SCIENTIFIC COMMITTEE
FIFTH REGULAR SESSION
10–21 August 2009
Port Vila, Vanuatu

ASSESSMENT OF THE POTENTIAL IMPLICATIONS OF APPLICATION OF CMM-2008-01 FOR BIGEYE AND YELLOWFIN TUNA

WCPFC-SC5-2009/GN-WP-17

John Hampton[1] and Shelton Harley[1]

[1] Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia

Table of Contents

Executive Summary

CMM2008-01, adopted in December 2008, seeks to reduce fishing mortality on bigeye tuna by 30% from the 2001-2004 average level and limit yellowfin tuna fishing mortality to its 2001-2004 level, in order to maintain stocks at levels capable of producing the maximum sustainable yield (MSY). This objective is pursued though a combination of measures involving longline catch limits, purse seine effort limits, a closure relating to purse seine fishing using fish aggregation devices (FADs) and a closure of two high-seas pockets (HSP) to purse seine fishing. Most of these measures have various exemptions or alternatives built in and are phased in over the period 2009-2011. The purpose of this paper is to conduct a technical evaluation of CMM2008-01 to see if it is capable of meeting its objectives. The method used for the evaluation involves conducting stock projections over a ten-year period (2009-2018) using two alternative stock assessment models for each of bigeye and yellowfin tuna as a base. The alternative models for each species have different assumptions concerning purse seine catches, which are a major data uncertainty for both assessments. In conducting the projections, levels of longline catch (in the case of bigeye tuna), purse seine effort, and effort for other fisheries have been specified to reflect the various provisions of CMM2008-01. The levels of catch and effort in 2011 are assumed to be continued through 2018. We have attempted, where possible, to capture the various exemptions associated with these provisions. Where there is ambiguity in the application of the provisions, or where there are portions of the fishery that are unregulated by the measure, we have made what we believe to be conservative assumptions regarding future catch and effort levels. Thus, the estimated stock conditions should be regarded as "best case" outcomes, noting that there is significant uncertainty in how future catch and effort levels in the major fisheries will evolve.

The performance indicators used for the evaluation are the ratio of projected fishing mortality in 2018 to the fishing mortality at MSY (F/F_{MSY}) and the ratio of the projected spawning biomass in 2018 to the spawning biomass at MSY (SB/SB_{MSY}). F/F_{MSY} is an appropriate indicator for measuring performance in relation to the fishing mortality objectives, while SB/SB_{MSY} is appropriate for measuring performance in relation to the objective of maintaining stocks at levels capable of producing MSY. Separate projections were undertaken to estimate the individual effects of the longline catch limits (for bigeye tuna), purse seine effort limits, purse seine FAD closure and closure of the HSP to purse seine fishing. Projections were also undertaken incorporating all purse seine provisions combined and all purse seine and longline provisions combined. A base projection, which simply involved projecting forward the estimated 2007 fishing effort for all fisheries, was undertaken for comparison.

The projections showed that CMM2008-01 is highly unlikely to meet its objectives of a 30% reduction in bigeye tuna fishing mortality from the 2001-2004 level, or maintenance of the bigeye tuna stock at a level capable of producing MSY over the long term. The measures are predicted to result in little if any reduction in bigeye tuna F/F_{MSY} from the high levels in excess of 2.0 estimated for 2007-2008, and accordingly, SB is predicted to fall to around 0.4-0.6 of SB_{MSY}. The main reasons for the lack of effectiveness of the measure are (i) the reductions in longline catch do not result in the required reduction in fishing mortality on adult bigeye tuna; (ii) the increase in purse seine effort allowed under the measure, and the increase in purse seine catchability (fishing mortality per unit effort) that has occurred since 2001-2004, is not sufficiently offset by the FAD and HSP closures to reduce purse seine fishing mortality below 2001-2004 average levels; and (iii) the exclusion of archipelagic waters, which encompasses most of the fishing activity of the Indonesian and Philippines domestic fleets and significant amounts of purse seine effort in Papua New Guinea and Solomon Islands, from the measure effectively quarantines an important source of fishing mortality on juvenile bigeye tuna.

For yellowfin tuna, the current assessment estimates that recent $F/F_{MSY} < 1$ and $SB/SB_{MSY} > 1$. Projections assuming the various purse seine provisions of CMM2008-01 and 2007 levels of effort for all other fisheries (including longline) suggest that levels of fishing mortality in 2018 ranging from 8% below to 15% above the 2001-2004 average level could result under CMM2008-01. Yellowfin tuna spawning biomass in 2018 is predicted to be similar to the 2001-2004 average or to decline slightly from that level, and to remain above or close to the MSY level, depending on the stock assessment model assumptions used.

1 Introduction

At WCPFC5 in Busan in December 2008, a Conservation and Management Measure for Bigeye and Yellowfin Tuna in the Western and Central Pacific Ocean (CMM2008-01) was adopted (CMM2008-01). CMM2008-01 has the following objectives (paragraph 1):

- "*Ensure through the implementation of compatible measures for the high seas and EEZs that bigeye and yellowfin tuna stocks are maintained at levels capable of producing their maximum sustainable yield; as qualified by relevant environmental and economic factors including the special requirements of developing States in the Convention area as expressed by Article 5 of the Convention;*
- *Achieve, through the implementation of a package of measures, over a three-year period commencing in 2009, a minimum of 30% reduction in bigeye tuna fishing mortality from the annual average during the period 2001-2004 or 2004;*
- *Ensure that there is no increase in fishing mortality for yellowfin tuna beyond the annual average during the period 2001-2004 average or 2004; and*
- *Adopt a package of measures that shall be reviewed annually and adjusted as necessary by the Commission taking account of the scientific advice available at the time as well as the implementation of the measures. In addition, this review shall include any adjustments required by Commission decisions regarding management objectives and reference points.*"

The purpose of this paper is to evaluate whether the various provisions of the measure, if implemented as written, will meet the objectives stated in the first three dot points above. The evaluation comprises several steps:

- Specification of the levels of effort and catch that are allowed under CMM2008-01;
- Estimating the impact of those effort and catch levels on bigeye and yellowfin tuna stocks; and
- Evaluating the stock impacts in relation to the CMM objectives.

These steps are described in detail in the following sections.

2 Effort and catch allowed by CMM2008-01

2.1 Purse seine

The key purse seine measures contained in CMM2008-01 are:

- Limits on purse seine effort in EEZs[2] and on the high seas between 20°N and 20°S;
- Closure of the two high seas pockets (HSP) contained completely within the Convention Area between 20°N and 20°S (Figure 1); and
- A prohibition on purse seine sets on floating objects (FAD sets) in Aug-Sep of 2009 and in Jul-Sep 2010 and subsequent years.

2.1.1 Purse seine effort limits

CMM2008-01 has several provisions in which overall limits on purse seine effort are specified. Paragraphs 11 and 17 limit purse seine effort in the EEZs of FFA members who are Parties to the Nauru Agreement (PNA) to 2004 levels. Other non-PNA members are required to implement compatible measures to reduce purse seine fishing mortality on bigeye tuna in their EEZs (paragraphs

[2] EEZs do not include areas of territorial seas and archipelagic waters. CMM2008-01 does not apply to such areas, although paragraph 5 notes that "*The Commission encourages CCMs to ensure that the effectiveness of these measures is not undermined by a transfer of effort into archipelagic waters and territorial seas*".

12 and 18). Paragraph 10 requires members (excepting small developing State members and participating territories) to restrict purse seine effort on the high seas to their historical effort in 2004 or the average of 2001-2004. There is also an intent (paragraph 21) to develop a more comprehensive measure for the high seas in 2010.

To evaluate the measure, it is first necessary to translate these provisions into actual effort levels that can be used in stock projections. To do that, it is necessary to take account of other paragraphs in CMM2008-01 that provide exemptions of one sort or another for some Commission members. For the purpose of this evaluation, the following interpretations of CMM2008-01 have been made in relation to purse seine effort limits:

Archipelagic Waters

CMM2008-01does not apply to archipelagic waters (AW) or territorial seas. Both PNG and Solomon Islands have significant purse seine fishing activity within their AW (the situation of Philippines and Indonesia in respect of AW is dealt with separately later). Nevertheless, consistent with the principle of ensuring long-term sustainability of highly migratory fish stocks in the Convention Area in their entirety (Article 5 of the WCPFC Convention), fishing in AW needs to be considered in the evaluation as it has impacts on the stocks of bigeye and yellowfin tuna. For the purposes of the evaluation, we assumed that the level of AW effort in PNG and Solomon Islands that occurred in 2007 (the last year of complete data available at the time of writing) of **5,508 days** would be continued into the future. This is possibly a conservative assumption, given the onshore tuna processing developments that are currently underway in PNG and the efforts of the Solomon Islands Government to attract shore-based investment. A similar estimation could not be applied to territorial seas because coordinates are not available for many coastal states. However, the amount of purse seine fishing in territorial seas is not likely to be significant in the context of this evaluation.

Inclusion of existing agreements in the 2004 level of purse seine effort

Paragraph 7 of CMM2008-01 notes that the 2004 level of effort includes "*fishing rights organized under existing regional or bilateral fisheries partnership arrangements or agreements previously registered with the Commission by December 2006 in accordance with CMM2005-01, provided that the number of licences authorized under such arrangements does not increase and noting that the registration of bilateral agreements or arrangements does not provide a basis for establishing effort levels on the high seas*". Table 6 of WCPFC-TCC4-2008-10 lists the arrangements that have been registered for this purpose. These include the FSM Arrangement, US Treaty, bilateral agreements between the European Community and Solomon Islands, Kiribati and FSM, bilateral agreements between Korea and Marshall Islands, Nauru, PNG, Solomon Islands and Kiribati, and a bilateral agreement between New Zealand and Tokelau. Most of these agreements specify a number of vessels that are allowed to operate, although one (Korea/Solomon Islands) notes the vessel numbers as "unlimited" and another (New Zealand/Tokelau) does not supply a vessel number.

