.11	14.96	9.38	8.30	8.92	9.20	10.46	11.75
83	8.88	8.30	8.74	9.30	13.25	12.01	9.64	10.50	11.07	9.17	10.05	10.04
84	7.57	6.39	6.02	8.89	9.93	10.81	9.10	9.65	11.03	7.11	8.82	10.89
85	10.92	7.10	6.92	8.08	8.13	7.19	8.89	7.75	7.39	7.68	10.81	10.56
86	10.47	8.18	6.95	10.12	13.48	8.42	8.88	9.16	9.09	8.96	11.24	12.39
87	12.34	10.09	9.68	9.27	9.99	7.84	5.55	8.39	10.32	9.43	9.13	13.18
88	10.23	9.78	7.54	7.51	14.38	7.80	5.78	6.98	8.04	9.41	9.05	9.97
89	10.32	6.55	7.14	8.07	10.48	10.10	6.42	8.23	8.05	9.61	11.00	11.20
90	8.76	9.17	7.90	9.57	12.34	7.98	9.03	8.04	8.65	7.53	7.18	8.31
91	7.83	7.92	5.62	7.04	16.64	9.70	8.25	7.13	6.81	5.74	7.29	8.58
92	8.30	5.16	4.24	7.21	7.44	6.29	5.79	4.71	5.74	7.59	7.80	6.92
93	10.15	11.79	7.57	8.36	10.28	5.79	7.91	6.74	6.08	8.05	7.13	5.95
94	5.13	4.46	4.18	6.50	6.30	6.91	6.76	7.18	7.15	6.36	5.79	7.83
95	7.11	6.96	5.09	8.42	8.59	5.69	4.37	5.03	5.75	6.65	7.11	6.48
96	5.89	6.79	7.43	5.32	6.58	7.38	7.15	8.59	6.20	5.44	5.37	6.03
97	5.16	4.14	4.68	5.83	8.08	7.38	7.11	5.51	4.79	3.27	5.21	5.33
98	5.05	5.41	4.62	5.58	6.51	3.92	6.21	5.57	4.31	4.25	4.12	5.10

Table 1c. *Nominal CPUE (Total catch of BET in numbers/ Total number of hooks in thousands).*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	6.45	7.84	6.27	7.93	9.61	6.56	5.48	5.89	5.23	4.35	3.99	3.31
76	4.40	3.95	2.57	5.40	10.59	7.84	7.88	11.69	8.19	7.25	6.47	11.68
77	15.52	10.62	10.75	9.97	16.72	18.48	14.96	17.57	17.73	8.00	10.30	15.08
78	14.73	16.52	12.59	15.98	14.29	13.07	15.32	17.47	10.28	9.81	11.16	11.92
79	11.31	8.07	3.76	7.17	13.29	11.46	7.12	7.37	9.29	9.91	11.46	10.72
80	8.62	6.06	4.71	7.41	17.40	14.12	9.45	11.18	11.40	8.88	11.58	13.84
81	7.97	6.68	5.30	9.82	18.32	15.34	7.04	10.90	8.17	8.75	10.77	10.21
82	8.24	6.53	13.57	16.90	21.38	16.02	10.94	8.71	9.53	9.89	10.80	15.23
83	8.88	9.28	10.40	11.94	16.01	16.70	10.05	10.43	12.40	10.41	12.03	12.54
84	7.57	8.54	6.83	9.62	13.14	9.69	9.58	9.94	11.97	8.07	11.35	11.80
85	10.92	9.32	8.40	9.04	11.68	9.45	9.12	8.92	11.40	11.87	11.56	11.54
86	10.47	8.16	8.56	12.20	14.27	10.35	8.70	10.56	10.74	8.71	11.71	13.71
87	12.34	9.84	8.88	11.46	15.19	8.24	6.72	9.07	9.36	9.00	9.48	14.80
88	10.23	10.41	7.46	12.17	13.19	8.54	6.07	7.36	8.60	10.36	9.24	10.30
89	10.32	7.19	5.84	9.66	13.20	11.75	6.59	8.80	8.62	9.50	8.92	12.52
90	8.76	7.73	7.27	11.03	13.21	9.60	8.77	8.60	7.60	8.43	10.10	10.71
91	7.83	6.49	5.39	9.62	17.93	10.92	7.37	6.27	6.42	6.90	7.69	8.69
92	8.30	5.21	3.39	6.55	8.01	6.19	5.52	4.62	4.83	7.29	7.47	9.66
93	10.15	11.25	6.16	7.61	9.67	6.70	7.18	6.67	6.13	7.46	6.90	6.30
94	5.13	5.23	4.71	6.77	8.31	6.64	5.31	6.05	8.48	6.72	6.12	8.71
95	7.11	5.96	5.64	9.10	10.68	6.51	4.29	5.45	6.33	7.11	6.84	7.45
96	5.89	6.25	5.18	6.11	9.14	8.95	5.91	7.88	6.36	5.00	6.15	6.15
97	5.16	3.87	4.90	7.56	11.84	8.67	7.77	4.27	4.07	3.52	4.88	6.11
98	5.05	4.82	5.22	6.11	6.68	3.84	7.13	5.65	4.24	4.22	3.27	8.08

