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DRAFT: The development of new agreed CPUE series for use in future MP work

Written on behalf of the CPUE Modelling Group by

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Abstract

This paper is in response to the requests of the SAG and SC for new CPUE series for use in Management Procedure work. To develop these series the CPUE Modelling group held 7 internet based meetings. In all 20 working papers were presented to the Modelling Group. It was agreed that this scientific report be prepared for SAG to summarize and explain the scientific findings of the CPUE Modelling Group.

This paper gives background to the problems needing to be overcome in developing new CPUE series. These included the seasonal and spatially variable nature of the fishery and the problem of by-catch and of detecting effort directed at other tuna species. The group investigated the possible use of hooks per basket as a measure of targeting at other species but concluded that this measure was too heavily confounded with a progressive change in main line material to make it use a safe way of allowing for effort directed to other species. A key problem for any CPUE series is how it might or might not be affected by the market anomaly. The CPUE modelling group had previously considered this at its 2nd workshop in 2007. In the web meeting it did not feel able to propose new analysis and felt that the MP working group should handle this by considering a range of options.

The working group extended its 2nd workshop approach of using series based upon a fleet of core vessels that had been in the top tier for a specified number of years during the period 1986-2006. It was felt that this approach has merits both in choosing a more homogeneous fleet and also in choosing a fleet which seemed likely to be less affected by the market anomaly. However, since such fleet selection could only be carried back to 1986 this choice meant that some scheme for developing series for the pre 1986 period be developed. It was agreed to achieve this by using, as far as possible, the same statistical model as used for the core fleet data to analyses data from all vessels. This series could then be calibrated to the results of the core fleet and used to provide the pre 1986 CPUE series to be used in conjunction with results for the core fleet post 1986.

Data from Australia, Japan and New Zealand were prepared over the course of the web meetings. Eventually these consisted of 356210 record.

In deciding on how to define the new series the CPUE Modelling Group needed to decide on a number of key issues. Firstly whether to use shot by shot or data aggregated by 5*5 degree squares. The former brings more degrees of freedom to the analysis and potentially clearer definition of factors such as by-catch but the latter has the advantage that such data are available for international analysis and thus allow more transparency

in the preparation of results. It was concluded that both approaches produced rather similar trends since 1986. Thus it was then concluded that the 5*5 were more suited to an internationally agreed CPUE series but that the shot by shot data would form a very useful monitoring series to check that the agreed series stayed on track in the future.

A second issue was what statistical model should be used and what main effects and interactions terms be included in the Generalized Linear Model (GLM). After examining results of a series of competing GLM it was concluded that a log transformed model gave the best results. It was further concluded that the model

log(CPUE+0.2)=year+month+area+Lat5+area*month + year*Lat5+year*area

provided the best combination of main effects and interaction terms for the basic model.

A third issue was how to weight the results in order to provide the best combined series. The CPUE modelling group concluded that the traditional way of doing this by

- Firstly, forming the traditional constant and variable squares series with the results of the new GLM,
- Secondly, taking two weighted averages of these to form the proxy geostatistical and the proxy B-ratio series

remained the most likely way to span our uncertainty as to trends in overall stock abundance caused by any contraction in the species distribution and in fleet behaviour.

The final major problem was how to adjust for by-catch and more particularly for fishing effort directed towards other tuna species. Two approaches were considered which included adding extra explanatory variables to the basic GLM model applied to the core fleet data. These were with the CPUE of bigeye tuna and of yellowfin tuna or alternatively with the percentage of hauls in a 5*5 rectangle that contained by-catch. Both approaches performed adequately but the former was chosen. The linearity of these new variables was checked by also applying them as factors rather than as continuous variables. It was concluded they were sufficiently linear for our purposes and therefore adopted in continuous form. This correction could not be applied to the pre 1986 all vessels data for which by-catch data are not available. These were therefore analysed by the basic model.

The two CPUE series based upon these decisions on key points, and on some resulting technical issues were prepared and recently sent to the MP Working Group. The MP Working Group had been appraised by their June deadline of the format our final series would have so that they might develop software and begin their simulations. The CPUE Modelling group proposes further monitoring work to check as far as possible that the proposed series remain on trend.

要約

本文書は、管理方策作業に用いる新 CPUE シリーズについての SAG および SC からの要請に対する回答である。シリーズの開発に当たって CPUE モデリンググループは 7 回のインターネット会議を開催した。合計で 20 の文書が提出された。CPUE モデリンググループにおける科学的発見の要約と説明を SAG にするため、この議論の余地のない科学報告書を準備することが合意された。

本文書は、新 CPUE シリーズの開発において解決すべき問題のバックグランドを提供する。この問題とは、漁業の季節・空間的に変動する性質、混獲の問題、他のマグロ類を狙った操業の検出である。グループは、一鉢当たり鉤数が他魚種へのターゲッティング指標となるかを検討したが、幹縄材質の変化が問題を極めて複雑にしており、他魚種を狙ったと確実にいえる指標にはならないと結論付けた。CPUE シリーズの重要な問題の一つは、それが市場アノマリーの影響をどれほど受けているか、または受けていないのかという点である。CPUE グループはこの問題を 2007 年の第 2 回ワークショップで既に検討している。インターネット会議においては、新たな解析を提示できないと考えられ、この問題は MP 作業グループで様々なオプションを検討して扱うべきと考えられた。

グループは、第 2 回ワークショップの、1986-2006 年間に定めた年数間上位にいたコア船のアプローチを拡大した。この方法は、均質的な船団を選択することと、市場アノマリーの影響をあまり受けていないと思われる船団を選択することに長所がある。しかしこうした船団の選択は 1986 年までしか遡ることができず、1986 年以前のシリーズを開発する仕組みが必要となった。一先ず、コア船データに用いたのと同じ統計モデルを全船にも当てはめることで合意した。このシリーズをコア船の結果で補正し、1986 年以降のコア船シリーズと結合させる 1986 年以前の CPUE シリーズを作成する。

インターネット会議の間に、豪州、日本、ニュージーランドのデータが準備された。最終的に、356,210 操業のレコードとなった。

新シリーズを決定するために、CPUE モデリンググループはいくつかの重要問題について決定する必要があった。第 1 に、使用するのは操業毎データか 5 度 5 度区画に集計したデータかである。前者は解析時により多くの自由度となり、混獲等の要因決定を明確にする可能性がある。しかし後者には国際的な解析が可能であり透明性の高い結果となる長所がある。両アプローチ共に 1986 年からのトレンドは類似していると結論付けられた。操業毎データは合意されたシリーズが将来も同じ路線にあることをチェックするモニタリングとして極めて有用であるが、5 度区画データが国際的に合意された CPUE シリーズとしてより適していると結論付けられた。

第 2 の問題は、いかなる統計モデルを用い、いかなる種呼応かと交互作用を一般化線形モデル（GLM）に取り込むかである。様々な GLM を実施した結果、対数変換したモデルが最良の結果となった。また、以下のモデルが基本モデルの主効果及び交互作用の組み合わせとして最良との結論に達した。

log(CPUE+.2)= 年 + 月 + 海区 + 緯度 5 度 + 海区*月 + 年*緯度 5 度 + 年*海区

第 3 の問題は、最適に組み合わせたシリーズをもたらすために、いかに結果に重み付けするかである。CPUE モデリンググループは、以下の従来方法を用いることと結論付けた。

- まず、新 GLM で従来のコンスタントスクエアとバリアブルスクエアのシリーズを作成する。
- 次いで、両者の重み付け平均を取り、ジオスタットと B-ratio の近似シリーズを求める。

これによって、種の分布の縮小と漁船行動の縮小による全体の資源量トレンドへの不確実性をカバーするのに最も妥当な方法を維持する。

最後の問題は、混獲、特に他のマグロ種をターゲットとした努力量をいかに補正するかである。コア船データに当てはめた基本的な GLM モデルに説明変数を追加する二つのアプローチが取られた。一つはメバチとキハダの CPUE で、他方は 5 度区画における混獲を含む操業数のパーセンテージである。両アプローチは適切だったが、公表されている方法であることから前者が選択された。これら新変数の直線性は、これらを連続変数ではなくファクターとして適用することでもチェックされた。その結果、我々の目的に対して十分に直線的であることが確認され、連続変数とすることとした。この補正は、混獲データが使用可能でない 1986 年以前の全船のデータには適用していない。1986 年以前のデータは基本モデルで解析した。

これらのキーポイントならびにいくつかの技術的問題に対する決定に基づき、2 つの CPUE シリーズが準備されて最近、MP ワーキンググループへ送付された。MP ワーキンググループは我々の最終シリーズの締め切りを 6 月と推定しており、彼らはソフトウェアを開発しシミュレーションを開始するだろう。CPUE モデリンググループは、提示したシリーズが同じトレンドにあるかを可能な限りチェックする今後のモニタリング作業を提案する。

1 Introduction

1.1 Requirement for a new series for MP work.

The need for additional work on a new CPUE series was agreed at the 2007 SAG/ESC

- ***SAG report noted the need for a new CPUE series:*** *"Given the magnitude of the uncertainty caused by the catch anomalies, the SAG considered that it was important to develop a new CPUE index to replace the 5 series that had been used in the past to condition the model."*
- ***ESC also noted this need:*** *"Participants noted that in the future it will be necessary to re-evaluate which CPUE series will provide the basis for the operating model and that it may be necessary to consider alternative CPUE series to those used in the past. It was also noted that any new CPUE series must also be examined in light of the market anomalies. A discussion on a default CPUE series was made and a list of future analyses needed was identified."*

Possible forms of future CPUE work were discussed at ESC 2007. This together with the initial work conducted at the May 2007 2nd CPUE Workshop in Shimizu (Anon. 2007) provided the start point for further thinking on new CPUE series during intersessional work during 2008. This report represents a summary of the discussions that occurred during the web-meetings and the authors note that not all meeting participants agreed on all aspects of the analyses.

