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REVIEW OF THE IMPLEMENTATION AND EFFECTIVENESS OF CMM 2008-01

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Review of the Implementation and Effectiveness of CMM 2008-01

Executive Summary

The paper provides a review of the implementation and effectiveness of CMM 2008-01 using the most current data and stock assessments available.

Implementation of CMM 2008-01

The implementation of the CMM was reviewed for its key components – purse seine effort, the FAD closure, the high seas pockets (HSP) closure, longline catches and catches by other fisheries. The main conclusions from the paper regarding implementation are as follows:

Purse seine effort

CMM 2008-01 has not been effective in constraining growth of purse seine effort, with effort (excluding domestic purse seiners based in Indonesia and Philippines) in 2010 estimated to have increased by approximately 22-27% compared to effort in 2004, and by 36-42% compared to the 2001-2004 average effort.

FAD closure

The FAD closure in 2009 seems to have been largely respected, with about 10% of observed fishing days (based on currently available observer data) during the closure period having activities that might be interpreted as, or supporting, FAD fishing. The proportion of bigeye tuna caught in unassociated sets during the closure was slightly higher than in previous years. Reasonable levels of catch and effort were maintained during the closure and 2009 was a record year for the purse seine fishery overall. The proportion of associated sets in the ten months of 2009 that were not closed to FAD fishing was high, with the total number of associated sets in 2009 being the highest since 2004 and the second highest ever.

High seas pockets closure

Available data from all sources indicate that the HSP closure since 1 January 2010 has largely been respected. However, the closure has clearly not resulted in a removal of effort from the fishery, as 2010 purse seine effort looks like being around 10% higher than the previous record level in 2008-2009. The additional effort that has occurred in 2010 appears to have occurred mainly in PNA waters, with the eastern high seas not subject to an unusual increase in effort in 2010.

Longline catches

The longline catch of bigeye tuna in 2009 was 65,596 tonnes, the lowest since 1996. The catch represents a 21% reduction from the average bigeye catch in 2001-2004. The longline catch of yellowfin tuna in 2009 was approximately 9% less than the average catch in 2001-2004.

Other fisheries

For fisheries other than purse seine and longline, total catches for 2009 are slightly less than their respective average levels for 2001-2004 for both bigeye and yellowfin tuna.

Effectiveness of CMM 2008-01

The paper also reviewed the effectiveness of the CMM, in particular in reducing the fishing mortality of bigeye tuna as recommended by the Sixth Regular Session of the Scientific Committee (SC6).

A grid of generic stock projections was compiled according to a detailed request by SC6. The projections incorporated changes in longline catch, purse seine associated effort and Indonesian and Philippines domestically-based effort. The changes in catch or effort for these three fishery groups ranged from a 50% reduction to a 30% increase, as per the SC6 request. The detailed results of the projections for the three species (bigeye, skipjack and yellowfin tuna) are posted on the WCPFC 7 web page as Microsoft Excel files.

Within the many combinations investigated, there is a relatively small subset, summarized in Table 4, that achieves the objective of the CMM in reducing bigeye tuna fishing mortality to a level consistent with MSY. Typically, significant reductions in at least two of the three fishery components are required to achieve MSY conditions. However, for the subset of projections in which F_{MSY} for bigeye tuna was achieved, the reductions in total catches that result are relatively minor, a maximum of 5.6%. This is because (i) there is some degree of increase in the three stocks under all scenarios in the subset; (ii) we assume that effort reductions for purse seine associated sets are compensated by transfer of that effort to purse seine unassociated sets; and (iii) in scenarios that reduce effort targeted at smaller fish (purse seine associated sets and Indonesia and Philippines domestic fisheries), some of the catch forgone is taken by fisheries targeting these fish at larger size (longline and purse seine unassociated sets).

The SC6 request called for information on three additional scenarios – (i) the implementation of the CMM as written, taking into account available information to date from the fisheries; (ii) the implementation of the CMM without exemptions; and (iii) the implementation of an additional high seas closure in the region 10°N-20°S, 170°E-150°W, referred to as “the eastern high seas”.

(i) For the implementation of the CMM as written, we estimate that a 14% reduction in bigeye tuna overfishing (F/F_{MSY} reducing from 1.49 to 1.42) can be expected.

(ii) In the absence of the various exemptions and exclusions built into the measure, our best estimate of the amount of bigeye tuna overfishing expected to be removed is 50% (F/F_{MSY} reducing from 1.49 to 1.26).

(iii) The eastern high seas have on average accounted for approximately 4% of purse seine effort in the WCPFC Convention Area, although utilization can be higher during *El Niño* periods. The proposed closure of the eastern high seas, under the assumption that the historical effort in this area would not be redistributed, is estimated to remove 8% of bigeye tuna overfishing (F/F_{MSY} reducing from 1.49 to 1.45). While this percentage reduction is small, it is large relative to the percentage of purse seine associated set effort removed (3.2%), due to the relatively high vulnerability of bigeye tuna to purse seine associated sets in this region.

1 Introduction

[CMM 2008-01](#), 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 currently pursued through a combination of measures including 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 to be phased in over the period 2009-2011.

In section 2 of this paper, we review the implementation to date of the key elements of CMM 2008-01. This review covers primarily the year 2009, for which data are now reasonably complete, but also includes incomplete information for 2010 where possible. The key elements of the CMM reviewed here are purse seine effort levels, the 2009 FAD closure, the high seas pockets closure to purse seine fishing, longline catches of bigeye and yellowfin tuna, and catches of bigeye and yellowfin tuna by fisheries other than purse seine and longline.

Section 3 of the paper focuses on the estimation of the effectiveness of the CMM in achieving its stated objectives. This is to a large extent an update of previous work ([WCPFC6-2009/IP17](#), [WCPFC-2009/IP18](#)) using the most recent assessments of bigeye, yellowfin and skipjack tuna presented to the Scientific Committee. The analysis also includes an assessment of the impacts of a variety of combinations of catch and effort levels on bigeye tuna overfishing and on the catches of all three species, as recommended by the Sixth Regular Session of the Scientific Committee (SC6).

2 Implementation of key elements of CMM 2008-01

In this section we briefly review, on the basis of available data, the implementation to date of the key elements of CMM 2008-01 as they pertain to the achievement of the objectives.

2.1 Purse seine effort

[CMM 2008-01](#) specifies certain limits on purse seine effort between 20°N and 20°S, as follows:

- Effort (measured in days fished) in the EEZs of PNA members combined is limited to no greater than 2004 levels;
- Compatible measures to reduce purse seine fishing mortality on bigeye tuna in the EEZs of non-PNA CCMs; and
- Effort on the high seas (measured in days fished) is limited for each individual CCM to no more than the 2004 or 2001-2004 average level¹
- Exemptions, exclusions and variations to the above include:
 - Small Island Developing States in paragraph 10 with respect to high seas effort;
 - Fleets of 4 vessels or less in footnote 2 of the CMM;

¹ Since the CMM provides a choice between 2004 and 2001-2004, it is assumed that CCMs would always choose the higher of the two.

- Preservation of existing rights under registered regional or bilateral fisheries partnership arrangements or agreements in paragraph 7; and
- Exclusion of archipelagic waters.

Purse seine effort in PNA EEZs (excluding archipelagic waters) in 2004 was 30,586 days ([WCPFC-2010-20](#), Attachment 5, Table 1). The comparable effort estimate for 2009 is 31,555 days, an increase of 3% over the 2004 level and an increase of 13% over the 2001-2004 average. Also, effort in archipelagic waters of PNG and Solomon islands, which is not limited by CMM 2008-01, increased from 3,123 days in 2004 to 6,168 days in 2009.

Most of the effort in non-PNA EEZs occurs in the EEZs of Indonesia and Philippines. It is difficult to determine recent trends in purse seine effort in these EEZs for several reasons: (i) logsheet data are not available for Indonesia, therefore no reliable estimates of purse seine effort are available; (ii) some logsheet data have been provided for Philippines purse seiners for 2004 and subsequent years, but the coverage rate of the data is unknown and therefore reliable estimates of total purse seine effort cannot be determined; and (iii) in both Indonesia and Philippines, the proportions of purse seine effort that occur within archipelagic waters is unknown.

On the high seas, total purse seine effort in 2004 was 15,386 days ([WCPFC-2010-20](#), Attachment 5, Table 2). This estimate is higher than previously reported because of the recent provision of logsheet data for Philippines purse seiners. High Seas effort in 2009 is 12,611 days, but this value may be revised upwards pending further submission of data by the Philippines purse seine fleet in particular.

Because of the difficulties of specifying purse seine effort of Indonesian and Philippines purse seiners both in their EEZs and on the high seas, it is not currently possible to precisely determine total purse seine effort in days fished in 2004 and subsequent years. However, based on the available raised logsheet data to 2009 and VMS data for 2008-2010 (see section 2.3), purse seine effort in the WCPFC tropical purse seine fishery in 2010, excluding domestic purse seiners based in Indonesia and Philippines, is estimated to have increased by approximately 22-27% compared to effort in 2004, and by 36-42% compared to the 2001-2004 average effort.

2.2 FAD closure

Information on the implementation of the FAD closure from 1 August to 30 September 2009 has been previously reported to both SC6 ([WCPFC-SC6-2010-MI-WP-03](#)) and TCC6 ([WCPFC-TCC6-2010-09a](#)). The key findings of [WCPFC-SC6-2010-MI-WP-03](#) were:

- On the basis of logsheet data, most vessels (~70% of the vessels that fished at any time during 2009, which is about average) continued to fish through the 2009 FAD closure, recording moderate catches of skipjack tuna in particular in unassociated sets;
- Catches of skipjack in FAD sets in the months following the closure were very high, with October 2009 recording the highest ever monthly catch of skipjack in the history of the WCPO purse seine fishery;
- Overall, 2009 was a record year for both skipjack and total tuna catch in the purse seine fishery, indicating that the FAD closure did not have an adverse effect on fishery performance;
- However, the rate of FAD usage during the 10 months of the year outside of the closure was high, with the number of FAD sets recorded overall in 2009 being the highest since 2004 and the second highest ever.

