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**REPORT FROM THE STOCK ASSESSMENT PREPARATORY WORKSHOP,
NOUMEA, FEBRUARY 2008**

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1 Introduction

In 2008, SPC/OFP is tasked with conducting stock assessments for bigeye tuna, south Pacific albacore, and skipjack tuna, for presentation to the fourth Scientific Committee meeting (SC4) of the WCPFC. In preparation for these assessments, OFP hosted a technical workshop to address a range of issues specific to the individual assessments, including data issues and potential model sensitivities, and generic issues relevant to all assessments, such as model diagnostics, alternative biological reference points (BRPs), model projections, and technical issues related to applying the stock assessment models to consider alternative management options (see Appendix 1).

The preparatory workshop had no formal status within the WCPFC process; instead it was viewed as an informal meeting of technical experts with a mutual interest in the key assessments. Invitations to participate in the workshop were limited to individuals and agencies with the expertise to contribute directly to the technical issues being considered at the meeting. Attendance at the meeting was funded by the participants. Unfortunately, participation at the meeting was relatively limited (Appendix 2), although there were enough participants to discuss and debate the key issues.

In preparation for the workshop, a range of analyses had been undertaken to investigate the key outstanding issues identified in previous assessments, as aided by the analysis of various data inputs to the assessment models. These analyses were used to focus discussion of the key issues at the workshop. This report documents the results of the various analyses presented at the workshop, key deliberations on specific issues, and various recommendations for progressing the stock assessments in 2008. This report will be presented to SC 4 as an information paper, serving as background material for the principal stock assessment working papers.
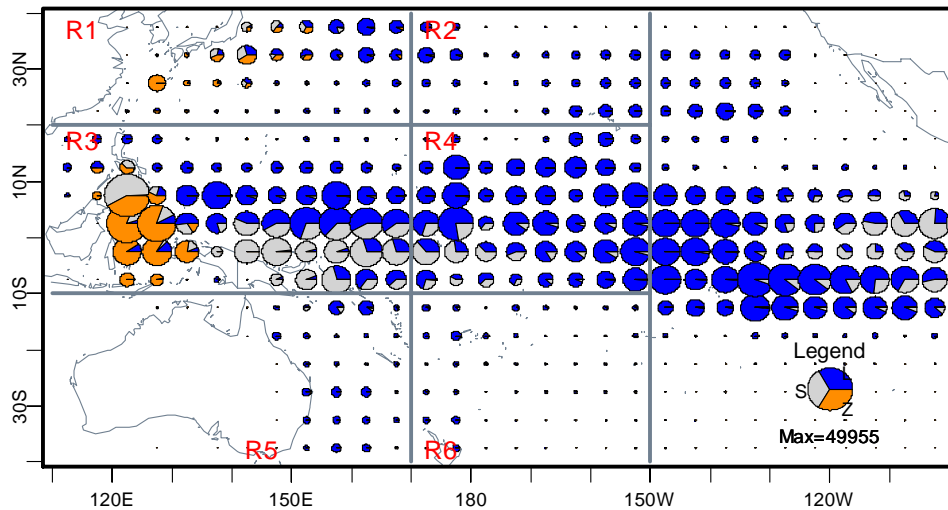
2 Bigeye tuna

In preparing for the workshop a number of outstanding items were identified to be addressed in the 2008 stock assessment for bigeye tuna. These principally related to explaining the strong increase in estimated recruitment over the last decade and continuing high levels of recruitment, and aligning the fishery configuration with that of the 2007 yellowfin stock assessment. The specific items included in the agenda were, as follows.

   i. Fishery structure. Including additional fisheries to align with the yellowfin stock assessment model. Figure 1 presents the regional structure of the model.
   ii. Changing the configuration of the size (length and weight) data sets, especially for the Japanese longline fisheries.
   iii. Exploratory analyses – what is driving the recent increase in estimated recruitment, especially within region 3?
   iv. Is there evidence of spatial heterogeneity in the growth rate of bigeye tuna (as observed for yellowfin)?

v. Determining the appropriate weighting of the size data in the stock assessment model.

vi. Considering the range of sensitivity analyses to conduct for the 2008 assessment, including sensitivities to increasing longline catchability (efficiency), alternative M-at-age schedules, movement parameterization, selectivity of old age classes for small fish fisheries, and Indonesia and Philippines catch history assumptions.

2.1 Fishery structure

The 2007 yellowfin stock assessment model included five more fisheries than the 2006 assessment: Japanese coastal purse-seine and pole-and-line fisheries (region 1), an equatorial pole-and-line fishery (region 3), separated Indonesian and Philippines artisanal fisheries (region 3), and a Japanese longline fishery in PNG waters (previously included in the principal longline fishery in region 3).

Figure 1. Distribution of cumulative bigeye tuna catch from 1990–2004 by 5 degree squares of latitude and longitude and fishing gear; longline (blue), purse-seine (grey), and other (dark orange). The maximum circle size represents a catch of 50,000 mt. The grey lines indicate the spatial stratification of the model.

The purse-seine and pole-and-line fisheries were added to account for catch that was previously not included within the stock assessment models. The Indonesian and Philippines artisanal fisheries were separated to enable a more explicit exploration of the uncertainty in the catch histories (past and recent) from these two fisheries, particularly given that recent catch data from the Philippines fishery are considerably more reliable than those from the Indonesian artisanal fishery. A separate longline fishery was created in PNG waters because smaller fish (both yellowfin and bigeye tuna) are observed from this area than from the rest of region 3 (see http://www.wcpfc.int/sc2/pdf/SC2_ME_IP2.pdf).

The workshop agreed that the changes in fishery structure applied to the 2007 yellowfin assessment should also be used in the 2008 bigeye stock assessment, as the rationale for making these changes was equally relevant to bigeye. In addition,

maintaining an equivalent fishery structure would enable a direct comparison of the likely outcome of any management options considered for either species. It was agreed that the changes in the fishery structure should be included in the stock assessment model in a step-wise manner, to assess the impact of the inclusion of each fishery (see sensitivity analyses, Section 2.6).

The inclusion of the coastal Japanese fisheries had previously been hampered by the lack of size data from these fisheries. However, prior to the workshop, staff of the Japanese National Research Institute of Far Seas Fisheries had provided a comprehensive set of size data for inclusion in the 2008 assessment.

There was also discussion regarding creating an additional fishery within the bigeye stock assessment model by separating anchored FAD purse-seine fishing from the composite associated sets purse-seine fishery within region 3 (anchored and drifting FADs and log sets). This would be done principally to permit consideration of alternative management options that may include/exclude the purse-seine fisheries within the archipelagic waters of PNG and the Solomon Islands. These fisheries are principally conducted around anchored FADs. It was considered that additional work was required to ascertain whether the catchability and/or selectivity of the anchored FAD sets differed from other associated set types in the region.

2.2 Configuration of size frequency data

Compiling the size data (length and weight) in previous bigeye stock assessments has simply involved aggregating all fish measured by fishery/time strata. This approach assumes that all length and weight samples are representative of the catch. However, for some longline fisheries, there is evidence of spatial heterogeneity in the size composition of the catch, and the distribution of sampling effort may not conform to the distribution of the catch (see http://www.wcpfc.int/sc2/pdf/SC2_ME_IP2.pdf). Consequently, simply aggregating all samples may result in biased size (length and weight) frequency distributions in the input data set.

To address this issue, a scheme for selecting and aggregating the size data was developed and applied to the input data used in the 2007 yellowfin stock assessment. The scheme was accepted at SC-3. An equivalent approach was applied to the bigeye size data available from the Japanese longline fleet to construct size frequency distributions for the six principal longline fisheries. The procedure is as follows.

i.   The catch (in numbers of fish) for the fishery/quarter was aggregated to a spatial resolution equivalent to the spatial resolution of the length/weight data (a common resolution of 10*20 lat/long was used, although data are provided at a number of different resolutions and subsequently pooled to 10*20).

ii.   The spatial strata that accounted for most (at least 70%) of the catch in the fishery/quarter were identified.

iii.   Each of the main spatial strata (ii) was required to include a minimum of 20 fish sampled for length/weight. Otherwise, the length/weight composition for the fishery/quarter was not computed.

iv.   Fish lengths/weights sampled from each stratum were combined and weighted in proportion to the catch in each stratum. The resulting length/weight

distribution was scaled to represent the total number of fish measured in the fishery/quarter.

These protocols excluded a large proportion of the length samples collected from all the principal longline fisheries (Table 1). This is mainly due to insufficient length samples being collected from the main areas where the catch was taken. For weight frequency data from longline fisheries in regions 1, 3, 5, and 6 (fisheries 1, 4, 10, 12), there was no substantive change to the number of fishery/quarter samples included in the model.

For the longline fisheries in regions 2 and 4 (fisheries 2 and 7), few length or weight samples met the criteria (Table 1). However, given that there is no indication of significant spatial heterogeneity in the size data from these regions (see http://www.wcpfc.int/sc2/pdf/SC2_ME_IP2.pdf), it was decided to proceed using all available size data from these two fisheries in formulating the comparative data set.
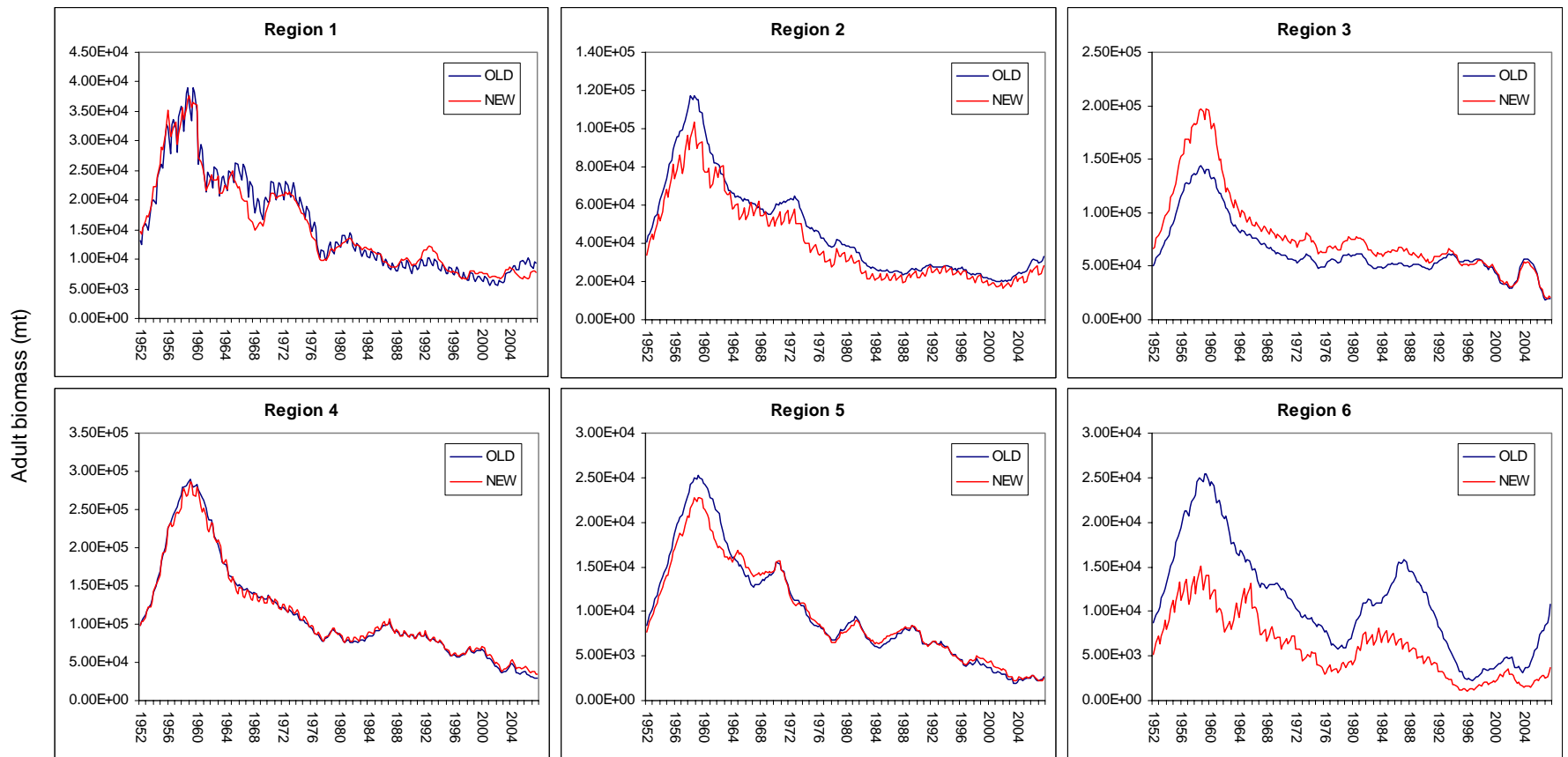
The sensitivity of the WCPO bigeye stock assessment to changes in configuration of the size data sets was examined by comparing trends in adult biomass for each of the six regions (Figure 2). For most of the regions there was very little difference in the adult biomass trajectory using the two approaches for aggregating the size data. The exception was region 6 for which there was a considerable loss of size data when the new criteria were applied (see Table 1), although this region accounts for a small proportion of the total bigeye biomass.

The changes in the configuration of the size data also resulted in an improved fit to the remaining size data for some fisheries, most notably the length data for the longline fishery in region 1, and a removal of length data from the longline fishery in region 3 (Figure 3 and Figure 4). However, there remain apparent conflicts in the size data for some fisheries that require further investigation, especially the longline fishery in region 2 post 1980. It was noted that Japanese training vessels – a major source of size frequency data in regions 2 and 4 – may retain and measure small fish compared to commercial longliners. However, these data alone do not explain the conflict in the model (larger fish size predicted from the model compared to observed) as smaller fish were observed in data from both training vessels (length samples) and commercial longliners (weight samples). It was suggested that this might be resolved by estimating two selectivities for this fishery, pre and post 1980, creating two fisheries.

During the workshop, there was considerable discussion regarding the approach used to configure the size data. There was concern about some of the criteria used as these could result in a rejection of a significant proportion of the data. Most of these concerns appeared to be allayed when it was evident that the changes in the size data set were having a minimal impact on the biomass trends from the alternative model runs.

Table 1. A comparison of the number of fishery/quarter length (left) and weight (right) frequency samples from the principal longline fisheries (columns) by decade included in the bigeye stock assessment data set applying the new data criteria (top panel) compared to the previous approach (bottom panel). The main differences in the data sets are highlighted in yellow. The new data criteria were not applied to fishery 2 and fishery 7.

Length data — Fishery (region)

New criteria	1(1)	2(2)	4(3)	7(4)	10(5)	12(6)
1950	10	24	2	21	1	0
1960	7	11	10	21	7	0
1970	2	34	4	40	3	2
1980	0	28	0	40	0	6
1990	0	35	0	40	2	15
2000	3	19	1	27	0	3

Weight data — Fishery (region)

New criteria	1(1)	2(2)	4(3)	7(4)	10(5)	12(6)
1950	0	12	10	13	6	0
1960	2	31	22	32	17	2
1970	12	29	21	40	21	0
1980	25	34	27	40	23	20
1990	12	40	31	37	6	28
2000	7	17	20	20	0	0

Length data

Previous	1(1)	2(2)	4(3)	7(4)	10(5)	12(6)
1950	28	24	26	21	8	3
1960	31	11	28	21	20	13
1970	29	34	40	40	31	20
1980	22	28	35	40	14	6
1990	39	35	40	40	37	21
2000	16	17	24	23	24	13

Weight data

| Previous	1(1)	2(2)	4(3)	7(4)	10(5)	12(6)
1950	14	12	17	13	8	7
1960	31	31	32	32	29	13
1970	36	29	40	40	32	18
1980	40	34	40	40	38	20
1990	40	40	40	37	30	7
2000	19	16	24	19	21	4

Figure 2. Comparative trends in adult biomass by region from the WCPO stock assessment model using size data configured using the new criteria (NEW) and the old approach (OLD). Note that the new approach was not applied to the longline size data from regions 2 and 4 (fisheries 2 and 7).

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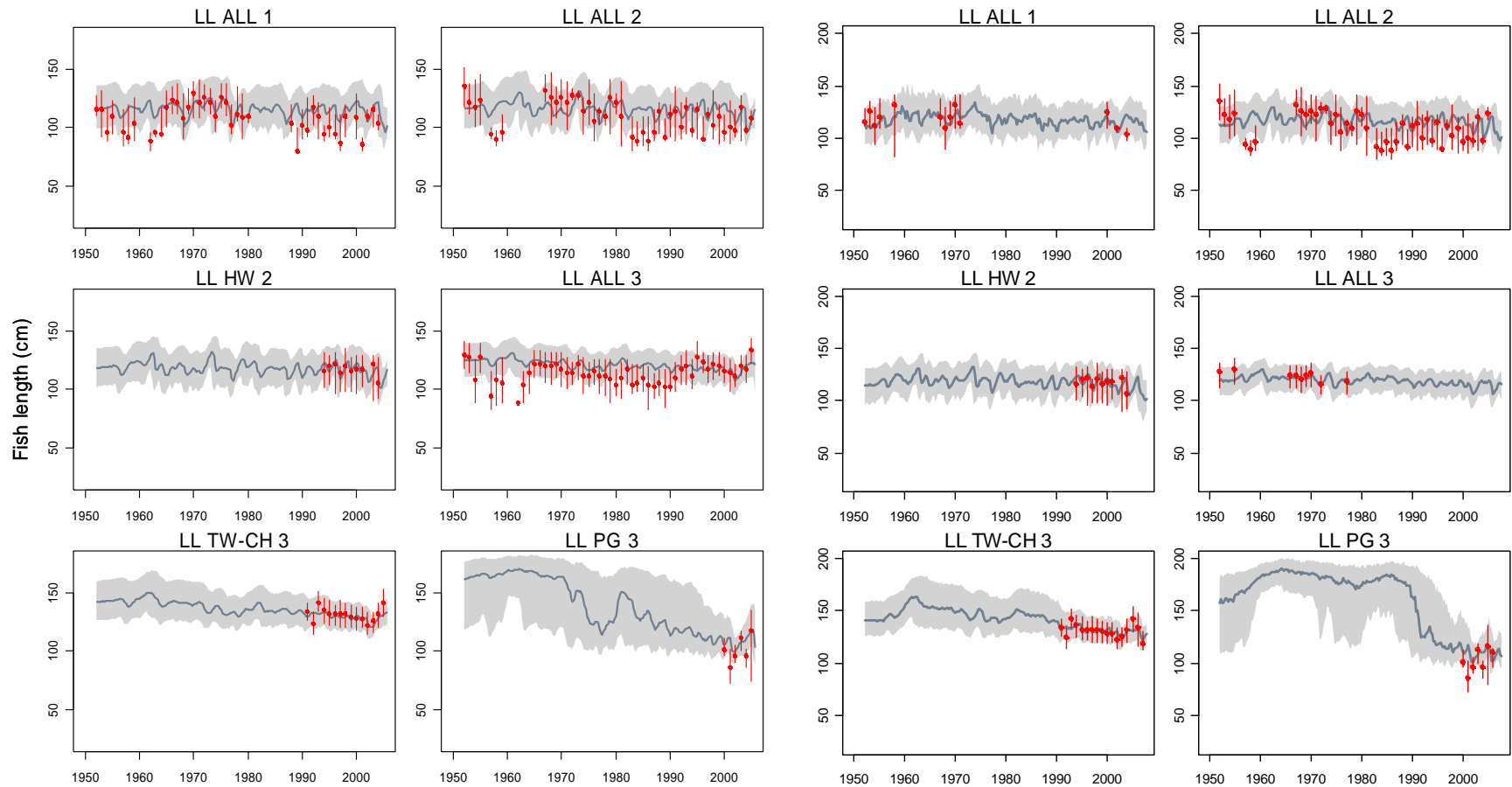
Figure 3. A comparison of fits to the length frequency data by fishery for the longline fisheries in regions 1-3 using the old approach to aggregate the size data (left) and the new approach (right); observed catch-at-size (red points) and predicted (grey line) median fish length (FL, cm) of the exploitable population. The confidence intervals (red lines) represent the values encompassed by the 25% and 75% quantiles. The figures are for illustrative purposes - the structure of the two models is not entirely consistent; the left panel is from the 2006 assessment and the right panel is from a model run with the LL ALL 3 fishery split at 1985.
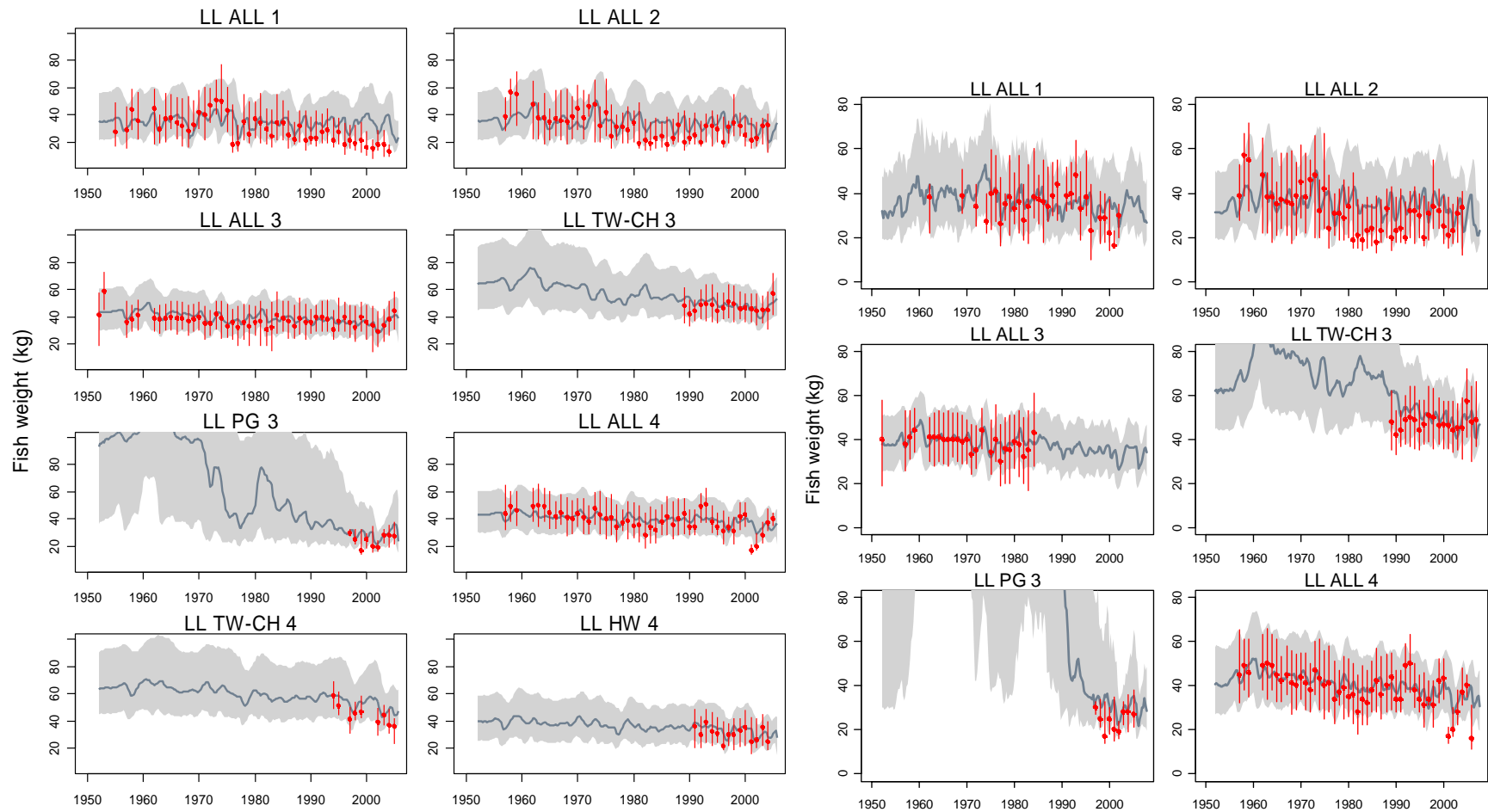
Figure 4. A comparison of fits to the weight frequency data by fishery for the longline fisheries in regions 1-3 using the old approach to aggregate the size data (left) and the new approach (right); observed (red points) and predicted (grey line) median fish weight (kg). The confidence intervals (red lines) represent the values encompassed by the 25% and 75% quantiles. The figures are for illustrative purposes - the structure of the two models is not entirely consistent; the left panel is from the 2006 assessment and the right panel is from a model run with the LL ALL 3 fishery split at 1985.

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There was also considerable discussion about what was the appropriate sample size to use when constructing the length/weight frequency. Under the current scheme, the sample size is defined as the total number of fish measured from all spatial strata used to derive the aggregate size composition (step iv). An alternative is to use the total number of fish sampled from the key strata (i.e. those strata that account for at least 70% of the catch). Another alternative is to formulate an "index of representativeness" for the size samples (i.e., an index that reflects how closely the distribution of samples corresponds to the spatial distribution of the catch) and use this to scale the respective sample size for the fishery/quarters.

These alternative approaches will be explored in the 2008 bigeye stock assessment and the impact of each change in the configuration of the size data will be compared to a model run that retains the old approach for aggregation of the size data (see sensitivity section).

A more urgent issue is to ascertain why the size (length and weight) samples from the longline fisheries in regions 2 and 4 (fisheries 4 and 7) are poorly representative of the distribution of the catch; i.e. fail to meet the new criteria for configuration of the size data. Further investigation of these data may provide an explanation for the poor fit to these data in the model, particularly from 1980.

2.3 Recruitment patterns

Recent (2003–2006) stock assessments for WCPO bigeye tuna have been characterized by a strongly increasing trend in recruitment, reaching a level of at least 50% higher than the long term average over the last decade. Most of the trend in increasing recruitment has occurred within region 3 of the WCPO model domain.