1.2 Working procedure through web-meetings.

ESC proposed 3 possible processes for achieving the standardization before SAG 2008.In practice the MPWG required answers as to at least the format of the new series by June and this set the immediate priorities for the work. Since there was little enthusiasm amongst members for a meeting during 2008 a series of web meeting were organised by Jim Ianelli and Bob Kennedy and chaired by John Pope to encourage and to focus the intersessional work. A report of the process of these meetings is included elsewhere. It was agreed however that a scientific report be prepared for SAG by key working group members to explain the scientific findings of the group.

1.3 Desirable features of new CPUE series

Early on in the work, the following desirable features of a new CPUE series were considered:

1. Be one agreed series rather than multiple series as at present
2. Robust -to any expected changes in fleet behaviour and to any effects of Market anomaly.
3. Simple –if possible
4. Backed up by external monitoring of issues of concern (e.g. zero catches and HPB/nylon) to provide early warning of serious bias in the agreed MP series that might trigger an exception procedure.
5. Unbiased- should indicate main trend of SBT population.
6. Transparent. -Should be capable of calculation by CCSBT secretariat.
7. Does not change our general perception of the recent stock trajectory unless such change can be firmly established.

This list helped the group identify sensible solutions. It was, however, recognised that it would not always be possible to determine whether the series did have the desirable feature (e.g. is unbiased) or not.

1.4 Objective of paper

The objectives of this paper are to provide a roadmap to the intersessional work of the CPUE modelling group and in particular to explain the reasons for the choice of the new CPUE series proposed to the MPWG.

1.5 Organisation of paper

Section 2 deals with the problems involved in specifying a CPUE series, the data set used and the decisions taken as to the best solutions. Problems associated with preparing a CPUE series for SBT are considered in subsections 2.1 to 2.5. subsection 2.6 describes the data set while subsections 2.7 to 2.13 describe the detailed decisions that had to be considered in order to specify the most suitable CPUE series for MP work. Each of subsections 2.7 to 2.13 includes details of its objective and of the method used, the results obtained and the conclusions reached. Since progress on the problem evolved through a series of web meetings these subsections do not represent a chronological sequence but rather the distillation of our work and findings. Section 3 contains the detailed specification of the CPUE series proposed for the MPWG to use and section 4 conclusions and thoughts on monitoring and other ongoing tasks.

Results in these subsections are summaries of those in a series of working papers by T. Itoh (WP 1-19) and by E. Lawrence (WP20) that are available in the CPUE Modelling subsection of the documents pages of the CCSBT website. These are specified in the following text as WP# and are listed in annex A. **Readers should note that some**

information contained in these WPs is specified as being confidential in nature. Ideas and conclusions in the paper are based upon seven web meetings of the CPUE Modelling WG that took place between January and July 2008.

Where runs are specified in the text, figures or tables where possible these are linked to those of the relevant WP i.e. Run 11.6 refers to run 6 in WP11.

2 Problems and possible solutions

2.1 Seasonal nature of fishery

Southern bluefin tuna is a highly migratory species with a distribution ranging from the south Atlantic, the southern Indian Ocean to New Zealand. It therefore shows strong seasonal and areal changes in its biomass distribution and therefore its CPUE. The 2007 workshop (2^{nd} CPUEWS, figure 3) presented distributional charts to illustrate this. The traditional solution to this problem is to take account of spatial and temporal variation in distribution by explaining CPUE variation using an General Linear Model (GLM) of the CPUE which uses multiple factors and their interactions to best explain the variation.

In addition to seasonal changes by area, there have been large changes in the overall spatial coverage of the fleet over time. This is considered further in section 2.11.

2.2 Possible by-catch issues including hooks per basket

A possible problem in developing reliable year trends is the effect that changes in the SBT targeting behaviour of fisheries might change through time. This might occur in any long line (LL) fishery. Targeting of effort towards other tuna species is most likely to occur at the northern boundary of the distribution of SBT. Any changes in targeting practices through time may then distort trends in the CPUE of SBT. This problem was found to be particularly noticeable in the CPUE series from the Taiwan LL fisheries which are generally conducted further north (Ref 2^{nd} CPUEWS report). These data were not therefore included in the data base. For those data that were included WP3 shows a series of figures which detail the distribution of strata where hauls with zero catch of SBT exceeded 50% of the total. While a null haul of SBT might occur by chance anywhere, those areas and times which show high percentages of hauls with no SBT are likely to be those where targeting of other species is occurring (except in a case where biomass levels are at an extremely low state).

Targeting at other tuna species can also occur at the boundaries of fishing seasons when these apply. The LL fisheries of Japan, which provide the major part of the LL CPUE data, have between 1989 and 2005 had official fishing seasons. During the season the fishery was managed by an Olympic scheme of management. Moreover, as part of this management scheme fishing seasons have varied in duration from year to year. Table 2.1.1 shows the dates of the fishing season for each year and area (Sakai *et al.* 2007). Since catch outside these seasons should be focused on other tuna species the CPUE of SBT in months that span the start or finish of the fishing season may well be low in some years due to part of the effort being targeted at other species. Results of the 2007 workshop emphasised that this posed a problem in interpreting CPUE series. Different time trends tended to occur if data for months 4 to 9 were analysed rather than data confined to the fishing season.

These problems are important to address because, while in the past the fishing season was a useful indicator of SBT targeting, fishing seasons do not form a part of the new Japanese fisheries system. Hence, for a CPUE series to be useful in the future some other indicator of targeting at SBT than season needs to be developed.

The solution to targeting problem is to develop some measure of SBT targeting. Traditionally hooks per basket (HPB) has been seen as a measure of targeting since more HPB results in the gear being fished deeper and this indicates the targeting of bigeye tuna rather than SBT.

The CPUE modelling group initially included HPB in their analyses. However, it was noticed that this inclusion caused spurious trends. See table 1 of WP1. The reason for this was that there was a marked change in HPB deployed at and after about 1993. This break in the pattern of HPB usage resulted from a change to nylon main lines in this period. Figure 2.2.1 shows the progressive introduction of nylon main lines in the period from 1993 to 2004 and also the lack of information outside these years. Thus the gear material and the HPB measure was heavily confounded with the year signal that we wish to identify. Figure 2.2.2 shows that including HPB with the traditional (Takahashi et al. 2001) general model causes a rising trend in CPUE. It also shows that including the line material helps to correct this for those limited years for which this data are available. After wrestling with this problem the working group decided that because of unknown biases it was dangerous to use HPB as a by-catch indicator and other by-catch indicators needed to be sought. However, the working group considered that HPB might potentially be useful in the future and that HPB should be monitored to give warning of future changes in fishing behaviour.

At the workshop possible indicators of by-catch were considered that took the ratio of SBT to total tuna catch as a by-catch indicator. In practice this also seems to be flawed as an indicator because the information it contains on SBT catch which might be expected to be correlated with SBT CPUE. Thus the CPUE modelling WG was forced to fall back on measures that were independent of SBT catch or CPUE. These are described in more detail in section 2.12.

2.3 Market anomaly considerations

Problems caused by the Market anomaly were discussed at length in the 2006 SAG and ESC. The 2007 CPUE Workshop considered the problem but was unable to come up with any analysis that showed CPUE series to be affected by the market anomaly or any data or analysis that showed that CPUE was unaffected by the market anomalies. During the intersessional web meetings the question was raised repeatedly but no new analyses could be agreed on and the CPUE modelling WG concluded that for now this problem would have to be tackled by the MPWG using a range of options for the market anomalies' effect on CPUE series. While we had no ready solution this was considered a puzzle that the CPUE modelling group might return to when it had more information and time after the delivery of the new CPUE series.

2.4 Reasons for choice of core fleet approach

One of the more useful developments of the 2007 CPUE workshop was the concept of the core fleet. This is a subset of the total fleet composed of vessels chosen to represent the vessels that most intensely and consistently harvest SBT. It is difficult to follow vessel effects through time due to a high turnover of vessels but the core fleet concept helps to select vessel with consistently high catch. If this happens to imply the selection of vessels with consistently high fishing power, it may help standardise this factor. A secondary motivation for the choice of a core fleet was that vessels that have registered the highest catches would seem to be less likely to have under recorded their catches, although there is not evidence to confirm this is the case.

2.5 Definition and limitations of core fleet

The idea of "core vessels", as discussed at the second CPUEWS, was adopted. The core fleet should be composed of the top fishing vessels. The same program developed at the second CPUEWS was used, but the number of SBT age 4+ was used instead of the number of SBT in all ages. The protocol used in selecting core vessels is to select vessels if a vessel was represented in the top *x* catching vessels in a single year more than *y* times during 1986-2006.

The precise criteria x and y of choice how many years y a vessel was in the top x does not seem to influence outcomes very much. Figures 2 and 3 in WP3 illustrate this point. The main drawback of the core fleet is that the concept cannot readily be carried back before 1986. Nor indeed can analysis of by-catch. The view of the CPUE modelling group is that given current uncertainties about the historic record it is more important to have a reliable CPUE series to carry forward into the future than to be able to carry the series back to the early days of the fishery. However, the MPWG have requested that they have results that will allow them to go back to early years if necessary and this required some compromise between the need for a sound ongoing series and a historical series. This is considered in the next section.

2.6 The combined 'old' (all vessels) and 'new' core fleet solution.

Documentation: WP15.

Historical series pre 1986: The compromise suggested by the chair of the MPWG was that parallel "old" series based on all vessels be used to fill in the historical CPUE record for the pre 1986 period. These would be analysed using the same statistical model (less any by-catch adjustment) and the same area weightings that are used to produce the "new" core fleet CPUE series. The "old" series will be simply calibrated to correspond to the new series based on the ratio of the summed CPUE values of the "new" CPUE series and of the "old" CPUE series over the period 1986 to 2006. The CPUE modeling group advises the MPWG to use the new (Core fleet) model CPUE series when it can (i.e. from 1986) and uses the old series when it must (i.e. pre-1986).