[WCPFC-TCC6-2010-09a](#) focused on behaviour of vessels during the FAD closure as recorded by observers. At the time that the TCC paper was prepared, processed observer data represented 16% of the vessel days fished during Aug-Sep 2009. Table 1 presents updated observer data, representing 31% of total days fished, on vessel behaviour during the 2009 FAD closure. On the basis of these data, observers reported some activity of the vessel related to drifting FADs on approximately 10% of days. This observed FAD involvement might have been due to misunderstanding by purse seine operators of what constituted FAD fishing; hopefully, with the tightening of definitions as per [CMM 2009-02](#), this misunderstanding will not have occurred for the 2010 FAD closure.

Additional observer data were also available to assess the species composition of unassociated sets sampled by observers during the FAD closure. These updated data suggest an overall percentage of bigeye tuna in the catch of around 1.2% (Table 2). This is slightly higher than in previous years, and could to some extent reflect the FAD involvement in declared unassociated sets referred to above; however, a higher bigeye species composition in purse seine sets generally would also be consistent with the more easterly disposition of fishing (where bigeye catch rates tend to be higher) that occurred in 2009 due to the *E/ Niño* event that began mid-year.

At the time of writing, little information from logsheets or observers regarding the 2010 FAD closure (1 Jul – 30 Sep 2010) was available.

2.3 High seas pockets closure

[CMM 2008-01](#) established a closure to all purse seine fishing in the two high seas pockets (HSP) shown in Attachment D of the CMM from 1 January 2010. Previous analyses ([WCPFC6-2009/IP17](#)) have determined that the impact of the closure on bigeye tuna overfishing depends on what happens to the purse seine effort that would have otherwise fished in the HSP (approximately 7,400 days per year in 2001-2004, or about 14% of the total managed purse seine effort). If that effort is removed from the fishery, there is a small reduction in F/F_{MSY} , while if the effort is redistributed, there is a small increase in F/F_{MSY} – under the assumption that such effort would redistribute to the eastern high seas areas (EHS)² given the existing limits on EEZ effort (see Table 7, [WCPFC6-2009/IP17](#)). In this section, we examine the available data for 2010 to assess the impact of the HSP closure on both the distribution and the amount of purse seine effort since the 1 January 2010 closure came into effect.

Figure 1 shows the distribution of purse seine effort in 2010 from three independent sources of data – logsheets, observer and VMS data. Both logsheet and observer data are currently incomplete, and 2010 data from both of these sources will continue to accumulate well into 2011. The VMS data are an integrated data set comprising data from the WCPFC and FFA VMS databases. The logsheet and observer data sets show similar patterns, with both HSP largely, but not completely, devoid of effort. The VMS data also show clear gaps in activity in the HSP, although there is some vessel occurrence there, presumably for transiting purposes. Historically, the proportion of total purse seine effort occurring on an annual basis in the HSP has been about 10-20% (Figure 2); in 2010, on the basis of

² For the purpose of this paper, we define the eastern high seas as the high seas areas of the WCPFC convention area between 10°N and 20°S and east of 170°E. That part of the high seas pocket bounded by the EEZs of Federated States of Micronesia, Marshall Islands, Nauru, Kiribati, Tuvalu, Fiji and Solomon Islands that is east of 170°E is excluded from this definition.

available logsheet data, it is 1.6%. It therefore seems that the HSP closure has been largely respected.

The next question is – has the HSP closure resulted in a removal of effort from the fishery? To address this question, we examined raised logsheet data for recent years up to and including 2009, and VMS data for 2008-2010, based on the integrated WCPFC and FFA data sets. Figure 3 shows the monthly evolution of purse seine effort for 2004-2009, based on raised logsheet data. The top two lines, indicating the highest levels of effort, are for 2008 and 2009. In Figure 4, similar information based on VMS data for 2008, 2009 and to 31 October 2010 is presented. It is clear that the amount of purse seine effort in 2010 is tracking considerably higher than in 2008 and 2009, and if this trend continues to the end of 2010, overall purse seine effort will be 10-15% higher than the previous two record years. This indicates that the HSP closure has certainly not resulted in a removal of effort from the fishery, nor has it apparently impeded the growth in purse seine effort.

The final question is – where has this additional effort in 2010 occurred? The distribution of purse seine effort is known to be influenced by the *El Niño* – Southern Oscillation (ENSO) cycle, with effort tending to disperse to the east during *El Niño* (where there are more high seas areas) and to contract to the west during *La Niña*. During the second half of 2009 and first quarter of 2010, an *El Niño* event was in progress, and from the second quarter of 2010 the system began to revert to *La Niña* conditions. The effect on purse seine effort distribution is evident in Figure 5 (upper panel), with an increase in effort in the EHS from about June 2009 to March 2010. Historically, higher utilization of the EHS has corresponded with the *El Niño* events in 1997-98 and 2002 (Figure 5, lower panel). However, apart from the shift expected with the 2009-2010 *El Niño*, there appears to be no obvious increase in effort in the EHS resulting from the closure of the HSP. This is confirmed in Figure 6 and Figure 7, which show the distribution of purse seine vessel activity from VMS data among PNA waters, the HSP, the EHS and other areas (other EEZs and high seas areas) for recent years, including 2010. On the basis of these data, it would appear that the reduction in effort in the HSP has been more than compensated by an increase in effort in PNA waters in 2010.

2.4 Longline catch

[CMM 2008-01](#) established certain bigeye longline catch limits for CCMs other than Small Island Developing State (SIDS). These limits, with some exemptions and variations, are based on reductions (10%, 20% and 30% in 2009, 2010 and 2011, respectively) from 2001-2004 average bigeye longline catches and are aimed at achieving an overall 30% reduction in bigeye longline catch from 2001-2004 or 2004 levels. The various exemptions and variations are:

- SIDS are exempted from the measure and therefore have no limits on bigeye catches by their domestic longline fleets;
- Non-SIDS CCMs with a base catch of <2,000 tonnes of bigeye tuna are limited to 2,000 tonnes;
- China, Indonesia and USA use 2004 as the base, rather than 2001-2004;
- The limits for China will remain at 2004 levels pending agreement regarding the attribution of Chinese catch taken as part of domestic fisheries in the EEZs of coastal states; and
- The reductions specified for 2010 and 2011 shall not apply to fleets with a total longline catch of <5,000 tonnes and landing exclusively fresh fish. This exemption effectively applies to the United States only.

The base bigeye tuna catches by flag were provided in [CMM 2008-01](#) Attachment F. The inferred limits under the CMM as well as provisional catches by flag for 2009 are provided in [WCPFC-2010-20](#) Attachment 5, Table 3. The most notable revisions to the base catches compared to Attachment F in the CMM are a slight increase in the Chinese Taipei catch (from 15,854 to 16,126 tonnes) and a major decrease in the Indonesian catch (from 8,413 to 2,192 tonnes). Both of these revisions are consistent with the latest data provided by these CCMs and have been used in the most recent assessments.

The sum of the bigeye catch limits for 2009 is 82,987 tonnes. This figure does not include catches of SIDS, which, as noted above are not subject to any limits. The total average bigeye longline catch for 2001-2004 was 83,270 tonnes, which is very close to the sum of the 2009 limits. Therefore, the actual limits in place for 2009 would not necessarily result in a significant regulated reduction in bigeye tuna longline catch. However, the actual bigeye catch provisionally recorded for 2009 was only 65,596 tonnes, the lowest since 1996. The main reason for the fall was greatly reduced catches by two major fishing nations – Japan (13,399 tonnes in 2009 compared to their limit of 25,290 tonnes), and Korea (15,239 tonnes in 2009 compared to their limit of 19,304 tonnes)³. It is not yet known if these catch reductions were due to reductions in effort by these fleets, or due to poor performance (low catch per unit effort). That will be an important issue for future assessments.

[CMM 2008-01](#) also limited longline catches of yellowfin tuna to their 2001-2004 average levels for each CCM, excluding SIDS. The catches from 2001 to 2009, along with the inferred limits for each CCM, are provided in [WCPFC-2010-20](#) Attachment 5, Table 6. Total annual yellowfin catch in 2001-2004 averaged 75,604 tonnes, and the inferred CCM limits, excluding SIDS catches, total 66,813 tonnes. In 2009, the provisional total longline catch of yellowfin was 69,077 tonnes, and so within the 2001-2004 average catch.

2.5 Gear types other than purse seine and longline

[CMM 2008-01](#) requires CCMs 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 20°N or south of 20°S, but excluding artisanal fisheries and those taking less than 2,000 tonnes of bigeye and yellowfin, shall not exceed the average level for the period 2001-2004 or 2004.” (paragraph 39). The reference to “fishing capacity” as the limited quantity makes monitoring of the measure difficult, as the term is not defined for the purpose of this CMM (although there is reference to fishing effort) and data are not comprehensively provided. In the absence of specific data on fishing capacity or fishing effort for most of these fisheries, catch has been used as a proxy. [WCPFC-2010-20](#) Attachment 5 reports bigeye tuna catches by gears other than longline and tropical purse seine in Table 4, and similarly for yellowfin in Table 5. In summary, the average bigeye catch for 2001-2004 was 12,818 tonnes, while the provisional catch for 2009 is 9,802 tonnes. For yellowfin, the average catch in 2001-2004 was 101,413 tonnes, while the provisional catch for 2009 is 98,089. Therefore, for both species, 2009 catches are slightly less than their respective average levels for 2001-2004.

³ On the other hand, China took 11,565 tonnes in 2009, compared to its limit of 9,314 tonnes.

3 Effectiveness of the measure

3.1 Introduction

The objective of this section of the paper is to present an updated evaluation of CMM 2008-01 as it relates to its major objective of maintaining stocks at levels capable of producing the maximum sustainable yield (MSY). This work responds directly to the request of SC6 (paragraph 273, [SC6 Summary Report](#)), to undertake the following analyses:

- A set of generic projections based on the following specifications:
 - Based on bigeye run 3d from the 2010 assessment
 - Using recent average recruitment in deterministic projections
 - Considering stepped changes in catch and effort from 2010 (30% increase to 50% decrease) for:
 - Longline catch
 - Purse seine associated effort
 - Domestic fisheries of Indonesia and Philippines
 - Repeated for the base-case model for yellowfin and skipjack tuna
- Three specific projections
 - Continuation of the provisions of CMM 2008-01 into the future, incorporating any new information regarding the implementation in 2009 and 2010.
 - As above but with all exemptions and special provisions removed.
 - Continuation of provisions of CMM 2008-01 into the future with the additional high seas purse seine closure as announced by the PNA with an assumption of no redistribution of effort.
- Assumed patterns of catch and effort for 2010 and 2011 will be based on the provisions of CMM 2008-01. It will also incorporate fishery behaviour observed during 2009 and 2010 under CMM 2008-01.
- Changes in catch and effort for the generic projections will be from 2012 onwards and will be relative to 2011 levels (as allowed under CMM 2008-01 assuming full compliance), but will also be reported relative “2001-2004 levels” from previous agreements.