The approach that we have taken is to check whether the vessel numbers that are listed are accommodated under the 2004 historical fishing effort (as documented by logsheet data provided to SPC and/or WCPFC). The number of EC purse seine vessels covered by the three bilateral agreements varies between 4-6. Four vessels fished in 2004, although apparently on a part-time basis. While some increase in effort over 2004 levels would be possible if all vessels fished full time, the numbers are relatively minor and the rights are restricted to three EEZs. Therefore the possibility of expanded EC purse seine effort has been ignored for the purpose of the evaluation. For the Korean agreements, 27 or 28 vessels are specified, although there is no limit for the agreement with Solomon Islands. In 2004, 27 Korean purse seiners fished, so it is assumed that their rights can be met from the 2004 level of effort. In the case of New Zealand, no limit on vessels is specified in the Tokelau agreement. However only 4 vessels fished in 2004 and this number has not increased. Given the relatively small number of vessels, and the fact that the right is in respect of just one EEZ, it is assumed that this right can also be met from the 2004 level of effort.

In the case of the two multilateral arrangements, the rights conferred are more significant because the numbers of vessels are higher and the geographic scope of the arrangements is wide,

essentially covering all PNA EEZs, and, it would appear, the high seas. In the case of the FSM Arrangement, the number of vessels specified is 36, whereas in 2004, 30 vessels fished. However, since FSM Arrangement vessels are now included in the PNA Vessel Days Scheme (VDS), and the fact that the number of vessels has declined in 2008 to 26, it is assumed for the purposes of the evaluation that the rights provided to the FSM Arrangement under paragraph 7 can be met from the 2004 level of effort in PNA EEZs.

In the case of the US Treaty, 40 vessels are able to fish widely throughout PNA (and other Pacific Island Parties to the US Treaty) EEZs and on the high seas. An additional 5 licenses are also available for joint-venture arrangements with Pacific Island Parties to the Treaty. In 2004 however, only 23 vessels fished, and vessel numbers declined to just 13 in 2006 fishing approximately 2,600 days. Since then, vessel numbers have increased strongly, with 31 vessels fishing for approximately 6,900 days in 2008. Additional vessels joined the fleet in 2009 and it is likely that the US will soon utilize all 40 licenses available under the Treaty. It is therefore necessary to make an adjustment to the 2004 PNA EEZ effort levels to allow for the increase in size of the US fleet to 40 vessels (assuming that the effort resulting from any joint-venture arrangements would be attributed to the respective Pacific Island Parties as domestic effort). We examined logsheet data for 2004 and determined that the average number of days fished by US vessels that were clearly full-time participants in the western and central Pacific fishery was 229. Using this average as a basis, we estimate that **9,172 days** in total would be required to sustain 40 full-time US vessels. This effort would cover PNA EEZs, other FFA member EEZs, US EEZs and the high seas within the WCPFC Convention Area. This method is consistent to that applied by the US for estimating their US EEZ and high seas purse seine effort limits (NOAA 2009).

PNA EEZs

Paragraphs 11 and 17 of CMM2008-01 commit members of the PNA to restrict purse seine effort in their collective EEZs to 2004 levels, subject to "existing arrangements" exemption (and noting that AW are not included in the EEZs). Total purse seine effort in PNA EEZs in 2004 is estimated to be 30,720 days. Removing the 2004 US purse seine effort of 2,766 days leaves a residual **limit for PNA EEZs of 27,954 days**. It is assumed that this limit includes FSM Arrangement effort, other domestic purse seine effort whether it occurs in national or other PNA EEZ waters (including any future joint-venture arrangements under the US Treaty) and bilaterally licensed effort, including those registered bilateral agreements mentioned above. It is noted that paragraph 6 of CMM2008-01 has been interpreted as providing a general exemption to small island developing States against anything in the measure that may prejudice their legitimate rights and obligations seeking to develop their own domestic fisheries. Whether PNA members may wish to invoke this exemption to expand their domestic purse seine effort to the extent that overall purse seine effort in PNA EEZs exceeds 2004 levels is currently uncertain. For the purpose of this evaluation, we have assumed that total PNA EEZ purse seine effort, excluding AW and US effort, will remain at 2004 levels.

Other EEZs

Paragraphs 12 and 18 of CMM2008-01 require non-PNA CCMs to "*implement compatible measures to reduce purse seine fishing mortality on bigeye tuna in their EEZs*". For the FFA members that are not members of the PNA, the small amount of effort that occurs in their EEZs is mainly US effort, which is covered under the 40 vessel provision of the US Treaty. Other purse seine effort in these EEZs totaled only **23 days** (the maximum of 2004 and 2001-2004 average effort, by EEZ), which is therefore assumed to constitute the non-US effort limit for FFA non-PNA EEZs (but noting that the paragraph 6 exemption also applies to most of these States).

The only non-FFA EEZs that have significant purse seine fishing in the WCPFC Convention Area are the US territories and possessions, Indonesia and Philippines. In the case of the US territories and possessions, the 40 vessel provision of the US Treaty referred to above includes their operations in US EEZ waters, so a specific allocation for those waters is not required for the evaluation.

Philippines and Indonesia needed to be treated differently for 2 reasons. First, reliable estimates of purse seine effort for their EEZs are not yet available. Therefore, it is not possible to specify limits

explicitly in terms of purse seine effort. Second, both Indonesia and Philippines are recognized by the United Nations as being archipelagic states. Coordinates for archipelagic baselines were not available for this evaluation; however, on the basis of general knowledge of where the major fishing activities occur in the EEZs, it is probable that a high proportion of domestic purse seine effort occurs in what is, or will ultimately be considered to be AW. Therefore, it is likely that a large proportion of domestic Indonesian and Philippines purse seine (and other gears) effort would be excluded from the measures in CMM2008-01. For the purpose of the evaluation, we have assumed a continuation of 2007 levels of fishing mortality for bigeye and yellowfin tuna for these fisheries. These specifications are generic to all non-longline domestic fisheries, including purse seine, in Indonesia and Philippines as these fisheries are aggregated in the stock assessment models.

High Seas

Paragraph 10 of CMM2008-01 requires CCMs to "*take necessary measures to ensure that the level of purse seine fishing effort in days fished by their vessels in areas of the high seas does not exceed 2004 levels or the average of 2001-2004*". Using the available historical raised logsheet data, and selecting the maximum of 2004 and the average of 2001-2004 for each vessel flag, we obtain a total purse seine effort for the high seas of 10,685 days[3]. However, because US high seas effort is included in the 40 vessel provision of the US Treaty, we need to subtract 1,038 days (US high seas purse seine effort in 2004) from this total to avoid double counting. Therefore, the total non-US high seas effort assumed in the evaluation is **9,647 days**.

Paragraph 10 also notes that "*this paragraph shall not apply to small developing state members and participating territories*". This essentially means that vessels flagged (or operating under charter, lease or similar arrangements) to FSM, Kiribati, Marshall Islands, PNG, Solomon Islands and Vanuatu, and any other small developing state members that may in future operate purse seiners under their flags or other recognized arrangements, currently have unlimited fishing rights on the high seas. The number of such vessels has varied between 40 and 51 in recent years. For the purpose of estimating high seas effort to be used in this evaluation, vessels flagged or chartered by small developing state members have been treated in the same way as other vessels. Therefore, the high seas effort and the total purse seine effort used in the evaluation should be regarded as conservative.

Total purse seine effort allowed by CMM2008-01

The total level of purse seine effort that is conservatively allowed under CMM2008-01 is estimated to be **52,304 days**. As noted above, this estimate excludes domestic purse seine effort in the EEZs of Indonesia and Philippines. The estimate is conservative because (i) the allowance, for the purpose of evaluation, for the AW of PNG and Solomon Islands, based on 2007 levels of effort, may be less than the effort that actually occurs; (ii) several small island States have plans to expand or develop their domestic purse seine fishing capacity, and it is currently unclear if these plans will be accommodated within total 2004 effort levels for EEZs; and (iii) the exemption given to small developing states for fishing on the high seas may result in greater high seas effort than is currently assumed in the evaluation. The levels of purse seine effort used for the evaluation in the various categories discussed above are summarized in Table 1.

To incorporate the purse seine effort into the bigeye and yellowfin tuna stock assessment models for evaluation purposes, it is necessary to attribute the effort to the individual fisheries that are defined in the models. The relevant purse seine fisheries defined in the stock assessment models are:

- Associated sets (equivalent to FAD sets) by quarter in model region 3 (west of 170°E)
- Unassociated sets by quarter in model region 3 (west of 170°E)
- Associated sets by quarter in model region 4 (east of 170°E)
- Unassociated sets by quarter in model region 4 (east of 170°E)

[3] We note that Philippines is currently assembling data to support a claim for additional high-seas purse seine effort to what is currently recorded in the SPC/WCPFC database. Should that claim be substantiated, total high-seas effort will likely increase.

Purse seine effort was attributed to these fisheries, by quarter, using the proportions of total purse seine effort for the period 1998-2007 by quarter, model region and set type. The distribution of the total purse seine effort of 52,304 days by these fisheries and by quarter is shown in Table 2.

Table 1. Levels of purse seine effort estimated to be allowed under CMM2008-01 subject to exemptions provided in the notes given below the table.

Category of purse seine effort	*Purse seine effort (days fishing)*
Allocation for 40 US vessels at 229 days fishing per year (average for full-time US vessels in 2004)	9,172
PNA EEZs 2004 (excluding archipelagic waters and US-flagged vessels)	27,954
Allowance for archipelagic waters (AW) in PNG and Solomon Islands (based on 2007 effort)[1]	5,508
Other FFA EEZs (excluding US-flagged vessels), maximum of 2001-2004 average and 2004	23
International waters, maximum of 2001-2004 average and 2004, by flag (excluding US-flagged vessels)[2]	9,647
TOTAL	52,304

Notes:

1. AW are not covered under CMM2008-01. The allowance shown is for the purpose of evaluation only and does not represent an actual limit to purse seine effort in AW.
2. Vessels flagged by or chartered to small developing members are exempt from this measure. For the purpose of the evaluation only, effort for such fleets has been assumed on the same basis as for other fleets, i.e. the maximum of 2004 and the average of 2001-2004, by flag.