2.7 Data and Considerations of model structure

Documentation: WP2. WP 15

Data Preparation: Data preparation are described in WP2 and updated in WP15. The latter modified the data set to include by-catch data from NZ and to exclude the 12 vessels with very high CPUE data in 2005. WP 15 shows useful cross tabulations of the data set. Table 2.7.1 shows the number of data records available by year and by country.

*2.8 Shot by Shot or 5*5 data?*

Documentation: WP9, WP11, WP17

Objective: To decide whether shot by shot or data aggregated into 5 degree Latitude by 5 degree Longitude squares should form the basis of the CPUE series.

Background: Technically working with finer scale data is to be preferred. Moreover, shot by shot data provide considerably more degrees of freedom than do aggregated data. However, due to commercial in confidence laws Japan can only make data aggregated at the 5*5 scale available internationally. Transparency of data analysis is a highly desirable feature of any CPUE series which is to be used internationally. Hence the main question to address here was whether the technical benefits of using shot by shot data would be sufficient to outweigh the loss of transparency their use would entail.

Methods: Trends in data analysed using 5*5 and shot by shot data were compared for a number of models. WP11 provides a wide basis for comparison. Runs made in this comparison are shown in table 2.10.1 of section 2.10.

Results: Figure 2.8.1 illustrates one such comparison for model 11.3 and model 11.15. These models were fitted with the basic factors plus the year*Lat5 interaction term. Results for the models with more detailed interactions terms were not at the time possible due to perceived problems with producing year trends from models with null cells, when/where no operation was carried out (it was April in Area 8 in this case). Figure 2.8.2 shows a comparison of the final model run on Shot by Shot and 5*5 after these problems with year trends were resolved.

Conclusions: Comparisons of the same model structure to Shot by Shot and 5*5 data suggest that both data sets give broadly similar trends through time. Thus, while there are certainly technical benefits to the use of Shot by Shot data, particularly with respect to by-catch questions, to use shot by shot data in the recommended series would entail a loss of transparency. By contrast transparency is inherent in the use of 5*5 data. Consequently it was felt that the standard CPUE series should be based upon the 5*5 series. However, to take advantage of the technical advantages of the Shot by Shot CPUE series these should be continued in background to provide monitoring tools to help ensure that the 5*5 data remains adequate to the task of providing an unbiased index of abundance. It should be noted that, selection of core vessels is at the shot x shot level and this step in the process is not transparent.

It was not possible for the Working Group to complete the necessary analysis intersessionally. It was recognised that there are a series of exploratory analyses that can only be done on the shot-by-shot data to determine whether there are important signals in CPUE series based on shot by shot data when analysed with more detailed models, that are not apparent in a CPUE series based on 5x5 data. It was considered that these analyses may be possible to pursue at the MPWS/SC meetings.

2.9 What error model to use Log Normal, Poisson or Negative Binomial?

Documentation: WP8, WP10, WP20 and Web proceedings 4 and 5, Maunder and Punt 2004.

Objective: to chose the most appropriate error structure between the competing error structure models - Log Normal with various assumptions about handling zero values, Poisson and negative binomial.

Background: Generalized linear models (GLMs) are the most common method for standardizing catch and effort data (Maunder and Punt 2004). Modern generalized linear modelling packages allow considerable choice of the statistical distribution and the link function (the functional link between the mean of the response and the linear combination of predictors). Making appropriate choices regarding the error distribution and link function is important in order to obtain sound statistical results.

A distinctive feature of CPUE data is that it is often zero inflated which means that the data contains more zeros than might be predicted from standard GLM models (McCullagh and Nelder, 1989). If we ignore this feature of the data and apply standard error models eg Poisson then problems with inference can occur. These problems occur if the Poisson assumption is not an adequate approximation to the conditional distribution of the data. In these cases Negative binomial or Quasi-poisson error distributions may be considered to be more appropriate. Alternatively when a log transformation or log link function is used with a normal error structure then zeros cannot be admitted and they must either be removed or avoided by adding a constant to the response variable.

Zero-inflated models and Delta approaches (Maunder and Punt, 2004) are two alternative approaches that may be used for dealing with zero inflated data. However, these approaches have been adopted less commonly in the fisheries literature.

Methods: Various GLMs were fitted to the data with different combinations of error distribution and explanatory variables. The AICs and distribution of residuals eg. Q_Q plots were used to judge the most satisfactory models. This process required a certain amount of discussion and iteration before agreement was reached on the best choice of model. Table 2.9.1 sets out a critical set of runs, Runs 10.1-10.13 shown in WP10. This allowed comparison of residuals between the various competing models and allowed the choices to be narrowed down. Final choices were based upon the following runs

Both with Ln Normal error

Model 20.0: ln(CPUE+0.2)=year+month+area+Lat5
Model 20.1: ln(CPUE+0.2)=year+month+area+Lat5+year*area
Model 20.2: ln(CPUE+0.2)=year+month+area+Lat5+year*month
Model 20.3: ln(CPUE+0.2)=year+month+area+Lat5+year*Lat5

and with Poisson error
Model 20.0p: CPUE=year+month+area+Lat5
Model 20.1p: CPUE=year+month+area+Lat5+year*area
Model 20.2p: CPUE=year+month+area+Lat5+year*month
Model 20.3p: CPUE=year+month+area+Lat5+year*Lat5
Shown in WP20.

More complex methods for dealing with zeros, for example delta approaches, were not considered due to a preference of the group to keep the CPUE analyses as simple as possible.

Results: WP10 provided comparison of the residuals of the log-normal (with small constant), Poisson, over-dispersed Poisson and negative binomial models. Figure 2.9.1 shows the resulting plots of the residuals for runs using the 5*5 data sets. These suggested that the negative- binomial model gave very poor residuals and could be eliminated from our choices. WP20 provided Q-Q plots that indicate the error distribution of the natural Logarithm of CPUE with additions of 0.2 to the dependant variable accorded far more closely to the normal distribution than did those from the Poisson model runs.

Conclusions: The residual plots and the Q-Q plots indicated that the Ln(CPUE+0.2) had residuals which more closely matched the normal (Gaussian) distribution than did residuals from either the Poisson or the negative-binomial models. Thus Ln(CPUE +0.2) was chosen as the preferred error model.

2.10 What main effects and interactions to include the final model?

Documentation: WP9, WP10, WP11, WP20. Web Discussions 1 to 5

Objective: to specify which factors and interactions to include in the GLM. Potential factors are area, month, latitudinal band, quarter and year.

Background: We wish to extract the best possible year signal (abundance index) from the data. Year signal is composed of the year factor and any interactions it has with other factors. Such year interactions imply different trends in different area and time periods that have later to be recombined by a weighting procedure. Fitting appropriate other factors and their interactions serves to remove real sources of variation and allows the year trend to be seen as clearly as any residual variation allows. However, fitting too many terms can be counterproductive since this uses up the remaining degrees of freedom in the model. The Akaike information criterion (AIC) is a means of judging the utility of adding additional terms to the model (Venables and Ripley, 2004). If a new term is useful it reduces the AIC considerably while if it uses up degrees of freedom while making only marginal improvements to the fit AIC will increase. The trick therefore is to fit sufficient but not too many terms to the model. As elsewhere parsimony was considered a virtue particularly in including year interactions. It was also considered, all else being equal, that model structures similar to those used in the past would be useful in preserving continuity of interpretation.

Methods: From the beginning of the web meetings the range of possible factors to include was discussed and modified and a number of runs made to explore possible combinations of factors. Web meetings 4 and 5 hardened these choices down to a relative few. Table 2.10.1 shows the organisation of runs made in WP11. These include 12 runs on 5*5 data and 12 runs on shot by shot data. The former are of more direct concern to this discussion. Some of these runs were duplicated in WP20. Details of the more extensive WP20 runs are shown in Table 2.10.2. Note that Quarter was not considered in the GLMs as it was not considered to explain additional variation beyond the Month factor.

Results: Table 2.10.3 shows the AIC results of the two analyses of the 5*5 data and those of the shot by shot data for comparison. There are minor differences between the two analyses which account for minor variation between the Australian and Japanese estimates of AIC but both tell the same story. While run 11.7 gives the best AIC this is but little improvement on run 11.6 in both cases.

Conclusions: Noting the modest increase in AIC obtained by adding the year*month interaction it was considered best to adopt model 6.

2.11 How to weight the area and other effects?

Documentation: Takahashi 2006, WP15.

Objective: To define the weighting to be applied to parameter values for area and other strata used in the GLM of CPUE so as to define the final CPUE series.

Background: Any GLM analysis which includes time interactions with other strata provides what are in effect a number of parallel time-series of CPUE. These must be added in a way that reflects the size of each strata and consideration also has to be given to the problem of how to handle the area components of strata (squares) for which no catch data are available. There are two extreme hypotheses as to the relative SBT biomass to be found in such unsampled cells. The first is to assume that tuna are distributed in such cells in the same fashion as in sampled cells (the constant squares [CS] hypothesis) while the second is to assume that no tuna exist in these cells (the variable squares [VS] hypothesis). The operation of the long-line fleets have contracted over time so the correct weighting to use for unsampled cells is important. In the past it has been agreed in CCSBT that both pure hypotheses are too extreme and the solution is to adopt some intermediate hypothesis which may be expressed by forming a CPUE series of weighted averages of the CS and VS CPUE series. However, opinion differed as to the correct weighting and two alternative weighted averages were adopted, 0.5 and 0.8 respectively. These provide what are called the proxy geostatistical and the proxy B-ratio CPUE series.

Approach: In the time available to it, the working group did not feel it would be able to improve on the past compromise of two series based upon the 0.5 and the 0.8 weightings. These are described in Takahashi 2006. However, some minor modifications to Takahashi's method were required to adjust it to the agreed GLM strata.