Table 1d. *Total number of five-degree squares fished.*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	28	30	27	23	17	26	32	32	26	24	19	16
76	23	26	17	16	18	9	8	10	11	8	5	3
77	5	8	8	9	8	7	7	13	8	11	17	21
78	19	18	19	22	10	19	23	17	21	18	20	18
79	21	21	17	18	12	11	11	12	15	17	15	13
81	20	30	19	19	15	8	7	14	19	27	26	25
80	15	23	16	18	18	9	13	13	11	20	22	15
82	28	26	26	19	13	12	19	20	25	25	33	25
83	33	36	31	20	11	10	18	23	22	26	24	19
84	36	31	27	19	14	17	21	23	15	21	17	18
85	29	33	27	18	16	21	20	23	18	18	13	21
86	33	46	41	14	13	13	17	18	10	21	26	27
87	43	40	36	14	7	9	5	5	8	25	31	29
88	36	34	27	10	8	7	7	11	19	22	31	24
89	35	29	22	21	7	9	10	9	8	10	16	23
90	32	27	18	11	5	9	8	10	14	21	23	25
91	24	25	25	16	7	7	9	10	14	21	16	22
92	28	21	11	8	6	7	6	6	6	14	17	14
93	19	12	11	5	8	9	10	11	14	13	22	20
94	27	30	19	13	11	12	10	16	11	15	28	30
95	28	19	19	15	12	13	13	14	14	16	20	22
96	34	29	20	16	14	15	12	19	21	31	30	33
97	45	36	28	16	18	19	19	21	19	25	40	47
98	47	46	41	25	20	28	23	14	11	25	31	26

Table 2. *Monthly results for the Japanese longline fishery only for squares that were fished in that month during 1977.*

Table 2a. *Total number of hooks (in millions).*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	2.06	2.02	2.06	1.96	2.05	1.63	1.27	1.21	1.34	1.40	1.07	0.78
76	1.06	1.02	1.23	0.91	0.93	0.57	0.22	0.36	0.47	0.48	0.22	0.12
77	0.17	0.38	0.45	0.41	0.36	0.38	0.49	0.56	0.53	0.71	0.81	0.79
78	1.75	2.44	2.36	1.68	1.28	1.16	1.48	1.08	0.70	0.81	1.07	0.95
79	1.17	1.26	1.20	0.62	0.61	0.51	0.35	0.43	0.52	0.91	0.94	0.85

Table 2b. *Average CPUE of bigeye tuna (in number of fish /1000 hooks).*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	8.56	6.17	8.43	10.68	10.73	4.79	7.06	6.01	4.96	4.15	2.91	3.16
76	4.91	3.10	5.14	6.16	10.74	12.51	—	13.63	12.25	6.69	—	12.37
77	13.12	10.62	10.75	9.97	16.72	18.48	14.96	17.57	17.73	8.00	10.30	15.08
78	16.34	19.38	13.59	14.26	14.55	10.79	12.90	15.35	10.64	8.06	8.73	9.94
79	14.87	7.48	6.02	3.36	17.23	15.48	12.33	5.66	8.51	8.59	10.43	10.63

Table 2c. *Nominal CPUE (Total catch of BET in numbers/ Total number of hooks in thousands.*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	6.68	5.12	6.69	8.39	8.59	4.56	6.68	7.40	4.91	3.62	3.16	3.67
76	8.49	3.28	4.43	9.02	11.25	12.14	—	13.93	13.57	7.53	—	8.49
77	15.52	13.44	10.44	8.80	14.11	16.31	13.40	17.16	19.78	9.43	11.23	12.34
78	14.77	18.85	10.51	13.76	14.27	10.17	14.20	13.92	9.82	7.85	8.84	9.42
79	17.90	4.53	10.32	7.12	16.13	15.48	12.33	8.16	9.14	5.85	10.14	10.54

Table 2d. *Total number of five-degree squares fished.*

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
75	5.00	8.00	6.00	8.00	7.00	5.00	6.00	7.00	4.00	6.00	6.00	8.00
76	3.00	6.00	3.00	4.00	6.00	3.00	0.00	5.00	3.00	3.00	0.00	2.00
77	5.00	8.00	8.00	9.00	8.00	7.00	7.00	13.00	8.00	11.00	17.00	21.00
78	4.00	3.00	6.00	6.00	6.00	6.00	7.00	6.00	7.00	7.00	9.00	11.00
79	4.00	3.00	5.00	3.00	3.00	1.00	1.00	4.00	4.00	6.00	7.00	8.00

Figure 4. *Nominal CPUE for all squares fished and only for those squares that were fished in 1977.*