Table 2. Purse seine effort (days fished) estimated to be allowed under CMM2008-01 in the absence of other measures.

Quarter	*Region 3*		*Region 4*	
	Associated sets	Unassociated sets	Associated sets	Unassociated sets
Q1	6,279	5,175	1,130	239
Q2	5,829	5,217	1,437	907
Q3	4,963	4,272	2,114	2,059
Q4	5,361	3,987	1,853	1,482

2.1.2 High-seas pockets closure

Paragraph 22 of CMM2008-01 provides for a closure of the two HSP framed within the rectangle as shown in Figure 1 from 1 January 2010. The proportion of total purse seine effort in the Convention Area (excluding AW) between 20°N and 20°S that occurred in these HSP in 2001-2004 averaged 14%. Assuming a continuation of the distribution of purse seine effort that occurred in 2001-2004, the total effort attributed to the HSP would be 7,439 days.

CMM2008-01 makes no mention of what would happen to this effort following the closure of the HSP. One scenario is that the effort would simply disappear. A second scenario is that it would move to other high seas areas, primarily to the east in model region 4, that remain open. Both of these scenarios have been tested in separate model runs. Note that CMM2008-01 does not allow for the absorption of this effort into the surrounding EEZs through a corresponding increase in the EEZ limits, therefore such a possibility has not been evaluated. The allocation of purse seine effort to model fisheries and quarters, incorporating the HSP closure under the two effort-displacement scenarios is given in Table 3.

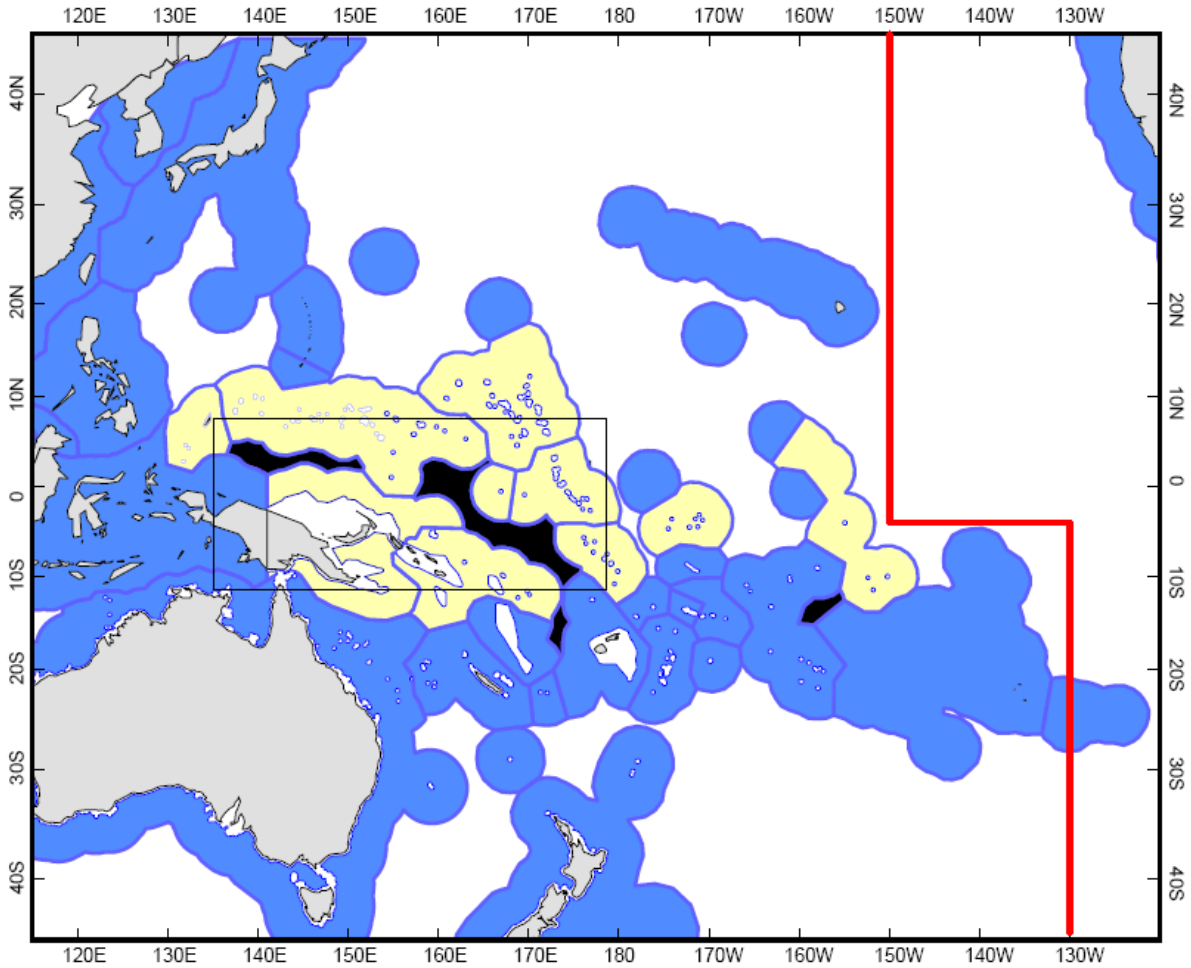

Figure 1. The WCPFC Convention Area. PNA EEZs are shown in yellow, non-PNA EEZs in blue. High-seas pockets wholly enclosed between 20°N and 20°S are shown in black. The two high seas pockets framed within the rectangle are those referred to in CMM2008-01 paragraph 22, to be closed effective 1 January 2010. Archipelagic waters within the EEZs of PNG, Solomon Islands, Vanuatu and Fiji are shown in white. Archipelagic waters for Indonesia and Philippines are not shown because baseline data were not available.

Table 3. Purse seine effort (days fished) estimated to be allowed under CMM2008-01 with the high-seas pockets closure and two scenarios for the displaced effort.

Effort disappears	*Region 3*		*Region 4*	
Quarter	Associated sets	Unassociated sets	Associated sets	Unassociated sets
Q1	5,377	4,206	879	101
Q2	4,929	4,304	1,332	790
Q3	4,298	3,674	1,889	1,936
Q4	4,726	3,459	1,650	1,315
Effort redistributes	*Region 3*		*Region 4*	
Quarter	Associated sets	Unassociated sets	Associated sets	Unassociated sets
Q1	5,377	4,206	2,032	1,208
Q2	4,929	4,304	2,337	1,820
Q3	4,298	3,674	2,779	2,657
Q4	4,726	3,459	2,488	2,010

2.1.3 FAD closures

CMM2008-01 paragraphs 11 and 13 provide for a closure of FAD fishing in EEZs and high seas, respectively, during August and September 2009. Paragraphs 17b and 19 extend the FAD closure to 3 months (July – September) from 2010. This measure has been evaluated by assuming that FAD effort during the closures changes to non-FAD, or unassociated-set effort. It is assumed that during the unrestricted parts of the year, the proportions of FAD effort and unassociated-set effort remain as per their 1998-2007 average proportions.

CMM2008-01 paragraphs 15 and 16 outline an alternative to the FAD closure on the high seas in 2009. This alternative involves eligible members undertaking to reduce their bigeye tuna purse seine catch by 10% relative to 2001-2004 average levels. Such a reduction would be required for the total catch, not just that component on the high seas. At the time of writing, it was uncertain which members would be approved by the Commission to implement the alternative measure (although three members have indicated they will be operating under the provisions of paragraph 15 and 16 in 2009). Also, it is unclear whether a similar alternative measure will be available from 2010. Because of this, we did not attempt a formal evaluation of the alternative measure. If some members do implement the alternative, we assume that it will have equivalent effect as the high-seas FAD closure.

The allocation of purse seine effort to model fisheries and quarters, incorporating the FAD closure from 2010, is shown in Table 4. A similar table incorporating both FAD and HSP closures is shown in Table 5.

Table 4. Purse seine effort (days fished) estimated to be allowed under CMM2008-01 incorporating a FAD closure in July – September and a switch of FAD effort during the closure to unassociated-set effort.

Quarter	*Region 3*		*Region 4*	
	Associated sets	Unassociated sets	Associated sets	Unassociated sets
Q1	6,279	5,175	1,130	239
Q2	5,829	5,217	1,437	907
Q3	1,379	7,856	0	4,173
Q4	5,361	3,987	1,853	1,482

Table 5. Purse seine effort (days fished) estimated to be allowed under CMM2008-01 with the July – September FAD closure and high-seas pockets closure incorporating two scenarios for the displaced effort.

Effort disappears	*Region 3*		*Region 4*	
Quarter	Associated sets	Unassociated sets	Associated sets	Unassociated sets
Q1	5,377	4,206	879	101
Q2	4,929	4,304	1,332	790
Q3	1,379	6,711	0	3,923
Q4	4,726	3,459	1,650	1,315
Effort redistributes	*Region 3*		*Region 4*	
Quarter	Associated sets	Unassociated sets	Associated sets	Unassociated sets
Q1	5,377	4,206	2,032	1,208
Q2	4,929	4,304	2,337	1,820
Q3	1,379	6,711	0	5,319
Q4	4,726	3,459	2,488	2,010

Figure 2 summarizes the total levels of purse seine effort, classified by associated and unassociated sets, obtained for the various CMM2008-01 provisions, compared to the actual effort history, as used in the bigeye and yellowfin tuna assessments, since 2001. For all of the CMM scenarios developed, total purse seine effort is similar to or greater than the historical high effort in 2005 and 2008. For FAD (or associated) set effort, the range for the different CMM scenarios is similar to that observed during 2001-2008. However, it is clear that even perfect implementation of all provisions of the CMM (second to last bar of Figure 2), will not meet the bigeye tuna objective as stated in paragraph 8, i.e. achieving a 30% reduction in fishing mortality in the purse seine fishery.