3.2 Methods

The methods employed followed the guidelines recommended by SC6. For the generic projections of bigeye tuna, run3d was used. This was the “base” model employed to illustrate detailed results in the 2010 bigeye assessment. Its main distinguishing features included:

- Use of aggregate longline CPUE indices, with no adjustment for increasing fishing power;
- The steepness parameter of the stock recruitment relationship was estimated at a high level (0.99), meaning that average recruitment is relatively insensitive to reduction in the spawning biomass; and
- Purse seine catches were based on a correction derived from “spill sampling” trials.

Further information of the assumptions and results of this assessment model can be obtained from the 2010 bigeye assessment document ([WCPFC-SC6-2010-SA-WP-4](#)).

For the equivalent runs for yellowfin tuna, we updated the most recent (2009) base-case assessment – see the 2009 yellowfin tuna assessment document ([WCPFC-SC5-2009-SA-WP-3](#)) for details – with an additional year of data in order to synchronize the projection period with that for bigeye tuna. For skipjack tuna, it was necessary to redefine the purse seine and Indonesia and Philippines-based domestic fisheries to make them consistent with the fisheries defined for bigeye and yellowfin. This was accomplished with no substantial change to the 2010 base-case skipjack assessment results – see the 2010 skipjack tuna assessment document ([WCPFC-SC6-2010-SA-WP-11](#)) for details.

The evaluation of a specific management strategy was undertaken using a deterministic projection from 2010-2021, with 2009 being the terminal year of the assessment. For 2010 and 2011, we specified catch or effort to approximate the implementation of CMM 2008-01 as it is currently occurring, i.e. we assumed that:

- Longline catches of bigeye would remain the same as in 2009. This assumption was deemed to be reasonable because the total 2009 catch of the longline fleets that are limited by the measure (60,354 tonnes) was already less than 70% of the sum of their base levels (90,164 x 0.7 = 63,115 tonnes). Likewise, longline catches of yellowfin tuna were assumed to remain at their observed levels for 2009.
- Total purse seine effort levels would remain at their 2009 levels. This was subsequently found to be an optimistic assumption, with indications being that 2010 purse seine effort could be some 10% higher than 2009.
- Purse seine effort was distributed between associated (FAD) and unassociated set types as per 2009, but with an adjustment to allow for the extension of the 2009 two-month FAD closure to three months in 2010 and 2011.
- Given the preliminary observations of the HSP closure in section 2.3, no specific modifications of purse seine effort distributions were required (at the coarse spatial resolution of the stock assessment model) to model the fishery's response to this closure.
- Effort for all other fisheries in 2010 and 2011 would remain at the same levels as for 2009.

These conditions were then used as a base (i.e. catch or effort scalar of 1.0) for the projections from 2012 through 2021. For the generic projections, we applied catch or effort scalars of 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2 and 1.3 to each of the (grouped) longline fisheries, purse seine fisheries (associated sets) and Indonesia and Philippines-based domestic fisheries. The relationship of these scalars to 2004 and 2001-2004 average levels of longline catch and purse seine associated set effort is shown in Table 3.

The application of the 9 catch or effort scalars to each of the 3 fishery groups in all possible combinations resulted in 9^3 (729) projection scenarios for each of bigeye and yellowfin tuna, and 9^2 (81) projection scenarios for skipjack (since there are no commercially significant longline fisheries in the skipjack assessment, there are only two fishery groups).

Note that the scalars for the purse seine fishery were applied only to the associated set component. This was done to mimic the use of FAD closures to modify purse seine effort. Consequently, we allowed any reduction (increase) in associated set effort to result in a corresponding increase (reduction) in unassociated set effort, to simulate the transfer of effort from (to) associated sets to (from) unassociated sets. For example, for an associated set effort scalar of 0.7, it was assumed that the 30% of associated set effort removed from that component would transfer to the unassociated set component, as was observed during the 2009 FAD closure.

For the three species, projections were undertaken using recent (1999-2008) average levels of recruitment estimated in the stock assessment models, as recommended by SC6. The performance of a given projection catch-effort scenario was evaluated using:

- The level of F_{2021}/F_{MSY} for bigeye tuna, as an indicator of the extent to which overfishing is impacted by the projection scenario. We did not consider B_{2021}/B_{MSY} or SB_{2021}/SB_{MSY} because the assumption of constant recent average recruitment in the projections invalidates these ratios⁴.
- The catches of bigeye, skipjack and yellowfin tuna by fishery, as an indicator of the possible impact of the performance of the fishery resulting from a projection scenario.

We did not specifically present F_{2021}/F_{MSY} for yellowfin and skipjack, as these remained less than 1.0 across the range of projections considered.

3.3 Results and discussion

3.3.1 Generic projections

The full results of the generic projections can be downloaded as Microsoft Excel files from the WCPFC 7 web page in the same location as this paper. The files incorporate filters on the three scalars to facilitate selection of specific scenarios that members might wish to investigate.

Graphical summaries of the results are presented in Figures 8-10 to illustrate some of the main points. In Figure 8, the response of bigeye tuna F_{2021}/F_{MSY} to isolated changes, in turn, in longline catch, purse seine associated effort and Indonesia-Philippines domestic effort is shown. The figure illustrates that F_{2021}/F_{MSY} has a slightly greater response to changes in Indonesia-Philippines domestic effort than to the other two fishery groupings. Note that, over the range of changes investigated, isolated reduction to only one of the fishery groups is not sufficient to reach a F_{2021}/F_{MSY} of 1.0.

Figure 9 shows more detailed results of simultaneously varying purse seine associated effort (on the x-axis), longline catch (the different lines in each graph) and Indonesia-Philippines domestic effort (the different graphs). Here it can be seen that bigeye tuna fishing mortality would be close to the MSY level with scalars of 0.7 in each fishery group. This is reasonably consistent with the SC6 advice that an overall reduction in fishing mortality of 29% from 2005-2008 average levels (or 20% from the 2001-2004 average level and 38% from the 2008 level – see [WCPFC-SC6-2010-SA-WP-4](#), Tables 6 and 7) would be required to reduce bigeye tuna fishing mortality to a level consistent with MSY.

There are a number of other combinations of catch/effort that would result in achieving fishing mortality at MSY for bigeye tuna (Table 4). Typically, significant reductions in at least two of the three fishery components are required to achieve MSY conditions. However, interestingly, the reductions in total catches that result are relatively minor, a maximum of 5.6%. This is because (i)

⁴ Recent average recruitment for bigeye tuna is considerably larger than the level of recruitment predicted from the stock-recruitment relationship (SRR). Because of the nature of the estimated time-series trend in recruitment in the bigeye assessment, the SC believes that recent average recruitment is a better estimator of future recruitment than the predictions from the SRR. It can be shown that use of this higher level of recruitment in the projections does not overly influence the estimates of projected F/F_{MSY} ; however, the estimates of projected B/B_{MSY} will be overestimated. This is because B_{MSY} is still estimated on the basis of an equilibrium condition incorporating the SRR. If the higher level of recruitment was used in the computation of B_{MSY} , a higher value of the reference point would be obtained resulting in lower estimates of B/B_{MSY} . This inconsistency will be addressed in future bigeye tuna assessments.

there is some degree of increase in the three stocks under all scenarios in the subset; (ii) we assume that effort reductions for purse seine associated sets are compensated by transfer of that effort to purse seine unassociated sets; and (iii) in scenarios that reduce effort targeted at smaller fish (purse seine associated sets and Indonesia and Philippines domestic fisheries), some of the catch forgone is taken by fisheries targeting these fish at larger size (longline and purse seine unassociated sets).

To further demonstrate some of these interactions, we have plotted, as an example only, projected catches by species and gear for the 30% reduction (scalars of 0.7) scenario for each of longline bigeye catch, purse seine associated set effort and Indonesia and Philippines domestic effort (Figure 10). Here we can see that the reduction in catches of all species in the purse seine associated set fishery is more than compensated by increased catches in the purse seine unassociated set fishery – this occurs both because of the transfer of effort and the increased availability of the larger sized fish of the three species. This is also demonstrated in species aggregated form in Figure 11 – the overall reduction in total catches is relatively minor.

3.3.2 Specific projections

SC6 requested an evaluation of three specific scenarios:

- Continuation of the provisions of CMM 2008-01 into the future, incorporating any new information regarding the implementation in 2009 and 2010.
- As above but with all exemptions and special provisions removed.
- Continuation of provisions of CMM 2008-01 into the future with the additional high seas purse seine closure as announced by the PNA with an assumption of no redistribution of effort

It is possible to express the first two scenarios reasonably accurately by choosing the most appropriate runs from the generic projections. This involves choosing scalars for each of the fishery groups considered in the generic projections (i) consistent with the existing provisions of CMM 2008-01; and (ii) consistent with those provisions but without the various exemptions. The rationale for the choice of scalars for both of these scenarios is described below.

Longline bigeye catch The base longline catch (i.e. scalar of 1.0) used in the projections was equivalent to 65,596 tonnes. The actual longline catch consistent with the CMM is undefined because of the SIDS exemption, but if we assume (i) continuation of all SIDS catches at their 2009 levels; (ii) continuation of all other catches of less than 2,000 tonnes at their 2009 levels; and (iii) the 2011 catch limits for those fleets that are currently limited by the CMM, we obtain a total long-term bigeye catch by longline “allowed” by the CMM of 63,262 tonnes, slightly less than the base catch. Therefore, we will assume that continuation of the base longline catch (scalar = 1.0) is consistent with the provisions of CMM 2008-01.