An exploratory analysis was conducted, based on the 2006 assessment model, to examine the key data sets that are influencing the recruitment trends, particularly within region 3. This was to examine the possibility that the increasing recruitment is not real, but an artefact of inaccuracies in the data and/or the model. Initially, a restricted version of the model was investigated: a single region model that encompassed region 3 only. After examining the various data sets from region 3, four hypotheses were developed to explain the recruitment trend.

i. Increasing recruitment may be needed to explain the strong increase in the catch of small bigeye, particularly since the mid 1990s, from the Indonesian and Philippines artisanal fisheries and from the purse-seine associated sets fishery in the region (Figure 5).

ii. An increase in the size of bigeye tuna caught by the Japanese longline fishery in region 3 since at least the mid 1980s (Figure 6). The model may account for the increase in the size of bigeye by significantly increasing recruitment to allow more fish to reach larger sizes and ages. The increase in fish size coincided with a steady increase in the hooks-between-floats (HBF) of the longline gear from the Japanese fleet in the same region. It is hypothesized that the increase in HBF and consequential increase in fishing depth may have resulted in a relative increase in the selectivity of larger bigeye.

iii. Increasing recruitment may be needed to explain a general increase in the proportion of small bigeye tuna in the purse-seine associated sets fishery from 1995 onwards (Figure 7).

iv. Since 1990, Chinese and Taiwanese offshore longline fisheries that have developed in Micronesia. These two fleets generally catch larger bigeye tuna than the Japanese longline fleet (Figure 8 and Figure 9). The model may be increasing recruitment to account for the increasing catches of large fish.

These hypotheses were tested by examining the sensitivity of the recruitment series (for region 3) to each data set, by down-weighting or altering the model inputs.
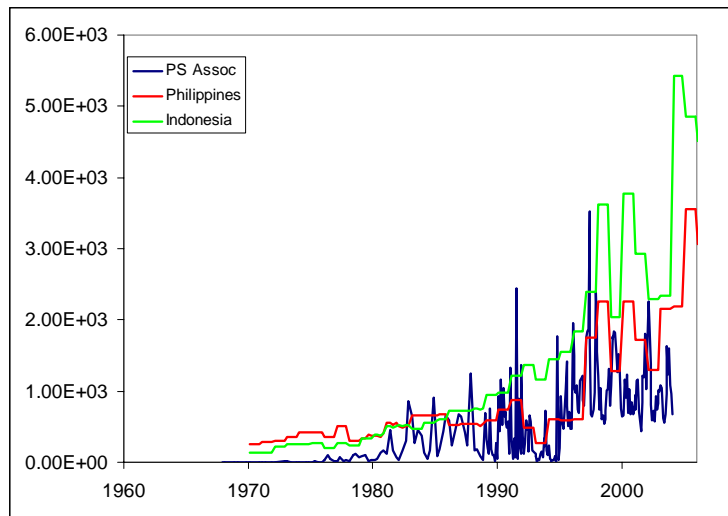
Figure 5. Quarterly catches of bigeye tuna (mt) from the three fisheries within region 3 that catch small bigeye tuna.
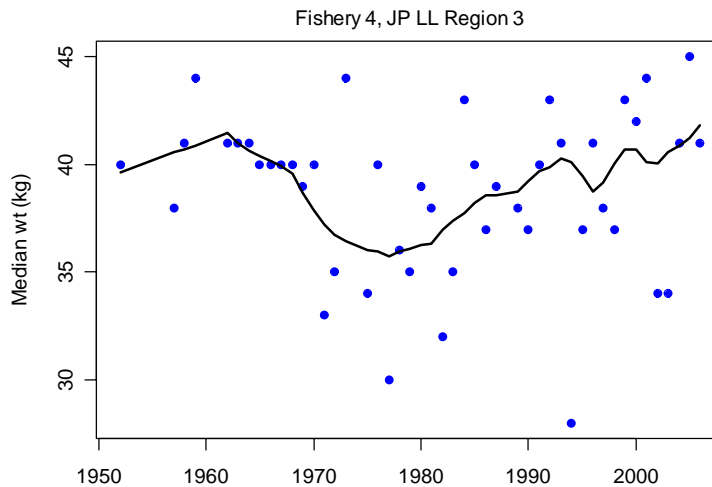

Figure 6. Trend in median bigeye tuna weight (unprocessed weight, kg) from the Japanese longline fishery operating in region 3.
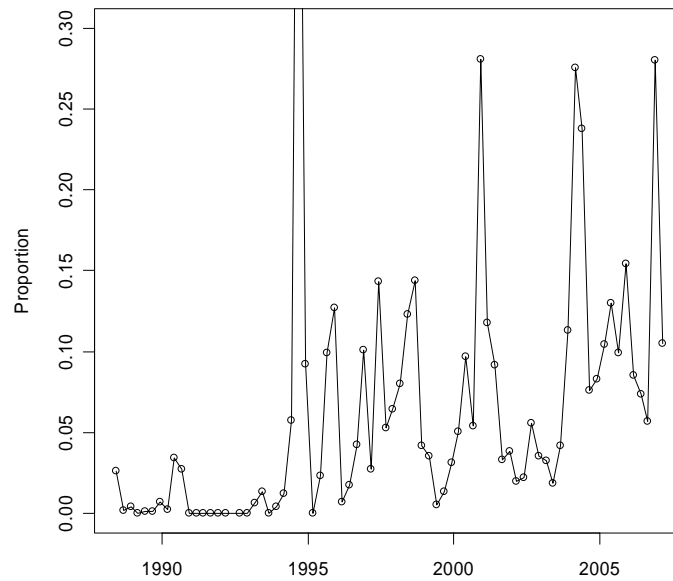
Figure 7. The proportion of small (less than 40 cm FL) bigeye tuna in the length samples collected from the region 3 purse-seine associated set fishery (all associated set-types combined), by quarter.

The impact of the recent increase in the small fish catch was examined by reducing the catch of the three fisheries (Indonesia, Philippines, and associated purse-seine sets) by 50% for the post 1995 period. The trends in relative recruitment were very similar to the base case, although relative recruitment reduced slightly after 1995 (Figure 10). Instead of accounting for the reduction in small fish catch by reducing recruitment, the main response of the model was to reduce the temporally varying catchability of the three fisheries in the post 1995 period by approximately one third (compared to the base case run).

To assess the potential influence of the increase in the size of fish from the Japanese longline fishery, the base case model was configured with the longline fishery split into two time periods: pre-1985 and post-1985. The size data from the post-1985 fishery was down-weighted to the extent that it no longer influenced the model likelihood (sample size = n/10,000). The resulting change to the estimated recruitment series (relative to the base case) was very minor and, thereby, it was concluded that these size data were not influential. Similarly, the size (length) data from the purse-seine associated set fishery (region 3) was also down-weighted with no discernable effect on the estimated recruitment time series.
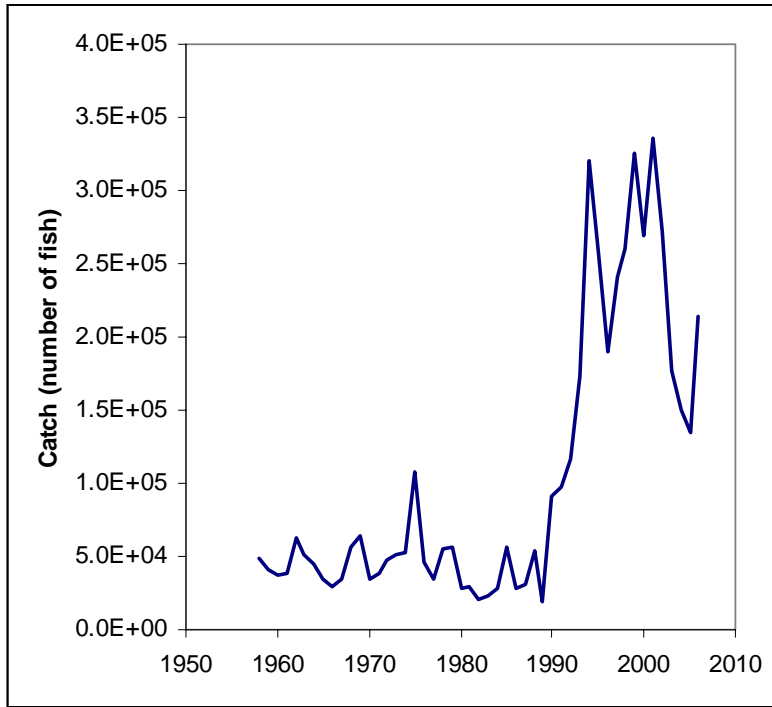
Figure 8. Annual catches (number of fish) from the Chinese/Taiwanese offshore longline fleet operating in Micronesia (region 3).
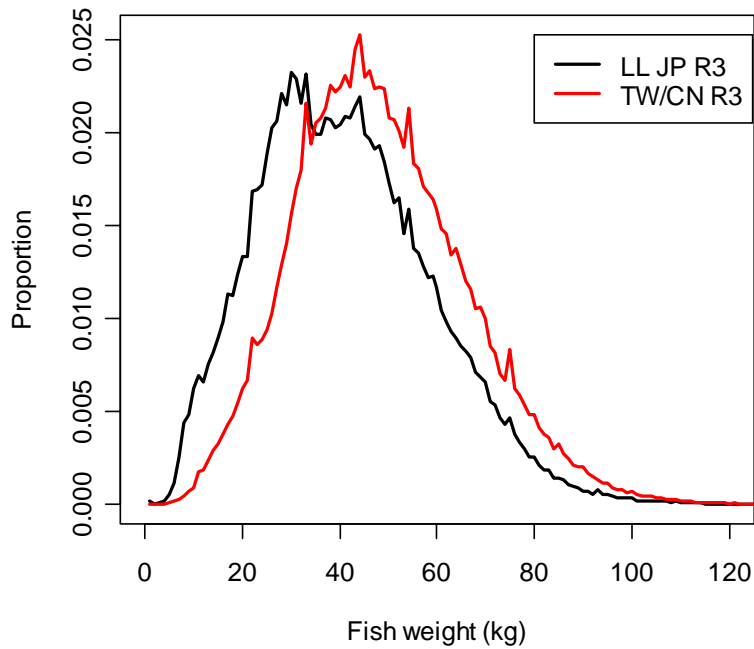

Figure 9. A comparison of the weight frequency distribution (1990 onwards) of the sampled bigeye catch from the Japanese longline fishery in region 3 and the Chinese/Taiwanese offshore longline fleet operating in Micronesia (region 3).

A similar approach was applied to the size data from the Chinese/Taiwanese offshore fleets operating in Micronesia. These data were down-weighted (sample size = n/10,000) and the estimated recruitment series compared to the base case run (Figure 11). The resulting recruitment series did not display the strong temporal trend evident in the base case model, with recruitment fluctuating about the average level for most of the model period. Recruitment estimates in the last decade were more variable than the earlier period although the average of these indices remained at about the long-term average (1950–2005), with the exception of the high recruitment estimated for the final year of the model (Figure 11).

A further scenario was conducted in which the catch from the Chinese/Taiwanese offshore fleet was reduced to 20% of the level included in the base model. The recruitment series estimated for this scenario was essentially equivalent to the base case model run, indicating that these catch data were not influential.

It was concluded that the size data from the Chinese/Taiwanese offshore fleet were having the largest influence on the recruitment estimates from 1990 onwards. The influence of these data was further explored by extracting size data from the fishery and including these as dummy data in two earlier time periods of the model (1974–79 and 1984–89). The recruitment series derived from these two scenarios displayed the same underlying trend as the base case, except that in both scenarios the recruitment estimates were higher in the period immediately preceding and during the time period of the dummy data sets (i.e. 1974–79 and 1984–89). However, the elevated level of recruitment was still considerably lower than during the post 1990 period.

This confirmed that the size data from the Chinese/Taiwanese offshore fleet were at least partly responsible for the higher recruitment after 1990, but there is clearly also an interaction with other data in the model. The model may have increased the recruitment during the latter period to provide old fish for the Chinese/Taiwanese fishery (estimated to select age classes 12 and older) while the younger age classes are being subjected to relatively high levels of fishing mortality (Figure 12).
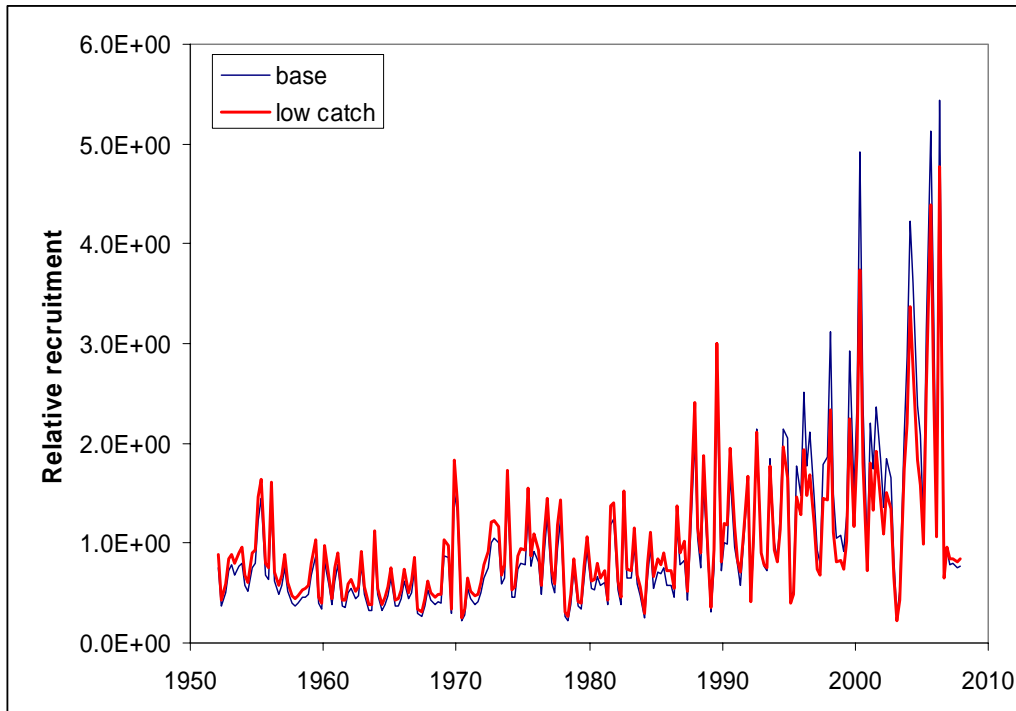
Figure 10. A comparison of the normalised recruitment trends from the region 3 base case model and a model run with a 50% reduction in the catch of small fish post 1995. There is little change in the estimated magnitude of relative recruitment, highlighting the lack of influence that the magnitude of the catches of small fish has on recruitment estimates in the model.
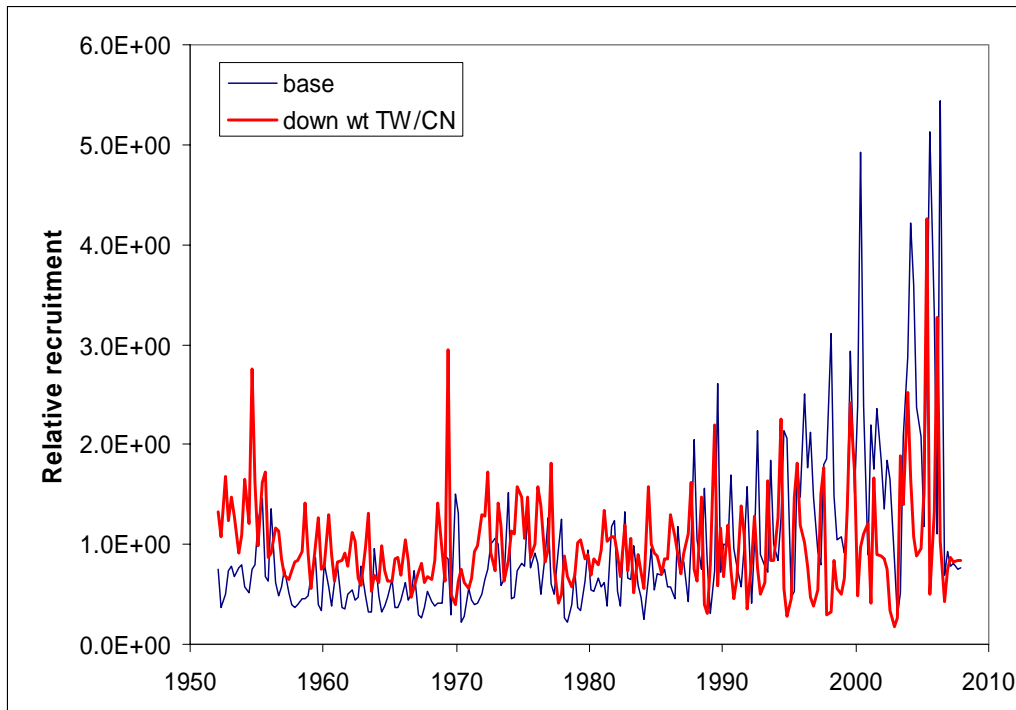
Figure 11. A comparison of the normalised recruitment trends from the region 3 base case model and a model run with the Chinese/Taiwanese size data heavily down-weighted. Down-weighting removes most of the recruitment trend, suggesting that the catches of large fish are affecting the recruitment estimates.
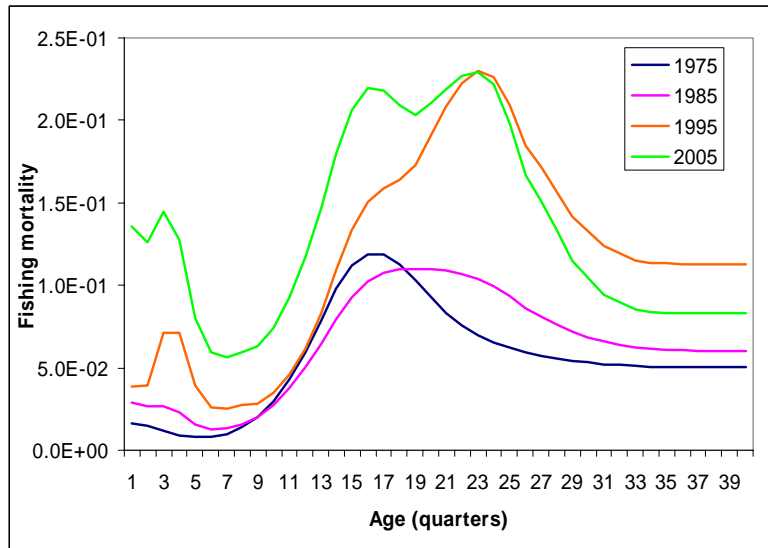
Figure 12. Fishing mortality at age for four time periods (1975, 1985, 1995 and 2005) estimated from the region 3 base case model for bigeye tuna.

During the last 15–20 years, the Chinese/Taiwanese offshore fishery has operated from a number of locations throughout Micronesia, principally Palau, Yap (FSM), Pohnpei (FSM), and Majuro (RMI). The fleet catches larger fish in Palau and western FSM waters than in eastern FSM waters. Various alternative fishery configurations were investigated in the region 3 model to determine whether the separation of these fisheries was influential, particularly with respect to the recruitment time series (Figure 11). The main scenario explored was to separate the FSM and Palau fisheries and further separate the Palau fishery into two periods (pre- and post-1990), estimating separate catchabilities (temporally variant) and selectivities for each fishery. In addition, the following scenarios were examined.

- Alternative selectivity parameterisations for the Palau and FSM fisheries.
- Relaxing the penalty on the effort deviates for the Palau fishery (fish flag 13 = 1).
- Relaxing the penalty on the catchability deviates for the Palau fishery (fish flag 15 = 1).
- Increasing the frequency of temporal change in the catchability for the Palau fishery (fish flag 23 = 1).
- Progressively reducing the selectivity of the older age classes in the principal longline fishery (with constant catchability).

None of these changes to the structural assumptions of the model affected the underlying trend in either the recruitment or adult biomass series. Despite having the (complete) freedom to increase catchability during the last decade, the catchability for the Chinese/Taiwanese offshore fishery(ies) actually remained relatively constant. Therefore, the model is achieving a better overall fit to all data sets by increasing the recruitment in recent years rather than by increasing catchability of the Chinese/Taiwanese offshore fishery.

The conclusions from the single, region 3 model were then further tested using a WCPO 6 region model very similar to the model used for the 2006 WCPO bigeye stock assessment. In this case, it was necessary to down-weight the size data from the

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Chinese/Taiwanese offshore fisheries in both regions 3 and 4 as the two fisheries share a common selectivity.

For the WCPO, total recruitment for the base case run was similar to the trend for the region 3 model; i.e., a steady increase in recruitment from 1990 onwards. Whereas, for the scenario with the size data down-weighted for the Chinese/Taiwanese offshore fisheries, recruitment during the latter period was at or about the long-term average (Figure 13).
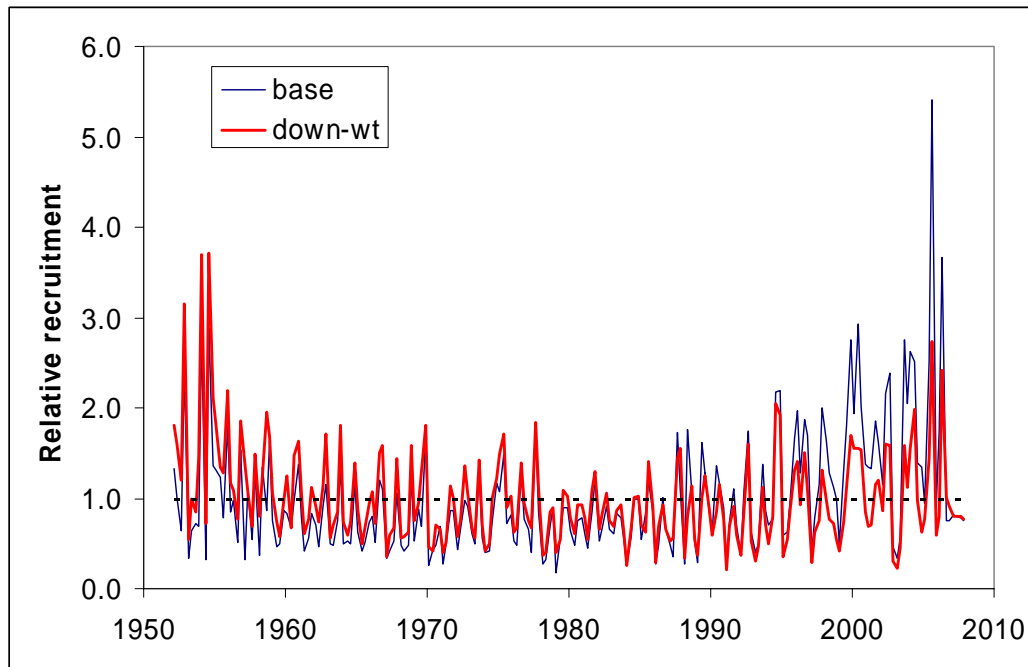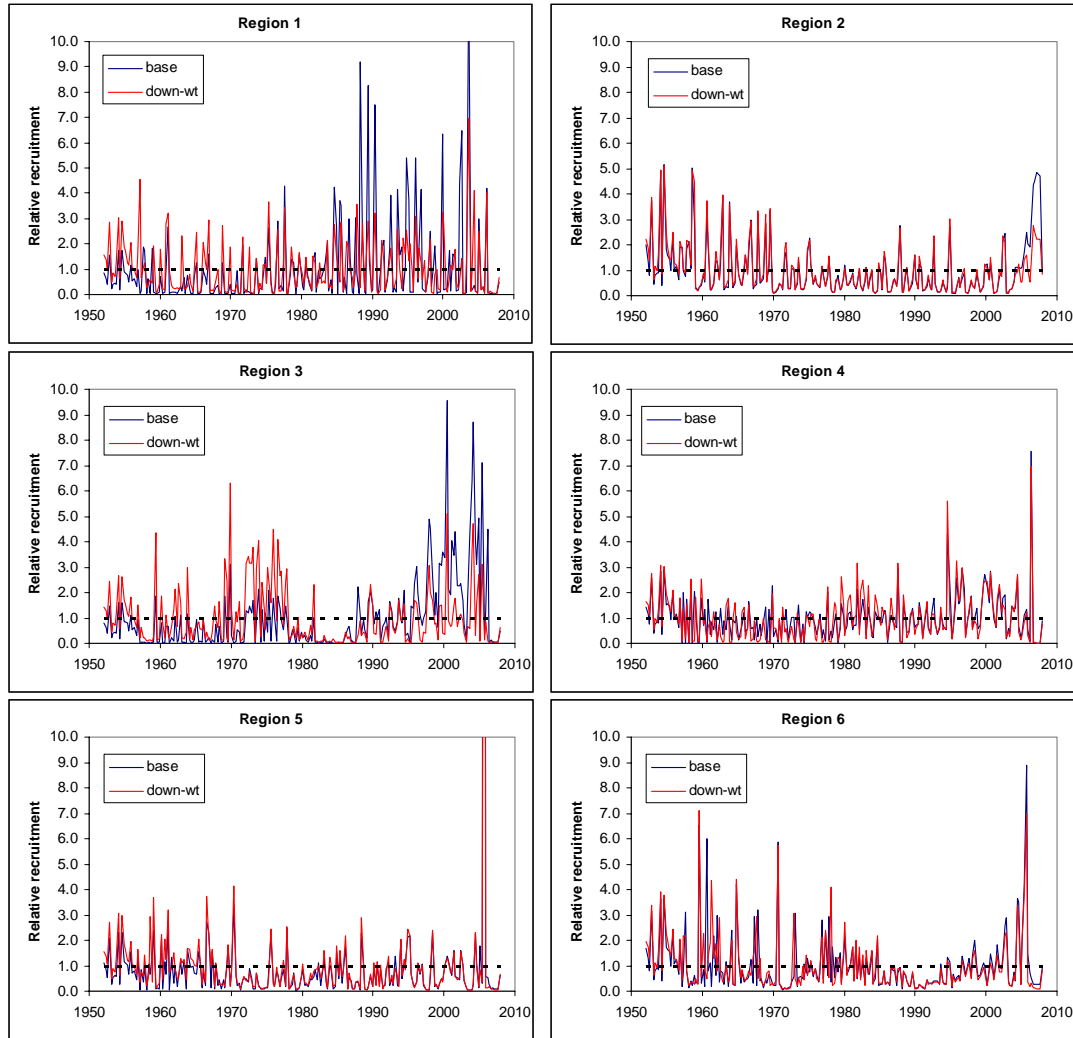

Figure 13. A comparison of the normalised recruitment trends from the WCPO base case model and a model run with the Chinese/Taiwanese size data heavily down-weighted. The dashed line represents the mean of the normalised recruitment series (1.0).