Conclusions: Using the agreed GLM model Two CPUE series would be prepared for both the "old" (all vessels from 1969 To 2006) and the "new" (core fleet, 1986 and onwards). These would be calculated as the 0.5 and 0.8 weighted averages of the CS and VS area weighted CPUE series. The correct weighting formulae to use are given in Annex B.

2.12 If and how to account for by-catch targeting ?

Documentation: WP16, WP17 and WP18 and web discussions of 17-18/July and 30-31/July, WP12 also refers, Anon. (1996):), Punt et al. 1996.

Objective: To decide whether the core series should be corrected for by-catch or not.

Background: Earlier work at the 2007 2nd CPUE workshop had suggested that by-catch was important particularly at the margins of the SBT season and area. First attempts to include by-catch indicators were made in WP16 but there was general concern that indicators that included the catch of SBT were suspect since this would be expected to correlate with the SBT CPUE. Punt et al. 1996. Thus thought was given at the 17-18th July web meeting to propose alternative approaches that only used by-catch information.

Methods: Two approaches were considered for correcting the core series for possible changes in targetting. One proposed by D. Butterworth following the published approach of Anon. (1996) adds terms to the Ln(CPUE) regressions for by-catch (linear) of yellowfin Tuna and bigeye tuna. However it is important to note the conditions under which this approach holds are that

a) the true abundance of the bycaught species is constant over time (or at least without trend), and

b) the proportion of the total effort targeted at the bycaught species is small.

Although the assumptions are unlikely to hold (for bigeye and yellowfin tuna), the group decided to do some exploratory analyses including the bycatch of these two species as covariates. In addition one must take care NOT to include as co-variates the CPUEs for species that co-occur with the target species; common environmentally induced CPUE fluctuations then lead to a positive correlation (rather than the negative correlation that arises from targeting) which simply confounds the standardisation sought.
The alternative method proposed by J. Pope involved adding a term for the % of hauls in each 5*5 cell that contained by-catch tunas. A third method was proposed by J. Ianelli, similar to the latter approach, but was a static measure of how much each 5*5 cell was influenced by by-catch. Since previous work suggested that the problem of by-

catch would be most serious if it varied from year to year and because time was short this method was not trialled. Details of runs made are to be found in WP17. Data were limited in the core vessel (x=63 and y=3) in Area 4-9 in Month 4-9 between 1986 and 2006. Shot-by-shot data or aggregated data by 5x5 degrees and month (5x5 data) were used. If hooks in a 5x5 degree and month was less than 10,000, the records were deleted for the 5x5 data.

Results: The first two adjustment methods both gave what were considered useful reductions in AIC, compared to the no adjustment case. Table 2.12.1 shows the AICs for the different runs. Figure 2.12.1 shows the q-q plots for these 5 runs.

Additional methods: Both these methods introduce by-catch as a continuous variable and thus both assume a linear response to their by-catch variables. To check this assumption further work was conducted to test the linearity of these responses by including them as a series of factors rather than as a continuous variable. Factors used were (Level 1 : 0 and ≤ 2, Level 2 : >2 and ≤ 4, Level 3 : >4 and ≤ 6, and Level 4 :>6) for the D. Butterworth method and (Level 1 : 0 and ≤ 0.25, Level 2 : >0.25 and ≤ 0.5, Level 3 : 0.5 and ≤ 0.75, and Level 4 :>0.75 and ≤ 1.0) for the J. Pope method.

Additional results: Table 2.12.2 shows the AIC results of these calculations. As may be seen by comparing the AICs from runs 18.4 and 18.5 and runs 18.6 and 18.7, including the responses as 4 factor levels (runs 18.5 and 18.7) does marginally reduce AIC compared to using a continuous variable (runs 18.4 and 18.6) for both methods. The correction appears to decrease factors in a fairly monotonic fashion (see parameter values in Table 2.12.3) with increasing factor levels.

Conclusions: It was agreed that the statistics indicated it was worthwhile to make an adjustment for by-catch and moreover since fleet behaviour might vary in this respect in the future it was best that an adjustment was included in anticipation of future changes. The additional work suggested that using factors gave only modest increases in AIC for both methods and that responses were to decrease the parameter estimates as factors increased. It was therefore concluded that a continuous variable was adequate and was less complicated than using factors for both methods. The second (J. Pope) method gave the lower AIC but since there was not a great difference between the two methods the first (D. Butterworth) method was chosen because its q-q plot was somewhat more linear than method two.

Our tentative decision is to adjust for by-catch using the two continuous variables of by-catch of yellowfin tuna and of bigeye tuna as proposed by DB. However, by-catch data are not available to all members and this is also a transparency issue.

2.13 Notes on detailed decisions

Minor decisions on constants added to zeros, data omitted, dealing with null strata, minimum hooks fish per strata exclusions etc are described in 3.1.

3 Final Series Chosen

3.1 Detailed description of the CPUE series proposed for use by the MP Working Group.

Documentation: WP19

Data used: Data were limited in the core vessel (x=63 and y=3) in Area 4-9 in Month 4-9 between 1986 and 2006. Shot-by-shot data or aggregated data by 5x5 degrees and month (5x5 data) were used. If hooks in a 5x5 degree and month was less than 10,000, the records were deleted for the 5x5 data. Area 5 and Area 6 were combined as Area 56. Records of anomalously high CPUE (>120) were deleted after aggregated in 5x5 data.

GLM runs: The calculation was performed through GLM procedure of SAS package (SAS. Ver. 9.1.3). The full model was as follows.

$$\log(CPUE+0.2) = Intercept + Year + Month + Area + Lat5 + BET\_CPUE + YFT\_CPUE + (Month*Area) + (Year*Lat5) + (Year*Area) + Error,$$

where *Error* $\sim N(0,\sigma 2)$, *Area* is the CCSBT statistical area, *Lat5* is latitude in five

degree, *BET_CPUE* is the CPUE of bigeye tuna and *YFT_CPUE* is the CPUE of yellowfin tuna. Note that *BET_CPUE* and *YFT_CPUE* were used as the continuous variables. All the parameters were significant ($p < 0.01$).

Statistics: The Q-Q plots of the GLM run is shown in WP19. Figure 1. The residual distribution of the GLM run is shown in WP19 Figure 2. Parameters values estimated, as well as GLM result, are available in the Excel file attached to WP19.

CPUE series: Because there was a null category (no records of operation in the category) in *Month*Area* in April Area8, SAS package did not provide annual standardized CPUE. Instead the annual standardized CPUE was calculated manually by using R (ver. 2.7.1 for Windows) assuming the lacking parameter value was same as that in May Area8. The confidence interval of CPUE was not available at the present time.

From the standardized CPUE, five CPUE series (no area weighting, constant square area weighting, variable square area weighting, w0.5 and w0.8) were produced by the method described in Takahashi (2006).

Two CPUE series were combined for w0.5 and w0.8. One CPUE series was based on the core vessel between 1986 and 2006 mentioned above. The other CPUE series was based on all Japanese vessels between 1969 and 2006 have been used in the CCSBT. The CPUEs between 1986 and 2006 were adjusted by multiplying the average value of the CPUEs between 1986 and 2006 of the 1969-2006 series.

CPUE 1969-1985: As in the historical 1969-2006 series.

CPUE 1985-2006: (The new 1986-2006 series) x (average of 1986-2006 of the historical 1969-2006 series)

The adjusted and combined CPUE series are shown in Fig. 3.1.1. Values are available in the Excel file attached to WP19.

4 Recommendations

4.1 Adoption of CPUE series

The authors understand that provisionally the CPUE modelling group recommend that the agreed two series be adopted for use in future MP work. These series should be continually monitored against the results of parallel series in order to give early warning of potential biases that might arise in the future. Minimum monitoring actions are considered below.

4.2 Need for various monitoring actions to ensure ongoing viability of series.

To ensure as far as possible that any future bias in the proposed CPUE series is detected at an early stage it is proposed that a set of monitoring series be developed. Likely contenders are

1. Series based upon shot by shot data analysed to the same model as the proposed series.

2. Series that consider other measures of by-catch than that used in the final analysis.

4.3 Future work

Will be discussed and specified by the CPUE Modelling Group during SAG/ESC 2008. Future work discussed in this report includes:

- Monitoring a Shot by Shot level series (with equivalent model structure to the 5x5 series)
- Monitoring HPB for changes in fishing behaviour
- Continue looking at better ways to account for targeting (including the method used to incorporate bycatch information)
- Further consideration of market anomolies

4.4 Unresolved questions

The CPUE modelling group did not feel able to add to the advice on the effect of market anomaly on CPUE series that it made at the 2007 CPUE WS. This needs to be taken into consideration when the longline CPUE series is being used in analyses.

5 Acknowledgements

The Authors would like to acknowledge all members of the CPUE Modelling WG whose ideas this paper are based upon. In particular we wish to thank R Kennedy and J. Ianelli for organising and running the web meetings together with the colleagues of T. Itoh and E Lawrence who assisted in preparing working documents.