If the various exemptions were not in place, the long-term bigeye catch by longline should be no greater than 70% of the 2001-2004 average catch. This catch is 58,259 tonnes ($83,270 \times 0.7$ – see [WCPFC-2010-20](#), Attachment 5, Table 3), which would be equivalent to a scalar of approximately 0.9.

Purse seine The base level of purse seine effort used in the generic projections incorporates the three month FAD closure, consistent with the provisions of the CMM. As noted, the HSP closure appears to result in redistribution rather than removal of effort, and so is inconsequential in terms of

direct conservation benefit. The total level of purse seine effort represented by the base level in the projections is considerably larger than either 2004 or the 2001-2004 average, but it could be argued that this is allowed under the CMM because of the preservation of rights under existing regional and bilateral agreements (particularly important in view of the increase in US purse seine effort since 2004) and the exemption of SIDS for fishing on the high seas. We will therefore proceed under the assumption that the base level of purse seine effort (scalar = 1.0) is consistent with the CMM as written.

In the absence of the various exemptions, total purse seine effort would be limited to the 2004 level, which is approximately 90% of the base level used in the projections. Therefore, the purse seine scalar in the absence of exemptions would be 0.9.

Indonesia and Philippines Domestic Fisheries These fisheries are a combination of purse seine and other miscellaneous gears, with longline fisheries having been covered explicitly under the flag-based longline measure. CMM 2008-01 is somewhat vague regarding the responsibilities of Indonesia and Philippines. For the non-purse seine and longline gears, they are required to maintain total “capacity” of these fisheries to no greater than 2001-2004 or 2004 levels. According to the data submitted ([WCPFC-2010-20](#), Attachment 5, Table 4), this has been achieved, at least in terms of bigeye catch. For purse seine, they are required to take measures “compatible” with those of PNA EEZs to reduce purse seine fishing mortality of bigeye. This would imply something equivalent to a three month FAD closure in their EEZs. Because purse seine and other non-longline gears for Indonesia and Philippines are modelled as a unit in the assessment models, it is difficult to say what sort of modification of the base level (scalar = 1.0) would be consistent with the requirements of the CMM. Some small reduction would be appropriate, as the majority of the EEZ catch (i.e. excluding archipelagic waters) is likely to be purse seine. It is understood that approximately half of the total catch in Indonesian and Philippines waters occurs in the EEZ component, and that most of that is purse seine directed at FADs. If we therefore apply a scalar of 0.75 (consistent with a three month FAD closure) to half of the fishing activity in Indonesia and Philippines, we obtain an overall scalar for the combined fishery of approximately 0.9.

The main “exemption” in respect of Indonesia and Philippines is the exclusion of archipelagic waters from the measure. If archipelagic waters were included, the “compatible” reduction might be somewhat greater, depending on the amount of purse seine fishing that occurs in archipelagic waters. For the sake of completing the hypothetical “no exemptions” scenario, we will assume that a scalar of 0.8 for these fisheries would be appropriate.

The set of scalars for the first two specific scenarios would then be:

Fishery group	CMM 2008-01	No exemptions
Longline	1.0	0.9
Purse seine associated sets	1.0	0.9
Indonesia and Philippines domestic	0.9	0.8

For the CMM scenario (1.0, 1.0, 0.9), we obtain an estimate of F_{2021}/F_{MSY} of 1.42, approximately a 5% reduction from the base scenario level of F_{2021}/F_{MSY} (1.49) and representing a 14% reduction in overfishing.

For the “No exemptions” scenario (0.9, 0.9, 0.8), we obtain an estimate of F_{2021}/F_{MSY} of 1.26, approximately a 16% reduction from the base level of F_{2021}/F_{MSY} and representing a 50% reduction in overfishing.

For the third specific scenario (closure of the eastern high seas, as being proposed by the PNA), the following was undertaken:

- We first computed the typical level of effort in the proposed closure area (the high seas area within the boundaries 170°E-150°W, 10°N-20°S) and assumed that this effort would be removed from the fishery under a closure. The total fishing days removed would be 2,229, or 4.6% of the base purse seine effort. When broken down by associated and unassociated set effort, the reductions are 3.2% and 6.0%, respectively. Considering just the WCPFC convention area east of 170°E, 18% of the total purse seine effort would be removed, 13% and 22%, respectively, for associated and unassociated purse seine effort.
- We then repeated the base projection with purse seine effort by set type in the eastern model region reduced by the above amounts, holding other fishery catch and effort at their base values.

The removal of purse seine effort as described above results in a reduction of F_{2021}/F_{MSY} from 1.49 to 1.45, representing an 8% reduction in overfishing. While this percentage reduction is small, it is large relative to the percentage of purse seine associated set⁵ effort removed (3.2%). This is because bigeye tuna appear to be particularly vulnerable to purse seine fishing by associated sets in this region, as indicated by relatively high catch per unit effort (Figure 12).

4 Conclusions

The main conclusions from the paper regarding the implementation of CMM 2008-01 to date are as follows:

- a. CMM 2008-01 has not been effective in constraining growth of purse seine effort, with effort (excluding domestic purse seiners based in Indonesia and Philippines) in 2010 estimated to have increased by approximately 22-27% compared to effort in 2004, and by 36-42% compared to the 2001-2004 average effort.
- b. The FAD closure in 2009 seems to have been largely respected, with about 10% of observed fishing days (based on currently available observer data) during the closure period having activities that might be interpreted as, or supporting, FAD fishing. The proportion of bigeye tuna caught in unassociated sets during the closure was slightly higher than in previous years. Reasonable levels of catch and effort were maintained during the closure and 2009 was a record year for the purse seine fishery overall. The proportion of associated sets in the ten months of 2009 that were not closed to FAD fishing was high, with the total number of associated sets in 2009 being the highest since 2004 and the second highest ever.
- c. Available data from all sources indicate that the HSP closure since 1 January 2010 has largely been respected. However, the closure has clearly not resulted in a removal of effort from the fishery, as 2010 purse seine effort looks like being around 10% higher than the previous

⁵ Bigeye tuna is caught predominantly in associated sets by purse seine, with much smaller amounts caught in unassociated sets.

record level in 2008-2009. The additional effort that has occurred in 2010 appears to have occurred mainly in PNA waters, with the eastern high seas not subject to an unusual increase in effort in 2010.

- d. The longline catch of bigeye tuna in 2009 was 65,596 tonnes, the lowest since 1996. The catch represents a 21% reduction from the average bigeye catch in 2001-2004. The longline catch of yellowfin tuna in 2009 was approximately 9% less than the average catch in 2001-2004.
- e. For fisheries other than purse seine and longline, total catches for 2009 are slightly less than their respective average levels for 2001-2004 for both bigeye and yellowfin tuna.

The main conclusions of the paper regarding the effectiveness of CMM 2008-01 are as follows:

- a. Projections were conducted incorporating changes in longline catch, purse seine associated effort and Indonesian and Philippines domestically-based effort ranging from a 50% reduction to a 30% increase.
- b. Within the many combinations investigated, there is a relatively small subset, summarized in Table 4, that achieves the objective of the CMM in reducing bigeye tuna fishing mortality to a level consistent with MSY.
- c. Typically, significant reductions in at least two of the three fishery components are required to achieve MSY conditions. However, for the subset of projections in which F_{MSY} for bigeye tuna was achieved (Table 4), the reductions in total catches that result are relatively minor, a maximum of 5.6%. This is because (i) there is some degree of increase in the three stocks stock under all scenarios in the subset; (ii) we assume that effort reductions for purse seine associated sets are compensated by transfer of that effort to purse seine unassociated sets; and (iii) in scenarios that reduce effort targeted at smaller fish (purse seine associated sets and Indonesia and Philippines domestic fisheries), some of the catch forgone is taken by fisheries targeting these fish at larger size (longline and purse seine unassociated sets).
- d. For the implementation of the CMM as written, and taking into account the information on implementation to date, we estimate that only a 14% reduction in bigeye tuna overfishing can be expected.
- e. In the absence of the various exemptions and exclusions built into the measure, our best estimate of the amount of bigeye tuna overfishing expected to be removed is 50%.
- f. The above observations reinforce previous conclusions that the various provisions of the CMM are not sufficient for it to be able to meet its objectives with respect to bigeye tuna.
- g. The eastern high seas have on average accounted for approximately 4% of purse seine effort in the WCPFC Convention Area, although utilization can be higher during *El Niño* periods. The proposed closure of the eastern high seas, under the assumption that the historical effort in this area would not be redistributed, is estimated to remove 8% of bigeye tuna overfishing. While this percentage reduction is small, it is large relative to the percentage of purse seine associated set effort removed (3.2%), due to the relatively high vulnerability of bigeye tuna to purse seine associated sets in this region.

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Table 1. Descriptive statistics for various vessel behaviours used during the CMM 2008-01 FAD Closure (1 Aug – 30 Sep, 2009), according to observer reports (31% coverage of fishing days).

Number of observer trips	130	
Number of fishing and searching days	2,513	
Number of sets	1,528	
Number of nights drifting with fish aggregation lights (activity =14)	38	1.5%
Number of days setting or investigating Drifting FADs (SCH_ID = 4)	56	2.2%
Number of days reported as “No fishing, drifting with floating object” (Activity = 12)	125	5.0%
Number of days reported with any activity related to a drifting FAD (Activity=9,10,12,23,24,25,26)	260	10.3%

Table 2. A comparison of tuna species composition samples from unassociated sets during the CMM 2008-01 FAD closure period (1 August – 30 September 2009), with the same period in previous years: 2008 and 2002-2007. (Source: observer data; the definition of ‘large’ yellowfin and bigeye is fish > 80cm).

YEAR (Aug-Sep)	Samples	SKIPJACK		YELLOWFIN			BIGEYE			TOTAL
		MT	%	MT (small)	MT (large)	%	MT (small)	MT (large)	%	MT
2002-2007	709	119.2	24.9%	12.6	342.9	74.3%	1.6	2.1	0.8%	478.4
2008	245	28.8	12.9%	3.1	189.7	86.2%	0.3	1.9	1.0%	223.8
2009	462	120.6	62.2%	5.0	65.9	36.6%	1.0	1.3	1.2%	193.8

Table 3. Relationship of scalars used in the projections (based on catch and effort conditions assumed for 2010 and 2011) to longline catch and purse seine associated set effort in 2001-2004 and 2004.