At a sub-regional level, most of the change in the relative trends in recruitment occurs in regions 1 and 3, with lower recruitment in both regions from 1990 onwards (Figure 14). The reduction in recruitment in region 1 is due to this region acting as a source for recruitment in region 3, via the estimated movement coefficients (a movement of 24% of fish from region 1 to region 3 in the first quarter). The transfer of fish from region 1 to region 3 results in a moderation of the temporal trend in the numbers at age in both regions by age 4-5 quarters.

In conclusion, the recent increase in recruitment may be inferred by the model at the sub-regional and the WCPO scale from the fact that large (old) fish have been caught in region 3 in recent years, despite the high fishing mortality on the younger age classes. However, the reason for the model selecting this solution against other alternative solutions, such as increasing catchability of the Chinese/Taiwanese offshore fishery, remains unclear, although it is probably inter-related with the other observed trends in size data from other fisheries (increase in fish size from the Japanese longline fishery and an increase in the proportion of very small fish, less than 40 cm FL, in the purse-seine fishery). Given that the trend in recruitment is strongly influenced by one data set, from a fishery with a relatively limited spatial

domain, we cannot be confident that the increase in recruitment is genuine (as opposed to a model construct). Therefore a sensitivity analysis will be undertaken as part of the 2008 bigeye assessment to further examine the influence of including the Chinese/Taiwanese size data.

Figure 14. A comparison of the normalised recruitment trends by region from the WCPO base case model and a model run with the Chinese/Taiwanese size data heavily down-weighted. The dashed line represents the mean of the normalised recruitment series (1.0). Using the down-weighted data, the biggest changes to recruitment are a lowering of relative recruitment in regions 1 and 3 post-1990.

It was noted that the recruitment pattern may also be influenced by the assumed age-specific pattern of natural mortality (M) included in the model, particularly the level of M for the older age classes (age classes vulnerable to the Chinese/Taiwanese fishery). During the 2008 assessment, the influence of the current M-at-age scheme will be investigated via sensitivity analyses (see Section 2.6).

2.4 Spatial variation in growth

In the 2007 yellowfin stock assessment, there was evidence of spatial variation in the growth of juvenile yellowfin with lower growth rates in the western equatorial region (region 3) than in the sub-equatorial regions, principally region 1. The overall WCPO growth rate estimated in the stock assessment model was strongly influenced by the faster growth rates detected in the size data from region 1. An equivalent investigation was undertaken for bigeye tuna, whereby separate growth parameters were estimated for the WCPO (6 region model) and for regions 3 and 4 (two single region models). The size data sets included in these models were configured to include the data at monthly (rather than quarterly) time intervals.

The analysis did not reveal any substantive differences in the estimated growth rates from the region 3 and WCPO models, but the region 4 model estimated a higher *Linfinity* growth parameter (Figure 15a). The growth from region 4 of the model was more consistent with the growth estimated for the EPO fishery (Mark Maunder), although all four models estimate similar growth rates for the first 15 age classes. However, there are considerable differences in the estimates of the standard deviation of length-at-age, with the two single region models estimating considerably lower standard deviations across all age classes compared to the WCPO model (Figure 15b). The latter is more typical in that the standard deviation of length-at-age is estimated to increase steadily with increasing age; a pattern also observed in the growth estimates from the EPO model. It was noted that some of the growth parameters (such as std dev) may be poorly determined and there is a need to examine the variance associated with the parameter estimates as large standard deviations may reflect different growth rates among regions.

Overall, based on the analysis, it was concluded that there is no strong evidence within the model to indicate significant sub-regional differences in the growth rate of bigeye within the WCPO. However, it may be worth reviewing this conclusion after including additional size data from the Japanese coastal fisheries. These data will be incorporated into the bigeye stock assessment for the first time in 2008.

2.5 Weighting of size data

The WCPO bigeye stock assessment model includes a substantial amount of size (length and weight) frequency data from most of the key fisheries, in particular the longline fisheries and the purse-seine (associated set) fisheries. The 2006 assessment revealed that the weighting (effective sample size) assumed for these data in the model likelihood can be highly influential in the overall assessment. There is also a significant body of scientific literature that highlights the issue and provides guidance as to determining appropriate effective sample sizes for these types of data.

An exploratory analysis was undertaken to investigate alternative weightings of the size frequency data using the region 3 bigeye model. Four alternative weighting schemes were used; three schemes divided the actual sample size (number of fish measured, n, up to a maximum of 1,000) by an arbitrary value of 10, 20 (the two values used in the 2006 assessment) or 50 and using an iterative reweighting approach following McAllister and Ianelli (1997).

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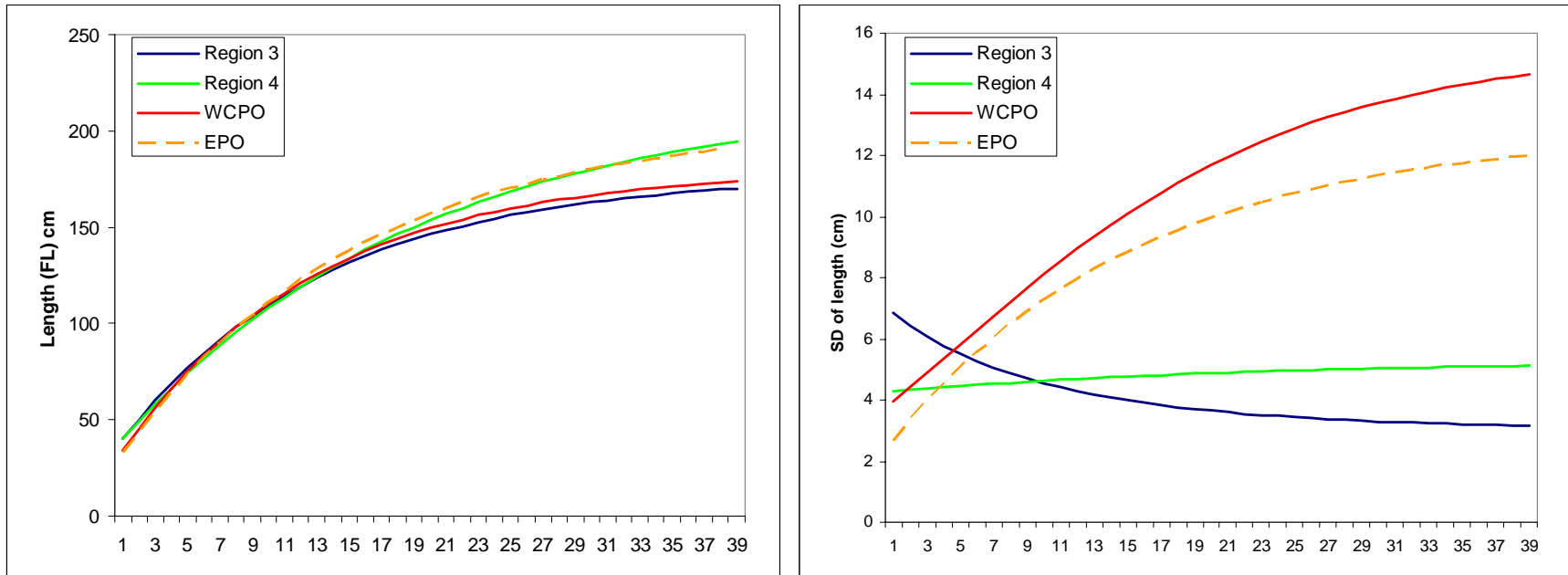
Figure 15. Estimated growth (left figure) and standard deviation of length at age (right figure) for bigeye tuna from WCPO, region 3, and region 4 MFCL models. For comparison, the growth of bigeye tuna from the EPO is also presented (source: Mark Maunder, IATTC).

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Progressively reducing the effective sample size (from n/10 to n/20 to n/50) resulted in comparable trends in total and adult biomass, although the magnitude of the initial biomass level and the extent of the decline in biomass, particularly adult biomass, increased; i.e. more closely aligned to the decline in the longline CPUE index (Figure 16).
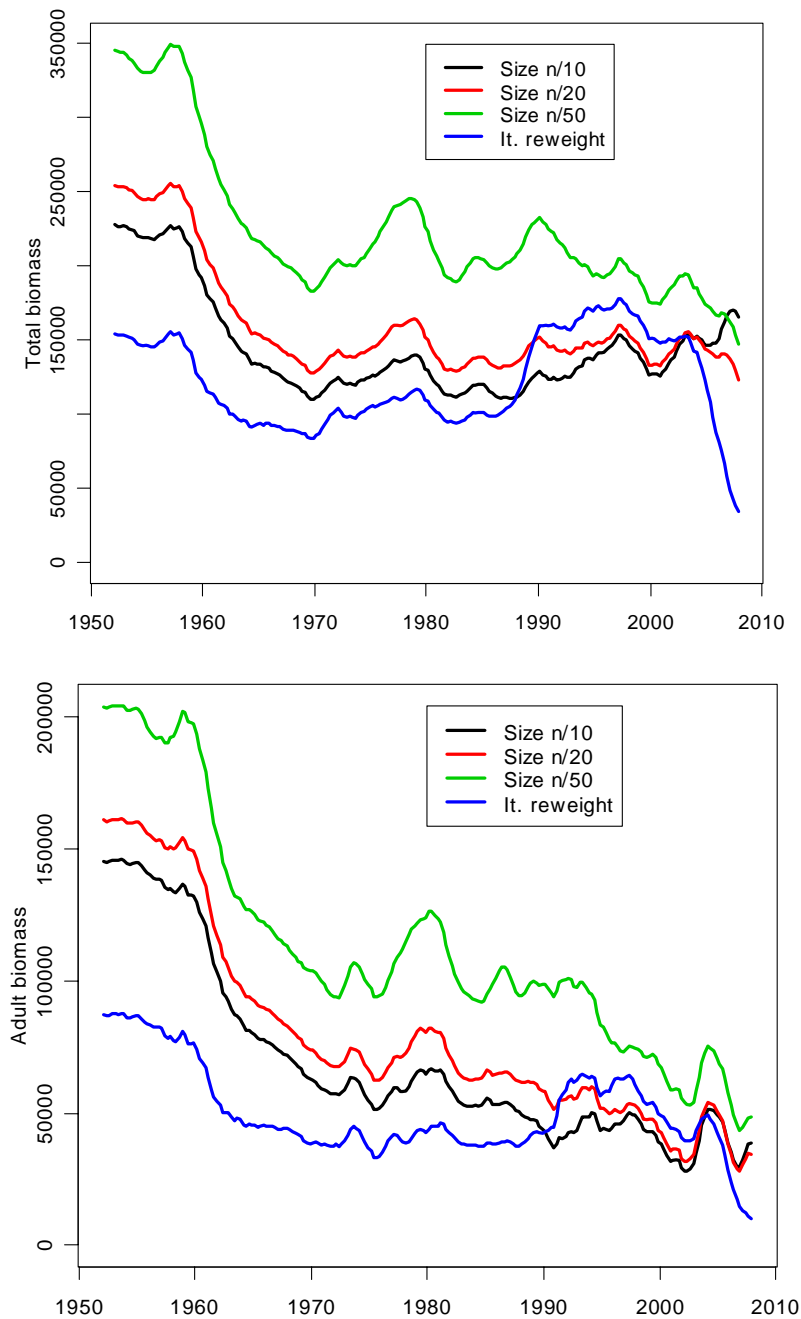
Figure 16. Trends in total (top) and adult (bottom) biomass from the region 3 bigeye model using different weightings to the size frequency data sets included in the model.

The iterative reweighting was conducted to derive a fishery-specific effective sample size rather than for individual quarterly samples. The reweighting procedure increased the weight given to the size data, especially the weight-frequency data from the longline fisheries (Table 2). For example, the weight data from fishery 1 is given an effective sample size of 98.8 (988/10) when applying the n/10 weighting scheme, whereas the iterative reweighting assigns these data an effective sample size of 494 – a five-fold increase in the effective sample size.

Table 2. Average fishery specific sample sizes for length frequency data and weight frequency data (actual, n, with a maximum of 1,000) for the fisheries included in the iterative reweighting procedure (region 3 model) and the effective sample sizes determined from the iterative reweighting.

FISHERY		ACTUAL (n) lf data	wt data	EFFECTUAL	
LL pre 1985	1	734	988	245	494
TW/CN LL	2	700	950	350	950
PNG LL	3	96	350	16	39
LL Bismarck	9	210	357	52	119
LL post 1985	11		1000		1000
PS Assoc	4	472		43	
PS Unassoc	5	137		23	

The iterative reweighting procedure resulted in lower initial biomass (total and adult) than the other weighting schemes. While early trends in relative biomass were comparable, they later deviated considerably. The iterative reweighting resulted in a strong increase in biomass in the early 1990s and a sharp decline in biomass in the last few years. The increase in biomass in the 1990s was driven by a very strong increase in recruitment at about that time – stronger than the base case model (see Figure 10). Overall, the iterative reweighting approach substantially improves the fit to the size data sets at the expense of the fit to the catch and effort data from the principal longline fisheries (pre- and post-1985) for which catchability is assumed to be temporally invariant. This is evident in the strong temporal trends in the effort deviates for these fisheries (consistently positive effort deviates before 1970 and from 1985 to 1992).

However, assuming a very high effective sample size may cause the model to rely too much on the size frequency data to provide information about changes in fishing mortality. This is particularly true if there have been significant temporal changes in the selectivity that are not explicit in the assessment model.

The workshop agreed that effective sample sizes should be considered further in the course of undertaking the 2008 stock assessment. In addition, a number of specific approaches were suggested to advance the iterative reweighting procedure. It was considered that the iterative reweighting should focus on the size data from the principal longline fisheries in each region, as these data represent the only continuous time series of size data over the model period. It was further suggested that the

reweighting should be undertaken by fishery and decade to account for potential differences in the reliability of these data among regions and over the model time period. A default option of assuming an effective sample size of n/20 for all fisheries would be used as a comparison with alternative weighting schemes.

2.6 Sensitivity analyses

The preceding sections have identified a number of sensitivity analyses to be undertaken for the 2008 bigeye stock assessment. New fisheries will be included in a step-wise manner, in order to assess the effect of each model change (Table 3). Model Run1 (Table 3) is equivalent in model structure to the 2006 bigeye stock assessment, enabling a direct comparison between the two assessments. Model Run6 will approximate the model structure used for the 2007 yellowfin tuna stock assessment.

Changes in the approach(es) used to configure longline size frequency data will also be assessed through a thorough examination of model diagnostics. Hopefully, this will identify a preferred model to serve as a "base case" and additional sensitivities will be undertaken relative to the "base case" model.

Uncertainty in catches
A range of sensitivities were identified at the workshop (Table 3). These included exploring a range of possible catches for the Indonesia and Philippines artisanal fisheries. During the workshop, Peter Williams (SPC) provided a description of how these catches were derived. It was accepted that the entire Indonesian catch history is extremely uncertain, whereas recent catch estimates from the Philippines were considered more reliable, although catches prior to 1995 remain highly uncertain. The model sensitivities will include the plausible range of catches for both the Philippines and Indonesian artisanal fisheries (with input from Peter Williams). As an aside, it was also suggested that an Information Paper be compiled describing the assumptions used to generate the Indonesian and Philippines catch histories.

Drew Wright (WCPFC Secretariat) also noted that there was a significant tuna catch by Vietnam (in adjacent waters); the tuna catch is estimated to be 30,000–40,000 mt per year total (50% LL and 50% PS) with up to 20% BET in the LL catches. This represents a substantial amount of catch that is not currently included in the model. Currently, WCPFC have no official catch statistics for Vietnam. As these become available the catch data will be incorporated into future bigeye stock assessments and assessment of other tuna species as relevant (yellowfin and skipjack).

Longline catchability increase
Previous (2005) stock assessments for bigeye tuna have undertaken sensitivity analyses that include an increase in the catchability (1% increase per year, compounded over the full history of the fishery ~ 50 years) of the principal longline fisheries. This is to account for the influence of changes in fishing efficiency, such as improvement in gear technology, that are not included within the GLM standardised CPUE analyses for these fisheries. Previous sensitivity analyses have simply assumed a 1% increase per annum in the absence of any quantitative analysis of historical changes in longline fishing efficiency.

A preliminary analysis presented at the workshop applied a 1% increase in longline catchability to the post 1985 period. The increase was applied to the latter period only

as this was the period when the Japanese longline fleet started to deploy more hooks-between-floats, presumably increasing fishing activity towards bigeye tuna (increasing HBF, etc). There was considerable debate as to what level(s) of assumed increase in catchability should be used in formulating a sensitivity analysis. In the end, it was stated that two sensitivities would be undertaken; a continuous 1% increase over the entire time period (i.e. from 1950) and a phase increase with 0.5% per annum up to 1985 and a 2% per annum increase in the subsequent period. It was noted that these were all assumed values and without justification in the scientific literature and there was debate about the timing of any major shift in targeting (1975, 1980, 1985). Ward (2008[2]) suggested an annual increase in Japanese longline catchability would be about 5%; however, most of the group considered this to be too high. It was agreed that, Peter Ward (BRS Australia), as the author of several qualitative papers on the subject, should provide some input into what values are used and provide a descriptive summary of changes in the longline fishery at SC 4.

Biological parameters
Recent bigeye assessments have incorporated a fixed, age-specific natural mortality schedule. However, the natural mortality (M) values for the youngest age classes are not based on empirical data, rather a linear decline in natural mortality for ages 1 to 5 with a relatively high value (0.2) for the first age class. The sensitivity of this assumption will be examined using a higher value of M for the first age class (0.4) and the corresponding increase in M for the 2–5 age classes. Further, the sensitivity of the model to a lower value of M for the older (12 and above) age classes will also be examined.

The spawning stock-recruitment relationship is currently derived from the entire series of recruitment and spawning biomass estimates. For recent assessments, this has resulted in a high value for the steepness parameter of the SRR (approx. 0.95). The sensitivity of the biological reference points to a more conservative value for steepness (0.75) will also be investigated.

The stock assessment model has considerable freedom to estimate movement coefficients for the transfer of fish between regions; these movement coefficients are frequently inconsistent with observed movements and/or the biology of the species. For example, the estimated high movement of fish from region 1 to region 3 is likely to be a model artefact rather than reflecting the true movement dynamics of the species. To explore the sensitivity of the model conclusions to the estimated movement parameters, a model with movement fixed at a low level (<< 1% per quarter transfer rates) will also be configured.

The movement parameters are also likely to interact strongly with the overall regional recruitment distribution and the temporally variant deviations in the regional recruitment distribution. A further sensitivity will be undertaken assuming a temporally invariant regional distribution of recruits.

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[2] Ward, P. 2008. Empirical estimates of historical variations in the catchability and fishing power of pelagic longline fishing gear. Rev. Fish. Biol Fisheries on line.

Table 3. Proposed model runs and sensitivity analyses for the 2008 bigeye stock assessment.

Run	Description	Size data configuration	Size data weighting
1	2006 model fisheries structure + additional and revised data (2 years).	As per 2006	n/20
2	As previous and *split ID and PH dom.*	As per 2006	n/20
3	As per 2. and split LL 3 (*separate PNG and remainder of LL3*).	As per 2006	n/20
4	As per 3. and *include JP coastal PL, PS and equatorial PL fisheries.*	As per 2006	n/20
5	As per 4. and *split PS associated in region 3 – anchored and log/dFAD*	As per 2006	n/20
6	As per 5 and with *change to JP LL size data compilation.*	Reweighting scheme, 70% catch threshold.	n/20, n=total measured.
7	As per 5 and with *change to JP LL size data compilation.*	Reweighting scheme, 70% catch threshold.	n/20, n=total measured of 70% qualifying cells.
8	As per 5 and *determine effective sample size for JP LL data based on representativeness of sampling.*	Reweighting scheme, 70% catch threshold.	Sample size indexed by representativeness of sampling.
9	As per 5 and use *iterative reweighting to determine effective sample size for JP LL data. Iterative reweighting by decade.*	Reweighting scheme, 70% catch threshold.	Iterative reweighting JP LL fishery/decade.
10	As per 5 and use *iterative reweighting to determine effective sample size for JP LL data. Iterative reweighting by decade.*	Reweighting scheme, 70% catch threshold.	Sample size based on index of representativeness.
	Sensitivities to be conducted on one (or more) of runs 6-10.	**Details**	
S1	Low PH domestic catch – lower bound of probable recent/historic PH catch.	To be determined – assistance from PW.	
S2	High PH domestic catch – upper bound of probable recent/historic PH catch.	To be determined – assistance from PW.	
S3	Low ID domestic catch – lower bound of probable recent/historic ID catch.	To be determined – assistance from PW.	
S4	High ID domestic catch – upper bound of probable recent/historic ID catch.	To be determined – assistance from PW.	
S5	Low ID and low PH (S1 and S3).	To be determined – assistance from PW.	
S6	High ID and high PH (S2 and S4).	To be determined – assistance from PW.	
S7a	Increasing JP LL catchability.	Increase catchability for all JP LL fisheries; 1% pa over the entire period.	
S7b	Increasing JP LL catchability.	Increase catchability for all JP LL fisheries; pre 1985 0.5% pa, post 1985 2% pa.	
S8	JP LL Selectivity pre/post 1975.	Estimate separate selectivities/catchabilities for JP LL 3 fishery pre- and post 1975. Link post 1975 q to q's from other regions.	
S9	Natural mortality – higher for young age classes.	Increase initial (age 1) M from 0.2 to 0.4, linear decline to age 5 (0.1).	
S10	Natural mortality – reduce for older age classes.	Reduce M to 0.05 for all age classes > 12 quarters.	
S11	Steepness – lower (0.75) value of steepness than estimated (0.95).		
S12	Low movement between regions.	Fix movement to be low (<<1%) between regions.	
S13	Regional recruitment deviates not estimated (i.e. zero).		

3 South Pacific albacore

3.1 Introduction

The 2005 stock assessment for south Pacific albacore (Langley and Hampton 2005) raised a number of issues about the albacore stock assessment. These issues were summarized as:

- Uncertainty regarding some key biological parameters (growth, natural mortality, maturity).
- Some issues regarding fit to catch and effort data – high effort devs to fit initial decline in TW CPUE.
- Temporal trend in the fit to the size frequency data.
- The two previous points indicate some conflict between the two main sources of data in the model.

The issue of uncertainty about key biological parameters was addressed in the 2006 update of the stock assessment (Langley and Hampton 2006). We examine the remaining issues and additional questions, and consider responses and analyses that may be carried out prior to the 2008 south Pacific albacore stock assessment.

The agenda included the following items:

i. Review of 2005 and 2006 assessments.
ii. Regional structure of model: single region vs multi region, movement dynamics (variable with size).
iii. Key issues; e.g. historical recruitment trends, trends in size composition from LL, biological parameters.
iv. Utility of data from the troll fisheries – do these data provide indicators of recruitment strength?
v. CPUE index, especially TW DWLL. Issues related to change in targeting (shift to BET). Analysis of logsheet data from Pago. Incorporate Pago-based JP, TW and KR data in a single index.
vi. Appropriate fishery structure to represent factors affecting selectivity and/or CPUE, such as seasonality.

Sensitivity analyses and model results presented in this document are mostly based on the model configuration from the 2006 stock assessment update (Langley and Hampton 2006). This is designated here as the base case run. Several examples are also taken from the 2007 comparison of modelling approaches (Hoyle and Langley 2007), which used the south Pacific albacore as an example, modified the 2006 MFCL stock assessment by removing the tagging data, and compared it with a version of the assessment using the assessment model Stock Synthesis 2 (Methot 2005).

Discussions at the informal stock assessment meeting led to a number of recommendations, and these are presented in this document together with the material on which they were based.

3.2 Spatial structure

The albacore assessment is based on a 4 area structure, with each fishery defined within a single area (Figure 17). Prior to the 2005 assessment these areas were defined as three separate regions within MFCL, with a separate recruitment estimate for each region, and movement rates estimated among regions. In the 2005 assessment the 4 areas below were modelled as separate regions in one scenario. However, the 2005 base case and the 2006 assessment modelled the population as a single homogeneous population, such that a single recruitment was estimated for the whole population, and extractions from one area affected the whole population.
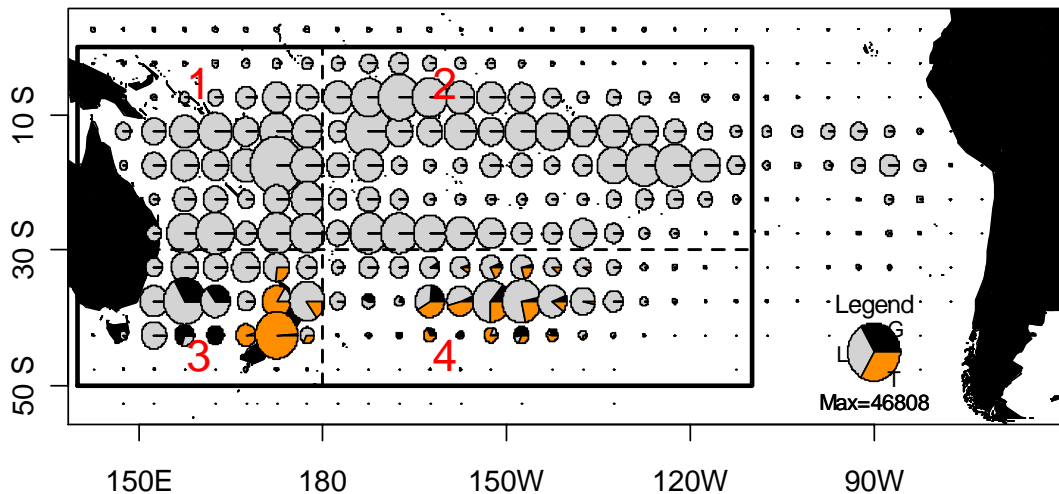

Figure 17: The spatial structure of the south Pacific albacore stock assessment, with fisheries separated into 4 areas, but the population modeled as a single unit. Key domestic fisheries are separated by the boundary at 180° west. (reference?)