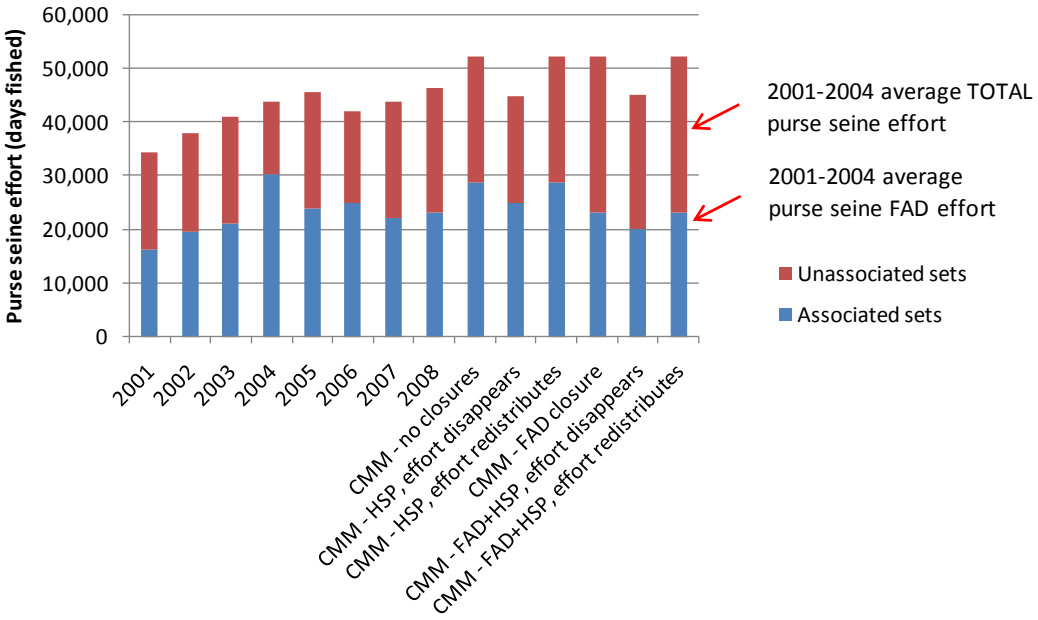

Figure 2. Comparison of purse seine effort estimated to result under CMM2008-01 with historical purse seine effort 2001-2008.

2.1.4 Other purse seine measures

Other provisions of CMM2008-01 relating to the purse seine fishery include FAD management plans, juvenile tuna catch mitigation research, catch retention, monitoring and exemption of developing skipjack purse seine fisheries. Of these, the catch retention provision could potentially impact stock status, if vessel operators choose to avoid setting on tuna of small size that would, in the absence of a catch retention rule, be caught and discarded. A widespread and persistent change in fishing behaviour of this sort could modify the overall size selectivity of purse seine gear, and generate some positive benefits for the stocks. However, at this stage, such a change in behaviour cannot be guaranteed, and even if it did occur it would likely be of only marginal benefit because of the high natural mortality rate of very small tuna. Therefore, we have not attempted to evaluate this measure at this stage, but can do so once data are available to quantify any change in fishing behaviour that results from the measure.

2.2 Longline

As per paragraph 31 of CMM2008-01, the total catch of bigeye tuna by longline fishing gear will be subject to a phased reduction such that by 1 January 2012 the longline catch of bigeye tuna is 70% of the average annual catch in 2001-2004 or, in the case of China, US and Indonesia, 2004. The catch of yellowfin tuna is not to be increased in the longline fishery from the 2001-2004 levels. The bigeye tuna catch reductions are to be phased in, with 10%, 20% and 30% reductions being achieved for years 2009, 2010 and 2011, respectively (paragraph 33).

There are several exemptions to this provision:

- Members catching less than 2,000 tonnes of bigeye tuna in 2004 are exempt from the reductions, and are required to ensure that their catch does not exceed 2,000 tonnes (paragraph 32). In these cases, we have assumed that the 2007 catches (last available year), which in no case exceeded 2,000 tonnes, are maintained.
- Neither the reductions for members catching more than 2,000 tonnes in 2004, nor the restriction to 2,000 tonnes for members not achieving this level of catch in 2004, applies to small island developing State members and participating territories in the Convention Area undertaking responsible development of their domestic fisheries (paragraph 34). No specific allowance for an increase in the bigeye tuna catches of such members beyond 2007 levels has been made in the evaluation. For this reason, the total longline catches used in the evaluation are probably conservative.
- The reductions for 2010 and 2011 do not apply to members with a total bigeye catch limit of less than 5,000 tonnes and landing exclusively fresh fish (paragraph 35). The only member to which this applies is US. While the wording of the paragraph is somewhat unclear, the current interpretation by the US is that the limit for 2009, 2010 and 2011 is 90% of the 2004 catch. This assumption has been used in the evaluation.
- The catch limit for China for 2009 and 2010 will remain at 2004 levels pending agreement being reached to develop an arrangement for the attribution of Chinese catch taken as part of domestic fisheries in the EEZs of Pacific Island Countries (paragraph 36). For the evaluation, we have assumed that the Chinese bigeye tuna catch will remain at the 2004 level in 2009 and 2010, but will be reduced to 70% of that amount in 2011.
- Indonesia is specifically referred to in footnote 3 of CMM2008-01 as having a base longline catch equivalent to their 2004 catch. However, the available data on Indonesian longline catch distribution suggests that the majority of the catch is taken in Indonesian archipelagic waters, which, as noted, is beyond the scope of CMM2008-01. Therefore, we have assumed a continuation of the 2007 longline catch for Indonesia.

The total bigeye catches that would result in 2009-2011 from the application of the above are shown in Figure 3. Catches for 2001-2007 are also shown for comparison. 2008 catches have not yet been reported. By 2011, the CMM is estimated to result in a 11% reduction in bigeye tuna catch from the average recorded in 2001-2004, subject to there being no increase in the 2007 levels of catches by small island developing states and others currently catching <2,000 tonnes annually.

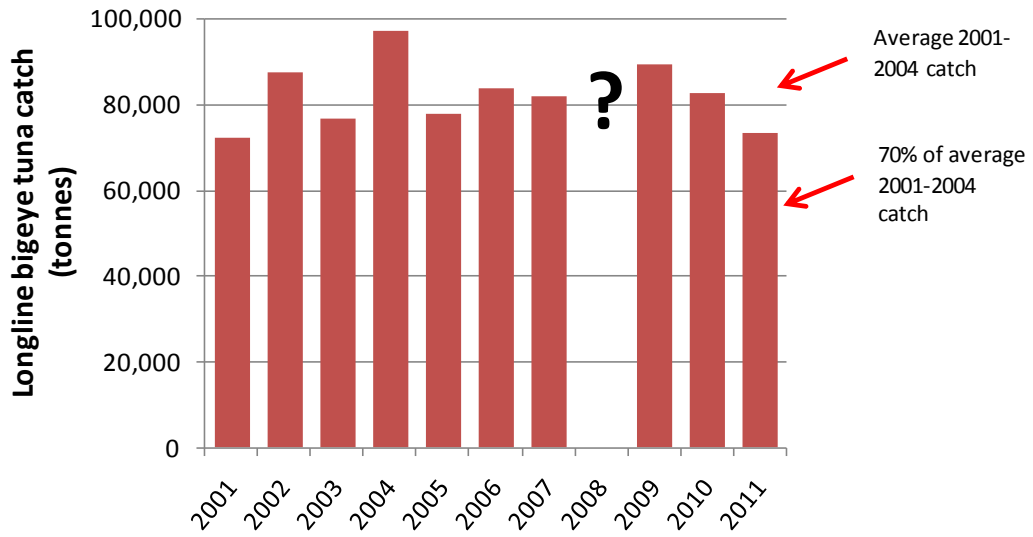

Figure 3. Catches of bigeye tuna by longline in the WCPFC Convention Area, 2001-2007, and catches allowed under CMM2008-01 for 2009-2011, subject to the assumptions given in the text. The total catch for 2008 has not yet been reported.

2.3 Other commercial tuna fisheries

Paragraph 39 of CMM2008-01 requires CCMs to "*take necessary measures to ensure that the total capacity of their respective other commercial tuna fisheries for bigeye and yellowfin tuna, including purse seining that occurs north of 20ºN or south of 20ºS, but excluding artisanal fisheries and those fisheries taking less than 2,000 tonnes of bigeye and yellowfin, shall not exceed the average level for the period 2001-2004 or 2004*". The fisheries included in this category are:

- The Japanese purse seine fishery in Japan coastal waters
- The Japanese pole-and-line fishery in Japan coastal waters
- Tropical pole-and-line fisheries
- Non-purse seine, non-longline domestic fisheries in Indonesia and Philippines
- The handline fishery in Hawaii

In most cases, recent annual bigeye catches by these fisheries have been less than 2,000 tonnes. The domestic fisheries in Philippines and Indonesia do take more than 2,000 tonnes of bigeye (and yellowfin) per year; however, the majority of such catches are believed to occur in archipelagic waters and therefore would be exempt from the measure. For the purpose of evaluation of the measure, we have assumed that the levels of fishing mortality estimated to have occurred in these fisheries in 2007 are continued into the future.

3 Impact of measures on bigeye and yellowfin tuna

The impact of the measures described in section 2 above on bigeye and yellowfin tuna stock status were investigated using the stock assessment models for both species presented as WCPFC-SC5-2009/SA-WP-04 (bigeye tuna) and WCPFC-SC5-2009/SA-WP-03 (yellowfin tuna).