Scalar in projections (applied to 2010-2011 catch or effort)	Longline equivalent scalars		Purse seine equivalent scalars	
	2001-04	2004	2001-04	2004
	1.3	1.08	0.88	1.48
1.2	1.00	0.81	1.36	0.98
1.1	0.91	0.74	1.25	0.90
1.0	0.83	0.67	1.14	0.82
0.9	0.75	0.61	1.02	0.73
0.8	0.67	0.54	0.91	0.65
0.7	0.58	0.47	0.80	0.57
0.6	0.50	0.40	0.68	0.49
0.5	0.42	0.34	0.57	0.41

Table 4. Projections which result in a F₂₀₂₁/F_{MSY} for bigeye tuna of close to 1.0. The top shaded row is the base projection.

Scalars			F ₂₀₂₁ /F _{MSY}	Projected catches (tonnes)				% reduction from total catch base
LL	PS ASS	IDPH		Bigeye	Skipjack	Yellowfin	Total	
1.0	1.0	1.0	1.49	123,734	1,420,154	549,639	2,093,527	
1.3	0.5	0.5	1.00	148,110	1,338,021	537,824	2,023,955	3.3
1.0	0.7	0.5	0.99	135,033	1,344,102	523,996	2,003,131	4.3
0.9	0.8	0.5	1.00	130,394	1,347,091	519,605	1,997,090	4.6
0.9	0.6	0.6	0.99	127,112	1,356,458	523,472	2,007,042	4.1
0.8	0.9	0.5	1.01	125,536	1,350,048	515,125	1,990,709	4.9
0.8	0.7	0.6	1.00	122,375	1,359,471	519,057	2,000,903	4.4
0.7	1.0	0.5	1.01	120,463	1,352,973	510,558	1,983,994	5.2
0.7	0.8	0.6	1.00	117,421	1,362,450	514,556	1,994,427	4.7
0.7	0.5	0.8	1.01	111,398	1,381,186	522,524	2,015,108	3.7
0.6	1.1	0.5	1.00	115,174	1,355,865	505,904	1,976,943	5.6
0.6	0.9	0.6	1.00	112,251	1,365,396	509,972	1,987,619	5.1
0.6	0.6	0.8	1.01	106,449	1,384,209	518,010	2,008,668	4.1
0.5	1.2	0.5	0.99	109,733	1,375,758	504,039	1,989,530	5.0
0.5	1.0	0.6	0.99	106,863	1,368,311	505,303	1,980,477	5.4
0.5	0.7	0.8	1.00	101,282	1,387,198	513,419	2,001,899	4.4
0.5	0.5	0.9	0.99	98,024	1,393,723	516,753	2,008,500	4.1

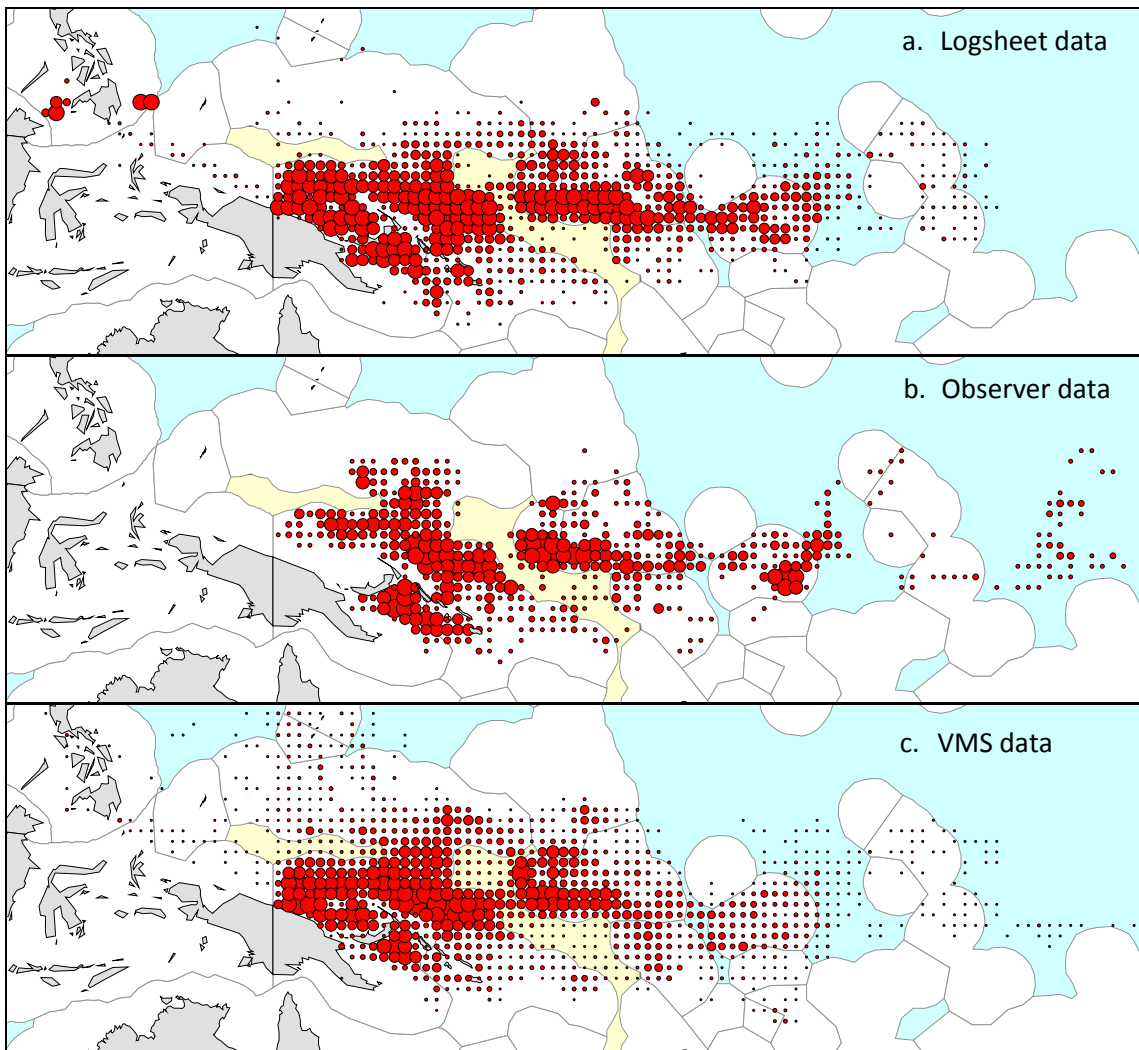


Figure 1. Distribution of purse seine effort (days) in 2010 from a. logsheet data, b. observer data, and c. VMS data.



Figure 2. Proportion of purse seine effort occurring in the two western high seas pockets that were closed to purse seine fishing from 1 January 2010.

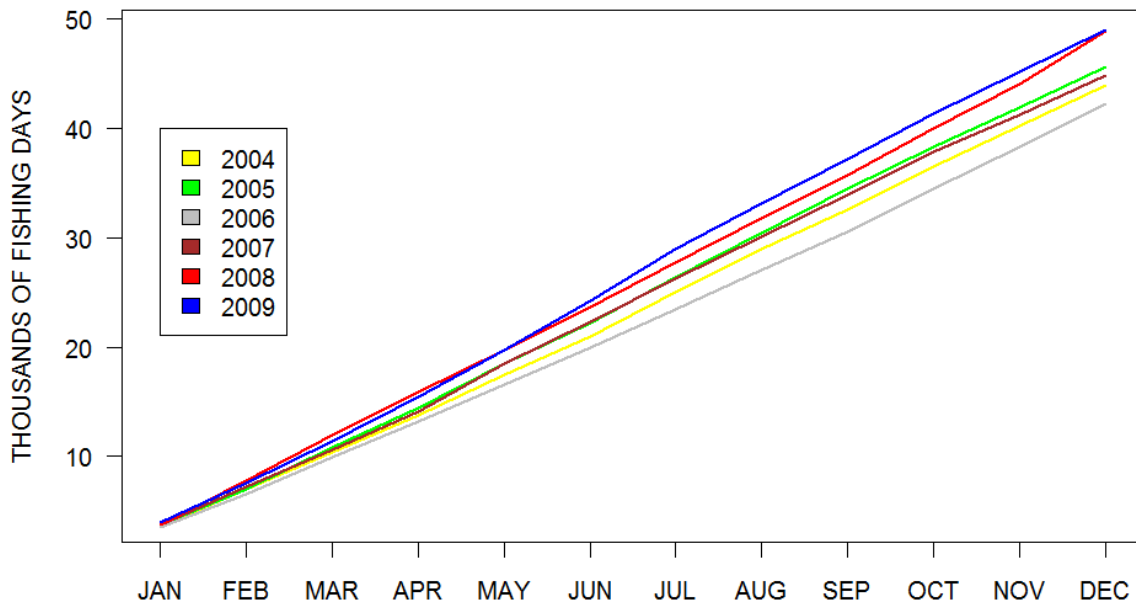


Figure 3. Cumulative monthly purse-seine effort in the tropical purse seine fishery, 2004-2009 (source: raised logsheet data; excludes Philippines and Indonesia-based domestic vessels).