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7 Tables

Table 2.2.1 Fishing season of Japanese SBT longliners. The area ranges are roughly identical to those of the CCSBT statistical area. (From Sakai et al. 2007 CCSBT-ESC/0709/SBT Fisheries/Japan)

	Off Cape (Area 9)			Tasmania (Area 4 & 7)			South Indian Ocean (Area 8)			Total
Year	Start	End	Days	Start	End	Days	Start	End	Days	days
1990	1-Apr	31-Jul	122	1-Apr	25-Jun	86	1-Jul	15-Aug	46	254
1991	15-Apr	31-Jul	108	15-May	31-Jul	78	15-Aug	30-Sep	47	233
1992	15-Apr	31-Jul	108	15-May	31-Jul	78	15-Aug	7-Oct	54	240
1993	15-Apr	3-Jul	80	15-May	30-Jun	47	15-Sep	17-Sep	3	130
1994	15-May	26-Jun	43	1-Jun	15-Jun	15	1-Sep	5-Oct	35	93
1995	15-May	25-Jun	42	15-May	20-Jun	37	1-Sep	10-Nov	71	150
1996	1-May	31-Jul	92	15-May	24-Jun	41	1-Sep	30-Nov	91	224
1997	1-May	31-Jul	92	21-Apr	8-Jul	79	1-Sep	14-Dec	105	276
1998	1-May	10-Aug	102	21-Apr	31-Jul	102	5-Sep	5-Dec	92	296
1999	1-May	10-Aug	102	15-Apr	10-Aug	118	1-Sep	1-Dec	92	312
2000	1-May	1-Aug	93	15-Apr	1-Aug	109	1-Sep	27-Dec	118	320
2001	1-May	1-Aug	93	15-Apr	15-Jul	92	1-Sep	28-Nov	89	274
2002	1-May	5-Jul	66	15-Apr	19-Jul	96	1-Sep	28-Nov	89	251
2003	1-May	8-Jul	69	15-Apr	30-Jul	107	1-Sep	16-Dec	107	283
2004	1-May	9-Aug	101	15-Apr	31-Jul	108	1-Sep	23-Dec	114	323
2005	1-May	27-Aug	119	15-Apr	31-Jul	108	1-Sep	13-Dec	104	331

Table 2.7.1 Number of data records used in the analyses in Area 4-9 and Month 4-9 by dataset (country) and year. (from Table 1 of WP15, revised)

	Dataset			
Year	AU	Japan	NZ	Total
1986		27,045		27,045
1987		26,825		26,825
1988		24,426		24,426
1989	1,156	23,953		25,109
1990	504	19,865	475	20,844
1991	1,204	18,244	460	19,908
1992	1,717	17,168	499	19,384
1993	2,001	14,632	486	17,119
1994	1,436	12,265	268	13,969
1995	800	12,678	373	13,851
1996		14,854		14,854
1997		16,322	379	16,701
1998		16,307	310	16,617
1999		14,453	306	14,759
2000		11,746	265	12,011
2001		14,075	198	14,273
2002		10,721	228	10,949
2003		11,563	294	11,857
2004		13,101	349	13,450
2005		13,319	198	13,517
2006		8,559	183	8,742
Total	8,818	342,121	5,271	356,210

Table 2.9.1 Used data, main effects and Interactions included in GLM runs in WP10. (from Table 1 of WP10)

Run−	1	2	3	4	5	6	7	8	9	10	11	12	13
Data													
resolution	5x5	5x5	5x5	5x5	5x5	5x5	5x5	SxS	SxS	SxS	5x5	5x5	SxS
whole/core	core	core	core	core	core	core	core	core	core	core	core	core	core
season	FS	FS	FS	FS	FS	4−9	4−9	4−9	4−9	4−9	FS	4−9	4−9
error distribution	logNormal	odPoissin	odPoissin	odPoissin	odPoissin	odPoissin	Poisson	odPoissin	Poisson	odPoissin	NegBin	NegBin	NegBin
Main Effect													
Year	●	●	●	●	●	●	●	●	●	●	●	●	●
Quarter	●	●	●	●	●	●	●	●	●	●	●	●	●
Month	●	●	●	●	●	●	●	●	●	●	●	●	●
Area	●	●	●	●	●	●	●	●	●	●	●	●	●
Lat5	●	●	●	●	●	●	●	●	●	●	●	●	●
Bycatch										●			
Inter−Action													
Year*Quarter													
Year*Month					●								
Year*Area			●	●	●					●			
Year*Lat5				●	●								
Quarter*Area	●	●	●	●	●	●	●	●	●		●	●	●

Table 2.10.1 Description of runs made in WP11. (from Table 1 of WP11)

Run	Model		Data
1	0	Y+M+A+Lat5	5x5
2	1	+Y*A	5x5
3	2	+Y*M	5x5
4	3	+Y*Lat5	5x5
5	4	+A*M	5x5
6	5	+A*M+Y*Lat5	5x5
7	6	+A*M+Y*Lat5+Y*A	5x5
8	7	+A*M+Y*Lat5+Y*A+Y*M	5x5
9	8	+Y*A+Y*M	5x5
10	9	+Y*A+Y*Lat5	5x5
11	10	+Y*M+Y*Lat5	5x5
12	11	+Y*A+Y*M+Y*Lat5	5x5
13	0	Y+M+A+Lat5	SxS
14	1	+Y*A	SxS
15	2	+Y*M	SxS
16	3	+Y*Lat5	SxS
17	4	+A*M	SxS
18	5	+A*M+Y*Lat5	SxS
19	6	+A*M+Y*Lat5+Y*A	SxS
20	7	+A*M+Y*Lat5+Y*A+Y*M	SxS
21	8	+Y*A+Y*M	SxS
22	9	+Y*A+Y*Lat5	SxS
23	10	+Y*M+Y*Lat5	SxS
24	11	+Y*A+Y*M+Y*Lat5	SxS

Table 2.10.2 Runs made WP20

Model 0: logCPUE=year+month+area+Lat5
Model 1: logCPUE=year+month+area+Lat5+year*area
Model 2: logCPUE=year+month+area+Lat5+year*month
Model 3: logCPUE=year+month+area+Lat5+year*Lat5
Model 4: logCPUE=year+month+area+Lat5+area*month
Model 5: logCPUE=year+month+area+Lat5+area*month + year*Lat5
Model 6: logCPUE=year+month+area+Lat5+area*month + year*Lat5+year*area
Model 7: logCPUE=year+month+area+Lat5+ area*month+year*Lat5+ year*area+year*month

Table 2.10.3 Results of the runs indicated in tables 2.10.1 and 2.10.2. The run numbers refer to the former tables numbering.

Data		5x5	5x5	SxS	
Model		AustAIC	JapanAIC	JapanAIC	Remark
Y+M+A+Lat5	Model0	7,095	6,990	334,701	
+Y*A	Model1	7,030	6,918	328,916	
+Y*M	Model2	7,075	6,959	320,871	With little effort cell
+Y*Lat5	Model3	6,983	6,865	324,636	
+A*M	Model4	6,974	6,865	331,741	No year trend
+A*M+Y*Lat5	Model5	6,864	6,743	321,037	No year trend
+A*M+Y*Lat5+Y*A	Model6	6,746	6,643	313,541	No year trend
+A*M+Y*Lat5+Y*A+Y*M	Model7	6,724	6,602	303,391	No year trend
+Y*A+Y*M	Model8		6,831	312,073	With little effort cell
+Y*A+Y*Lat5	Model9		6,784	317,644	
+Y*M+Y*Lat5	Model10		6,824	313,205	With little effort cell
+Y*A+Y*M+Y*Lat5	Model11		6,718	306,232	With little effort cell

Table 2.12.1
(after WP17 table 1)

Run	Description	SSQ	Parameters	AIC
17.01	No bycatch correction on 5*5 data.	985	192	4,776
17.02	No bycatch corrections no negative adjustment	985	192	4,776
17.03	DB By-catch correction on Shot by shot data.	80,508	194	280,674
17.04	JGP By-catch correction on 5 by 5 Data.	814	193	4,375
17.05	DB By-catch correction on 5 by 5 data	857	194	4,476

Table 2.12.2 AIC values for the seven runs in WP18.
(After WP18 table 1)

Run	Description	SSQ	N.para	AIC
18.1	No correction 5x5 data.	985	192	4,776
18.2	DB–Cont. var:(CPUE_BET, CPUE_YFT) SxS data	80,508	194	280,674
18.3	DB–Cat. var:(CPUE_BET, CPUE_YFT) SxS data.	77,379	198	276,258
18.4	DB–Cont. var:(CPUE_BET, CPUE_YFT) 5x5 data.	857	194	4,476
18.5	DB–Cat. var:(CPUE_BET, CPUE_YFT) 5x5 data.	808	198	4,361
18.6	JGP–Cont. var:(% by–catch hauls in 5x5 cells.) 5x5 data.	814	193	4,375
18.7	JGP–Cat. var:(% by–catch hauls in 5x5 cells.) 5x5 data.	776	195	4,276

Table 2.12.3 By-catch Factors for the DB and for the JGP methods.

Dependent	Parameter	Estimate	Biased	StdErr	tValue	Probt
DB method						
logCPUE	BcpueL5 1	0.997484	1	0.110246	9.05	<.0001
logCPUE	BcpueL5 2	0.259702	1	0.111058	2.34	0.0195
logCPUE	BcpueL5 3	0.078176	1	0.113396	0.69	0.4907
logCPUE	BcpueL5 4	0	1			
logCPUE	YcpueL5 1	0.659687	1	0.093841	7.03	<.0001
logCPUE	YcpueL5 2	0.01084	1	0.104391	0.1	0.9173
logCPUE	YcpueL5 3	-0.11194	1	0.118621	-0.94	0.3454
logCPUE	YcpueL5 4	0	1			
JGP method						
logCPUE	propTunaL 1	1.313239	1	0.064534	20.35	<.0001
logCPUE	propTunaL 2	1.325344	1	0.07324	18.1	<.0001
logCPUE	propTunaL 3	0.987295	1	0.073085	13.51	<.0001
logCPUE	propTunaL 4	0	1			

8 Figures

Figure 2.2.1 (after WP5-Fig.1, revised) 1 Frequency of operation by the main line material. Others included traditional cotton lines.