Due to difficulty in estimating biologically reasonable movement parameters for the multi-region model, the single-region model will again be used as the base case run for the 2008 assessment. An albacore tagging project currently under way may provide better estimates of movement coefficients in the future. If time is available, the multi-region model will be revisited and options explored for constraining and estimating movement parameters. Movements are known to vary with age and season, but this has been difficult to parameterise; changes in MFCL coding may help to model this appropriately. Allowing for seasonally variable selectivity is a way to deal with movements in the single region model. Given the regional fishery definitions, it should not be difficult to switch back to a regionally-structured model. The workshop agreed that it would be useful revisit and explore the multi-region model, especially given the recent development of domestic fisheries and their likely expansion.

A 'gap' in the map of aggregated catches is apparent in the central eastern Pacific, in region 2. There was some discussion of whether this represents a gap in fish distribution or access. The break in distribution may be real, given similar patterns of chlorophyll distribution (Polovina *et al.* 2008). The spatial distribution of the albacore longline fishery is highly seasonal – more northward in first half of year and southern in the second half of the year. The current spatial boundary at 30 S might be moved north 5 degrees to reflect the gap in distribution. Such a change might also make fish size distributions more uniform within regions (see length frequency analysis later). However, part of the rationale for the split was that CPUE patterns north and south of

30S are different. The spatial structure of the albacore model needs further investigation.

In previous assessments, 23 fisheries have been defined by region and flag (Figure 18). CPUE series from the Taiwanese fisheries are used as the main indices of abundance in the model. Troll fisheries, with their size selection of smaller fish, may provide information on recruitment. Key Pacific Island domestic fisheries in sub-equatorial regions of the model are also defined separately.

Some catch and biomass in the eastern Pacific (east of 110 W) are not included in the model. The catches are estimated to be relatively small compared to catches and biomass from the modelled region. Also, the main fleet (Taiwanese) targeting albacore in the EPO has greatly reduced effort and catches of albacore in the EPO in recent years, possible to zero effort. In addition, the swordfish fisheries in the EPO have minimal catches of albacore as bycatch. This area could be included as a sensitivity analysis in the new assessment but the workshop agreed that this catch would be unlikely to affect the model.
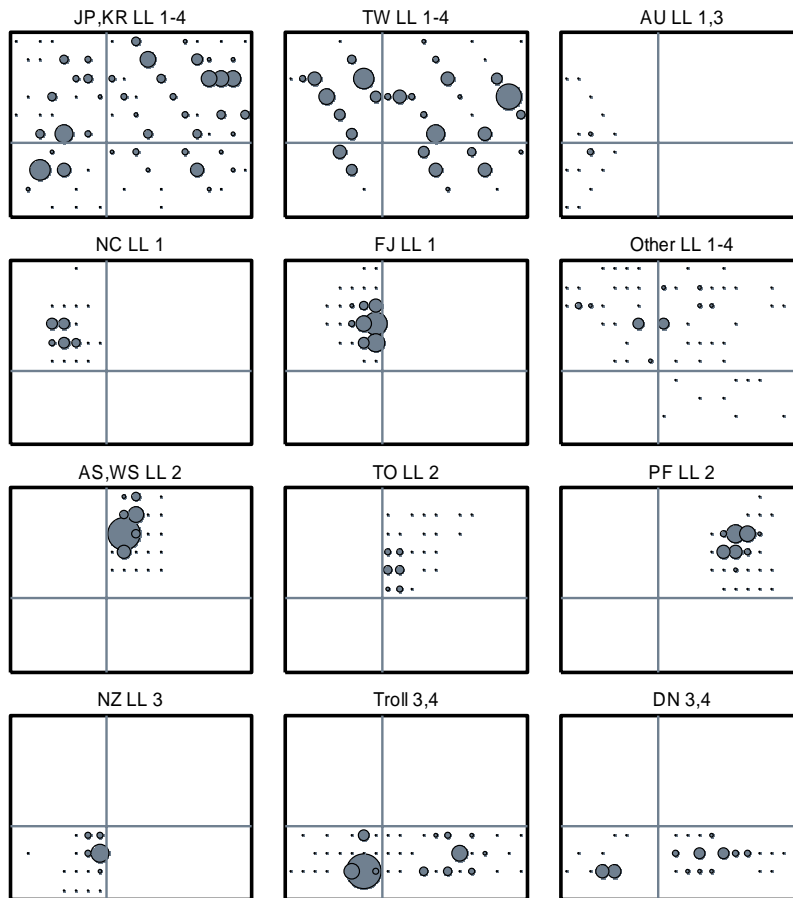

Figure 18: Stratification of fisheries in the south Pacific albacore stock assessment (Langley and Hampton 2005).

3.3 Albacore reproductive potential

Possible changes to the parameterization of albacore reproductive parameters were explored. These are described in detail in a separate paper (Hoyle in prep.). Briefly,

the meeting recommended adding new information based on sex ratio and maturity at age to the base case; investigating the length-weight relationship; and rerunning the biological sampling analyses with steepness fixed at 0.75 and 0.9.

3.4 Catchability

In the MFCL model, catchability parameters are estimated for each fishery. The Taiwanese longline fisheries are assumed to retain the same catchability through the time series, apart from seasonal offsets. This assumption provides the model with regional indices of abundance, and stabilizes the population estimates.

For other fisheries, however, temporal catchability deviates are estimated, representing variation and trends in catchability through time (e.g. see regions 1 and 2 in Figure 19). For example, the combined Japan-Korea longline fisheries show a large decline in catchability in the early part of the time series, reflecting changes in targeting from albacore to bigeye tuna.
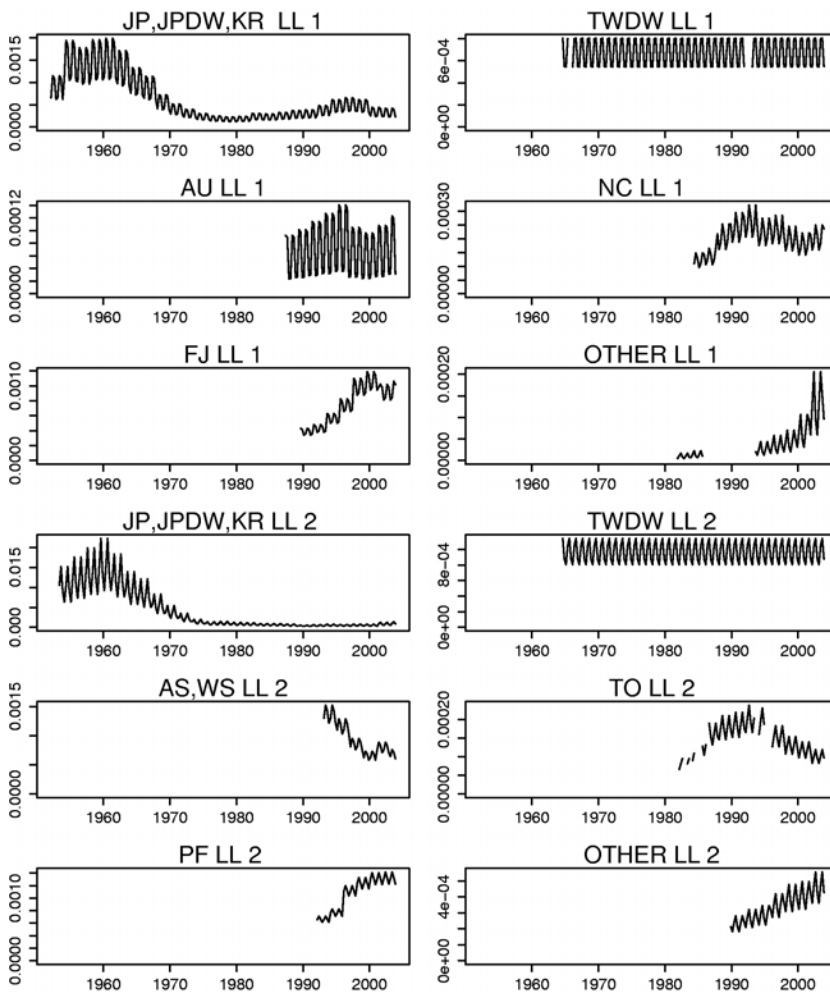

Figure 19: Catchability estimates for region 1 and 2 longline fisheries (Langley and Hampton 2005).

Strong trends are also apparent in some of the Pacific Island longline fisheries, including both increases and declines in estimated catchability. These trends may reflect either the changing performance of small, developing fleets, changes in local abundance due to local depletion or environmental effects (Langley 2006b), and/or biases in the model's estimate of abundance due to actual decline in the catchability of the Taiwanese longline fisheries.

Whatever is causing these trends, the decision about the frequency and penalty on the catchability deviates can be influential for the model outputs, including reference points. The default approach used in most MFCL assessments, and applied to all fisheries in the SP albacore assessment, is to estimate a deviate every 24 months, with a standard deviation of 0.1. When the catchability series is made more flexible, with deviates estimated quarterly and standard deviation of 0.2, the biomass trajectory changes for several periods, but particularly at the end of the time series (Figure 20). The trajectory is similarly declining but biomass is lower, and the decline is a greater proportion of the overall biomass. This change occurs because the catchability deviates penalize rapid changes in the modelled abundance. This penalty may not be, in this case, a bad thing, since the trends in abundance (and hence the catchability of other fisheries) implied by the Taiwanese time series and the length frequency data, may be unrealistic. There may be useful information in the CPUE time series of other fisheries. The problem is the arbitrariness in the selection of the frequency and penalty weights for the catchability deviates. A more appropriate approach would be to;
a) use information from each fishery to determine appropriate rates of potential change in catchability, and
b) for those fisheries where such information is not available, reduce the effort deviate penalty so that the CPUE does not influence abundance estimates.

It was recommended that catchability deviates and effort deviate penalties be reconsidered and assessed during the 2008 albacore stock assessment, through sensitivity analyses.
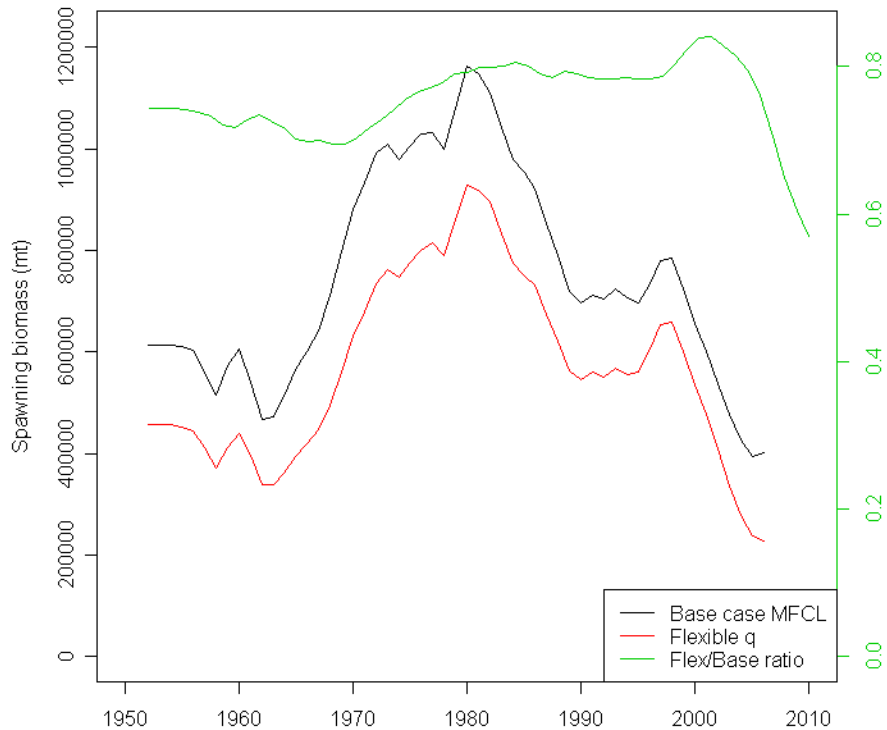
Figure 20: Comparison of spawning biomass estimates for the 2007 base case MFCL model with a model with catcbaility deviates estimated quartlery.

During discussion it was highlighted that since the last stock assessment (2006), for which the longline data ended in 2003, there has been a shift in targeting by the Taiwanese fleet towards BET and YFT (see BET section) which may not be fully reflected in the data. The new NMFS-SPC Pago-Pago data project (discussed in more detail later in this document) will help to address this issue. The current data set has limited information on changes in targeting below the regional scale.

Given the trends observed in catchability for the Pacific Island longline fisheries, a number of additional approaches to modelling their CPUE may be considered, depending on the causes of the trends, such as changes in fleet size, targeting, oceanographic conditions etc. Given a sufficiently long time series of reliable data, environmental effects such as changed availability due to SOI-correlated changes in albacore distribution may be standardized out of the abundance index. Similarly, fleet performance effects may be removed from the index of abundance if characteristics such as skipper experience, vessel size, and fishing gear and configuration (e.g. HBF) are available. However, the effects of changes in abundance due to local depletion can only be accommodated by modelling at a local spatial scale, which is probably not feasible in MFCL. Since local depletion and locally variable oceanographic impacts are believed to occur (Langley 2006a), CPUE from Pacific Island domestic longline fisheries should be used cautiously, if at all, to index the abundance of the overall population in the MFCL model.

To test the effects of the influence of the different fisheries on biomass estimates, individual CPUE series were down-weighted within the model (one at a time) in order to determine which had most influence on the overall abundance. As expected, given

the use of catchability deviates in the other fisheries, the Taiwanese time series were most influential (Figure 21).
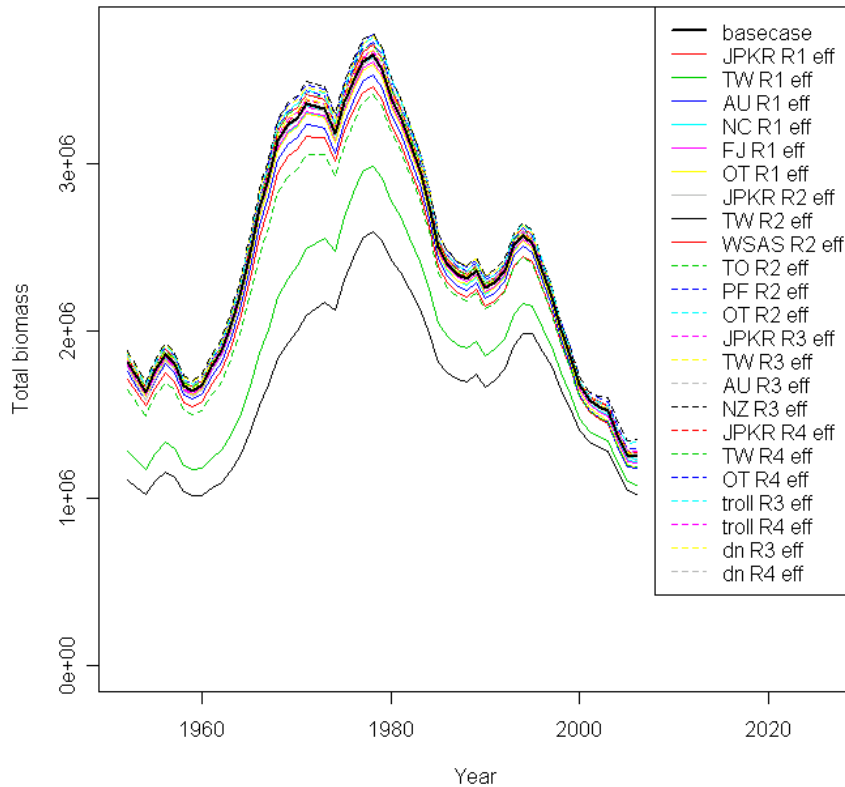
Figure 21: Comparison of the effects of CPUE time series on overall abundance and trends, by down-weighting each series in turn. By far the most influential times series in the model as currently implemented are the Taiwanese fisheries in region 2 and region 1.

3.5 Pago-Pago data

A new data set from longline vessels unloading in Pago-Pago will be analysed for inclusion in the 2008 albacore assessment. This is a large data set for Japanese, Taiwanese, and Korean vessels unloading in Pago, beginning in the 1960s. It derives from a US National Marine Fisheries Service (NMFS) Hawaii voluntary sampling programme for size and (operational level) logsheet data from these three fleets. The spatial coverage (regions 1 – 4) is good over many years, particularly in the 1960s and 1970s, with details on over 450,000 sets.

OFP has developed a joint project with NMFS to combine SPC and NMFS data into a composite database from the early 1960s until recent times. Operational-level detail may enable a better standardisation of CPUE, that may be tested in the new assessment as the index of abundance as an additional fishery. With Keith Bigelow, NMFS Hawaii, we will undertake the first analyses in April 2008. This is a major step in the ongoing development of the south Pacific albacore assessment.

3.6 Estimation of recruitment

Recruitment of albacore is thought to be variable among years due to changing oceanographic conditions, and capturing this variability will be important for the

albacore assessment. Residuals from the length frequency distribution of domestic longline fisheries suggest that some cohorts are not being detected by the model very well (Figure 22), although this may be contributed to by the cohorts not appearing in all length frequency samples. For example, residuals indicate a strong cohort appearing in the mid-late 1990's, much more strongly in the New Caledonian longline data than in the model. In discussion, it was suggested that this apparent cohort may in fact represent a trend in selectivity. There are also suggestions of the same cohort in other domestic longline fisheries in areas 1 and 2, but it is not apparent in the distant water longline fisheries.

The New Caledonia and Tonga longline fisheries have the most length frequency data for the period in question (Table 4). Data from the distant water longline fisheries for the same period are comparatively sparse and affected by lack of fit due to long term selectivity changes (Figure 32, Figure 33). The Taiwanese distant water fleets were progressively excluded from exclusive economic zones (EEZ's) in these regions during the 1980's and 1990's, limiting the areas fished.

It was suggested that checking the data of all fisheries for representativeness, as has been done with the bigeye and yellowfin longline data, would be useful.

The workshop raised the issue of the year-offset to set July as the first month in the model. Given that reproduction/recruitment occurs in July, this could make biological interpretations of parameters easier.
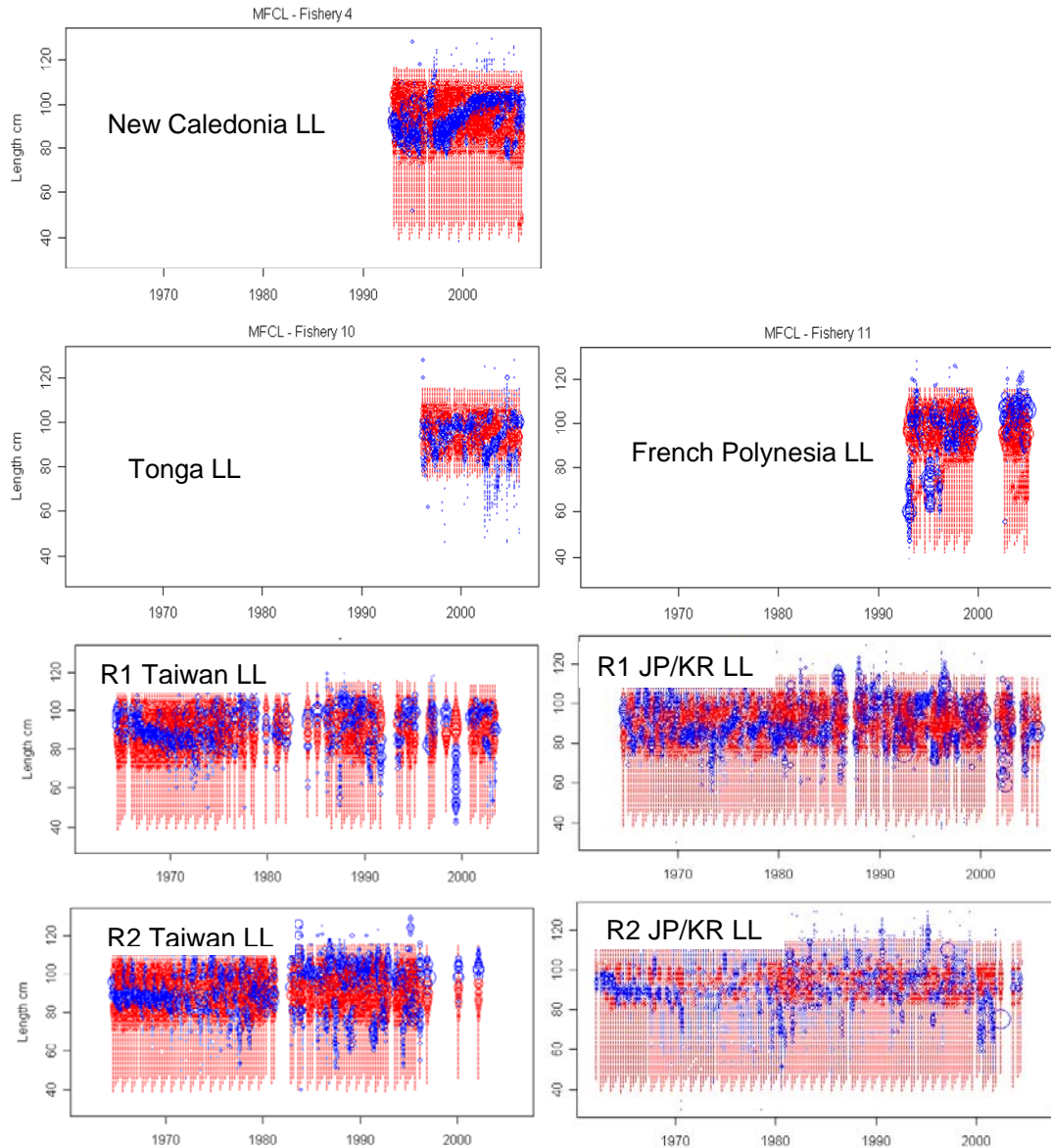
Figure 22: Residuals from length frequency distributions for the New Caledonian, Tongan, French Polynesian, Taiwanese and Japanese-Korean longline fisheries. Blue/red indicates where more/less fish were observed than predicted by the model. The domestic longline fisheries, which cover regions 1 and 2, appear to show the same strong cohort passing through the fishery (90 cm in about 1998).

Table 4: Length frequency sample sizes (max 1,000) by fishery for regions 1 and 2, 1993-2005. New Caledonia has the most consistent time series in region 1, and Tonga in region 2.

Yr.qtr	Reg 1					Reg 2					
	JP,KR	TW	NC	FJ	OT	JP,KR	TW	AS,WS	TO	PF	OT
1993.1	563	0	126	0	1000	307	0	0	0	580	0
1993.2	237	150	585	0	1000	1000	0	0	0	202	0
1993.3	1000	1000	1000	0	0	1000	400	0	1000	217	0
1993.4	952	1000	73	0	0	1000	200	0	1000	1000	0
1994.1	354	0	164	0	0	167	50	0	0	158	0
1994.2	812	147	353	0	0	1000	200	0	0	0	0
1994.3	1000	100	566	0	0	1000	200	0	0	15	0
1994.4	0	0	251	0	0	1000	50	0	0	0	0
1995.1	755	50	142	0	0	463	89	0	1000	189	15
1995.2	14	0	715	595	0	1000	50	0	1000	0	0
1995.3	1000	0	762	172	0	1000	50	0	1000	238	0
1995.4	707	0	752	213	0	1000	0	0	1000	706	0
1996.1	1000	0	22	0	0	144	99	0	145	1000	0
1996.2	81	0	0	202	191	1000	0	0	180	1000	0
1996.3	1000	731	1000	416	23	1000	0	0	142	1000	7
1996.4	7	1000	1000	0	0	38	50	0	316	1000	0
1997.1	0	918	1000	27	208	2	0	0	187	610	0
1997.2	293	0	1000	94	1	1000	0	0	335	243	8
1997.3	1000	0	1000	255	44	191	0	0	798	358	54
1997.4	0	0	1000	86	144	112	0	0	1000	1000	0
1998.1	463	0	1000	0	90	617	0	18	627	143	0
1998.2	1000	80	1000	103	1000	1000	0	0	1000	84	13
1998.3	219	0	1000	0	1000	1000	0	0	538	59	1
1998.4	17	0	1000	0	0	1000	0	0	1000	85	1
1999.1	31	0	1000	48	32	312	0	0	0	48	263
1999.2	1000	200	1000	34	53	1000	0	46	535	51	165
1999.3	50	0	1000	64	2	310	0	0	925	0	176
1999.4	60	0	1000	436	371	0	0	0	1000	0	1
2000.1	925	0	1000	0	0	148	150	0	294	0	0
2000.2	42	0	1000	0	543	86	0	0	1000	0	0
2000.3	0	0	1000	0	505	388	0	476	1000	0	0
2000.4	0	285	1000	0	240	175	0	440	1000	0	0
2001.1	0	196	1000	0	0	107	0	1000	1000	0	0
2001.2	0	50	1000	0	217	271	0	1000	936	0	0
2001.3	38	0	1000	0	1000	1000	0	1000	162	0	150
2001.4	0	170	1000	0	34	1000	0	1000	3	0	1
2002.1	27	1000	1000	0	1000	0	345	1000	1000	0	75
2002.2	5	1000	1000	80	1000	1	0	1000	1000	0	463
2002.3	67	1000	1000	693	1000	0	0	1000	1000	100	1000
2002.4	48	936	1000	326	1000	0	0	1000	1000	1000	1000
2003.1	967	1000	1000	1000	1000	0	0	1000	1000	1000	1000
2003.2	0	550	1000	529	855	0	0	1000	1000	1000	1000
2003.3	0	0	1000	1000	1000	150	0	1000	1000	251	1000
2003.4	0	0	481	1000	1000	0	0	1000	677	891	1000
2004.1	381	0	1000	1000	1000	139	0	892	382	619	1000
2004.2	246	0	1000	1000	1000	272	0	1000	1000	261	1000
2004.3	378	0	1000	1000	1000	0	0	1000	1000	654	1000
2004.4	0	0	1000	1000	1000	0	0	664	1000	213	1000
2005.1	350	0	1000	1000	398	0	0	212	391	0	1000
2005.2	0	0	1000	1000	1000	0	0	1000	1000	0	1000
2005.3	344	0	1000	1000	1000	0	0	1000	1000	0	1000
2005.4	0	0	1000	1000	1000	0	0	0	1000	0	449

Data from troll fisheries can be useful for estimating recruitment, since the troll fisheries target small albacore from a limited range of sizes (mainly 50-80 cm) and age classes (mainly 2–3 year olds). These age classes have more distinct size ranges than the larger, older fish selected by the longline fisheries, as they are growing much faster. Length frequency modes of small fish can therefore be picked up more easily than those of larger fish.