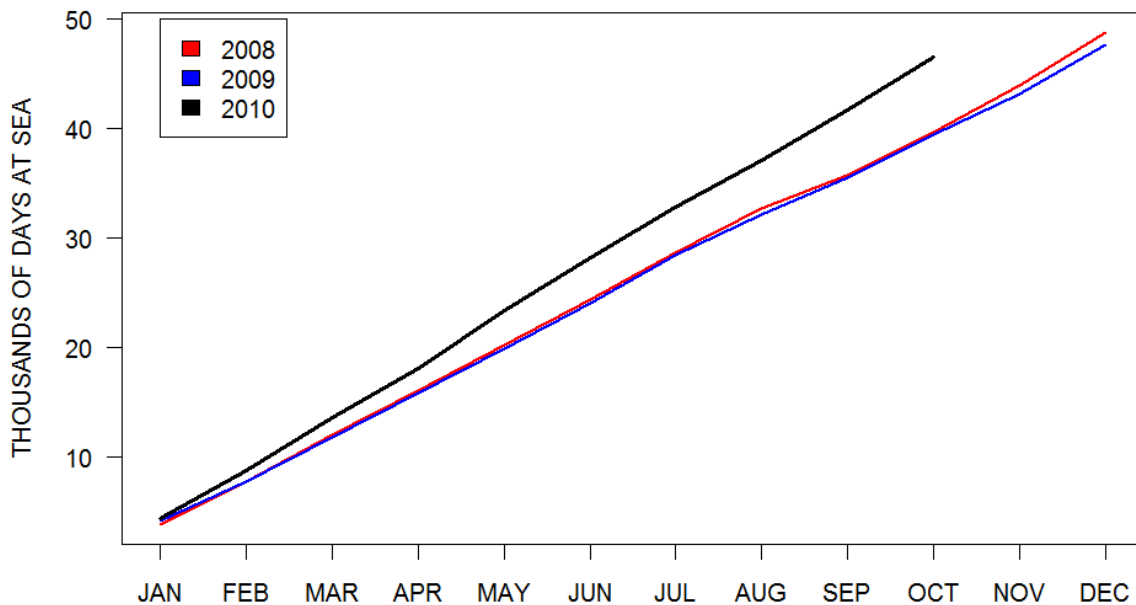


Figure 4. Cumulative monthly vessel activity (VMS days at sea) in the tropical purse seine fishery, 2009-2010 (source: WCPFC and FFA consolidated VMS data; excludes Philippines and Indonesia-based domestic vessels and vessels not covered by VMS).

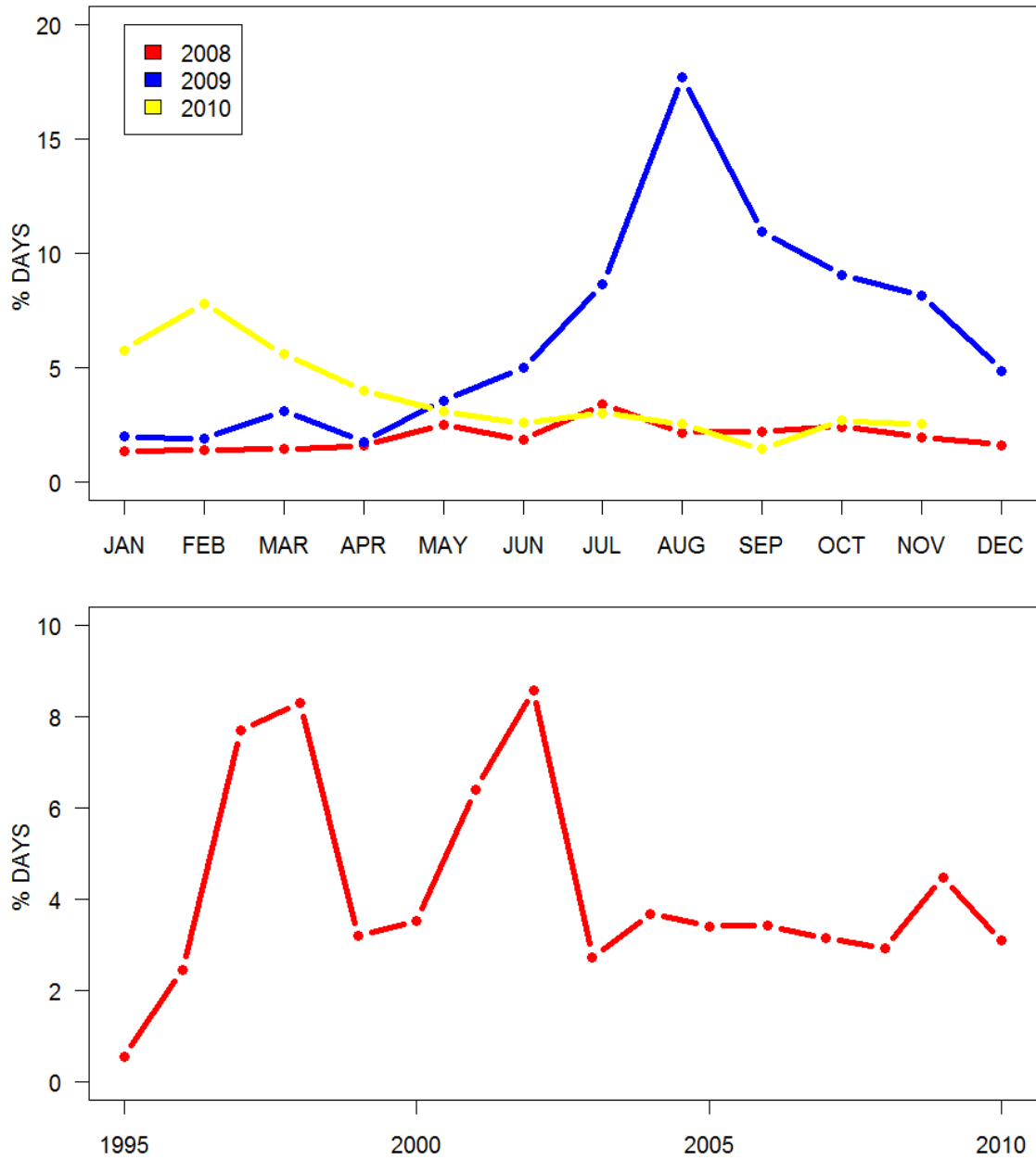


Figure 5. Percentage of vessel activity as indicated by VMS in the eastern high seas by month, 2008-2010 (upper panel) and percentage of purse seine effort as indicated by logsheet data in the eastern high seas by year, 1995-2010 (lower panel).

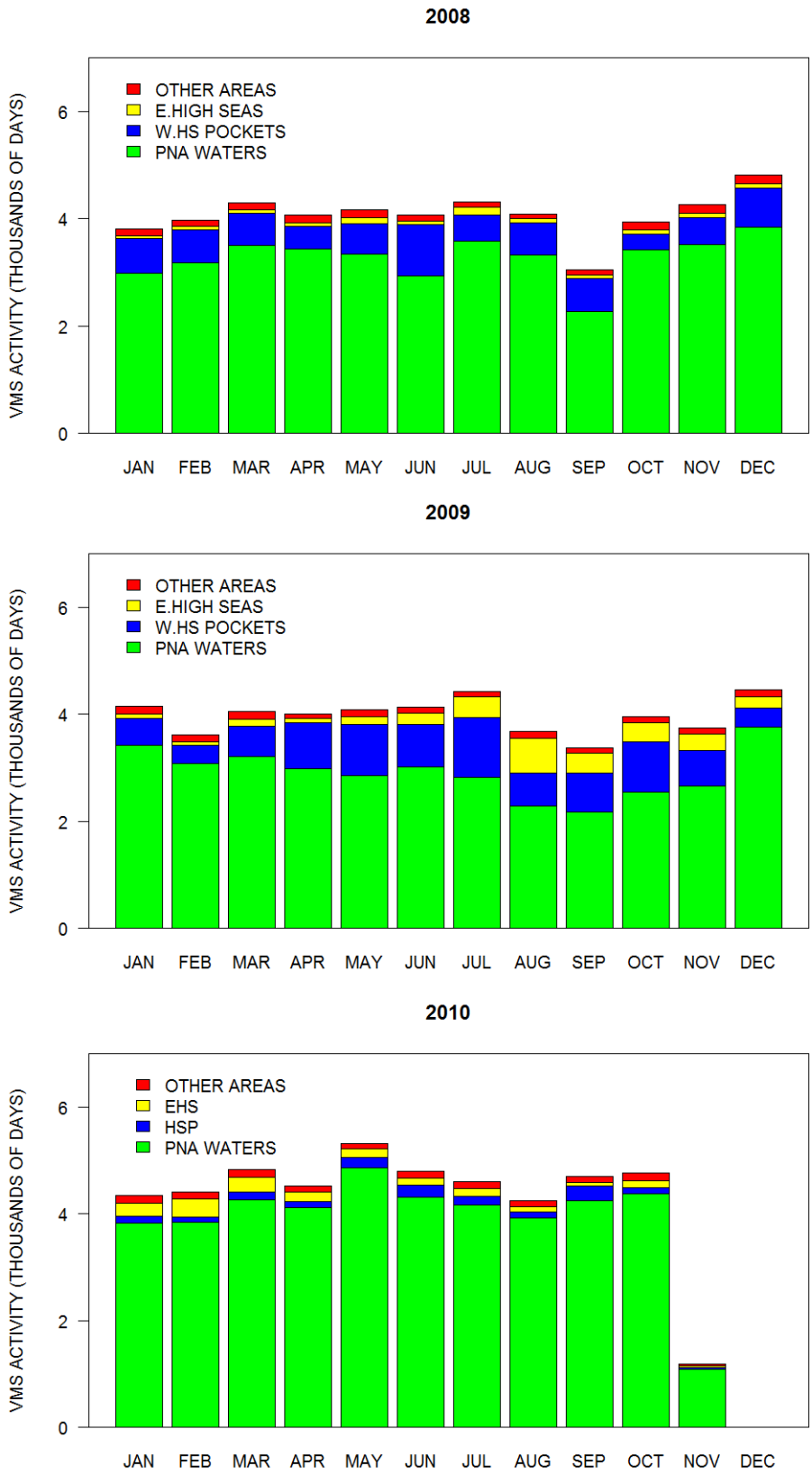


Figure 6. Purse seine vessel activity, as indicated by VMS reports, in various parts of the WCPFC tropical purse seine fishery (20N-20S) by month for 2008, 2009 and 2010.