3.1 Projection models

For bigeye tuna, two of the key stock assessment model runs were used as the basis of the evaluation – *Run10*, which is the model run that is most consistent with the 2008 bigeye tuna base case; and *Run14*, which uses purse seine catch estimates based on the observer spill sampling correction. For yellowfin tuna, we likewise used two runs, based on the "*CPUE low, LL sample high, LL q incr*" model with a stock-recruitment steepness parameter setting of 0.55 (see Table 9b, WCPFC-SC5/SA-WP-03). This model was chosen as one of the more conservative yellowfin models, again with either the base or the observer-spill-sample-corrected purse seine catches. The approach taken in evaluating a particular management scenario was as follows:

1. Longline catch and purse seine effort data for 2009-2011 reflecting the management scenario were mapped into the individual fisheries as defined in the stock assessment models. To do this, we used the 1999-2008 average distribution of purse seine effort by quarter, set type (FAD or associated sets and unassociated sets) and model region. The ten-year time period was used to encompass both *El Niño* and *La Niña* events.
2. The catch and effort in 2011 were assumed to be replicated through 2018, creating a ten-year projection period.
3. These data were used to project the bigeye and yellowfin tuna populations forward in time from Q1 2009 to Q4 2018. The main technical assumptions used in the projections were as follows:
    a. Recruitment in the projection period was generated via two methods, which were used for separate projection runs – (i) recruitment determined using the Beverton & Holt stock recruitment relationship (SRR) estimated/assumed in the stock assessment model; and (ii) recruitment determined as the average recruitment for each model region during 1998-2007, i.e. the most recent ten years of the model excluding the last year. These alternative recruitment assumptions were tested separately because future recruitment is highly uncertain, and the recent decade of bigeye recruitment has been well above that predicted by the SRR. It was therefore considered prudent to test the robustness of our conclusions to this key assumption about future recruitment.

b. Catchability for all fisheries was assumed to be constant at the terminal values obtained in the assessment.
c. Effort deviations (the variability in fishing mortality resulting from a given amount of fishing effort) were assumed to be zero in the projection period.
d. All other model parameters, including growth, natural mortality, selectivity, and movement, were assumed to operate in the projection period as estimated or assumed for the historical period.

4. MSY-based reference points (F_{MSY} and SB_{MSY}) and their corresponding reference point variables (F_{2018}/F_{MSY} and SB_{2018}/SB_{MSY}) were computed, based on the population and fishing mortality at age in the terminal year (2018) of the projection.
5. F_{2018}/F_{MSY} was compared to $F_{2001\text{-}2004}/F_{MSY}$ to measure the reduction in fishing mortality from the 2001-2004 average against the 30% reduction objective of CMM2008-01 in the case of bigeye tuna, and the no-increase objective in the case of yellowfin tuna. Similarly, SB_{2018}/SB_{MSY} was used to determine whether the management scenario maintained the spawning biomass at a level capable of producing MSY.

3.2 Projection scenarios

A number of projection scenarios were created to evaluate the potential impact of the different provisions of CMM2008-01. The scenarios, which were applied to the bigeye and yellowfin tuna projection models described above, are described in Table 6, below.

Scenario 0 is a "status quo" run to which the other scenarios can be compared. Scenarios 1 and 2 measure the impact of the levels of longline catch and purse seine effort, respectively, allowed under the CMM, with no other provisions implemented. Scenario 3 measures the impact of the HSP closure under the two scenarios for effort displacement. Scenario 4 measures the impact of the FAD closure. Scenario 5 measures the impact of both the HSP closure (with the two scenarios for effort displacement) and the FAD closure together. Finally, scenario 6 measures the impact of the purse seine measures and the longline catch restriction together.

Table 6. Description of projection scenarios used in the evaluation of CMM2008-01.

Projection scenario	*Longline catch or effort*		*Purse seine effort*		*High-seas pockets closure*		*FAD closure*
	2007 effort	CMM catch	2007 effort	CMM effort	Effort disappears	Effort redistributed	
0	X		X				
1[1]		X	X				
2	X			X			
3a	X			X	X		
3b	X			X		X	
4	X			X			X
5a	X			X	X		X
5b	X			X		X	X
6a[1]		X		X	X		X
6b[1]		X		X		X	X

1. Bigeye tuna only.

4 Performance in relation to objectives

4.1 Bigeye tuna

The stated objective of CMM2008-01 in respect of bigeye tuna is to achieve "*a minimum of 30% reduction in bigeye tuna fishing mortality from the annual average during the period 2001-2004 or 2004*". The use of "2001-2004 or 2004" in the objective is somewhat ambiguous, as it is not clear if the intent is to reduce from the higher or lower of these bases. We note however that estimated F/F_{MSY} for 2001-2004 is approximately 1.4 and a 30% reduction from this level is approximately 0.98. By contrast, the 2004 estimated F/F_{MSY} is approximately 1.8 and a 30% reduction from this level is 1.26. Given that the 30% reduction from 2001-2004 is consistent with F_{MSY}, and that returning the fishing mortality rate to F_{MSY} was the basis of SC4 advice to the Commission, we have also used this level as the basis for the evaluation of CMM2008-01.

Estimates of bigeye tuna F/F_{MSY} for 2001-2008 and in 2018 for each of the projection scenarios are shown in Figure 4. The results for the two assessment models using different purse seine catch estimates are similar, although the higher purse seine catch model is slightly more pessimistic. F/F_{MSY} is estimated to have increased sharply since 2003 and in the most recent year of the assessment model (2008) is >2. In other words, given the current age-specific exploitation pattern, the level of fishing is more than twice that resulting in MSY. This estimated increase in fishing mortality is due to several causes:

- A large increase in the reported catches of small bigeye tuna by the domestic fisheries in Philippines and, in particular, Indonesia (Figure 5). For Indonesia, the increase from 2003 to 2004 may be a statistical artifact, but these are the statistics presently available;
- Some increase in longline catch since 2001 (Figure 3);
- The increase in purse seine effort since 2001, and in particular an increase in FAD-based effort (Figure 2); and
- An estimated increase in purse seine catchability over time (see Figure 20 of WCPFC-SC5-2009/SA-WP-4), which means that a unit of purse seine effort in 2008 results in considerably more fishing mortality than it did in 2001-2004.

For the projections, we get slightly more optimistic results (i.e. lower F/F_{MSY} in 2018) under an assumption of future recruitment behaving according to the estimated stock recruitment relationship (SRR) compared to the 1998-2007 average (AV). This is because the recent average recruitment places more of the population in the heavily-fished regions compared to the long-term historical pattern captured by the SRR. Irrespective of this difference, we find that no scenario achieves even maintenance of the 2001-2004 level of fishing mortality, let alone a 30% reduction, as sought by CMM2008-01. While application of the longline catch limits alone (scenario 1) results in a small reduction in F/F_{MSY} compared to a continuation of current effort levels in all fisheries (scenario 0), none of the purse seine measures (scenarios 2-5), even when combined, result in much better outcomes than if the *status quo* were simply continued, with or without longline catch limits.

Some consideration of the age- and fishery-specific patterns of fishing mortality are required to better understand the failure of CMM2008-01 to reduce overall fishing mortality. Figure 6 provides estimates of age-specific exploitation rates (catch-at-age divided by population at age) of bigeye tuna from the two alternative assessment models considered, by fishery category, at three times – the average for 2001-2004, 2008 (the terminal year of the assessment) and 2018 for projection 6a (AV). From 2001-2004 to 2008, exploitation rates increased for most age classes, but the largest increases occurred for the younger age classes (1-8 quarters), due to increases in the domestic small-fish fisheries in Indonesia and Philippines (primarily age classes 1-3) and the purse seine fishery (primarily age classes 4-7). These increases in exploitation rates are consistent with the large increases in catch reported from 2004 in the Indonesian and Philippines domestic fisheries (Figure 5) and increases in purse seine effort and catchability. Smaller increases in exploitation rates occurred for the older age classes (17-40) resulting primarily from the longline fishery. The projected exploitation rates for 2018 have even higher rates for the youngest age classes (1-3), with some reduction in exploitation rates by the purse seine fishery for the intermediate age classes to about the 2001-2004

average level, and a small reduction for the older age classes to less than the 2001-2004 average level. These analyses confirm that none of the reductions implemented through CMM2008-01 – on juvenile bigeye tuna though measures directed at the purse seine fishery, or on larger bigeye though the longline measures – are really sufficient to have a substantial impact on fishing mortality.

An additional objective of CMM2008-01 is to ensure that "*bigeye and yellowfin tuna stocks are maintained at levels capable of producing their maximum sustainable yield*". The qualifying language associated with this objective relating to "*relevant environmental and economic factors, including the special requirements of developing States*", is not amenable to evaluation unless precisely specified; therefore we have simply presented the outcomes of the projections in terms of the spawning biomass in relation to spawning biomass at MSY (SB/SB_{MSY}). We leave it to others to consider if relevant environmental and economic considerations justify these outcomes.

Estimates of bigeye SB/SB_{MSY} for 2001-2008 and in 2018 for each of the projection scenarios are shown in Figure 7. The results for the two assessment models using different purse seine catch estimates are again similar, although the higher purse seine catch model is slightly more pessimistic. SB/SB_{MSY} is estimated to have decreased strongly between 2004 and 2008 and is currently estimated to be close to or beneath the value of 1, indicating an overfished state. The projections predict further decline in SB through 2018**,** to levels around 0.4-0.6 of SB_{MSY}. This is consistent with the F/F_{MSY} levels predicted to occur (Figure 4).

The ratios of F_{2018}/F_{MSY} to $F_{2001\text{-}2004}/F_{MSY}$ and SB_{2018}/SB_{MSY} are given in Table 7 for each of the projection scenarios to show the projection outcomes in relation to the objectives of the CMM.