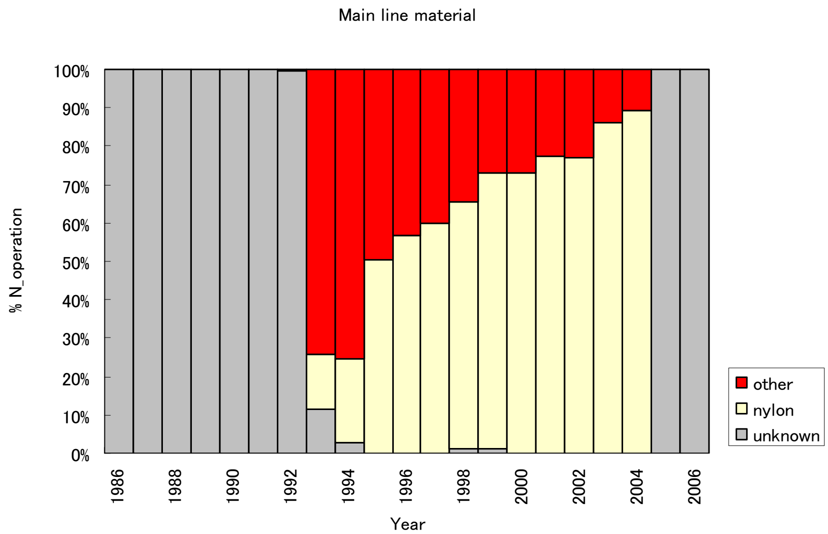


Figure 2.2.2 (From WP 5 Fig 6) Standardized CPUE by GLM for four models. Reference CPUE is based on the traditional model with the traditional data. Model 1 is the traditional model. Model 2 with HPB added while models 3 4 and 5 also include HPB but correct for main line material (only available for limited period).

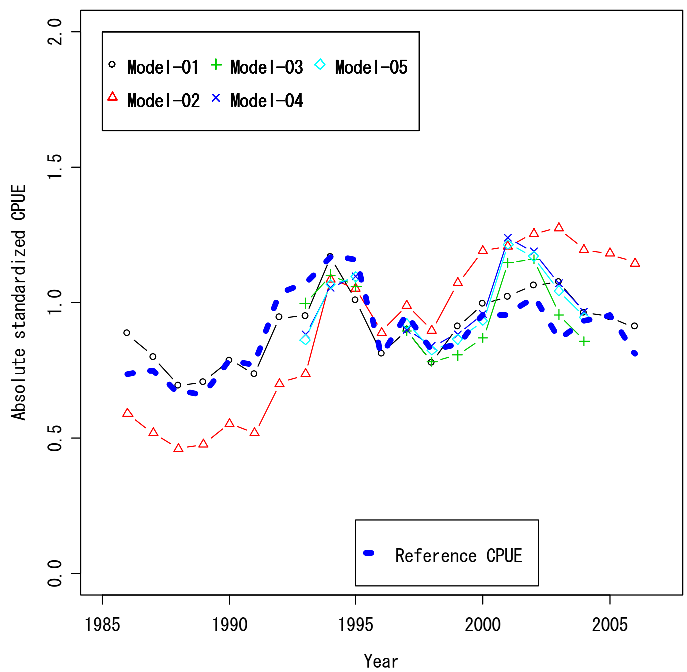


Figure 2.8.1 Annual standardized CPUE series for 5x5 (Model-11.03) and shot-by-shot (Model-11.15) for data of the core vessels (From WP11 figure 4)

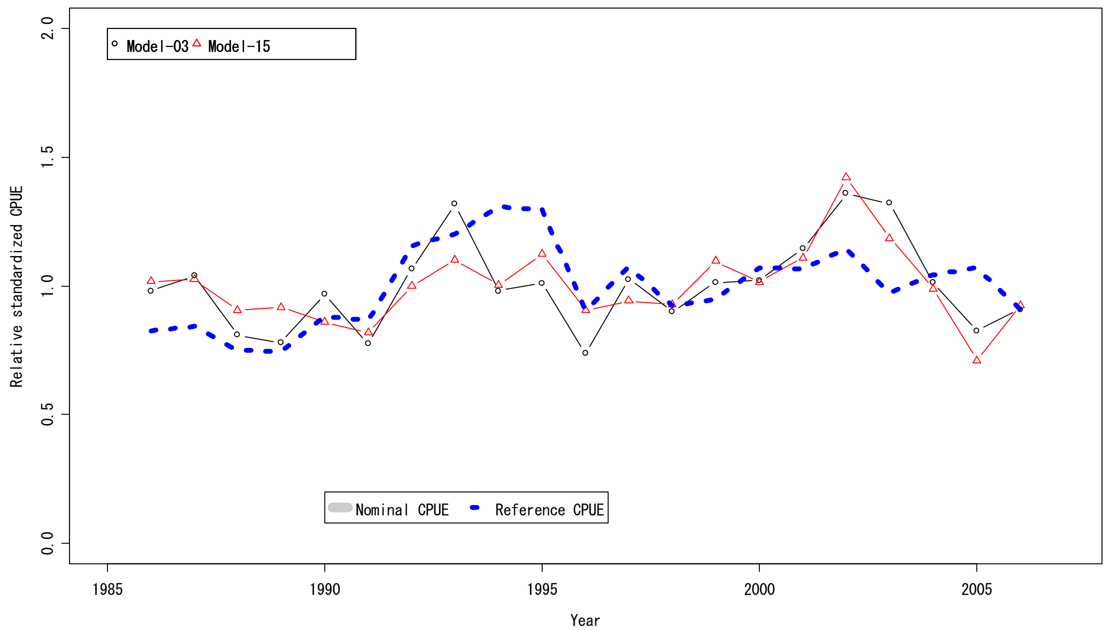
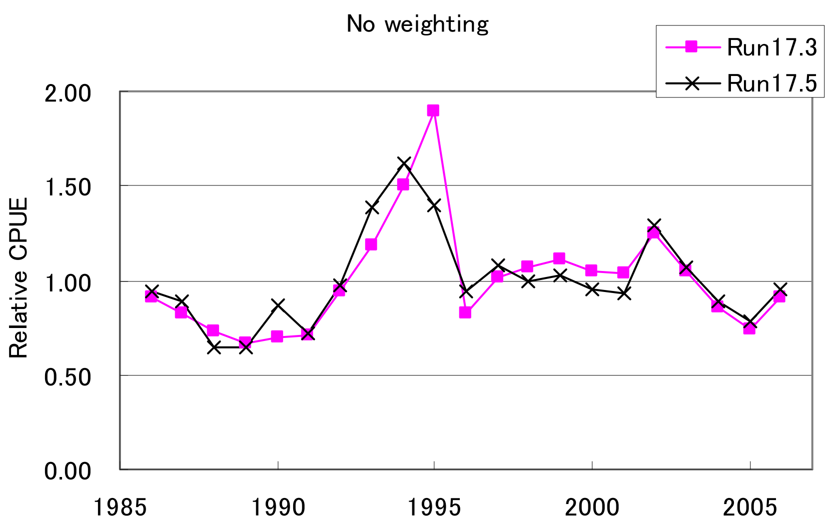
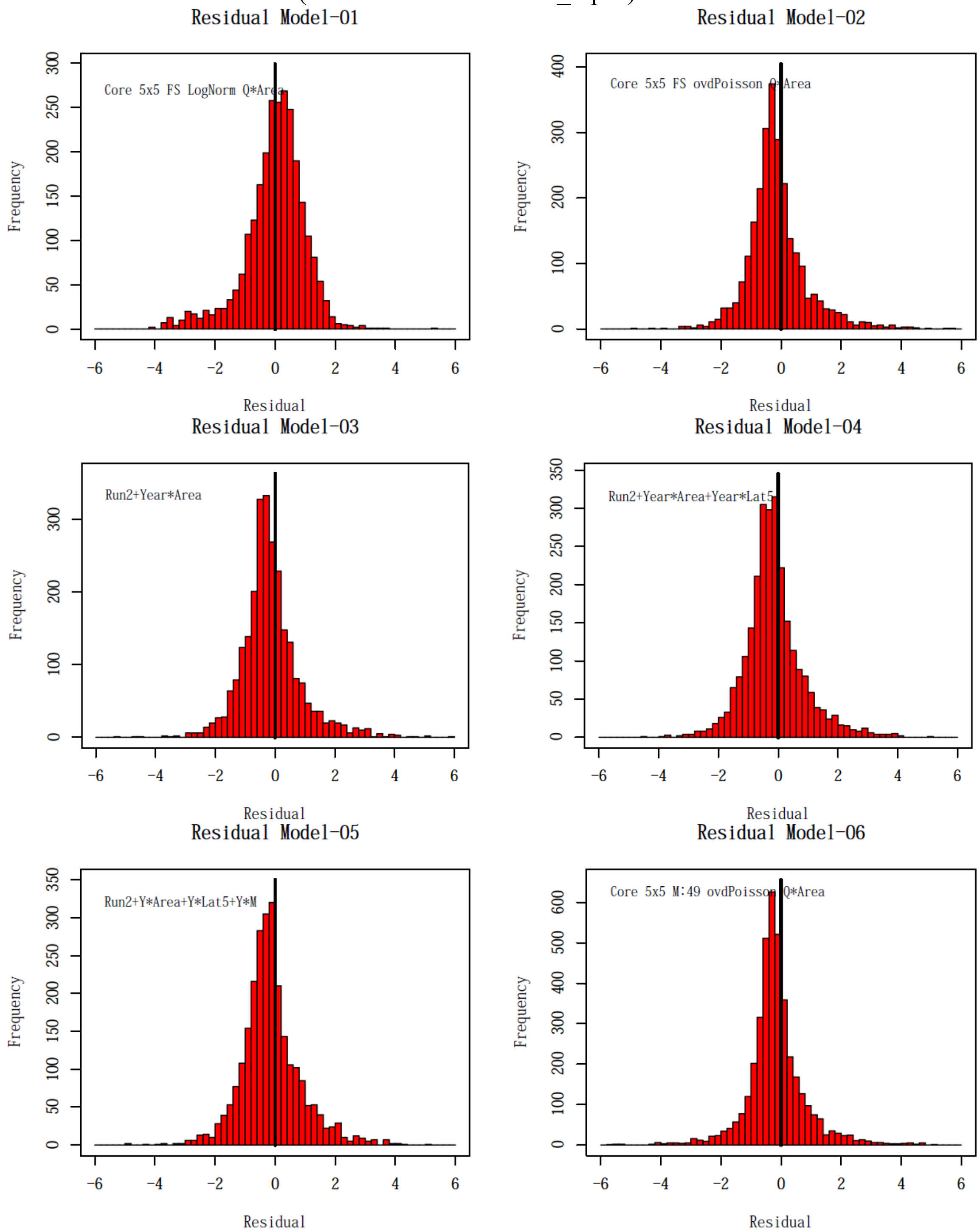
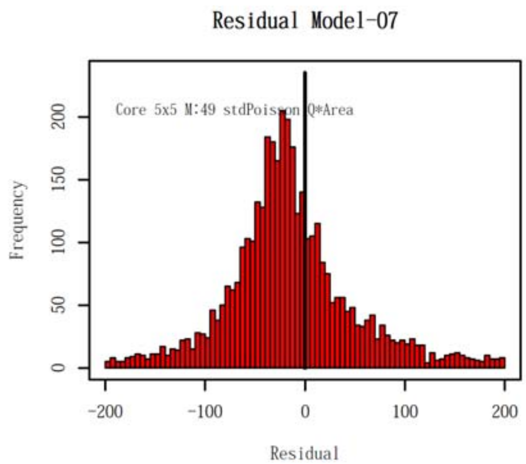