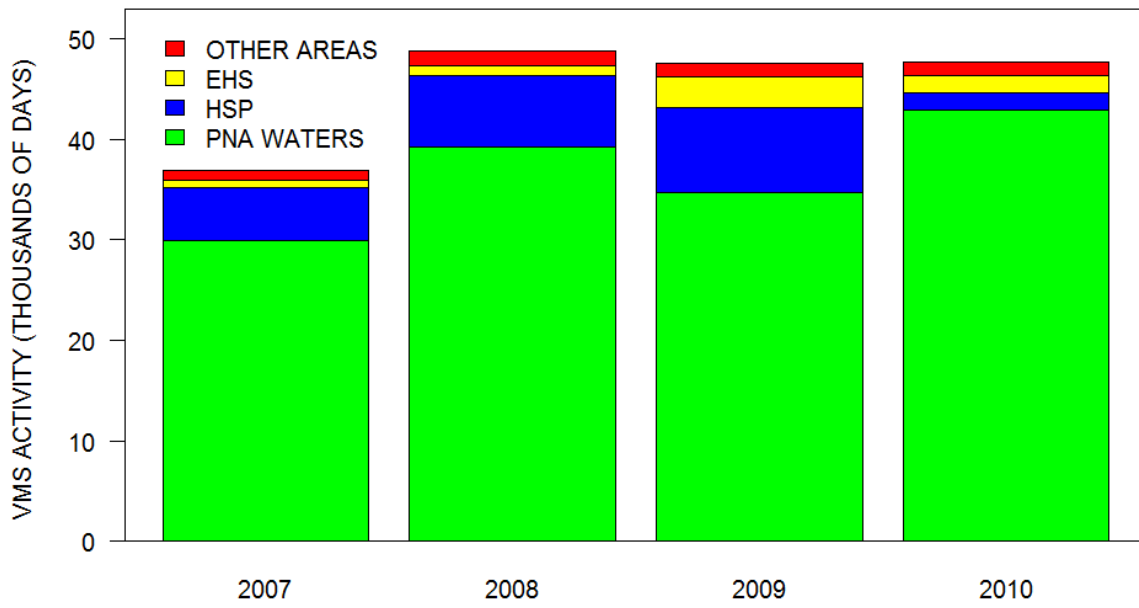


Figure 7. Purse seine vessel activity, as indicated by VMS reports, in various parts of the WCPFC tropical purse seine fishery (20N-20S) for 2008, 2009 and 2010.

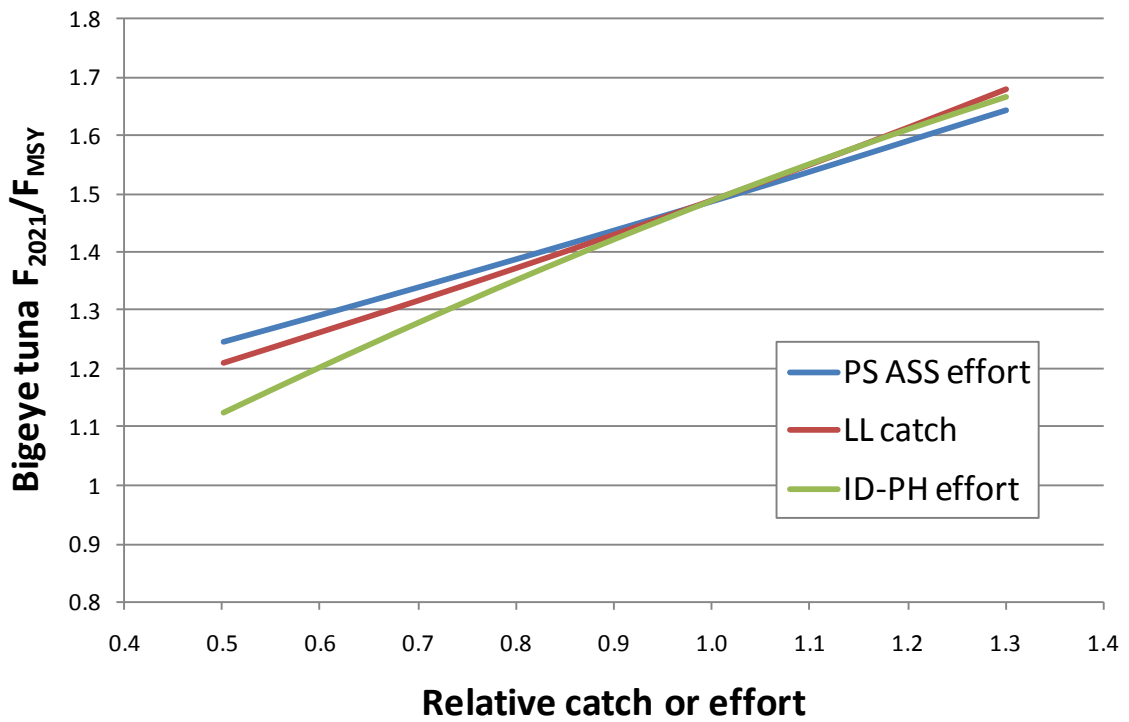


Figure 8. The response of bigeye tuna F_{2021}/F_{MSY} to varying purse seine associated set effort, longline catch and Indonesia-Philippines domestic effort individually, with the other two fishery groups fixed at the reference level of catch or effort (scalar = 1.0).

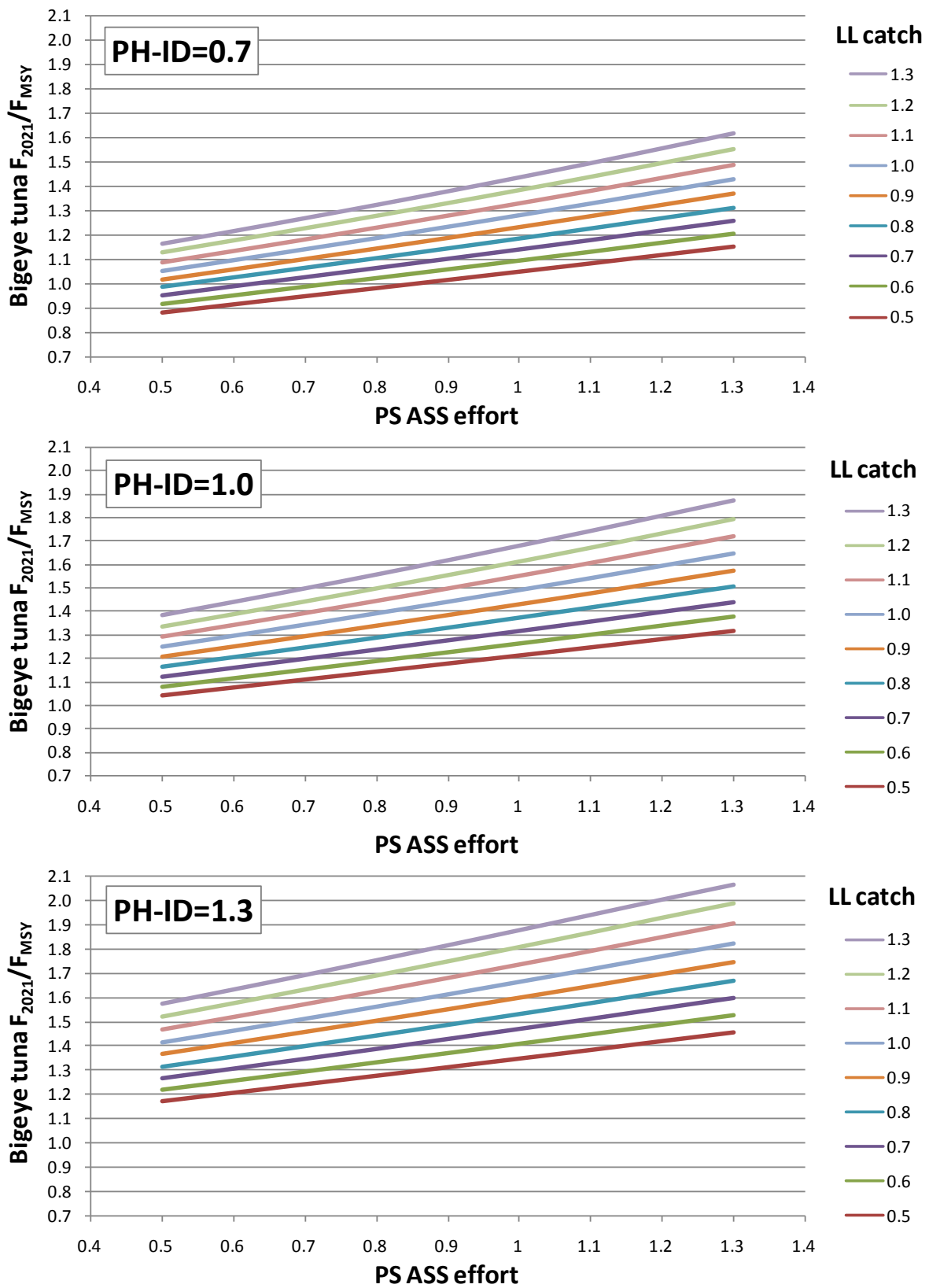


Figure 9. The response of bigeye tuna F_{2021}/F_{MSY} to varying purse seine associated set effort and longline catch for three different levels of Indonesia-Philippines domestic effort