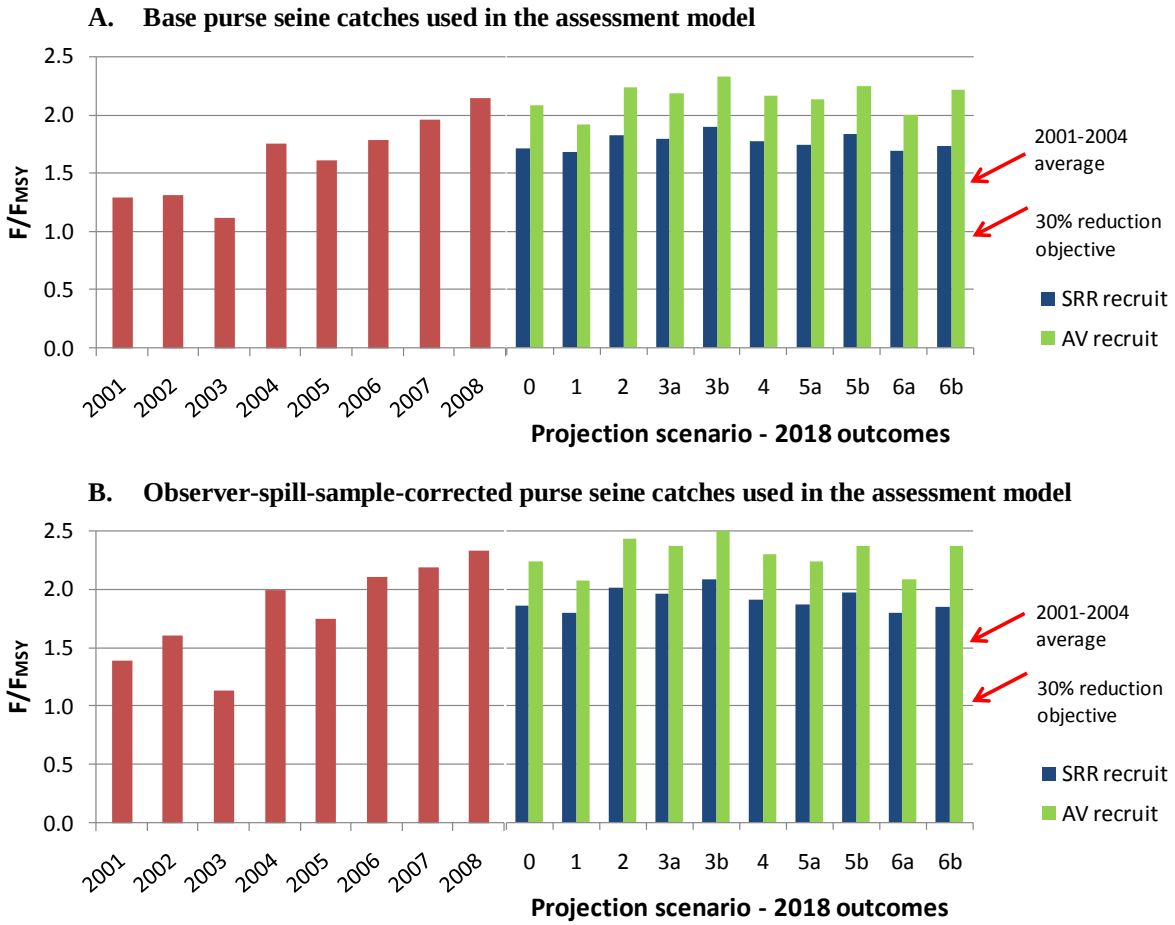

Figure 4. Estimates of bigeye tuna F/F_{MSY} for 2001-2008 from assessment model runs (red bars) and the terminal values from a 10 year projection (2009-2018) under different projection scenarios for two assumptions regarding future recruitment. Comparative values for the 2001-2004 average and a 30% reduction from the 2001-2004 average F_{MSY} (CMM2008-01 objective) are shown by the red arrows on the right.

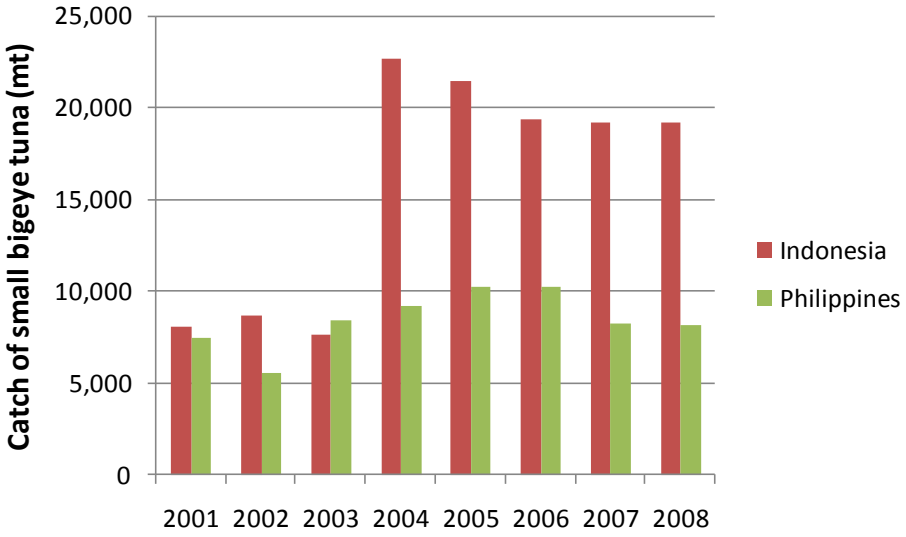

Figure 5. Catch estimates of small bigeye tuna, 2001-2008, provided by Indonesia and Philippines in respect of their domestic tuna fisheries.

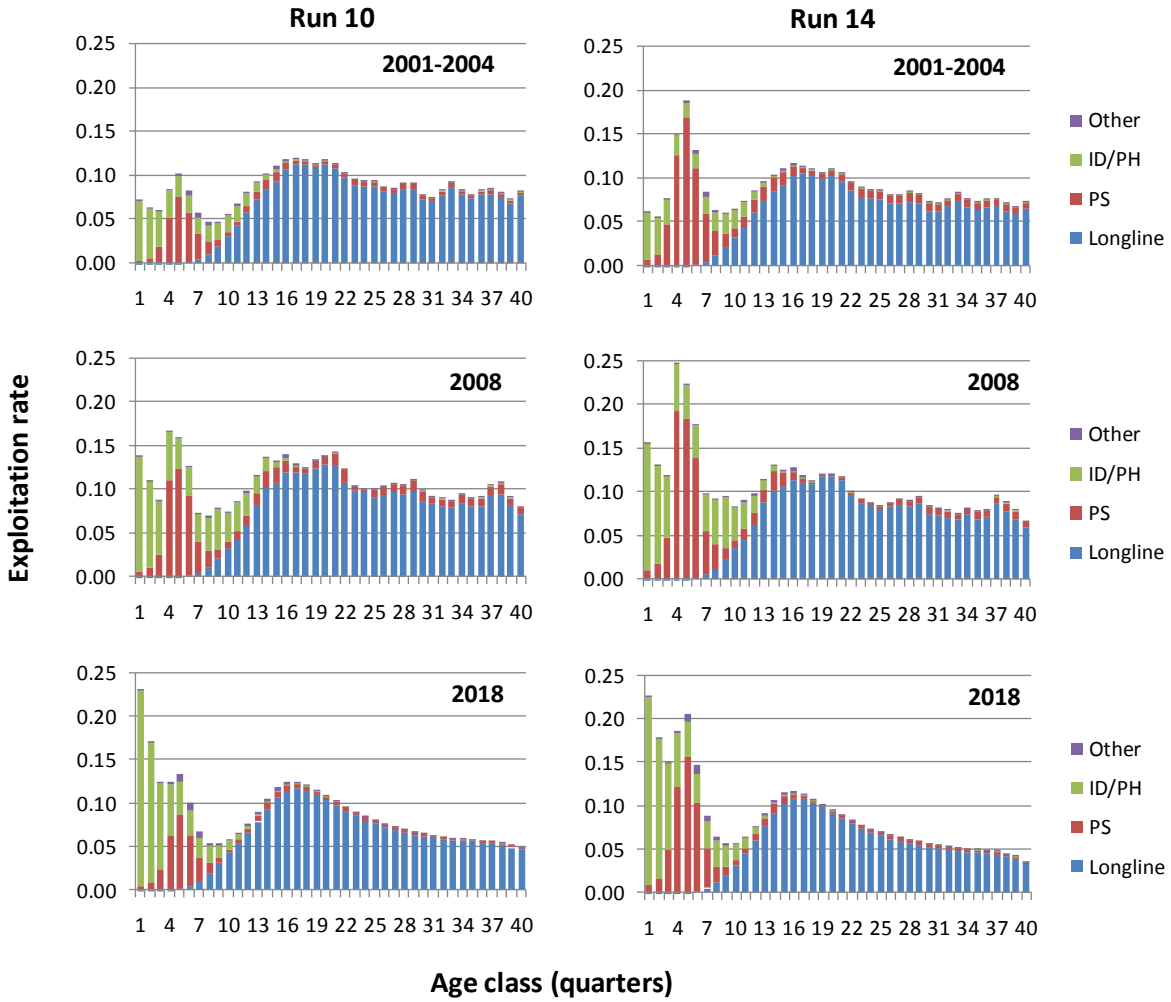

Figure 6. Estimates of age-specific exploitation rates (catch number-at-age divided by population number at age) of bigeye tuna for 2001-2004, 2008 and at the terminal year of projection 6a using the base purse seine catch (run 10) and the observer-spill-sample-corrected purse seine catch (run 14) bigeye tuna models.