It may be possible to improve the way the current version of the model treats data from troll fisheries, in order to obtain better estimates of recruitment. The current implementation of the model estimates catchability deviates, which permits catchability to change progressively. Forcing catchability to be constant resulted in recruitments that were scaled-down ('fix troll q' in Figure 23), and recruitment estimates were relatively lower early in the time series and higher later (Figure 24). Removing the catchability deviates resulted in the trend in the troll exploitable biomass being more closely aligned to this CPUE series.

Whether fixing catchability is appropriate depends on the true extent of systematic variation in troll fishery catchability. Standardization can be used to remove some trends from catch rate data, and a standardized time series is available for the New Zealand troll fishery (Unwin *et al.* 2005) for the period 1993–2004. These standardized data could be trialled in the model in place of the unstandardized data. Standardization has adjusted the time effects, but does not appear to indicate a significant trend in fishing power over this time period in the troll fisheries.
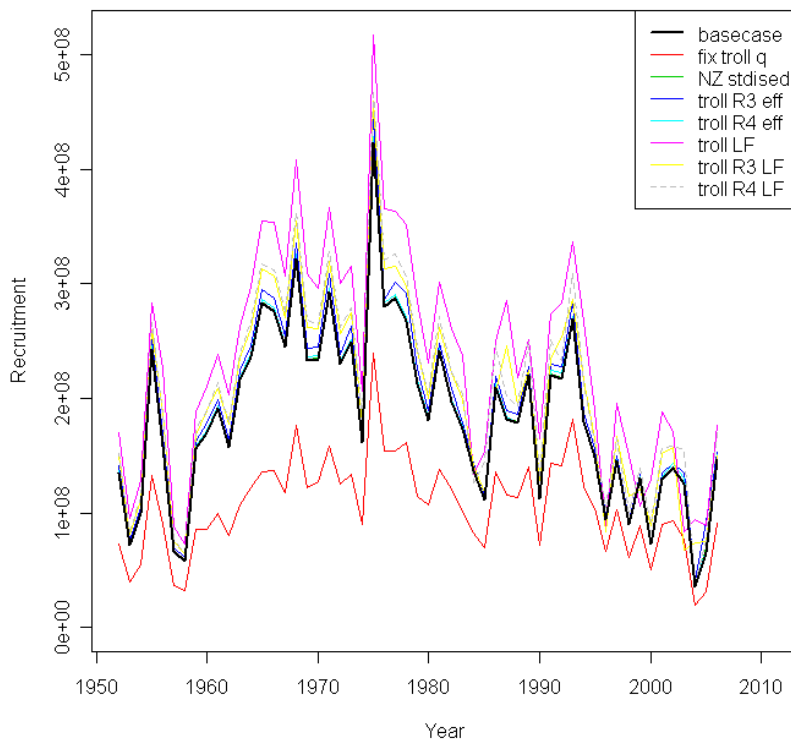

Figure 23: Estimates of annual recruitment under alternative scenarios relating to troll fishery data.

Recruitment strength also varied among years (Figure 24). These differences suggest that the troll CPUE data contain information about the relative level of recruitment among years, that is removed by using biennial catchability deviates.

Using the standardized New Zealand data would require splitting the fishery into two, pre and post 1993 as no standardized indices are available prior to 1993. In addition, effort data for the New Zealand fishery are unavailable before 1982. Splitting the fishery in both 1982 and 1993 would permit the 1982 to 1992 effort series to be used to index abundance, with no catchability deviates estimated.

However, there was some concern that, since the New Zealand troll data are localised, local availability may drive the CPUE as much as or more than true abundance. This would tend to blur any recruitment signal in the data.
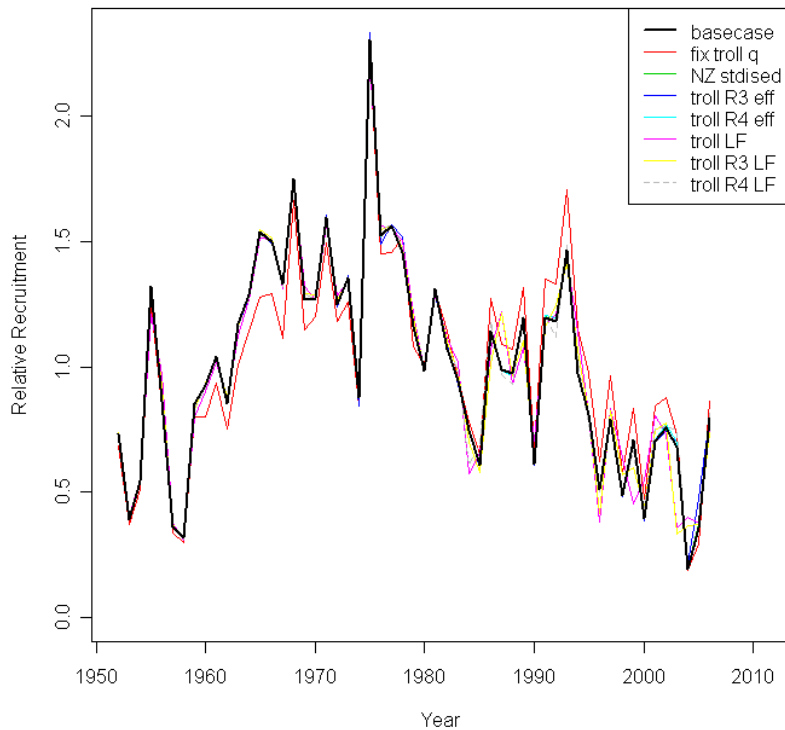
Figure 24: Estimates of relative recruitment by year under alternative scenarios relatng to troll fishery data

The troll fishery is relatively size selective, catching a narrow size and age ranges of albacore. As discussed in the 2007 comparison of MFCL and SS2 (Hoyle and Langley 2007), there is an interaction between the size selectivity of the fishery, estimates of growth rate and the variation of length at age, and the use of age-based selectivity by MFCL (Figure 25). Age-based selectivity is restricted by the distribution of lengths in the selected age classes. Size-based selectivity may be able to match the observed length range more precisely, if selectivity is truly a size-based process. This will be particularly true at the tails of the distribution, where modelled length-at-age may cut across actual selectivity at length. However, there may be a component of age-selectivity in albacore troll fisheries, given that the fisheries target the particular time-area where the fish are present. Thus 'selectivity' is strongly affected by fish behaviour and availability. Both age-based nor size-based selectivity show some lack of fit, with possibly worse fit at the tails for the age-based option (Figure 26).
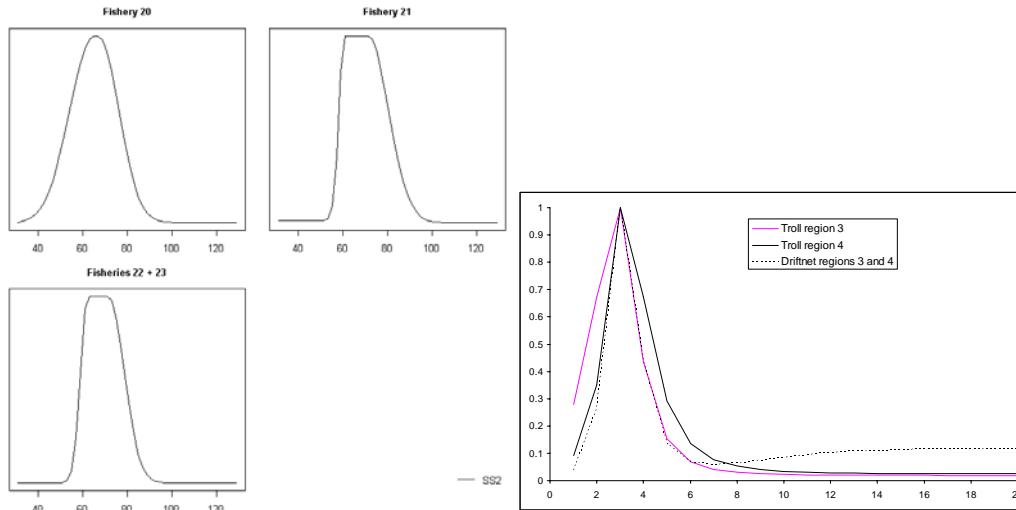
Figure 25: Selectivity at length for SS2 (left) and selectivity at age from MFCL (right) for fisheries 20 (region 3 troll), 21 (region 4 troll), and 21 and 22 (driftnet).
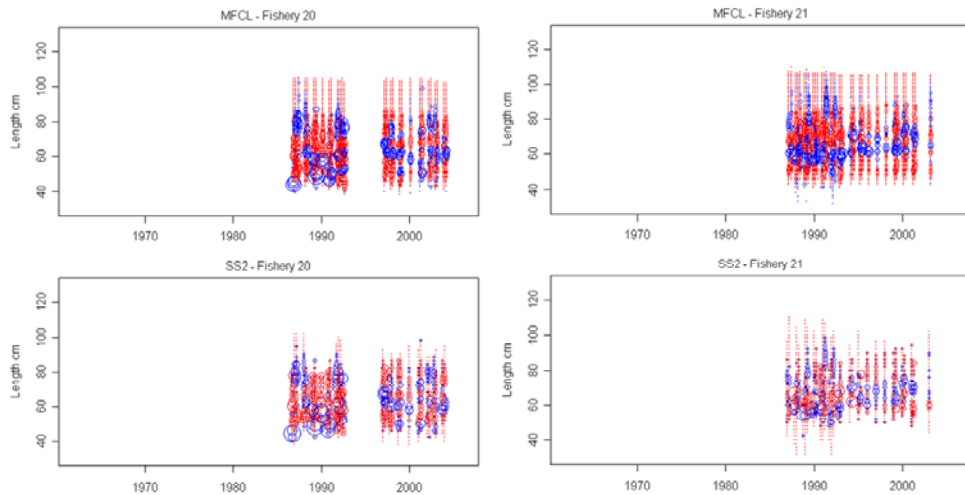
Figure 26: Residuals for the fit to troll length frequency data from region 1 (fishery 20) and region 2 (fishery 21) from MFCL (above) and SS2 (below).
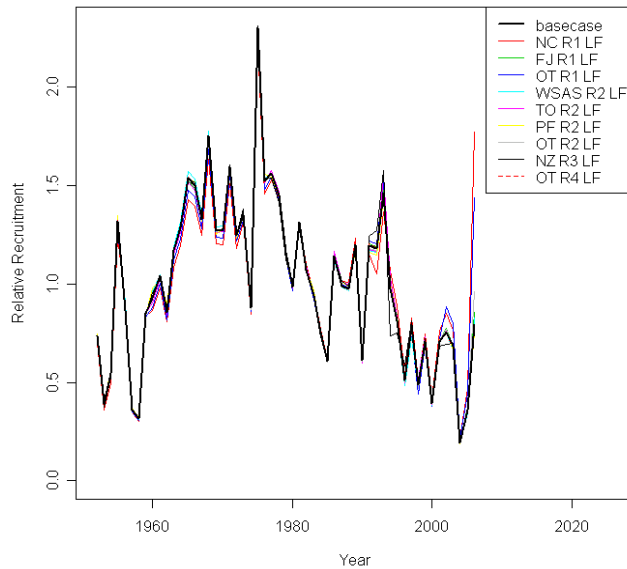
3.7 Longline length frequency data

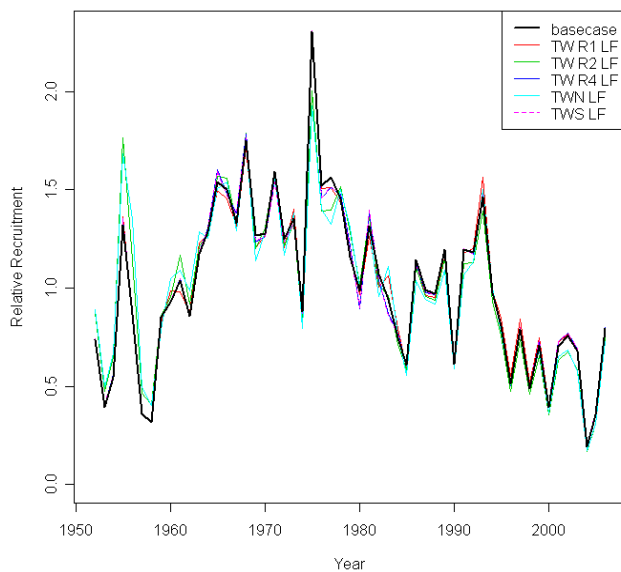Length-frequency data from longline fisheries affects the timing of recruitments and also drives biomass trends.

The effect of longline length frequency data on relative recruitment was examined by removing the influence of each fishery's data-set in turn. The domestic fishery length frequency data have relatively little effect on relative recruitments for most of the time series (Figure 27). This is largely because their length frequency data time series are short. However, data from the domestic fisheries dominates in the most recent periods (since 1990?) and has a strong effect on recruitment estimates for the last 1-2 years. In the last year of the model the Japanese-Korean longline fishery contributes only a small amount of length-frequency data in region 1, with the remainder coming from the New Caledonian, Fijian and Other in region 1, and Samoan, Tongan, and Other in

region 2. This is likely due to the exclusion of the Japanese-Korean fleets from many EEZs in regions 1 and 2, with relatively small areas of international waters available to these fleets in these regions.
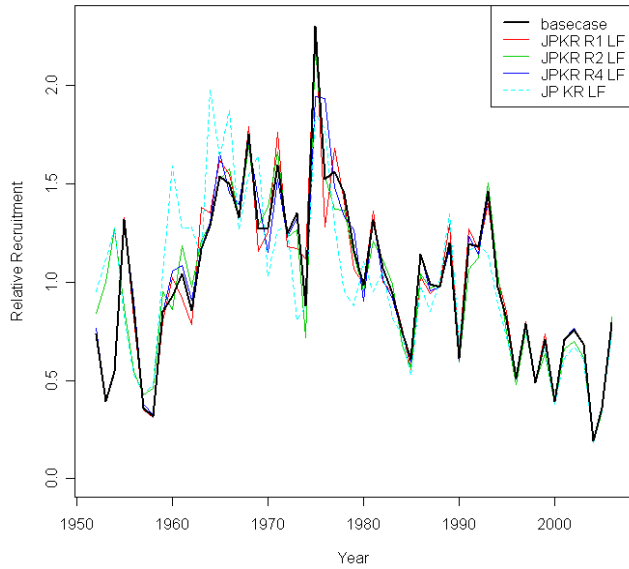
The Taiwanese length frequency time series also have small effects on relative recruitment (Figure 28). Length frequency data from region 2 reduce recruitment early in the time series and increase it towards the end of the time series. The Japanese-Korean length frequency data have more influence on relative recruitment (Figure 29), mainly in the early period modelled.

Figure 27: Relative recruitment estimates after down-weighting the length frequency time series from each domestic longline fishery in turn.

Figure 28: Relative recruitment estimates after down-weighting the length frequency time series from each Taiwanese longline fishery in turn.

Figure 29: Relative recruitment estimates after down-weighting the length frequency time series from each Japanese-Korean longline fishery in turn.

The absolute level of biomass is most strongly affected by the length frequency data from the Taiwanese longline fishery in region 2, without which overall biomass is estimated to be considerably higher. Data from the Taiwanese longline fishery in region 1 have a similar level of influence to the Japanese Korean longline fisheries in regions 1 and 2.

JP-KR   TW
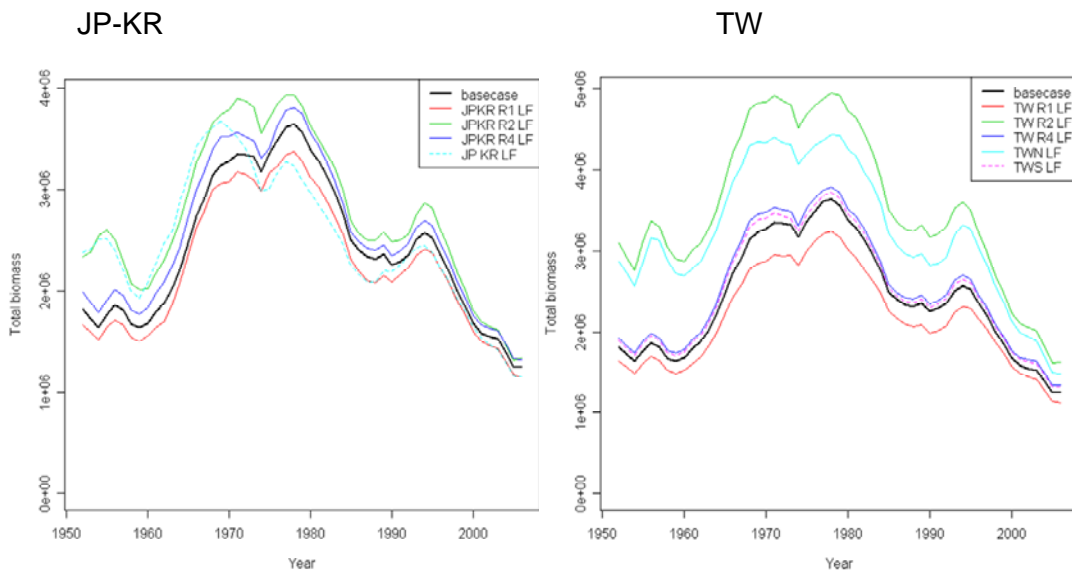
Figure 30: Total biomass estimates after down-weighting of length frequency data from Japanese-Korean fisheries (left) and Taiwanese fisheries (right). The Taiwanese fisheries have more effect on total biomass estimates than other fisheries in the albacore model.

Trends and patterns are apparent in the residuals from the Taiwanese and Japanese-Korean longline length frequency data. The trends suggest that long term changes in selectivity may have occurred in the fisheries as they are currently defined. The patterns suggest that there are problems with the data or with the model, and reflect conflict in the model between the information in the length frequency data and the CPUE data.

Systematic trends in fish size through time are apparent in the region 2 and 4 data for the Taiwanese and Japanese-Korean longline fisheries (Figure 31). Seasonal patterns (Figure 32) are also apparent in many of the length frequency time series.

Strong patterns are apparent in the residuals from the Taiwanese longline fishery, with considerably more variability and more outliers after 1970. These patterns are accompanied by changes in the sample size, suggesting a possible lack of representativeness in the later period (Figure 33). The workshop agreed that it would be helpful to remove samples not representative of catch, and reweight, using the process already applied to yellowfin and bigeye length frequency data. Iterative re-weighting may also be applied.
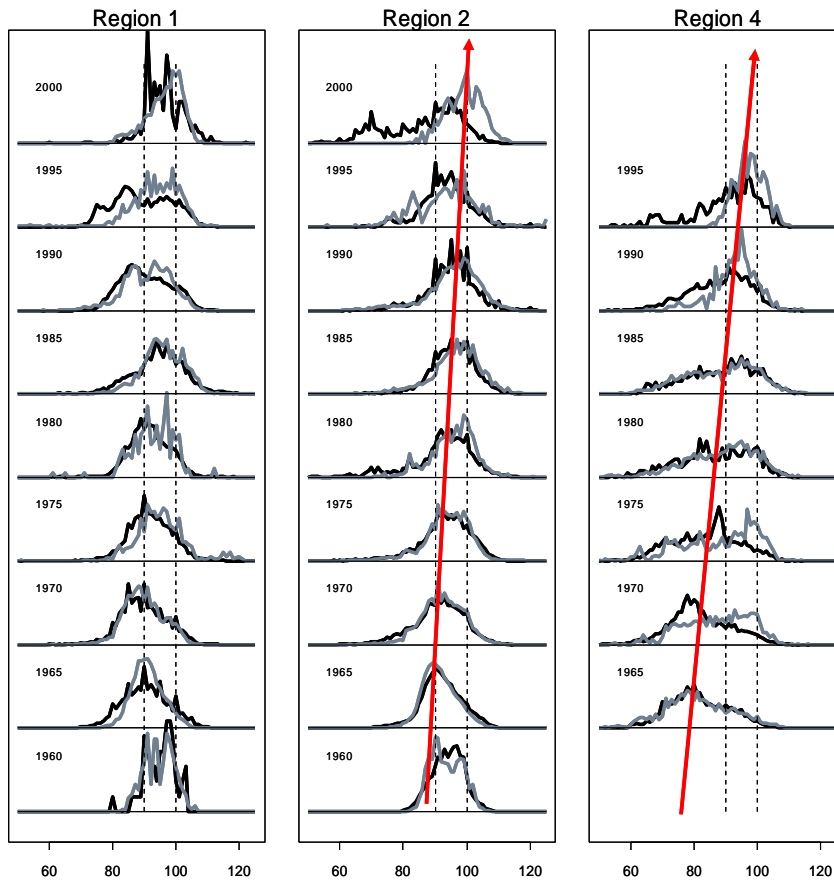
Figure 31: Trends in median length frequency for Taiwanese (grey) and Japanese-Korean (black) longline data from regions 2 and 4.
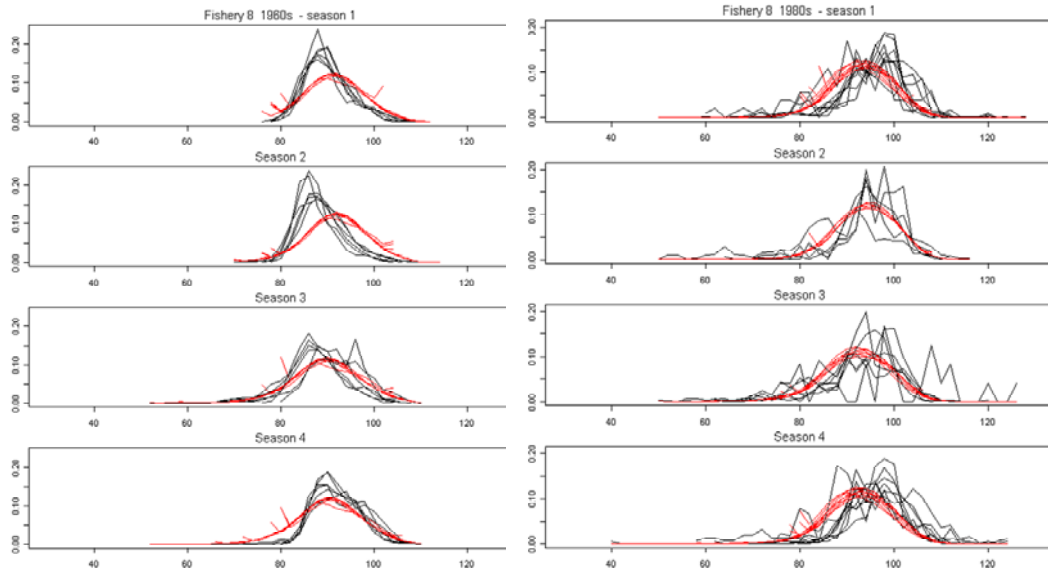
Figure 32: Seasonal and long term changes in selectivity for the Taiwanese longline fishery in region 2. Seasonal changes are apparent in the 1960's data, with the modal length considerably smaller in seasons 1 and 2 than in seasons 3 and 4. Long term changes between the 1960's and the 1980's, towards larger fish in the catch, are most apparent for seasons 1 and 2, but also occur for seasons 3 and 4.
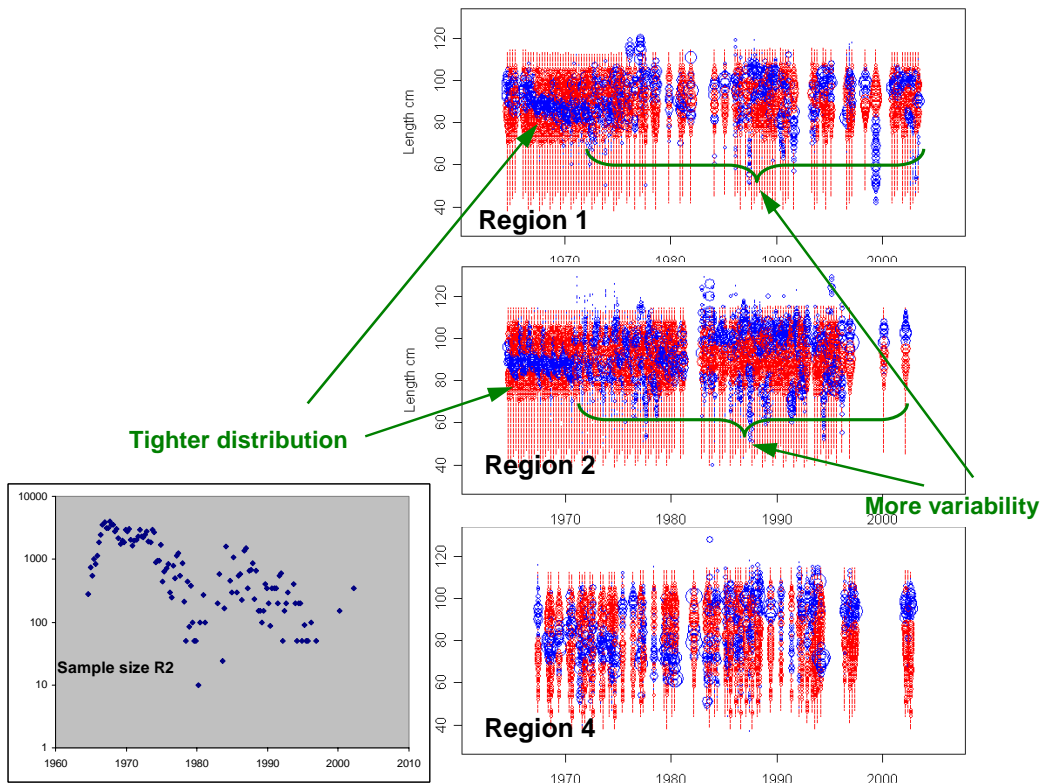

Figure 33: Patterns in length frequency residuals through time for the Taiwanese longline fishery in regions 1, 2, and 4 (right), and log sample size through time (left).