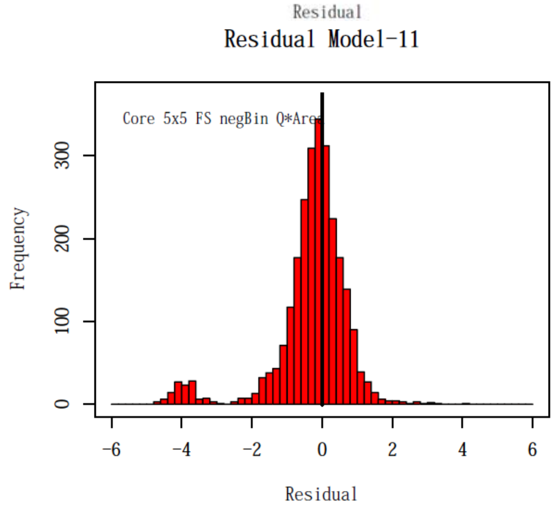
Figure 2.8.2 Estimated annual CPUE (relative to mean). Not area weighted (revised from WP17 figure 3).The relevant comparison s between run 17.3 and run 17.5 which fit the same model to S*S (Run 17.3) and 5*5 data (Run 17.5)



Figures 2.9.1 Residual plots for various applications (defined in table 2.9.1) of the Ln normal model (run 10.1), the over-dispersed Poisson model (runs 10.2 to 10.6), the Poisson model (run 10.7) and the negative-binomial model (runs 10.11 and 10.12) used on the 5*5 data set either for the fishing season or months 4-9 (after WP10 attachment_1.pdf)




Residual Model-07
Core 5x5 M:49 stdPoisson Q*Area
Frequency
0
50
100
150
200
-200
-100
0
100
200
Residual


Residual Model-11
Core 5x5 FS negBin Q*Area
Frequency
0
100
200
300
-6
-4
-2
0
2
4
6
Residual

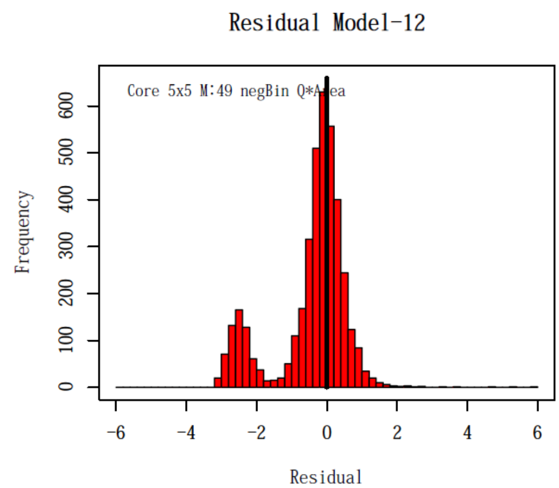

Residual Model-12
Core 5x5 M:49 negBin Q*Area
Frequency
0
100
200
300
400
500
600
-6
-4
-2
0
2
4
6
Residual

Figure 2.9.2 Q-Q plots for equivalent Log-normal runs (20.1.0 to 20.1.3) and Poisson runs (20.1.0p to 20.1.3p).

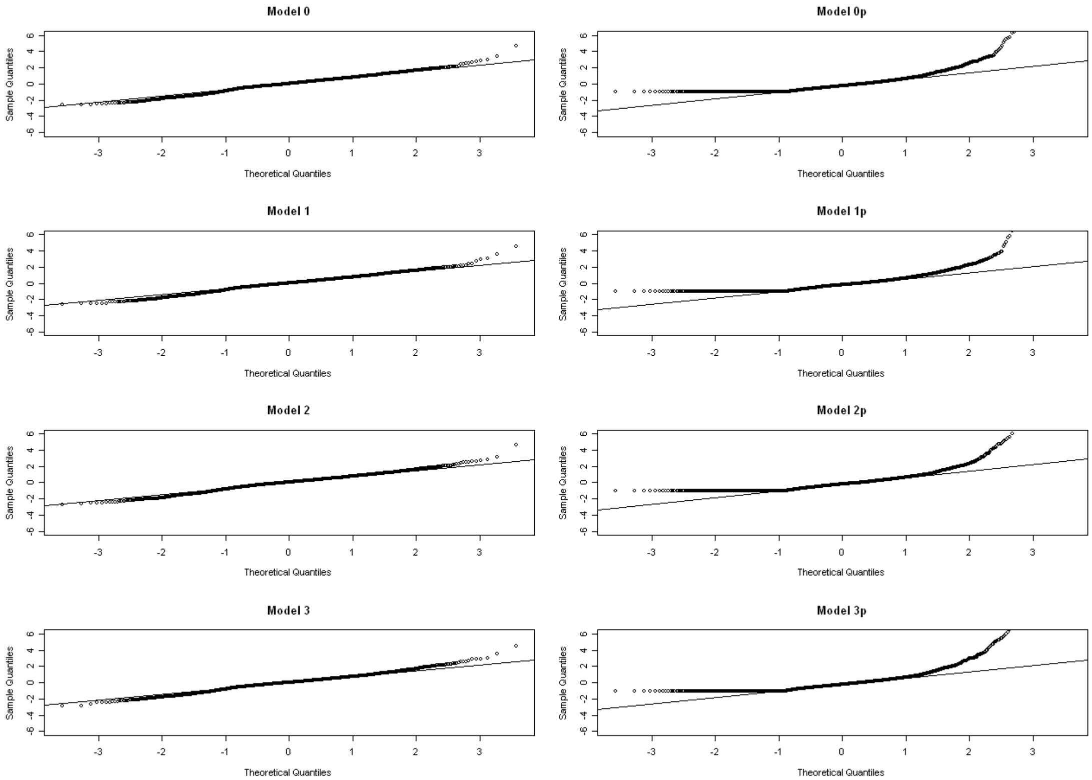


Figure 2.12.1

After WP17 fig 1. Results show Q-Q plots for runs 17.1-5. See Table 2.12.1 for key to runs.