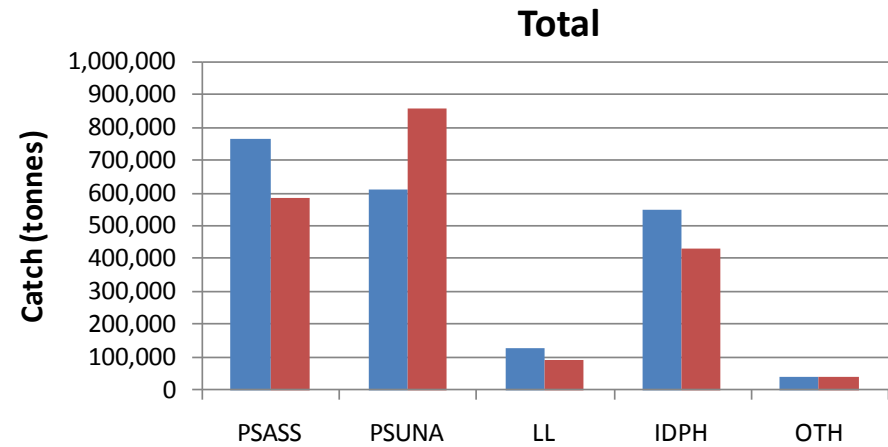
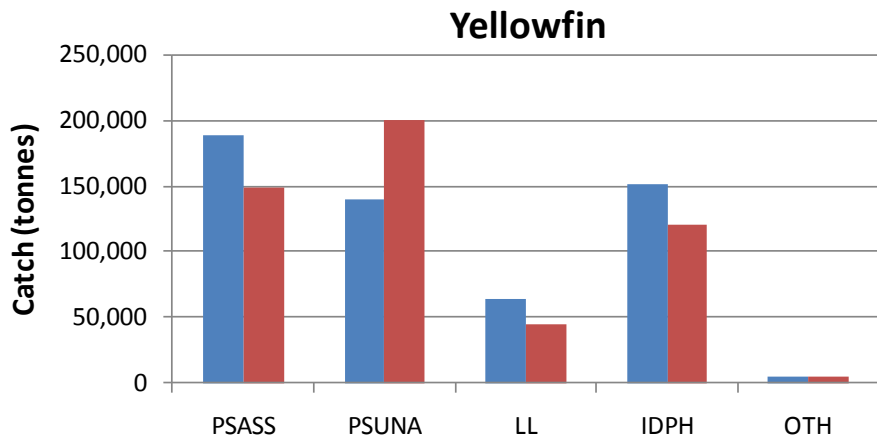
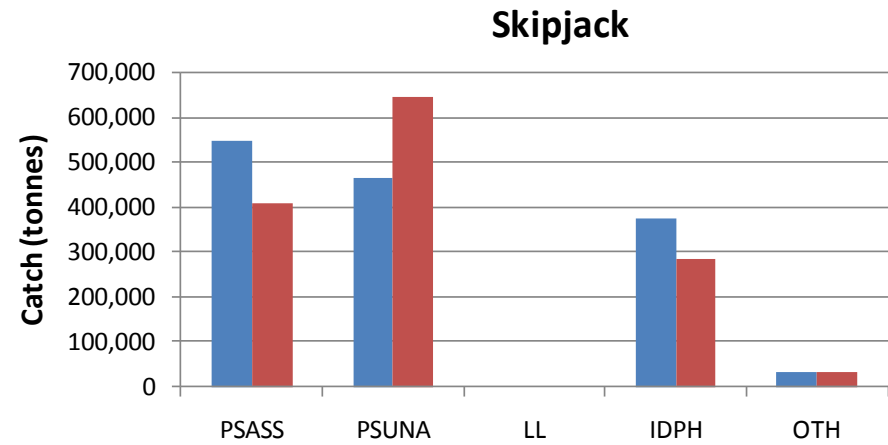
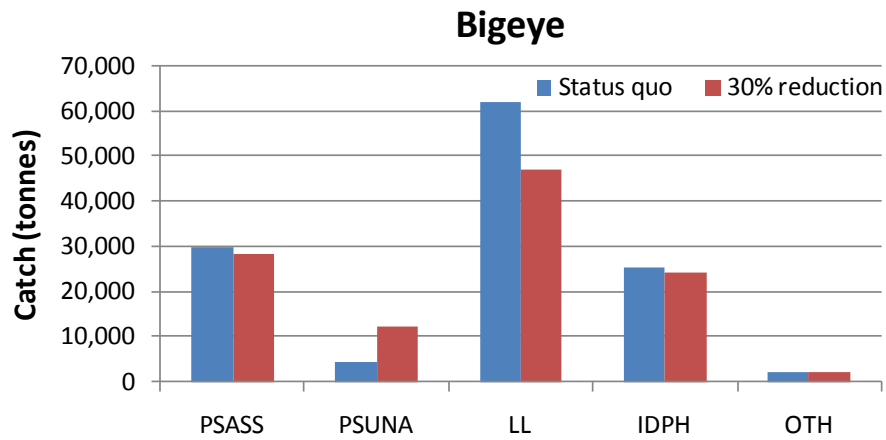


Figure 10. Projected annual equilibrium catches by species and fishery under the status quo (LL=1.0, PSASS=1.0, IDPH=1.0) and under a 30% reduction strategy (LL=0.7, PSASS=0.7, IDPH=0.7).

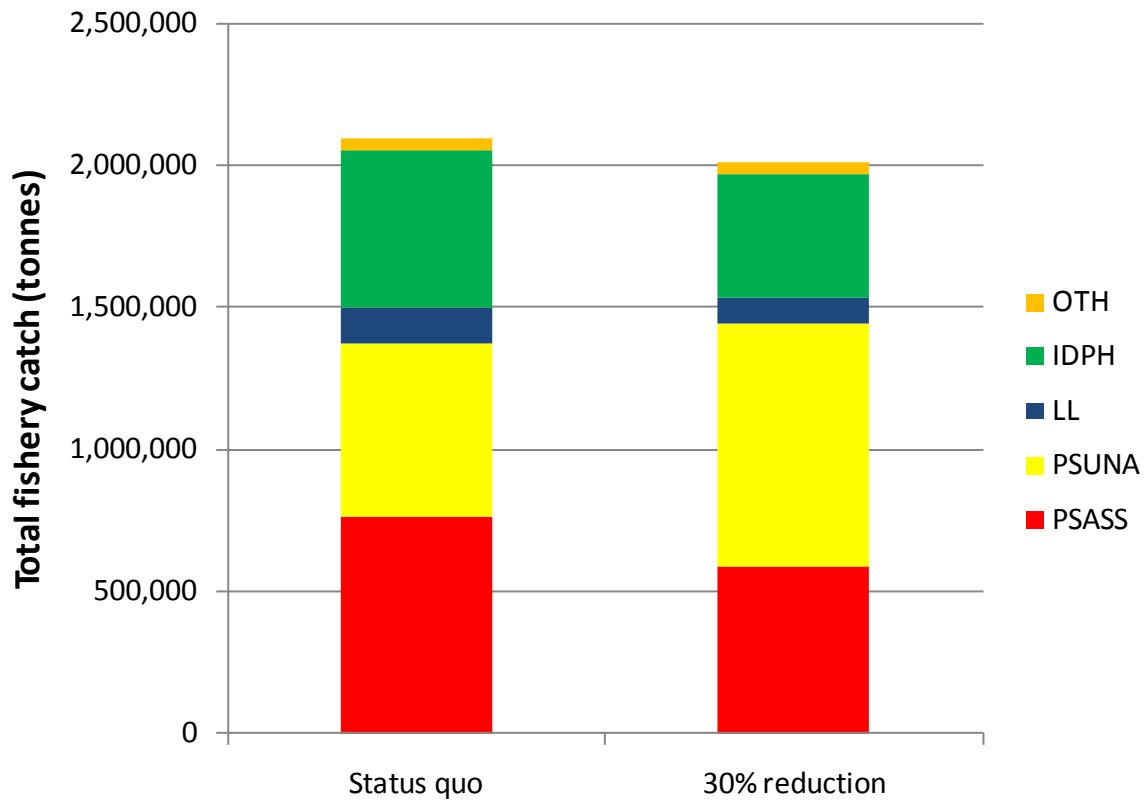


Figure 11. Projected annual equilibrium total catches fishery under the status quo (LL=1.0, PSASS=1.0, IDPH=1.0) and under a 30% reduction strategy (LL=0.7, PSASS=0.7, IDPH=0.7).

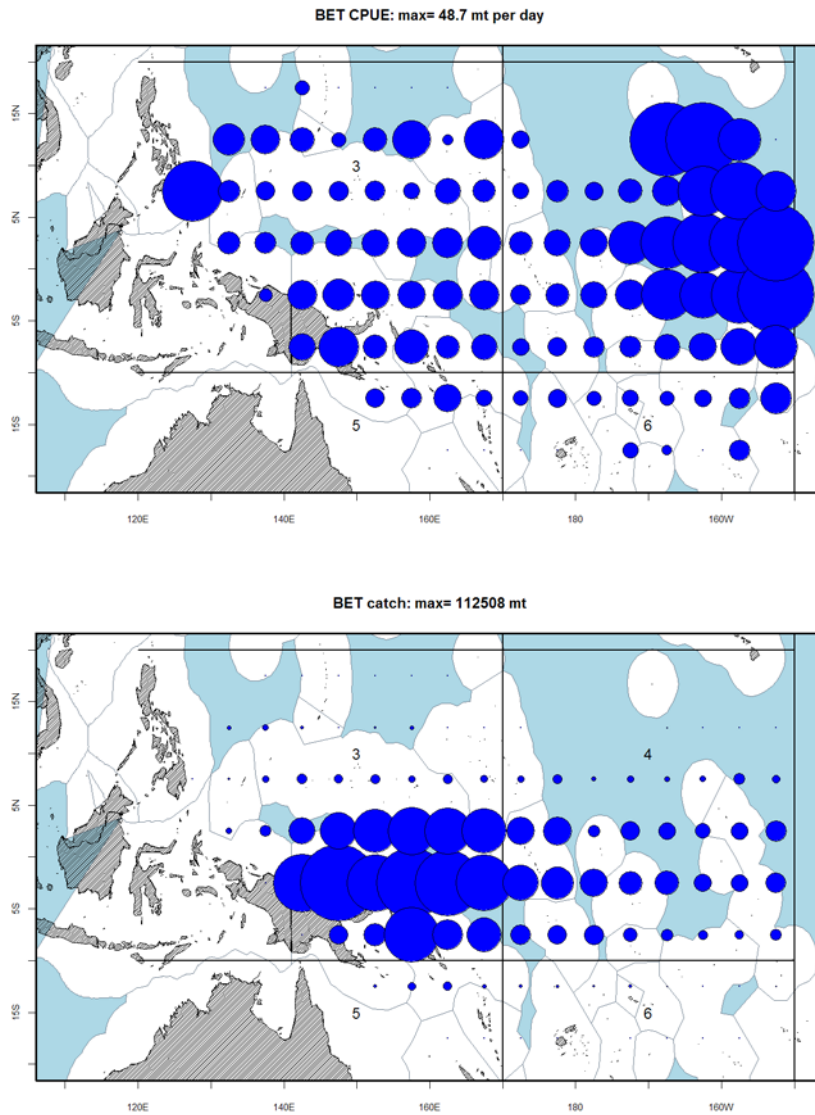


Figure 12. Bigeye tuna catch per unit effort (upper panel) and catch (lower panel) by purse seine associated sets. (Source: [WCPFC-SC6-2010-ST-IP-02](#))