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Patterns in the albacore length frequency data for all flags were examined more closely by analyzing the albacore length frequency data held by SPC with a generalized linear model, for each area separately. The stratified length frequency data are modelled with length as the dependent variable, weighted by frequency. Residuals were assumed to be normally distributed.

$$length_{y,m,lat,long} \sim f(year, month, latitude, longitude, flag)$$

This approach permits the contribution of each effect to be investigated separately.

There was significant monthly variation in average length, with longer fish caught in summer than in winter (Figure 34). This supported the earlier observation that selectivity varies seasonally, and indicated that the variation is not accounted for by other factors such as vessels varying their fishing location. The workshop agreed that taking seasonal selectivity into account would improve the model. This could be done by splitting the existing longline fisheries into 2 or 4 seasons.
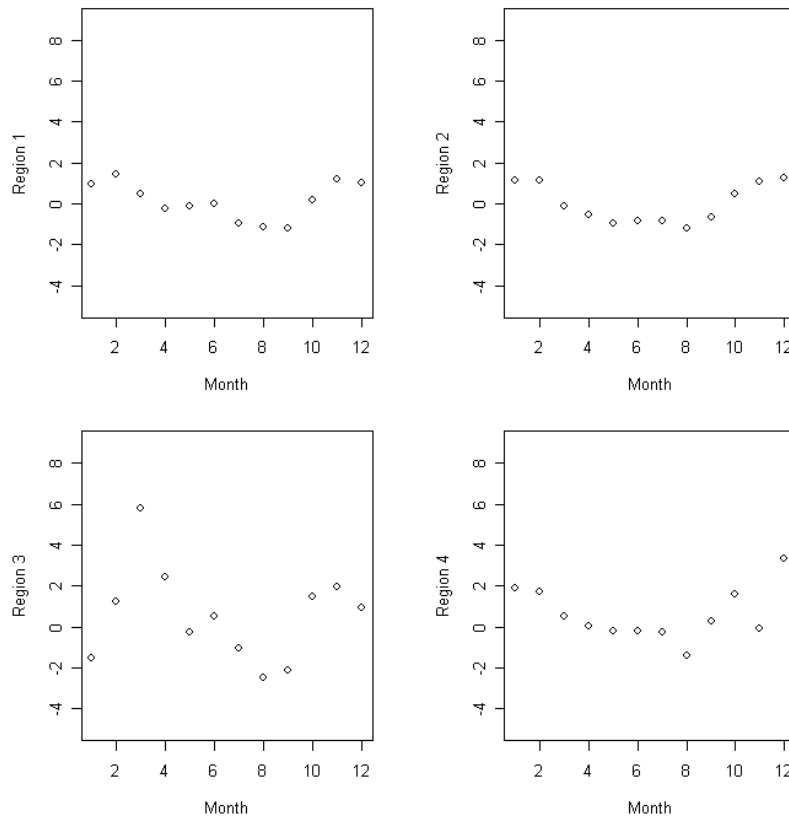
Figure 34: Expected length by season and region, as estimated with a generalized linear model taking into account flag, year, latitude, and longitude. The y-axis indicates relative change in fish length.

Variation by latitude was also apparent (latitudes and longitudes are reported here as the bottom left-hand corner of the five-degree square. In both regions 1 and 2, fish from between 25 and 30 degrees south latitude were smaller than those from further north (Figure 35). This may be related to the gap in catch distribution observed north of 25 degrees latitude (Figure 17). Moving the regional boundary north to 25 degrees

may improve the model by making selectivity more consistent within each region. However, it may cause some domestic fisheries to be split. The workshop agreed that the costs and benefits of this approach should be investigated.
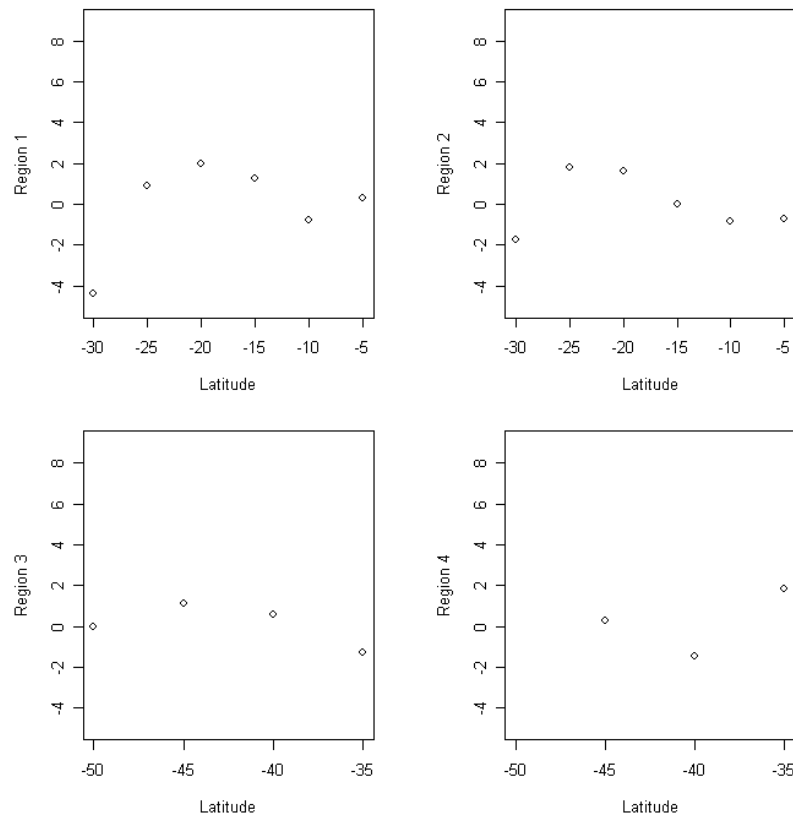
Figure 35: Expected length by latitude and region, as estimated with a generalized linear model taking into account flag, season, year, and longitude.

Results of the glm also indicted strong variation of length with longitude in the southern regions (Figure 36). Fish size increased further to the east. A trend of this type may be difficult to deal with. One approach would be to split the southern fisheries from north to south, at 155 degrees for region 3 and 210 degrees for region 4, resulting in a six-area model.

It was suggested that there may be some aliasing between year and areas, due to access arrangements and other issues. Additional glm analyses should therefore investigate interactions of year, season, and fleet with observed trends.
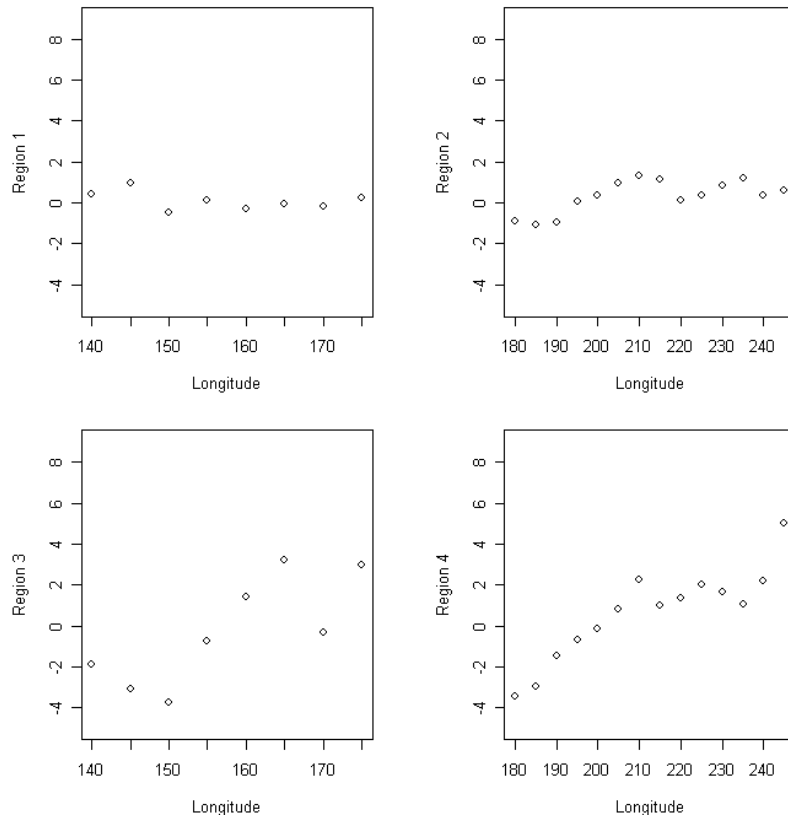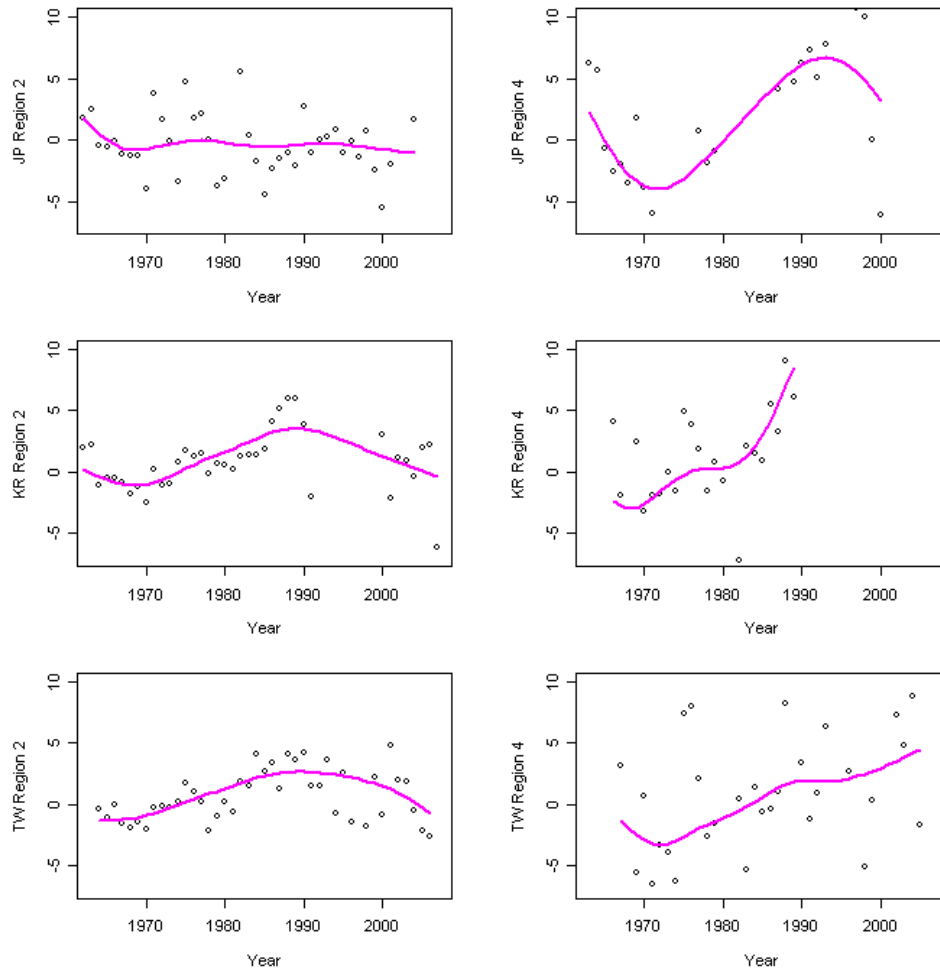
Figure 36: Expected length by longitude and region, as estimated with a generalized linear model taking into account flag, season, year, and latitude.

The model was run separately by region for each of the three main longline flags, Taiwan, Japan, and Korea. After taking into account variation in length associated with season, latitude, and longitude, trends in the year effects remain for some fisheries (Figure 37).

Year effect trends that are consistent among flags may be more likely to represent real trends in fish size (and therefore population size structure) than trends that differ among flags. However, some fishing practice-based effects on the size of fish captured may be shared among fleets, such as technology changes, and discarding and targeting driven by market demand.

Variation in year effect was compared between flags by region (Figure 38). In region 1, trends in Korean and Japanese sizes were similar until 1990 when variability increased. Taiwanese size trends were slightly more variable than other fleets but generally comparable. In region 2, Taiwanese and Korean sizes were remarkably similar until the late 1980's. Japanese data were also very similar until 1970 when they became more variable. This may reflect an earlier switch by the Japanese fleet to targeting bigeye tuna. In regions 3 and 4, average sizes increased from 1970 to 1990 for all three fleets, more strongly than in the northern regions.

Some of the trends in catch will have been caused by differing operational characteristics between the fleets. Combining the length frequency data with the Pago-Pago operational-level data may suggest ways to pool the length frequency data according to operational characteristics, into one or more fisheries.

Figure 37: Expected length by year and region, as estimated with a generalized linear model taking into account flag, season, latitude, and longitude.

Possible reasons for the observed long term selectivity changes were discussed, such as in regions 3 and 4, where much larger fish have been recorded more recently by the Taiwanese fleet. Fishing practices have changed, including the introduction of monofilament line. Pacific Island fleets have used monofilament gear throughout the data series. Depth of fishing (HBF) has changed for the key Asian fleets. Areas of fishing have changed due to exclusion of some fleets from some EEZ's in region 2, so that fleets may be fishing further south in region 2. It would be useful to examine trends in fishing location at the 5 degree or finer scale.

Another factor was suggested as possibly contributing to size changes in the fishery through time. Density-dependent growth, which was modelled in early versions of MFCL, may be resulting in larger fish in recent times due to reduced recruitment.

The influence of the contrasting selectivity apparent in the Taiwanese length frequency data could be examined by removing the early size data.
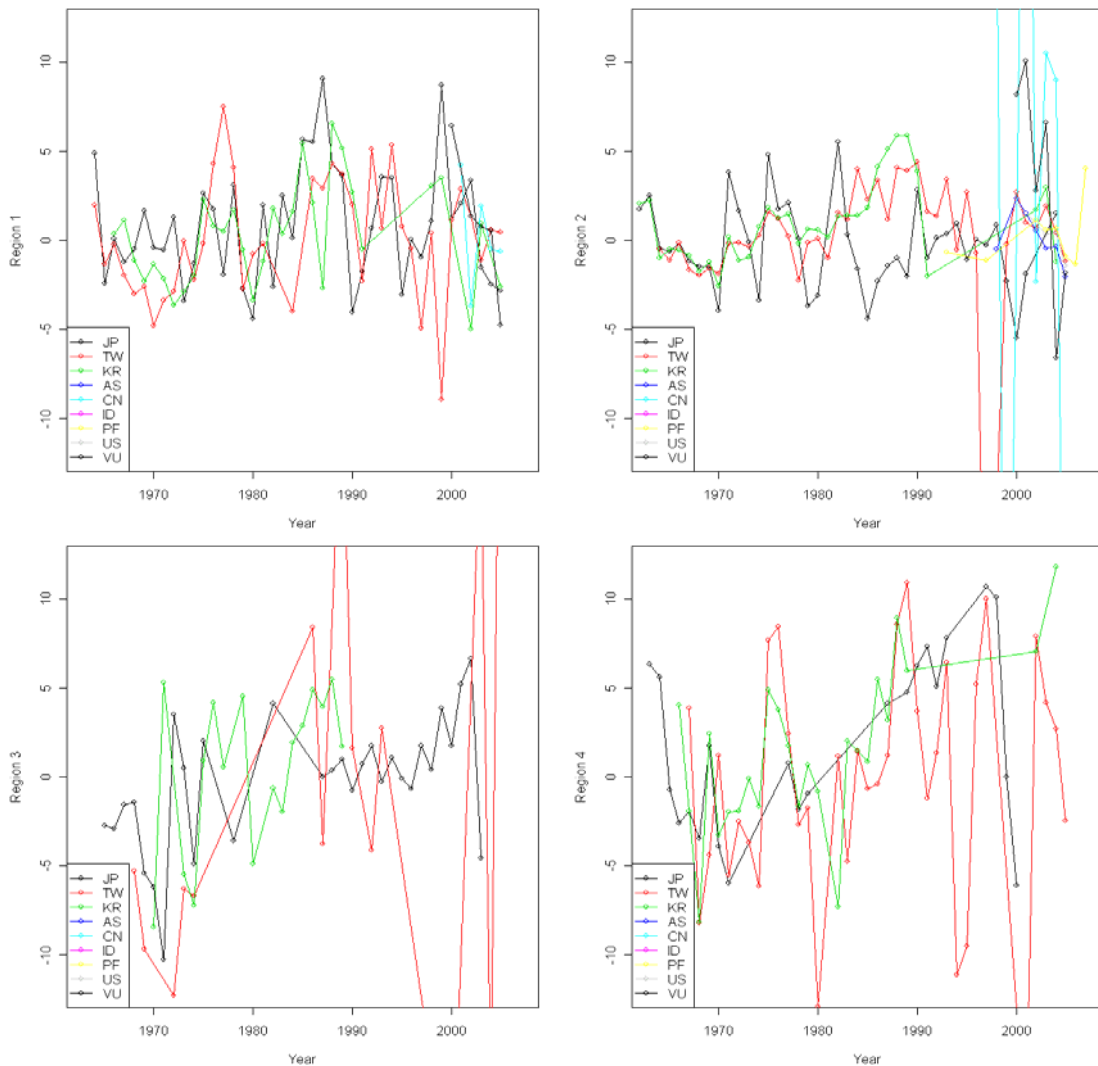
Figure 38: Year effects on observed fish length by flag for regions 1 to 4, indicating the degree of similarity in the length trends by flag.

The workshop agreed that iterative reweighting would be useful to balance the information in the length frequency data series appropriately.

The workshop agreed that it may be helpful to permit selectivity to decrease with age in some longline fisheries. Currently all selectivities are asymptotic. Migration between regions would result in some regions having lower availability of large fish – this could be accommodated through declines in selectivity at older ages.

3.8 Catch per unit effort data

The Taiwanese CPUE data are used as the principal indices of abundance. However, there are some serious problems with lack of fit at the start of the time series and at the end. The observed CPUE trends show an initial increase until about 1970, followed by general declining trend until the late 1990's, when the decline steepened (Figure 39). The most recent decline is thought to be due to a change in targeting

behaviour toward bigeye tuna. However, the observed trend in the CPUE data is quite different from the estimated total biomass trend (Figure 40). This difference is reflected in the systematic lack of fit indicated by the effort deviates (Figure 41).
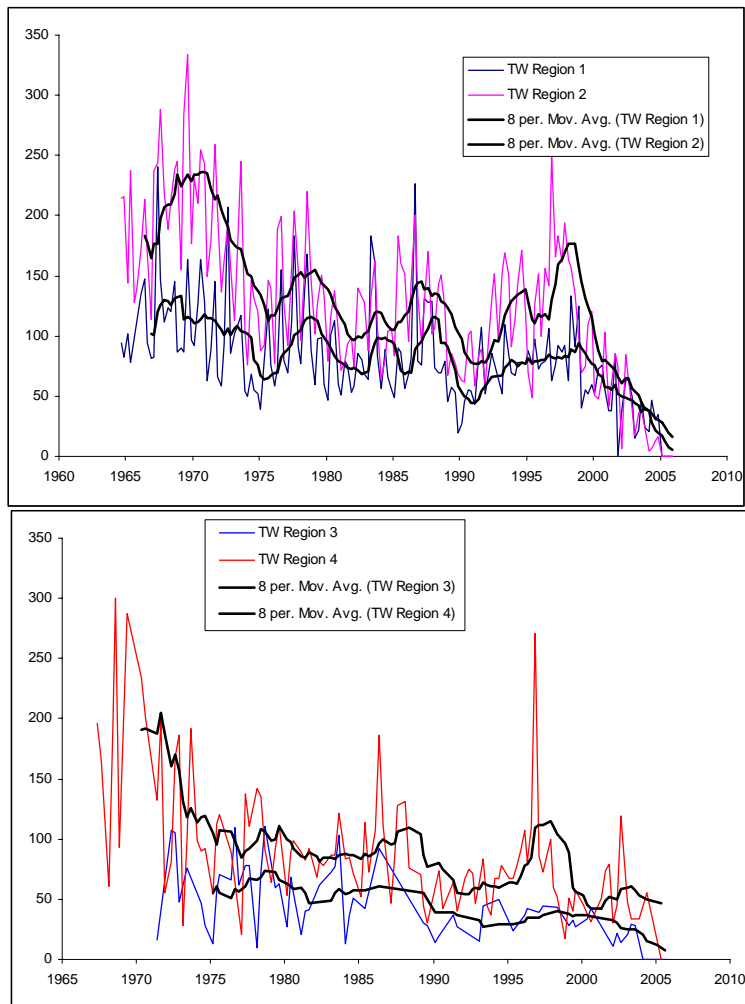

Figure 39: CPUE data for the northern (top) and southern (bottom) Taiwanese longline fisheries. The black lines giving the overall trend are 8 quarter (2 year) moving averages.

There was a general discussion of the conflict between the CPUE and length frequency data. Lack of fit to the strong decline in Taiwanese CPUE in 1960s and 70s resulting in strongly positive effort deviates, must be due to a strong contrary signal that causes MFCL to start biomass at a low level. Both the Japanese-Korean and Taiwanese length frequency data series are likely to contribute. One possible solution would be to fix the early effort deviates (using a high penalty weight) for one series at a time and see where the lack of fit occurs in the length frequency data. It may be necessary to remove some of the length frequency data. It is suspected that this may reduce the large increases in biomass estimated by the model between 1960 and 1980.
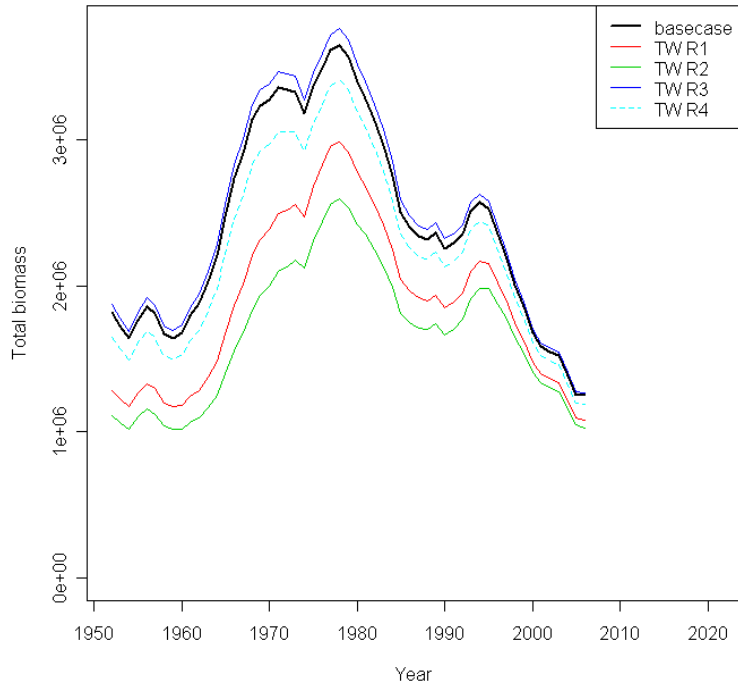
Figure 40: Estimated biomass trend for the base case run, and for scenarios in which the CPUE data from each of the regional Taiwanese longline fisheries is down-weighted in turn.
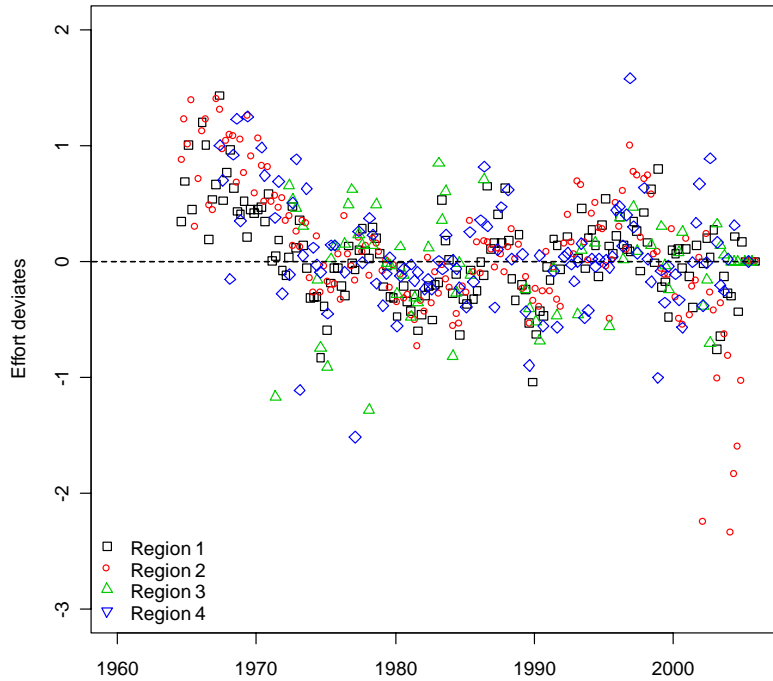
Figure 41: Estimated effort deviates from the four regional Taiwanese longline fisheries, indicating a systematic lack of fit at the start and at the end of the time series.