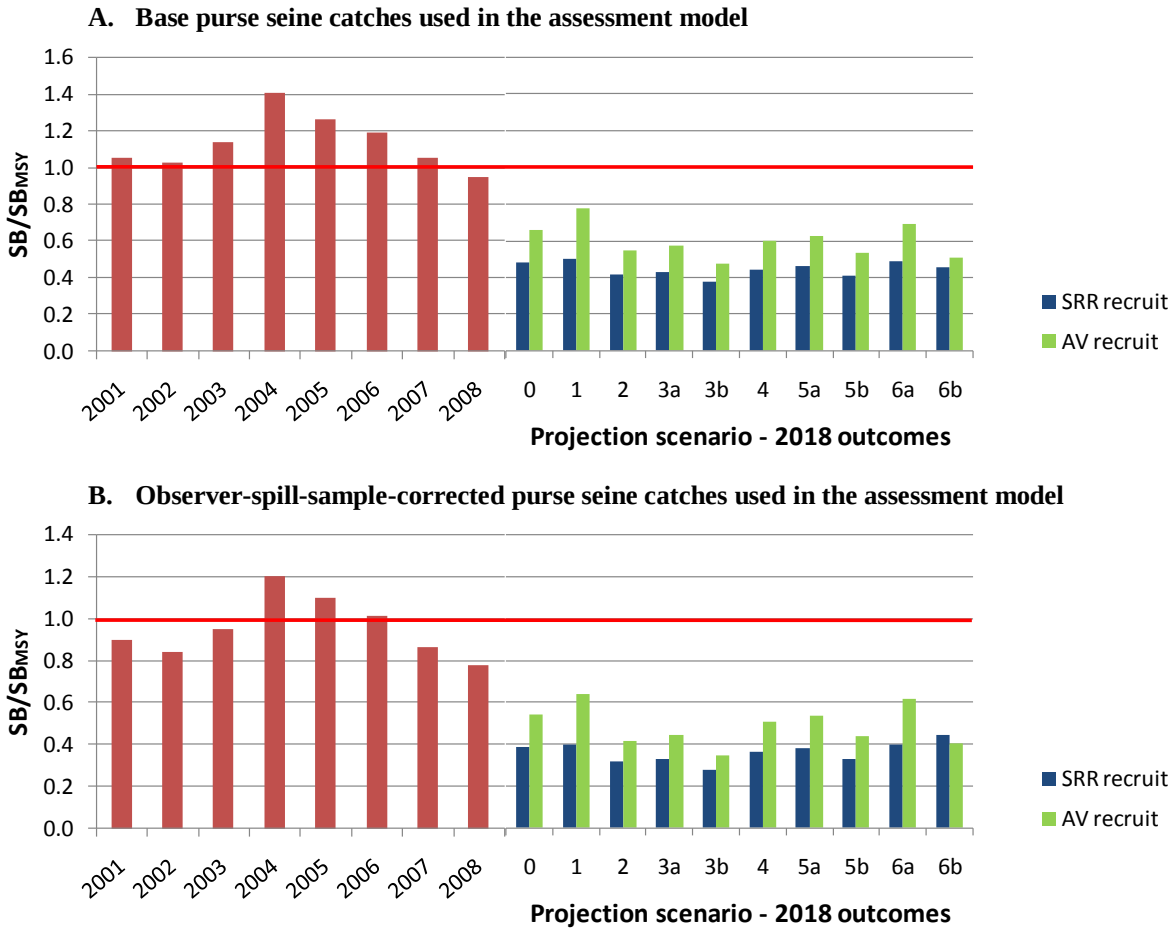

Figure 7. Estimates of bigeye tuna SB/SB_{MSY} for 2001-2008 from assessment model runs (red bars) and the terminal values from a 10 year projection (2009-2018) under different projection scenarios for two assumptions regarding future recruitment. The horizontal red line indicates the spawning biomass providing MSY.

Table 7. Projected values of bigeye tuna F_{2018}/F_{MSY} in relation to $F_{2001-2004}/F_{MSY}$ and SB_{2018}/SB_{MSY} for the two assessment models and two projected recruitment assumptions used in the evaluation.

Projection scenario	Ratio of F_{2018}/F_{MSY} : $F_{2001-2004}/F_{MSY}$				SB_{2018}/SB_{MSY}			
	Base PS catch model		Obs-spill-sample PS catch model		Base PS catch model		Obs-spill-sample PS catch model	
	SRR recruit	AV recruit	SRR recruit	AV recruit	SRR recruit	AV recruit	SRR recruit	AV recruit
0	1.22	1.49	1.21	1.46	0.48	0.66	0.38	0.54
1	1.20	1.36	1.18	1.35	0.50	0.78	0.40	0.64
2	1.30	1.59	1.31	1.59	0.42	0.55	0.32	0.42
3a	1.27	1.56	1.28	1.54	0.43	0.57	0.33	0.45
3b	1.35	1.66	1.36	1.65	0.37	0.48	0.28	0.35
4	1.26	1.54	1.25	1.50	0.44	0.60	0.36	0.51
5a	1.24	1.52	1.22	1.46	0.46	0.62	0.38	0.54
5b	1.31	1.60	1.28	1.55	0.41	0.53	0.33	0.44
6a	1.20	1.42	1.17	1.36	0.49	0.69	0.40	0.62
6b	1.23	1.58	1.20	1.54	0.45	0.51	0.45	0.41

In summary:

- The bigeye tuna longline catch restrictions (scenario 1) result in small reductions in fishing mortality compared to the *status quo* (projection scenario 0);
- Increased purse seine effort (scenario 2) and catchability compared to 2001-2004 results in higher fishing mortality on juvenile bigeye tuna;
- The HSP closure (scenario 3) will only result in a reduction in fishing mortality if the effort that would have otherwise fished in the HSP is removed from the fishery (3a). If the effort simply transfers to other high seas areas, as per scenario 3b, then the outcome in terms of fishing mortality and spawning biomass is predicted to be worse than if there was no closure of the HSP (scenario 2). This results because effort is being transferred to an area (model region 4) where the catchability of bigeye is estimated to be higher;
- The purse seine FAD closure (scenario 4) results in a small offsetting reduction in fishing mortality;
- Simultaneous implementation of all measures (scenario 6) will, at best, maintain fishing mortality at the high levels estimated for 2007-2008 in the assessment, and cause declines in spawning biomass to levels well below MSY levels.
- The measure fails in its objectives relating to bigeye tuna because the reductions in longline catch and the purse seine provisions fall well short of reducing fishing mortality in those components of the fishery to 30% less than 2001-2004 average levels. Even if those sectoral objectives were achieved, the overall objectives of the measure would not be achieved because the exclusion of the domestic fisheries of Indonesia and Philippines quarantines an important source of fishing mortality on juvenile bigeye tuna.

4.2 Yellowfin tuna

The objectives of CMM2008-01 with respect to yellowfin tuna are less demanding than for bigeye tuna. Whilst the maintenance of stocks at levels capable of producing MSY is required (with the qualifying language, as noted earlier), the main objective of the measure is that "*there is no increase in fishing mortality for yellowfin tuna beyond the annual average during the period 2001-2004 or 2004*".

Estimates of yellowfin tuna F/F_{MSY} for 2001-2008 and in 2018 for each of the projection scenarios are shown in Figure 8. Again, the results for the two assessment models using different purse seine catch estimates are similar, but with somewhat more pessimistic results being provided by the higher purse seine catch model. For the base purse seine catch model, levels of F/F_{MSY} (Figure 8) and SB/SB_{MSY} (Figure 9) in 2018 under the different projection scenarios are similar to the 2001-2004 average. For the higher purse seine catch model, increases in F/F_{MSY} from the 2001-2004 average of up to 9-15% are predicted to occur when all measures are implemented (scenario 5). Spawning biomass is predicted to decrease by 2018, but to remain at, or in excess of MSY levels, under both future recruitment hypotheses.

The ratios of F_{2018}/F_{MSY} to $F_{2001\text{-}2004}/F_{MSY}$ and SB_{2018}/SB_{MSY} are given in Table 8 for each of the projection scenarios.

In summary:

- Projection scenarios 5a and 5b, which combine purse seine effort, FAD closure and HSP closure, result in F/F_{MSY} being from 8% below to 15% above the 2001-2004 average level (although F/F_{MSY} remains <1.0).
- Most of the projection scenarios, including 5a and 5b, result in the spawning biomass remaining above (albeit marginally in some cases) the MSY level.