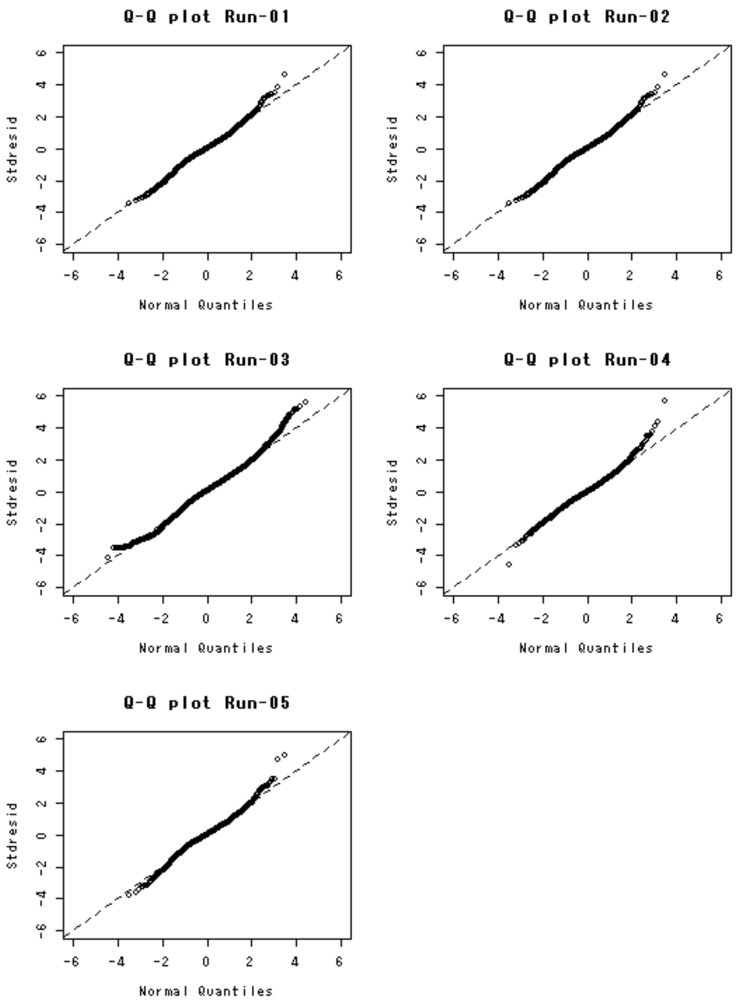
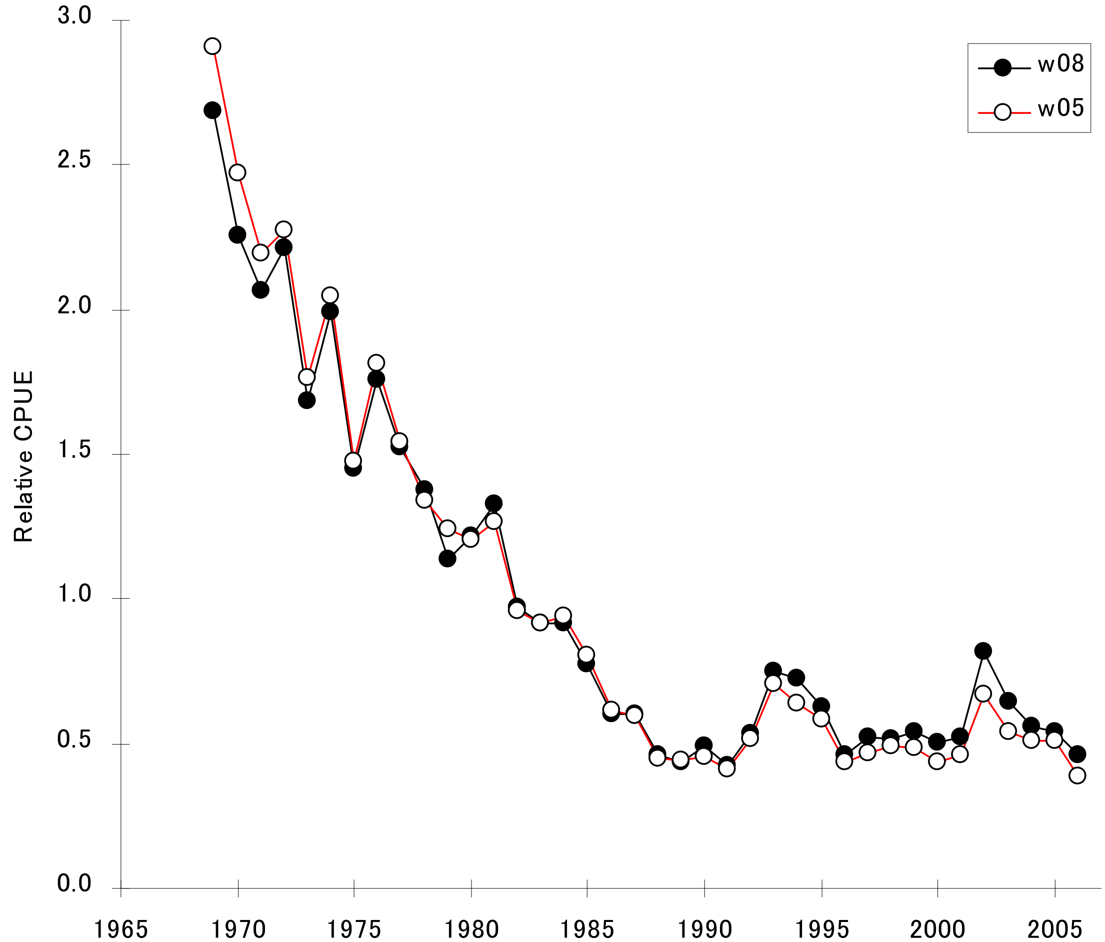


Figure 7. The final CPUE series proposed for use by the MPWG. (after WP19 Figure 3.)



Annex A

List of Working Paper for intercessional CPUE analysis

WP01: HPB and Diagnostics. Itoh, T.

WP02: Data Preparation. Itoh, T.

WP03: SBT Zero Catch operation in relation to targeting. Itoh, T. and O. Sakai

WP04: Reference CPUE series selection. Itoh, T.

WP05: Including the main line material for CPUE standardization. Itoh, T.

WP06: Influence of inclusion of quarter and/or month, as well as area and/or latitude in 5 degree, into the model for CPUE standardization. Itoh, T.

WP07: Exclude non-SBT targeting operation from the data for analysis. Itoh, T.

WP08: Treatment for zero catch data. Itoh, T. and H. Shono

WP09: Basic GLM runs for SxS and 5x5 data. Itoh, T.

WP10: Further analyses of CPUE standardization in terms of various error distributions. Itoh, T.

WP11: Runs after 4th web-meeting on CPUE standardization. Itoh, T.

WP12: Further analyses of CPUE standardization in terms of by-catch tunas. Itoh, T.

WP13: Substitution to the null cell when include Area*Month interaction into GLM models. Itoh, T.

WP14: Threshold of minimum hooks used in the data for standardization of CPUE. Itoh, T. and N. Takahashi

WP15: Data remake and revised GLM runs. Itoh, T.

WP16: Further analyses on SBT CPUE including information of by-catch tuna.. Itoh, T.

WP17: Further analyses on SBT CPUE including information of by-catch tuna.(2). Itoh, T.

WP18: Further analyses on SBT CPUE including information of by-catch tuna.(3). Itoh, T.

WP19: Candidate for the final standardized CPUE for MP. Itoh, T.

WP20: SBT CPUE Analysis. Lawrence, E.

Annex B

Data and Method used to Calculate B-ratio Proxy (w0.5) and Geostat Proxy (w0.8) CPUE Series

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1. Data

Catch (numbers of SBT in each age class from 0-20+ using proportional aging) and effort (hooks) data by year, month, quarter, SBT statistical area, and 5x5 lat/long are used. These data are restricted to months April to September, SBT statistical area 4-9, and the Japanese (1969-present), Australian joint venture (1989-1995) and New Zealand joint venture (1989-present) fleets. These data are included in “CPUE input data” provided in every year’s Data Exchange.

2. Method to Estimate B-ratio proxy (w0.5) and Geostat proxy (w0.8)

B-ratio and geostat proxies are calculated using the equation below.

$$I_{y,a} = wCS_{y,a} + (1-w)VS_{y,a} \quad (1),$$

where $I_{y,a}$ is the CPUE index for year y and age a, w is the weighting between the Constant Square (CS) and the Variable Square (VS) indices, $CS_{y,a}$ is CS index in year y for age a and $VS_{y,a}$ is VS index in year y for age a. Both $CS_{y,a}$ and $VS_{y,a}$ are normalized so that the mean value over all years equals 1.0. When w = 0.5, the index is B-ratio proxy (w0.5) series. The index is geostat proxy (w0.8) series when w = 0.8. Here, age a is 4-year-old and older.

3. CPUE Standardization by GLM

To obtain CS and VS indices for calculating B-ratio and geostat proxies described above, CPUE standardization by Generalized Linear Model (GLM) is conducted first. The following model is fitted to the data:

$$\log(CPUE_{yqmal} + \zeta) = \mu + Y + Q + M + A + L + Y*A + Q*A + Y*Q + \varepsilon \quad (2),$$

where

log	is the natural logarithm,
CPUE	is the nominal CPUE for age 4+,
y	is y-th year (1969-present),
q	is q-th quarter (2 and 3),
m	is m-th month (April-September),
a	is a-th SBT statisitcal area (4, 5 and 6, 7, 8, 9),
l	is l-th latitude (30, 35, 40, 45, 50),

ζ is 10% of the mean nominal CPUE (cf., Campbell et al. 1996),
μ is the mean CPUE (the intercept term),
Y is the effect of year,
Q is the effect of quarter,
M is the effect of month,
A is the effect of SBT statistical area,
L is the effect of latitude,
* indicates the interaction term, and
ε is the error term, $\varepsilon \sim N(0, \sigma^2)$.

The GLM procedure of the SAS/STAT statistical package software is used to conduct the standardization. Before conducting the GLM analyses, outliers of nominal CPUE for age 4+ are graphically detected by scatter plots of effort (hooks/1000) versus nominal CPUE (the number of fish/1000hooks). Detected outliers are removed from the data sets.

4. Area Indices

To obtain the CS and VS abundance indices as products of standardized CPUE and the extent of SBT distribution (i.e., density * area), area of SBT distribution is calculated based on the 1x1 degree square resolution. The area is calculated in the form of area index such that area size of 1x1 degree square along the equator is defined as 1, and area size for other 1x1 degree square of different latitude is determined as the proportion of the square area along the equator. Area index for CS is simply a union of fished 1x1 degree squares through all years (1969-present) and is calculated for each quarter, month, statistical area, and latitude combination. Area index for VS is a sum of fished 1x1 degree square areas and is calculated for each year, quarter, month, statistical area, and latitude combination.

The area indices for CS and VS are computed using the software “area_index2.exe” (For how to run the code, see the navigation document for calculating area index).

5. CS and VS abundance indices

With the estimated parameters obtained from CPUE standardization by GLM, the CS and VS abundance indices for calculating B-ratio and geostat proxies are computed by the following equations:

$$CS_{4+,y}=\sum_q \sum_m \sum_a \sum_l [(AI_{CS})_{(1969\text{-}present)} [\exp(\mu+Y+Q+M+A+L+Y*A+Q*A+Y*Q+\sigma^2/2)-\zeta]] \quad (3),$$

$$VS_{4+,y}= \sum_q \sum_m \sum_a \sum_l [(AI_{VS})_{yqmal} \exp(\mu+Y+Q+M+A+L+Y*A+Q*A+Y*Q+\sigma^2/2)-\zeta] \quad (4),$$

where

$CS_{4+,y}$	is the CS abundance index for age 4+ and y-th year,
$VS_{4+,y}$	is the VS abundance index for age 4+ and y-th year,
$(AI_{CS})_{(1969\text{-}present)}$	is the area index of the CS model for the period 1969-present,
$(AI_{VS})_{yqmal}$	is the area index of the VS model for y-th year, q-th quarter, m-th month, a-th SBT statistical area, and l-th latitude,
σ	is the mean square error in the GLM analyses,

and other symbols have the same meanings as described in the previous section.

With the estimated parameters obtained from CPUE standardization by GLM and area indices for CS and VS, the abundance indices of CS and VS are computed using the software "abund_indx_prg.exe" (For how to run the code, see the navigation document for calculating B-ratio [w0.5] and geostat [w0.8] proxies).