Changes in targeting may have affected both CPUE and selectivity, such as in the 1970s when Japan shifted from targeting yellowfin to bigeye. Taiwan have switched to targeting bigeye in the Pacific in recent years, as supported by changes in species composition data. Similarly, in the Indian Ocean, Taiwan switched from targeting

albacore to bigeye and yellowfin in the 1990's. The issue of cause and effect was raised: did Taiwan shift to bigeye due to albacore CPUE declining, or did the albacore CPUE decline as the Taiwan fleet switched to bigeye? Contrasting signals in other albacore fisheries are not consistent with the Taiwan CPUE trend, supporting the latter explanation. In any case, a shift in targeting will cause a relative decline in CPUE beyond what may have been seen otherwise. Including bigeye catch as a explanatory variable in a GLM standardisation model helps to account for shifts in targeting and flattens the decline in CPUE, but this approach is potentially misleading and not recommended (Hoyle *et al.* 2007).

The assumption of constant catchability in the Taiwanese data series was discussed. Assuming an increase in catchability comparable to that assumed in sensitivity analyses for bigeye (1% per year) may affect the large 'hump' of biomass in the 1960s/70s, although it is likely to also increase the conflict between the two data series. Standardising the Taiwanese CPUE data, given the Pago-Pago data series, may also improve the fit. The current data series is not standardised due to lack of information on gear configuration. In the Pago-Pago data, vessel names and registration details may be traced to permit a complete time series for index of abundance at a fine scale.

It was suggested that data issues such as gear configuration could be raised once more with commission members. One spin-off of the Pago-Pago project is that it will demonstrate the value of operational data.

A number of approaches will be considered for dealing with the lack of fit to the CPUE data. It is hoped that the early conflict will be resolved by cleaning and reweighting the length frequency data. However, the post-1995 conflict is likely to be due to a change of targeting. Options discussed at the meeting include splitting the Taiwanese fisheries in 1995, and analysis of the Pago-Pago data in order to understand and remove trends due to targeting. Both will be considered for the 2008 albacore assessment?

3.9 Summary of tasks

The following list of tasks was drawn from the preceding discussions and presented to the workshop. Priorities were allocated according to likely importance for improving the assessment

	Tasks	Status	Priority
1	Add sex ratio and maturity info to base case	base case	
2	Investigate length-weight relationship	data analysis / base case	
3	Rerun biological sampling analyses with steepness fixed at 0.75 and 0.9	sensitivity analysis	
4	Loosen catchability deviates on domestic longline fisheries	base case	
5	NZ troll - use standardized data, split fishery 1982, 1993; remove deviates post 1982 or 1993	sensitivity analysis	
6	Apply size-based selectivity to small fish (using SS2 instead of MFCL)	sensitivity analysis	
7	Down-weight early LL LF from all DW fleets, in several time scenarios	sensitivity analysis	
8	Apply criteria to check for representative length frequency samples in all DW LL, including trends in distribution of fishing effort / sampling	data analyses / MFCL runs	High
9	Split LL fisheries by season	base case	
10	Examine consequences of moving N/S division north 5 degrees	sensitivity analysis / base case	
11	Examine correlation between year and longitude effects in GLM on size	data analysis	
12	Consider splitting southern LL fisheries at longitudes 160 and 210	data analyses / MFCL runs / base case	
13	Standardize Pago-Pago data	data analysis	High
14	Examine feasibility of pooling DW fisheries, using Pago-Pago CPUE	data analyses / MFCL runs / base case	High
15	Reconsider long term trends in size given Pago-Pago information on fishing practices	data analyses / MFCL runs / base case	
16	Permit selectivity to decrease with age in some longline fisheries	sensitivity analysis / base case	
17	Iterative re-weighting to determine effective sample size for LF and CPUE data	sensitivity analysis / base case	
18	Explore multi-region model	MFCL runs	
19	Reconfigure year to June-July, so that recruitment can occur by default in month 1.	base case	

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4 Skipjack tuna

The last stock assessment for WCPO skipjack tuna was conducted in 2005. Key observations from that assessment were presented to the workshop. The main points highlighted were:

- The continued increase in the total catch of skipjack, principally by the purse-seine fishery.
- The regional structure of the WCPO model with two equatorial regions and four northern regions; the western (region 5) and eastern (region 6) equatorial accounting for 61% and 29% of the total WCPO catch and most of the remainder of the catch taken in two small regions off coastal Japan (Figure 42).
- The principal index of stock abundance in each region is the standardized CPUE index for the Japanese distant-water pole-and-line fleet (DWPL). These standardized indices are provided by scientists from the Skipjack tuna and Albacore section of the Japanese National Research Institute of Far Seas Fisheries. These indices are used to compute a standardized effort series in the assessment model with a temporally invariant catchability (shared between regions).
- The DWPL indices for the two equatorial regions are very similar and both reveal a strong increase (approx. 100%) in CPUE over the model period (1972–2005) (Figure 43).
- A good time series of length frequency data is available for most fisheries. Model diagnostics indicate a reasonable fit to these data by fishery/time period.
- A significant amount of tag release/recovery data are incorporated in the model; in the equatorial region tag data from the SPC programmes in 1977–1980 and 1989–1992 are incorporated in the model, while tag data from Japanese releases (1988–2005) are included for the four northern regions. For key fisheries, some information is available to inform the model regarding tag reporting rates.
- Natural mortality is estimated in the model.
- Regional weighting factors for the individual regions in the 2005 model were 0.22, 0.56, 1.00, 1.06, 1.42, and 1.75 for regions 1–6, respectively. These weighting factors contribute to the relatively high biomass apportioned to regions 4 and 6, at least relative to the level of catch from these regions.

Some of these observations were examined in further detail in preparation for the workshop. The preliminary analyses principally focused on the two equatorial regions within the WCPO using an assessment model formulated to include only those two regions (Figure 42), while maintaining the same fishery definitions as employed in the 2005 assessment. Preliminary runs using the two region equatorial model revealed that the model estimates of regional biomass from the model were very similar to the corresponding trends in biomass from the WCPO model (regions 5 and 6). Consequently, conclusions from the analyses undertaken using the equatorial model are likely to be equally relevant to the full WCPO model.
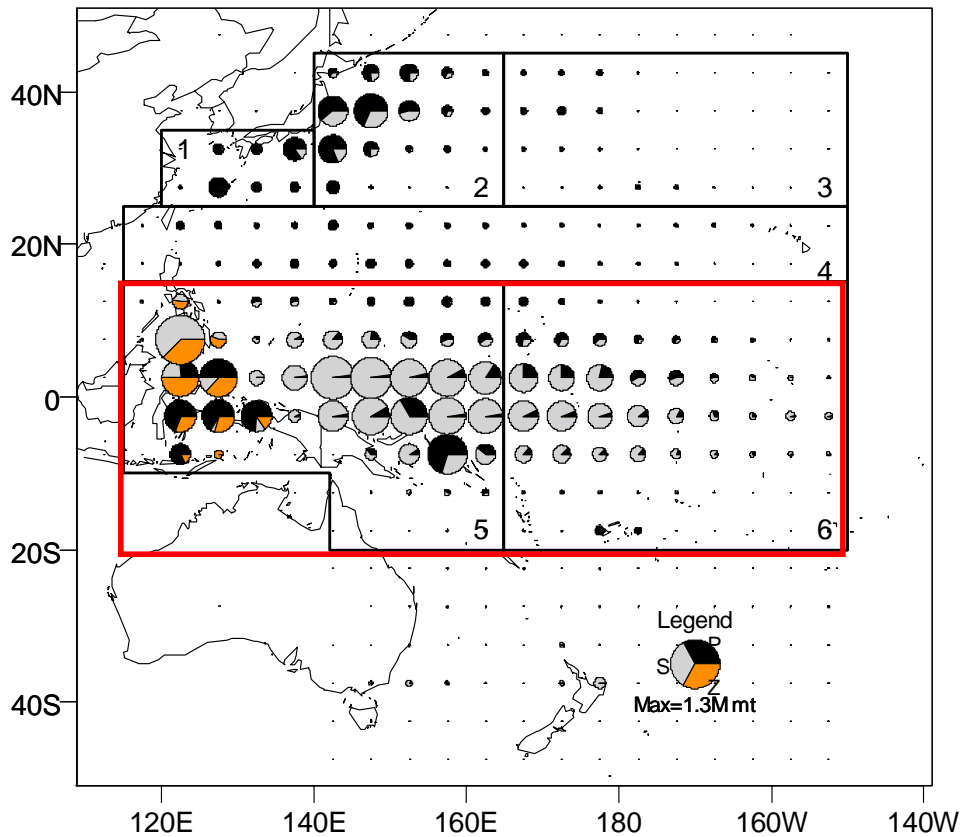
Figure 42. The six region model structure of the WCPO skipjack model with the red box encompassing the two regions included in the equatorial model.

4.1 DWPL CPUE indices

As noted, the region specific standardised CPUE indices provide the primary indices of abundance within the WCPO assessment model. Hiroshi Shono provided a summary of how these indices are calculated. A single model is computed for the entire WCPO with year, quarter and region included as factors in the model in addition to a range of variables that account for different modes of fishing operation (for example, albacore catch) and fishing technology (bird radar, sonar, SST forecast maps, and low temperature live bait tank). In addition, the model also includes numerous interaction terms. Vessel size and sub-regional spatial effects are not included. The region-specific year/quarter indices are computed from the relevant year, quarter, region*year and region*quarter terms.

The analysis has been routinely updated since it was first conducted in 1999. The current time-series of standardised indices are virtually identical for the two equatorial regions (Figure 43) and very similar to the trends in nominal CPUE (catch per day) in both regions (Figure 44).
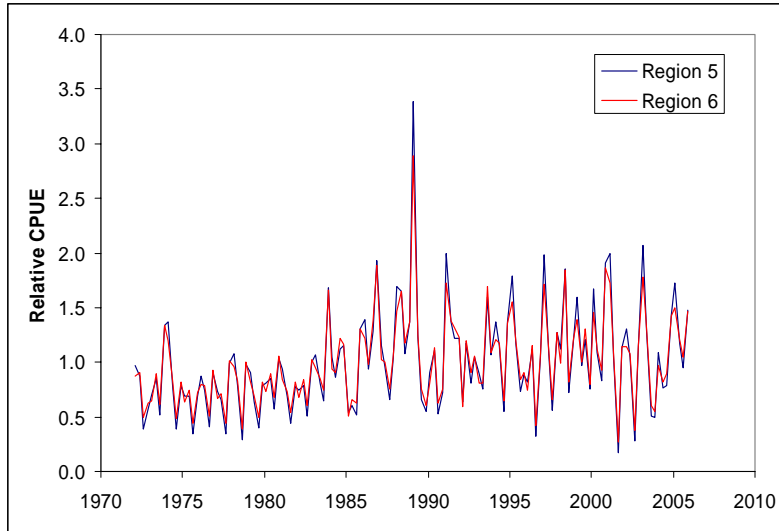
Figure 43. Standardised quarterly CPUE indices for the Japanese distant-water pole-and-line fleet in the two equatorial regions (5 and 6).
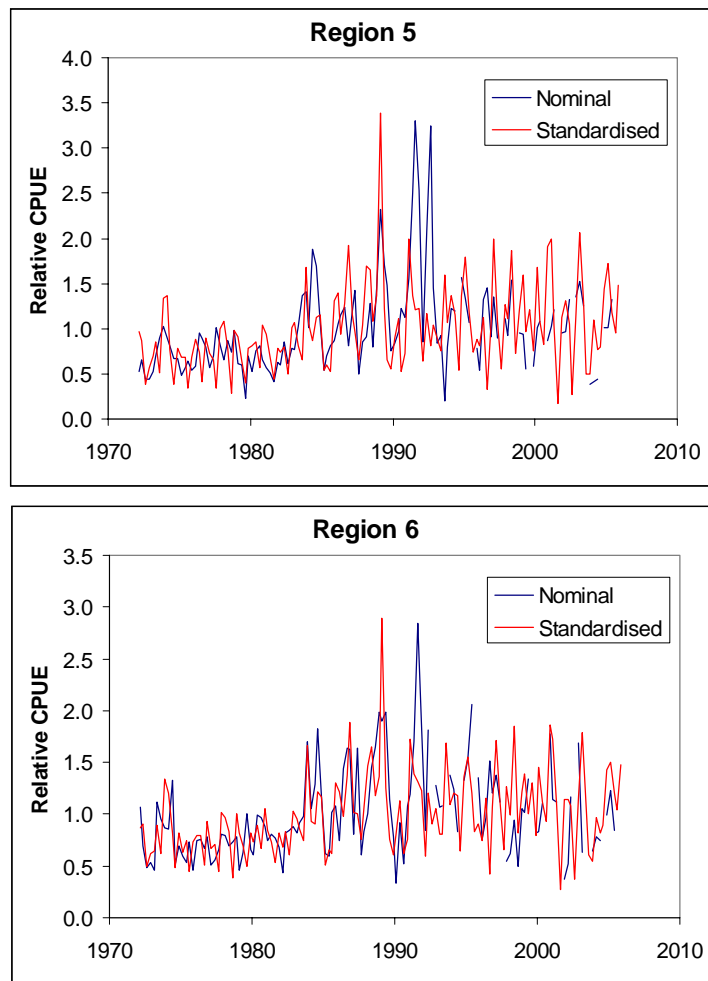
Figure 44. A comparison between nominal (catch/day) and standardised quarterly CPUE indices for the Japanese distant-water pole-and-line fleet in the two equatorial regions (5 and 6).

This result differs from earlier versions of the CPUE analyses (e.g. SCTB 12 1999 paper) which revealed significantly different trends in the standardised CPUE indices between the two equatorial regions. Differences between these regions seem likely given oceanographic influences such as the southern oscillation. The trends in the nominal and standardised CPUE indices were also significantly different in the earlier analysis conducted by NRIFSF; the standardised indices revealed a steady decline from the mid 1980s to the late 1990s. The changes in the indices with the inclusion of the subsequent years' data in the CPUE model need to be fully examined.

The large increase in CPUE during the mid 1980s may be attributable to a significant increase in the fishing efficiency of the pole-and-line fleet that is not accounted for in the CPUE standardisation. To investigate this hypothesis, the DWPL fishery within each region (of the two region equatorial model) was split into two separate fisheries in the model: pre- and post 1985. The model was then run with the freedom to estimate catchability independently for the two periods. The model estimated slightly lower catchabilities for the earlier period, but the change resulted in only a slight change in the biomass trajectory for both regions.

4.2 DWPL catchability increase

As noted, the catchability for the DWPL fisheries is assumed to be constant throughout the model period; i.e., the standardised CPUE indices derived for the DWPL fisheries are included in the model as an index of stock abundance. While the standardised CPUE analysis incorporated a range of factors that may account for changes in fishing efficiency of the fleet (e.g. bird radar, SST information and refrigerated live-bait tanks), it is plausible that some of the large increase in DWPL CPUE evident in the equatorial regions is explainable by increases in fishing efficiency that are not accounted for in the CPUE standardisation.

The sensitivity of the (two region, equatorial) model to the assumption of non increasing catchability for the DWPL fisheries was investigated by imposing a constant increase in the standardised effort series for these fisheries while maintaining the constant catchability. Three levels of quarterly increase were examined: 0.25%, 0.5%, and an extreme case of 1% per quarter (i.e. 4% per year, compounding). Increased fishing power resulted in a diminution of the increase in total biomass (and recruitment) between 1972 and 1990 (Figure 45), while the trends in relative biomass were comparable during the subsequent period.
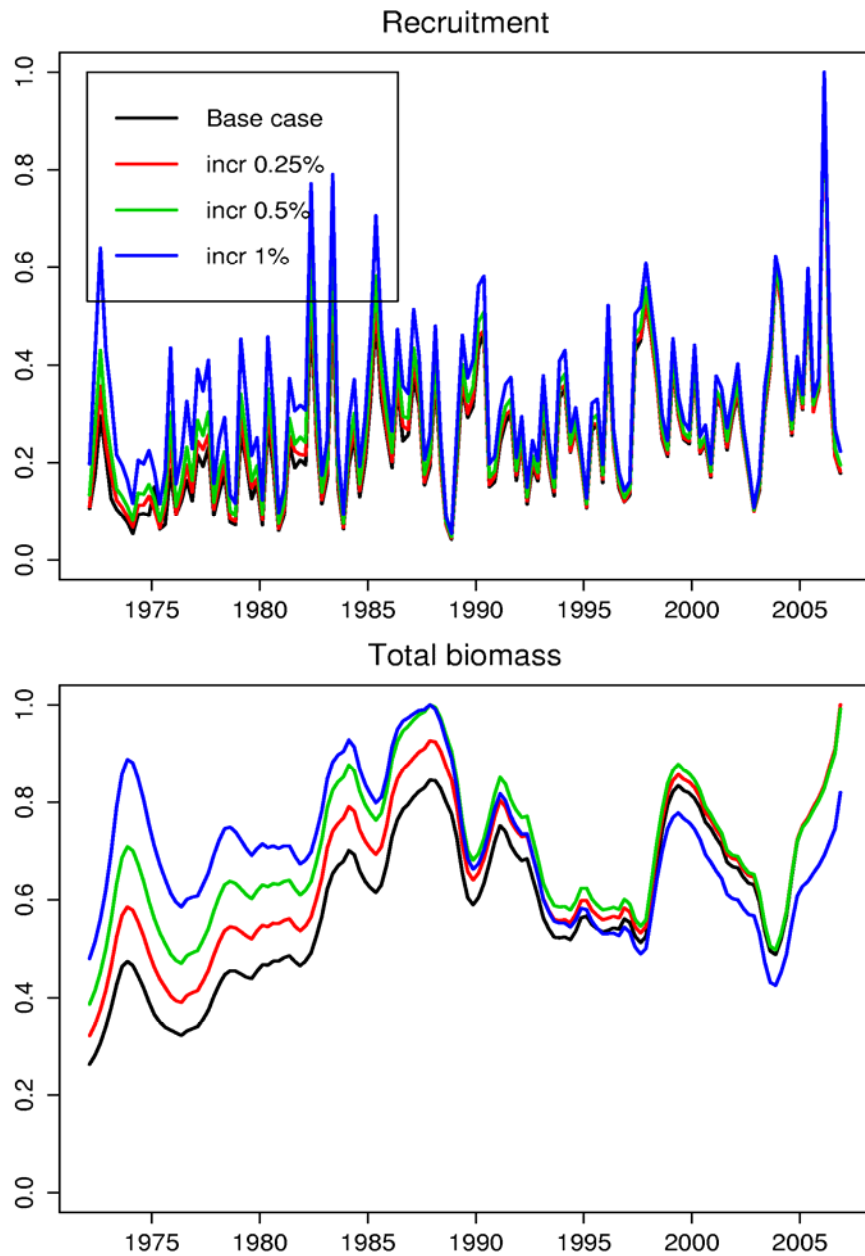
Figure 45. Relative trends in recruitment (top) and total biomass (bottom) for the two region, equatorial model with different assumed levels of catchability increase for the DWPL fisheries.

An examination of the likelihood from the four model runs revealed comparable values for the base case and the scenario with a 0.25% increase in fishing power, while the model fits deteriorated considerably with any further assumed increase in fishing power (Figure 46). Based on this criterion alone, it would appear that a 0.25% increase in fishing power per quarter (i.e. 1% per year) was a plausible alternative to the base case (no increase) and should be considered as a sensitivity analysis in the 2008 skipjack assessment.
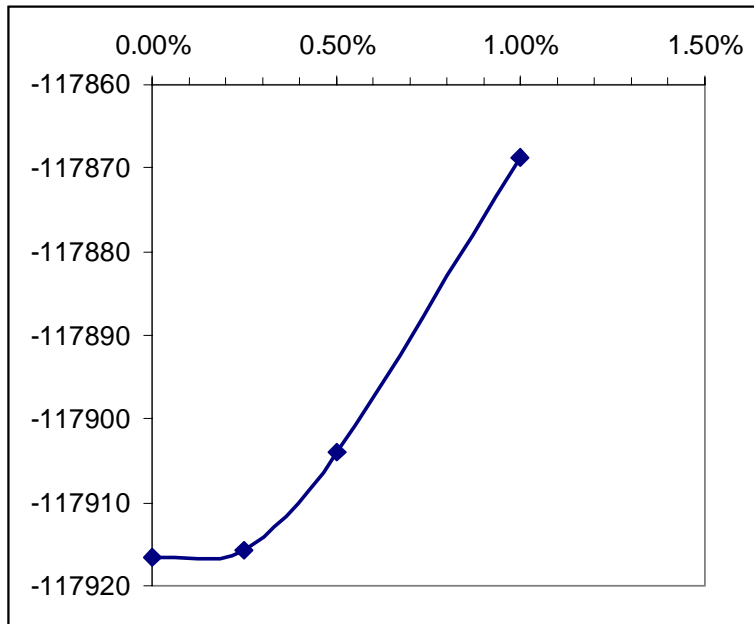
Figure 46. Values of negative log likelihood (y-axis) for the alternative fishing power scenarios (x-axis: base case 0%, 0.25%, 0.5%, and 1% per quarter).
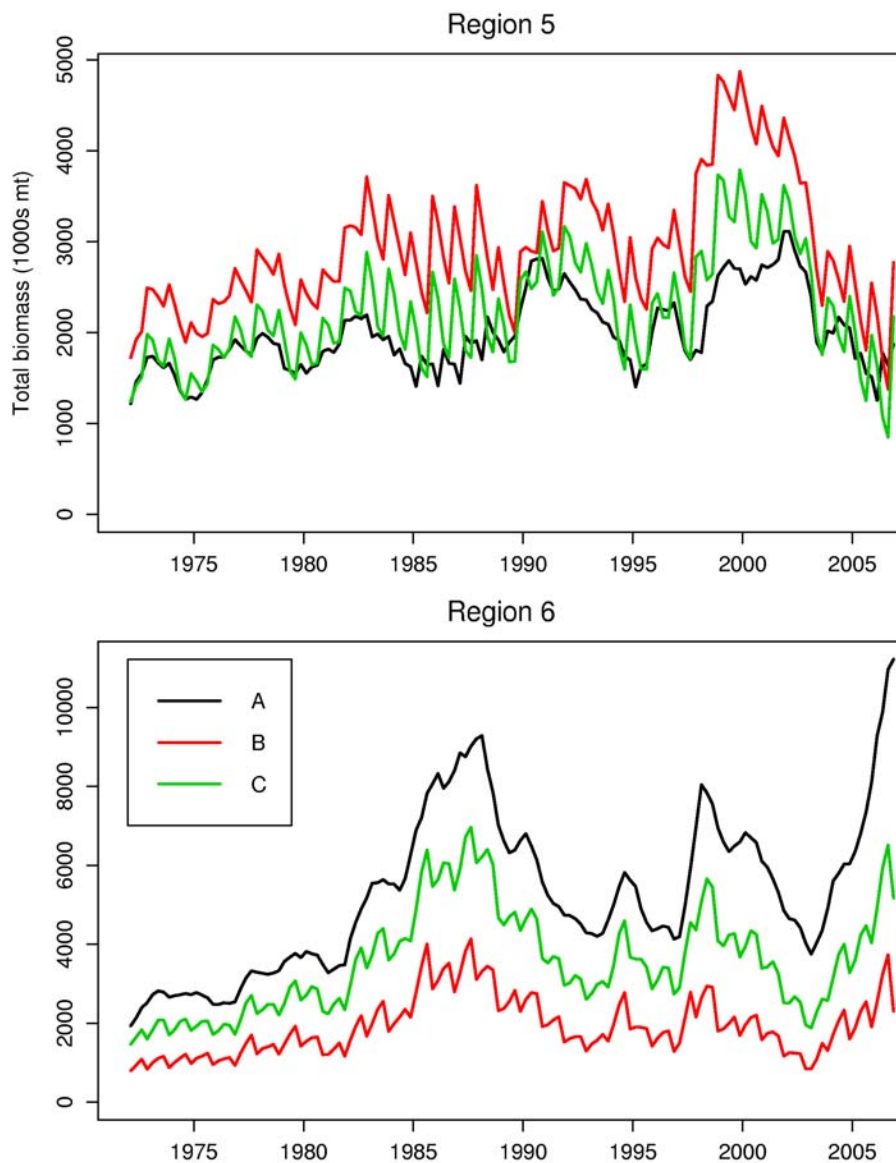
4.3 Regional weighting factors

A key assumption in the WCPO model is the relative weightings assigned to each region in the stock assessment model. The weighting factors effectively scale the magnitude of the biomass in each region, given the level of catch taken and the relative trend in the principal CPUE indices. Previous stock assessments for the WCPO have weighted the model regions by the relative area of each of the regions; however, this approach does not account for the density of fish in each region, potentially over-estimating the level of biomass in large regions with a low fish density.

To examine the influence of the regional weighting factors, three scenarios were examined using the two region, equatorial model, as follow.
   A. The weighting factors used in the previous WCPO stock assessment (region 5, 1.42; region 6, 1.75). This scheme reflects the larger size of region 6.
   B. Weighted by the total skipjack tuna purse-seine catch, by region (region 5, 0.8; region 6, 0.2). This scenario assumes the purse-seine catch is taken in direct proportion to abundance; likely to be an unrealistic assumption that results in a much greater emphasis given to region 5 in the model.
   C. A weighting scheme based on the CPUE of the pole-and-line fleet in each region multiplied by the area fished within the region (region 5, 0.7; region 6, 1.0).

The weighting scheme was highly influential in determining the total biomass level, particularly the level of biomass within region 6 (Figure 47). The options presented do not represent a range of plausible values for the regional weighting factors, rather the analysis serves to illustrate the importance of using appropriate values. Therefore, it is the recommendation of the workshop that sufficient attention is applied to determining the values used in the 2008 stock assessment. The most appropriate

approach would be to follow the rationale of Scenario C, in which the regional weightings integrate fish density (as inferred from CPUE data) and the size of the region.

Figure 47. Comparison of the trend in total skipjack biomass, by region, for the two regions included in the equatorial (two region) model using different regional weighting factors (see text for details).