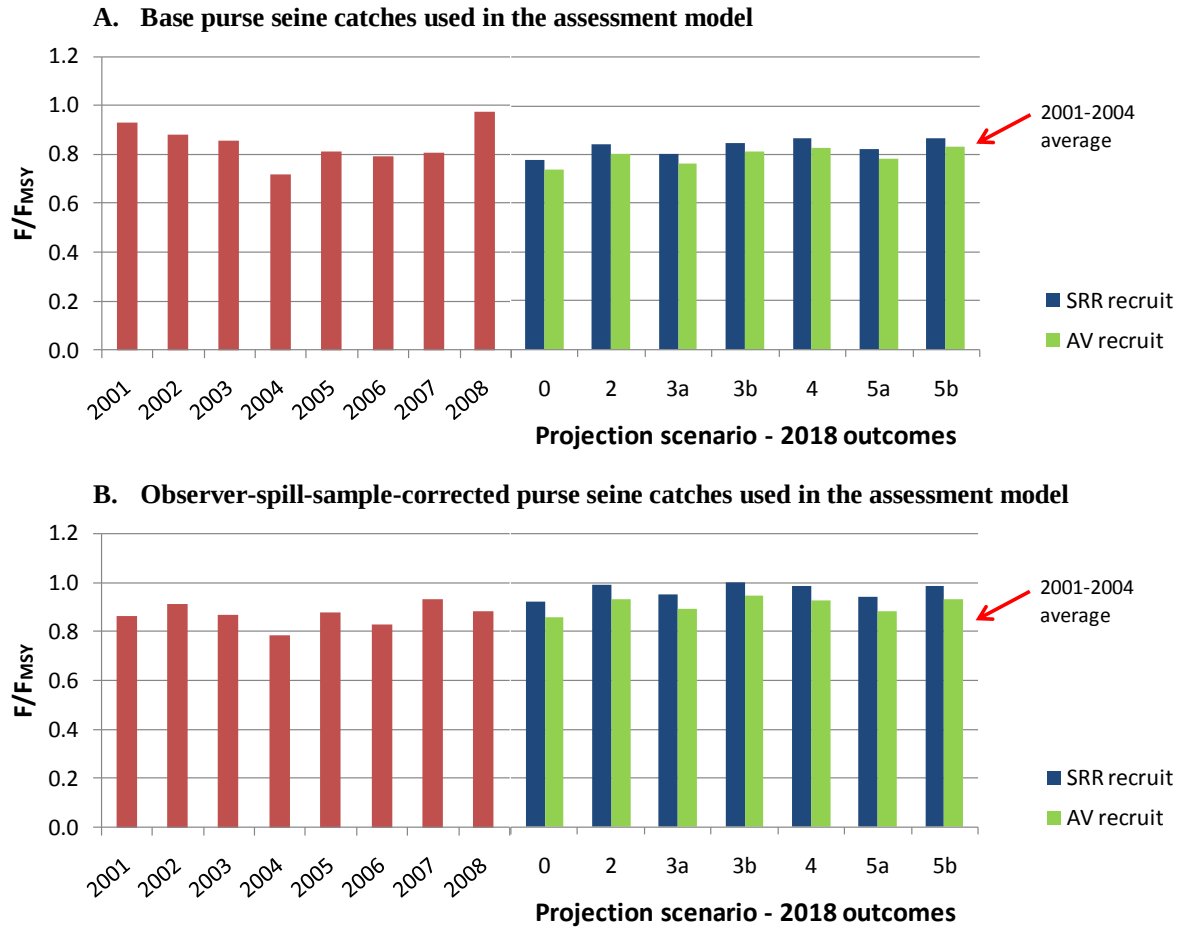

Figure 8. Estimates of yellowfin tuna F/F_{MSY} for 2001-2008 from assessment model runs (red bars) and the terminal values from a 10 year projection (2009-2018) under different projection scenarios for two assumptions regarding future recruitment. The 2001-2004 average F_{MSY} (CMM2008-01 objective) is indicated by the red arrow on the right.

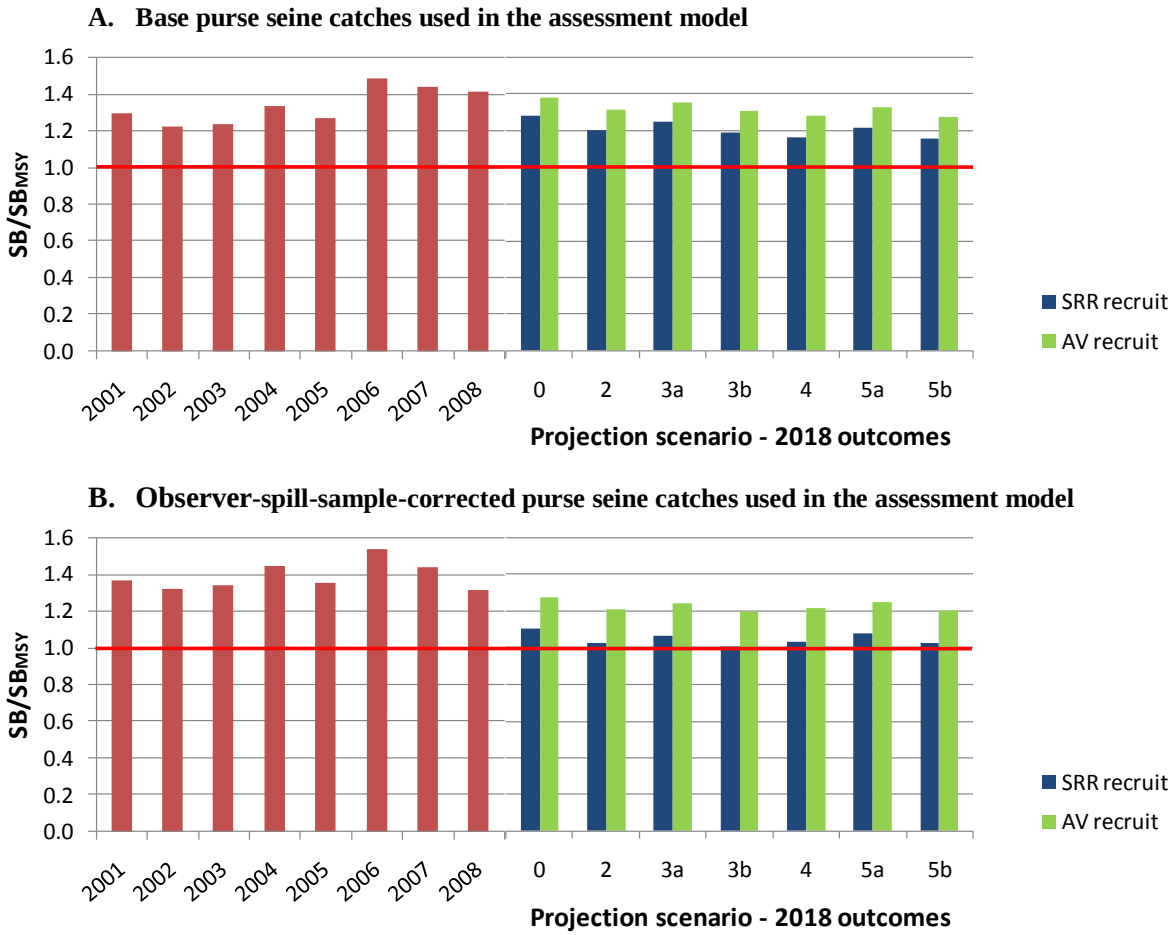

Figure 9. Estimates of yellowfin tuna SB/SB_{MSY} for 2001-2008 from assessment model runs (red bars) and the terminal values from a 10 year projection (2009-2018) under different projection scenarios for two assumptions regarding future recruitment. The horizontal red line indicates the spawning biomass providing MSY.

Table 8. Projected values of yellowfin tuna F_{2018}/F_{MSY} in relation to $F_{2001\text{-}2004}/F_{MSY}$ and SB_{2018}/SB_{MSY} for the two assessment models and two projected recruitment assumptions used in the evaluation.

Projection scenario	Ratio of F_{2018}/F_{MSY} : $F_{2001\text{-}2004}/F_{MSY}$				SB_{2018}/SB_{MSY}			
	Base PS catch model		Obs-spill-sample PS catch model		Base PS catch model		Obs-spill-sample PS catch model	
	SRR recruit	AV recruit	SRR recruit	AV recruit	SRR recruit	AV recruit	SRR recruit	AV recruit
0	0.92	0.87	1.08	1.00	1.29	1.38	1.11	1.28
2	0.99	0.94	1.16	1.09	1.20	1.32	1.03	1.21
3a	0.94	0.90	1.11	1.04	1.25	1.36	1.07	1.25
3b	1.00	0.96	1.17	1.11	1.19	1.31	1.01	1.20
4	1.02	0.98	1.15	1.08	1.17	1.29	1.03	1.22
5a	0.97	0.92	1.10	1.03	1.22	1.33	1.08	1.25
5b	1.02	0.98	1.15	1.09	1.16	1.28	1.03	1.21

5 Conclusions

The overall conclusions of the evaluation are as follows:

- CMM2008-01 will not achieve its objectives relating to a 30% reduction in bigeye tuna fishing mortality from 2001-2004 average levels, and would appear likely to maintain the high levels of fishing mortality in excess of MSY levels estimated since 2004.
- Small reductions in bigeye tuna fishing mortality resulting from the longline catch limits and purse seine FAD closure are more than offset by likely increases in fishing mortality resulting from higher purse seine effort and catchability.
- Closure of the high seas pockets will result in a small reduction in bigeye fishing mortality if the effort that would otherwise have fished in the HSP is removed from the fishery. If such effort transfers to other high seas areas, primarily to the east, the net effect is an increase in bigeye fishing mortality compared to no closure of the HSP.
- Bigeye tuna spawning biomass is predicted to continue its decline and reach levels of 0.4-0.6 that of SB_{MSY} by 2018 irrespective of the implementation of CMM2008-01.
- The measure fails in its objectives relating to bigeye tuna because the existing longline and purse seine provisions fall well short of reducing fishing mortality in those components of the fishery to 30% less than 2001-2004 average levels. Even if those sectoral objectives were achieved, the overall objectives of the measure would not be achieved because the exclusion of the domestic fisheries of Indonesia and Philippines quarantines an important source of fishing mortality on juvenile bigeye tuna.
- For yellowfin tuna, levels of fishing mortality in 2018 ranging from 8% below to 15% above the 2001-2004 average level could result under CMM2008-01. Fishing mortality in 2018 is predicted to remain less than F_{MSY} under the base purse seine catch model, and to be close to the MSY level under the higher purse seine catch model.
- Yellowfin tuna spawning biomass is predicted to be similar to the levels estimated for 2001-2004, and to remain above the MSY level, under the base purse seine catch model, but to decline slightly, and be close to the MSY level, under the higher purse seine catch model.

6 Acknowledgements

We acknowledge the assistance of Peter Williams in the compilation of the various data sets, and advice on the interpretation of CMM2008-01 provided by Prof. Martin Tsamenyi. Robert Campbell and Les Clark provided useful comments on an earlier draft. We also acknowledge the assistance of the authors and collaborators involved in the 2009 assessments for bigeye and yellowfin tuna.

7 References

Harley, S., Hoyle, S., Langley, A., Hampton, J. and Kleiber, P. 2009. Stock assessment of bigeye tuna in the western and central Pacific Ocean. WCPFC-SC5-2009/SA-WP-04, Port Vila, Vanuatu, 10–21 August 2009.

Langley, A., Harley, S.J., Hoyle, S., Davies, N., Hampton, J. and Kleiber, P. 2009. Stock assessment of yellowfin tuna in the western and central Pacific Ocean. WCPFC-SC5-2009/SA-WP-03, Port Vila, Vanuatu, 10–21 August 2009.

NOAA, 2009. International Fisheries; Western and Central Pacific Fisheries for Highly Migratory Species; Fishing Restrictions and Observer Requirements in Purse Seine Fisheries for 2009-2011 and Turtle Mitigation Requirements in Purse Seine Fisheries. Federal Register: 74 (103): 26160-26170.

WCPFC Secretariat, 2008. Review of CCM's implementation of, and compliance with, conservation and management measures. WCPFC-TCC4-2008/10 (Rev.3), Pohnpei, Federated States of Micronesia, 2-7 October 2008.