Given the sensitivity of the assessment to the regional weighting factors, and, given the virtually identical trends in the DWPL CPUE between regions 5 and 6, it is debatable whether it is necessary to include any regional structure within the equatorial stock assessment model. On this basis, a single region, equatorial model was configured using the equivalent fishery structure to the two region model and estimating separate catchabilities for the two DWPL fisheries. The resulting model yielded levels of absolute biomass that are lower than the total biomass from the various two region models (Figure 48). The simplifying assumptions of a single region model warrant the inclusion of this model in the suite of models included for

consideration in the 2008 stock assessment. The model provides the opportunity to more strongly focus on the core region of the fishery. The movement coefficients (constant wrt time) for the two region model are unable to capture the true movement dynamics of the equatorial region which are environmentally driven (ENSO). This may be a further rationale for combining the regions into a single equatorial region.
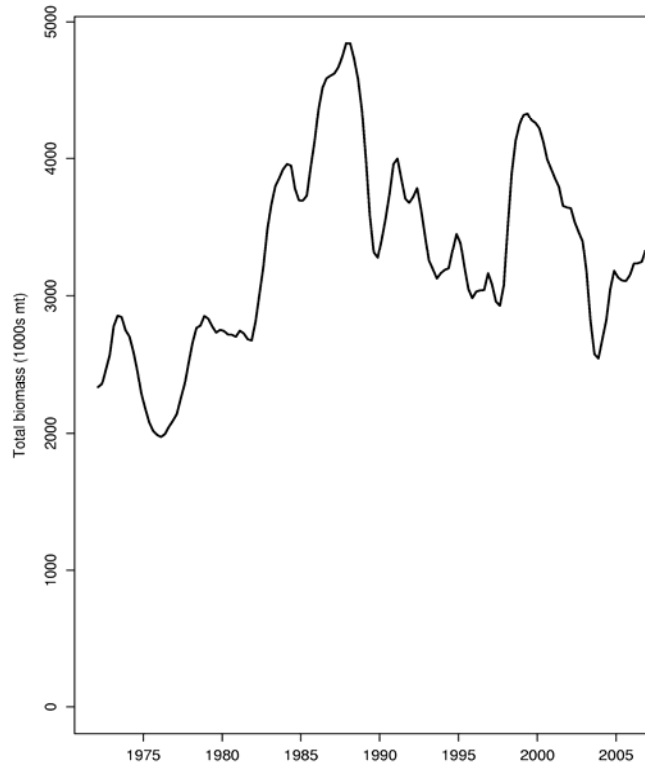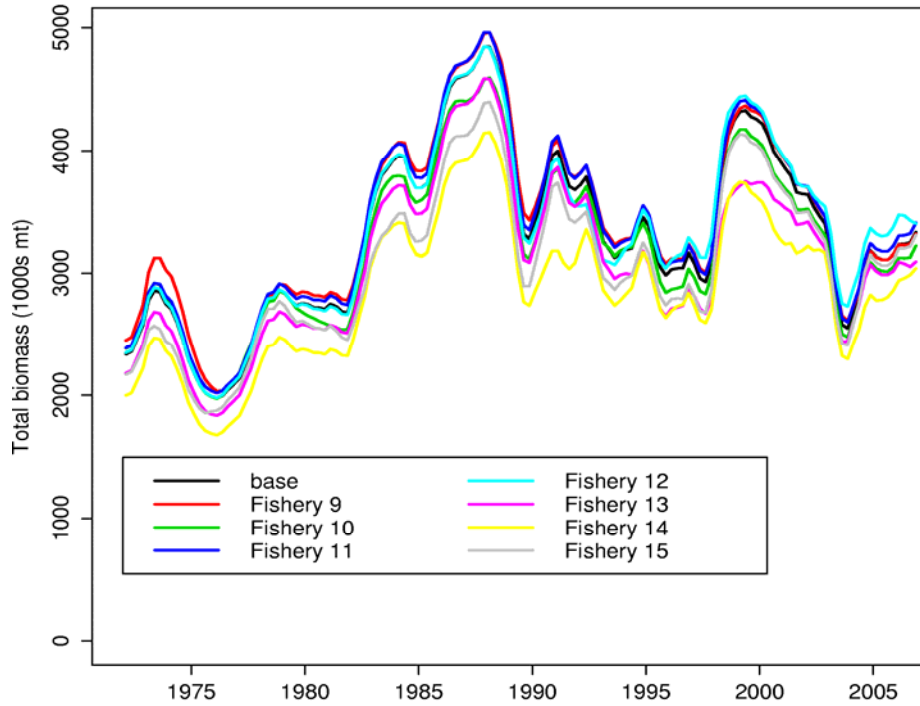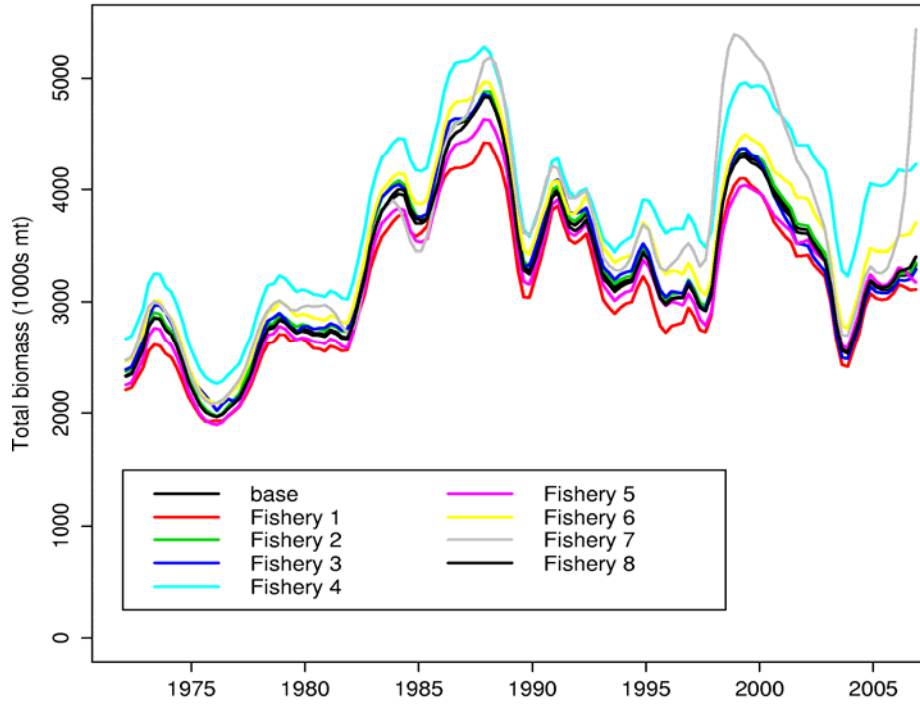

Figure 48. Trend in total biomass for the single region, equatorial skipjack model.

4.4 Length frequency data

The influence of the length data from individual fisheries was investigated by sequentially down-weighting the size data from each fishery in the single region, equatorial model. The size data from each fishery was down-weighted to an effective sample size of n/10,000 compared to n/10 in the base model. No single set of size data was particularly influential in the biomass trajectory from the model, although there was a slight increase in recent biomass when the size data from the purse-seine log fishery (fishery 4) and the Philippines domestic fishery (fishery 7) were down-weighted (Figure 49).

An iterative reweighting approach (as described in Section 2.5) was also applied to the length data from all fisheries. This approach resulted in a substantial down-weighting of the effective sample size of the two pole-and-line fisheries (n/38 and n/49), while the effective sample size from the other fisheries was maintained at about the level of the base case (n/10). The resultant trend in total biomass from the model was very similar to the base case model.
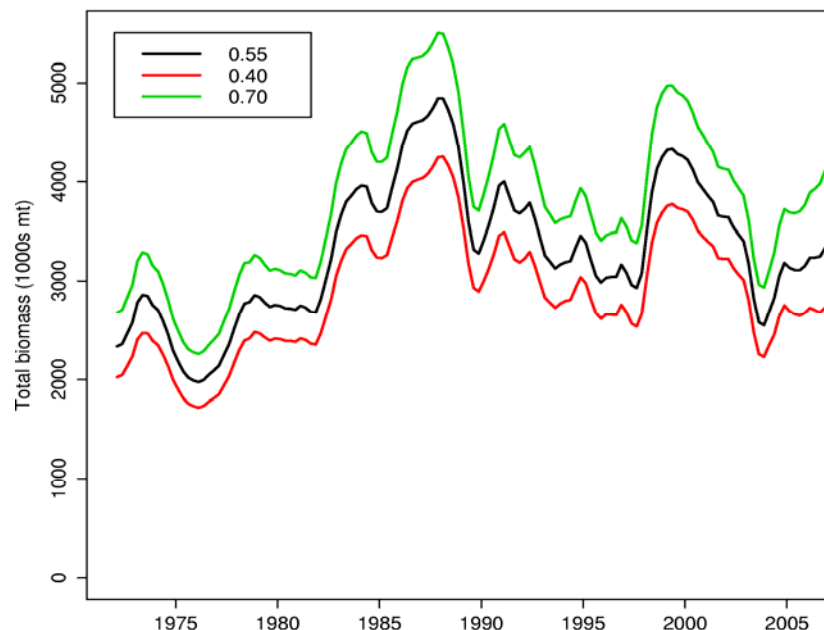
Figure 49. Trends in total biomass for the single region model (base) compared to the model with the length data from each fishery down-weighted. Results are plotted in two separate figures for clarity.

60

4.5 Tag reporting rates

The skipjack tuna stock assessment includes a significant amount of tag/release and recovery data. These data are influential in determining the level of absolute stock biomass when reliable estimates of fishery-specific tag reporting rates are available. Such estimates are available for the purse-seine fleet from the 1989–1992 SPC tagging programme. The observed reporting rate is used to inform the model via a prior. In the case of the purse-seine fishery, a highly informative prior is used (mean = 0.55, std dev = 0.05).

The sensitivity of the model to the observed reporting rate was investigated by comparing the model run with a lower (0.40) and higher (0.70) reporting rate (Figure 50). The change in total biomass was proportional to the increase/decrease in reporting rate, with approximately a 15% increase (decrease) in total biomass associated to a 15% increase (decrease) in reporting rate.

Figure 50. Trends in total skipjack biomass from the single region, equatorial model with three levels of tag reporting rate (mean of the prior) for the purse-seine fisheries. The prior reporting rate in the base-case is 0.55.

The model likelihoods deteriorated slightly with the alternative assumptions of lower (LL -116834.2 compared to -116838.9 for the base case) and higher (LL -116827.8) tag reporting rates.

It was noted that the model assumes this reporting rate for the entire purse-seine fishery; however, no observations of reporting rate are available for the earlier SPC tagging programme (1977–1980). It is reasonable to assume that reporting rates for this period may be lower than for the later period and this may be examined as a model sensitivity.

4.6 Outstanding issues

A range of model runs have been identified for the 2008 skipjack stock assessment (Table 5). The various model runs focus largely on the spatial scope and configuration of the model and a limited number of model sensitivities have also been identified.

Table 5. Proposed model runs and sensitivity analyses for the 2008 skipjack stock assessment.

Run	Description	Regional weighting	Size data weighting
1	WCPO, 6 region model, fishery structure equivalent to 2005	As per 2005 assessment	n/20
2	As per Run 1.	Alternative weighting scheme – to be determined.	n/20
3	Equatorial, 2 region model, equatorial fisheries equivalent to 2005.	To be determined.	n/20
4	Equatorial, single region model, equatorial fisheries equivalent to 2005.	Not relevant.	n/20
5	As per Run 2.	As per Run 2.	Iterative reweighting DWPL fishery/decade.
	Sensitivities to be conducted on one (or more) of runs 1-5.	**Details**	
S1	Increased fishing efficiency of DWPL fleet.	Increase 0.25% per quarter.	
S2	Tag reporting rates for the purse-seine fishery.	Assume a lower RR for the earlier period of the SPC tag releases.	
S3	Steepness parameter for SRR.	The last assessment estimated a moderate value for steepness (0.86), although a higher value may be more appropriate. Consider alternative (fixed) values of steepness.	
S4	Alternative catch histories for the Indonesian and Philippines fisheries.	To be formulated with advice from Peter Williams.	

A key outstanding issue is the influential DWPL CPUE indices. The apparent discrepancy between the current CPUE indices and the CPUE indices presented in earlier years needs to be further explored, given the similarity between the current CPUE indices between regions 5 and 6 and the similarity between the standardized CPUE and nominal CPUE in these two regions. The workshop considered that it would be useful for the updated analysis to be documented in an Information Paper to SC4.

John Hampton noted that considerable progress had been made in the development of the SEAPODYM for skipjack tuna in the WCPO. These results will be presented at SC4 by Patrick Lehodey and it will be informative to compare the outputs with the MFCL assessment results.

There was some discussion relating the modelling of predator-prey relationships. Skipjack is a common prey item for other large pelagic species and, given the reduction in the abundance of the predator species, the impact on skipjack tuna may have declined over time (a reduction in natural mortality). It is not possible to model this explicitly in the stock assessment, but it could be possible to create a "fishery" that accounts for these removals; for example, the fishery could be defined as the adult (estimated) biomass from the yellowfin and bigeye assessments.

Similarly, the model could be used to investigate the impacts of cannibalism on juvenile skipjack. It is possible that the recent increase in recruitment is attributable to a decline in cannibalism following the removal of larger skipjack by the fishery. If the

effect is strong then alternative relationships for the stock-recruitment relationship (e.g. Ricker curve) should be considered as a sensitivity analysis.

5 Generic issues

John Hampton provided an update on the recent tagging programmes within PNG and Solomon Islands waters. The results from these programmes are not available for inclusion in the 2008 stock assessments, rather some data should be available in 2009 once error checking has been completed. The availability of these data may require the spatial structure of the equatorial region to be revised to reflect the spatial coverage of the specific tagging programmes. This may facilitate the application of the stock assessment model to address management issues at a finer spatial resolution than currently possible.

John Hampton outlined recent developments of MFCL, in particularly the implementation of the catch conditioned model. This has the benefit of substantially reducing the number of parameters estimated (effort deviates). There is ongoing testing of the new code and the results of the catch conditioned model will be compared to the current code (and reported at SC4). However, it is not intended to use the catch conditioned version of MFCL for the 2008 stock assessments. There has also been considerable progress in the management of the MFCL code enabling the tracking of changes in the code and routine updates of the associated documentation and website. It is hoped that this will expanded into a more significant project leading to the rewriting and ongoing management of the code.

5.1 Data provision

There was discussion relating to the time-line for completing the 2008 assessments. NRIFSF undertook to expedite the provision of Japanese longline catch and effort data to enable more rapid progress on the bigeye tuna stock assessment.

There remain key data gaps in the bigeye stock assessment. The principal gaps identified during the workshop are as follow.
  i. Lack of reliable catch data from the Indonesian artisanal fishery.
 ii. Accuracy of catch estimates from Philippines. Potential to explore accuracy of longline catch figures via Philippines export receipts.
iii. No catch data from the Vietnamese fishery; potentially a significant bigeye longline catch (3,000–4,000 mt).
 iv. Uncertainty regarding the accuracy of the catch by some key longline fleets; e.g. the offshore fleets operating in Micronesian waters.
  v. Lack of comprehensive size frequency data from the Taiwanese and Korean distant-water longline fleets. Limited size data from these fleets have been provided in recent years, although the utility of these data are limited (lack of accompanying spatial information, low level of sampling).
 vi. Information on the level of discarding of bigeye tuna (and other species) from various components of the fishery (purse-seine and longline).
vii. Timeliness in the provision of catch and effort data from some key longline fleets.
viii. A lack of operational level data for the distant-water longline fleets which would assist in the interpretation of CPUE trends.

ix. Some key biological parameters remain poorly determined.

For south Pacific albacore tuna, the following data issues are likely to be important, but it is hoped that most will be addressed before the assessment.
 i. Representativeness of length frequency data from distant water longline fisheries.
 ii. Lack of operation-level data, or relevant stratification (e.g. HBF, line specific gravity, bait, target species), to help interpret CPUE trends and length frequency data.
 iii. Key biological parameters poorly determined.

For skipjack tuna, there is huge uncertainty regarding the recent and historic catch estimates for the Indonesia and Philippines fisheries. However, given the scale of these fisheries relative to the magnitude of the purse-seine catch, the influence of the assumed level of catch on the stock assessment results is likely to be lower than for bigeye and yellowfin tuna.

5.2 Model diagnostics and model selection

There were no additional diagnostics identified for presentation in the stock assessment reports. However, it was requested that more information be presented detailing the number of parameters and observations included in each of the model runs reported. Also, statistical criteria should be applied for the selection of the most appropriate model (e.g. AIC, BIC). It was noted that such criteria are only appropriate for comparing models with equivalent structural assumptions and data weightings and, consequently, it may only be feasible to use such statistical criteria to assess minor changes in the model parameterization. The selection of an appropriate base case model (or several alternative models) will require the application of a range of semi quantitative criteria applied to key data sets included in the stock assessment.

5.3 Biological reference points

The range of BRPs currently presented in the stock assessment reports was reviewed. These are principally based on the concept of MSY; this is consistent with the UNCLOS provisions within the Convention text of the WCPFC, although no formal BRPs have been adopted by WCPFC. In the absence of any formal agreement on BRPs by the Commission, it was considered that a wide range of alternative reference points should be presented. This may include (but not limited to) the fishing mortality BRPs $F_{0.1}$, $F_{20\%}$, $F_{30\%}$ and the associated biomass (total and spawning biomass) reference points.

In computing the BRPs, consideration should be given to the period used to determine "long-term" average recruitment, particularly if recent recruitment is significantly higher/lower than the average for the entire model period. It may also be appropriate to consider alternative values for the steepness of the SRR.

There is the potential to report BRPs at the subregional level. This would more explicitly highlight the impacts of fishing among the regions of the stock assessment model. It may also be possible to apply this approach to derive alternative exploitation patterns (among regions) that increase the utilization of the stock.

It was noted that the definition of "current" used in defining the BRPs should be explicitly stated; for example, $F_{current}$ should be given as $F_{2003-2005}$.

Previously, likelihood profiles have only been computed for B/B_{MSY} and F/F_{MSY} from the "base case" model. For the 2008 assessment, a likelihood profile will also be computed for SB/SB_{MSY} and, if possible, for the BRPs from selected sensitivity analyses. The generation of likelihood profiles is a computer intensive process and is limited, to some extent, by the availability of computing power. A range of hardware options are being explored by OFP to increase the capacity/utility of current computing resources.

5.4 Stock projections

Recent WCPO stock assessments have typically included forward stock projections, usually for a 5-year period. Such projections are highly dependent on assumptions regarding future patterns of fishing and recruitment (magnitude, variation, regional distribution). Consequently, the projections are highly uncertain and are best viewed in an equilibrium framework; i.e. the level of **equilibrium** biomass that will result from fishing at the projected level of fishery-specific fishing effort in five years time. It is not appropriate to apply the results of the projections to track biomass prior to attaining equilibrium, particularly during the initial period in the projection which is strongly influenced by the most recent estimates of recruitment (that are highly uncertain).

For the 2008 stock assessments, it was agreed to undertake projections based on the status quo levels of fishing effort, moderated, where appropriate, by any relevant Conservation and Management Measures (CMMs) introduced by the Commission.

Further, if specific draft management measures are formulated by the WCPFC secretariat in advance of the SC meeting, these measures can be considered in the stock assessments presented to SC4, including a consideration as to how these draft measures were interpreted in the framework of the stock assessment model (for example, purse-seine FAD closures, longline effort reductions). Post SC4, it will be possible to apply the stock assessment models to assess additional draft measures to be considered at WCPFC5. Such draft measures could include the phased reductions in fishing effort in some fisheries.

5.5 Reporting to SC4

At previous meetings of the SC, there has been criticism of the presentation of the stock assessment results, particularly the magnitude of technical detail presented. However, in the absence of other subsidiary bodies of the WCPFC there is no other forum to present and review the technical details of the stock assessments. This is clearly an issue that needs to be addressed in the forthcoming WCPFC Science Review and it may be more appropriate to constitute a subsidiary technical body of the SC. In the interim (2008), it is probably necessary to persist with the full technical presentation to the SC4 Stock Assessment Specialist Working Group.

At SC3, it was requested that a range of performance indicators be reported for those key species not being assessed in a given year. OFP are tasked to undertake this work for yellowfin in 2008. The range of performance indicators could include;
-   Recent catches for the key fisheries;

- Catch rates (kg/hhooks for longline);
- Spatial extent of a fishery (e.g. how many 1 x 1 or 5 x 5 squares were fished)
- Trend analyses (size, etc)

5.6 Relevance of the workshop

While non OFP participation at the workshop was limited, all participants stated they considered the workshop to be a worthwhile exercise and the participation should be expanded in future. From an OFP perspective, the timing of the workshop it necessitated the early start of the assessment work leading up to SC4. This ensured that sufficient time was available to further investigate some of the outstanding issues in the current stock assessments. The workshop provided the opportunity to discuss these issues in more detail than usually occurs internally or in the SC forum. The workshop also provided clear direction as to the analyses that will be undertaken and presented at SC4 with the agreement from the other non OFP participants.

Going forward, such a meeting could potentially subsume some of the responsibilities of the SC with respect to reviewing the stock assessment results at a highly technical level. A number of the participants were in favour of the workshop attaining the status of a subsidiary body within the WCPFC. Certainly, this is worth consideration during the WCPFC Science Review.

OFP thank all participants for their attendance and contributions at the preparatory workshop.

Appendix 1. Notice of Meeting and Provisional Agenda

STOCK ASSESSMENT PLANNING WORKSHOP
Secretariat of the Pacific Community
Noumea, New Caledonia
25-29 February 2008

The Oceanic Fisheries Programme (OFP) of SPC is contracted by WCPFC to undertake three species stock assessments in 2008: bigeye tuna, skipjack tuna, and South Pacific albacore. The results of these assessments will be presented at the Scientific Committee in August 2008. In preparation for these assessments, OFP is hosting a technical workshop to discuss key issues related each of these assessments.

To stimulate discussion, it is intended that OFP staff will present analyses of key data inputs included in each of the assessments as well as some preliminary results from the assessment models. Participants would also be encouraged to present any of their work that is relevant to the stock assessment of these species.

It is important to recognise that this meeting is not a formal WCPFC meeting. This is simply a technical meeting of experts who have a common interest in progressing the stock assessments of key tuna species in the WCPO. Nevertheless, the outcomes of the meeting will be documented and the report of the meeting will be submitted to the WCPFC Scientific Committee as a supporting document.

All travel costs are to be met by the participants, although eligible participants from developing countries who need funding support are encouraged to contact the WCPFC Secretariat, who may be able to assist.

The following is a preliminary agenda for the meeting. The meeting is intended to be informal and facilitate detailed discussions on each of the proposed agenda items. In preparation for the meeting, it is intended that participants are familiar with the recent stock assessment reports for the tuna species (a list of papers is attached).

Agenda

Monday, 25 February. 08:30 start

Morning   Welcome and introductions.

             Identify outstanding issues from past assessments (BET, ALB, SKJ).

             Discussion of anticipated outcomes from meeting.

             Update on PNG and SI tagging projects – potential for inclusion in 2008 assessments (JH).

             MFCL code: catch conditioned version (JH).

Afternoon   **BIGEYE TUNA stock assessment (Adam).**

       i.   Fishery structure. Additional fisheries included in model (JP Coastal, PL), etc. JP size data for coastal fleet.

       ii.   Changes to computation of size (length and weight) frequency distributions, esp. JP LL.

Tuesday   **BIGEYE continued.**

iii. Exploratory analyses – what is driving the recent increase in recruitment trend, esp. in region 3.
iv. Is there any evidence of spatial differences in growth rate for BET?
v. Indonesia (and PH) catch history and sensitivities.
vi. Indonesian size data – what information is available?
vii. Additional sensitivity analyses – zero selectivity old age classes for small fish fisheries, increasing LL catchability (efficiency), M, movement.
viii. Stock assessment model projections.
ix. SS2 model development.
x. Pacific wide assessment.

Wednesday   **South Pacific albacore tuna (Simon H)**

i. Review of 2005 and 2006 assessments.
ii. CPUE index, esp. TW DWLL. Issues related to change in targeting (shift to BET). Analysis of logsheet data from Pago. Incorporate Pago-based JP, TW and KR data in a single index.
iii. Key issues; e.g. historical recruitment trends, trends in size composition from LL, biological parameters (new data from AU age and growth study).
iv. Regional structure of model: single region vs multi region, movement dynamics (variable with size).
v. Appropriate fishery structure to represent factors affecting selectivity and/or CPUE, such as seasonality.
vi. Utility of data from the troll fisheries – do these data provide indicators of recruitment strength?
vii. Stock assessment model projections.

Thursday   **Skipjack tuna (Adam)**

i. Review of 2005 assessment.
ii. Updated data sets.
iii. Key issues; e.g. SA estimates very high biomass in areas with limited catch, recent high levels of recruitment, PL CPUE index (increasing catchability?).
iv. Regional structure of model: WCPO vs. equatorial, archipelagic waters.
v. Fishery structure: PS log/drifting FAD/anchored FAD.
vi. Tag data assumptions.
vii. Stock assessment model projections.

Friday

Morning   Outstanding issues, including reporting of any additional model runs undertaken, revisiting previous issues, etc.

Afternoon   Data provision for 2008 assessment.

Additional biological reference points to be reported at SC.

Management options analyses.

Presentation of results – diagnostics, key indicators, etc. Report from the meeting.

Appendix 2. Meeting participants

Participant	Nationality/Affiliation	Agency
Peter Ward	Australia	Bureau of Rural Sciences
Yu-Min Yeh	Chinese Taipei	Nanhua University
Hiroaki Okamoto	Japan	National Research Institute of Far Seas Fisheries
Hiroshi Shono	Japan	National Research Institute of Far Seas Fisheries
Drew Wright	WCPFC	WCPFC
Samasoni Sauni	FFA	FFA
SungKwon Soh	WCPFC	WCPFC
Adam Langley	SPC/OFP	
Simon Hoyle	SPC/OFP	
John Hampton	SPC/OFP	
Brett Molony	SPC/OFP	
Simon Nicol	SPC/OFP	
Karine Briand	SPC/OFP	
Don Bromhead	SPC/OFP	
Peter Williams	SPC/OFP	