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Analysis of the implementation and effectiveness of key management measures for tropical tunas

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1 Executive Summary

The paper provides a review of the implementation and effectiveness of key management measures for tropical tuna, using the most current data and stock assessments available. For the most part, these measures relate to CMM 2008-01 and its successors.

We have examined the key components of the measures – 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

Tropical purse seine effort has increased since the introduction of CMM 2008-01, with effort (excluding domestic purse seiners based in Indonesia and Philippines) peaking in 2011. VMS effort in 2012 was comparable to 2011 levels, and had increased by approximately 8% compared to effort levels in 2010. Further, stock assessment results indicate that the effectiveness of the effort has typically increased on top of the increase in total effort (i.e. effort creep may be occurring). Comparison of effort between logsheet fishing days and sets and VMS sources suggested that for some fleets there has been a change in how days are reported; specifically, days that would have previously been reported as days searching (which we count as fishing days) are now reported as days in transit (which we consider non-fishing days), which is inconsistent with effort reported in previous years. Further investigation is required.

FAD closure and FAD usage

The incidence of reported activity related to the use of drifting FADs during the FAD closures was considerably lower in the period 2010-2012 (5.6%, 9.6% and 3.2% respectively) compared to 2009 (19.2%). The observed incidence of vessels drifting at night with fish aggregation lights on increased from 2.4% in 2009 to 4.7% in 2010, but then fell to 2.3% and 1.2% in 2011 and 2012. There was some evidence of a slight decline in total effort (days) during the closures in recent years. In 2010, the proportions of effort associated with FAD usage outside the closure period, particularly the months immediately before and after the closure, were lower than is typically the case. In 2011, overall FAD usage returned to more typical levels prior to the 2011 closure, while in the remainder of 2011 and in 2012 the proportion of associated sets stabilised at around 40% of total set numbers. It is evident that several fleets (notably Japan, Philippines, New Zealand) have substantially changed their fishing operations, focusing more on unassociated set fishing in recent years than they had in the past, but it is not known if this is a deliberate strategy or rather a response to the availability of surface schools. Other fleets showed a decline in the proportion of FAD sets in 2012. In spite of this, the total estimated number of FAD sets made in 2011 was a record high, largely due to increased purse seine effort overall, with a slight decline in 2012.

Skipjack, yellowfin and total catches were slightly below average during the 2009 and 2010 closures. Sustained high total catches (particularly skipjack and bigeye) occurred between the 2010 and 2011 closures; however total (and skipjack) catches during the 2011 closure were almost half those seen during the previous closure months. Catches recovered somewhat following the 2011 closure, but did not reach the levels experienced earlier in that year, primarily due to continued relatively low skipjack catches. Catches of skipjack and overall catch levels recovered in 2012, and catches during the closure period were similar to those seen during 2009 and 2010 closures. Bigeye tuna catches were strongly reduced during closure periods compared to the other months of those years. However, the average size of the fish caught was generally higher for all species during the closures because of the larger average size of fish caught in unassociated sets. These larger average sizes, which have higher unit value, may offset to some extent the loss of revenue that occurs as a result of lower catches during the closures.

High seas pockets closure

Available data from all sources indicate that the HSP closure has largely been respected. Since January 2010, effort has been concentrated mainly in the EEZs.

Longline catches

The total average bigeye longline catch for 2001-2004 was 83,923 tonnes. In recent years, bigeye longline catch has increased slightly from 66,441 tonnes in 2010 through 67,557 tonnes in 2011 to 71,148 tonnes in 2012 (79%, 81% and 85% of the average catch for 2001-2004, respectively).

The effectiveness of bigeye catch reductions in reducing fishing mortality depends on whether the reductions occurred because of reduced fishing effort (which would imply reduced fishing mortality) or were simply the result of further declines in the bigeye stock. In the core area of the tropical longline fishery, the reduced catches have been paralleled by a decline in CPUE, which indicate that the recent catch declines could be more the result of further declines in adult bigeye tuna abundance than reduced fishing mortality. **Figure 9 has been updated, based on revised data received 31 July 2013.**

For yellowfin tuna, the longline catch in 2001-2004 averaged 75,712 tonnes. In 2010 and 2011, the catches were 75,582 tonnes and 75,393 tonnes respectively, and fell below the 2001-2004 average level in 2012 to 65,582 tonnes.

Other fisheries

For fisheries other than tropical purse seine and longline, total catches for 2010 and 2011 are reported to be less than their respective average levels for 2001-2004 for both bigeye and yellowfin tuna. 2012 catches for both species were slightly greater than the corresponding average 2001-2004 levels.

Evaluating management impacts on bigeye overfishing

In previous papers stock projections have been undertaken using the 'reference case' models for each key tropical tuna stock to assess the implications of status quo conditions and identify changes within the fisheries required to remove overfishing on the WCPO bigeye stock. In summary, this indicated that levels of effort and catch consistent with those reported in 2010 would achieve the elimination of bigeye overfishing by 2021. This was driven by several factors: the lower than usual FAD use in 2010, the lower longline catches, and a large (30%) reduction in reported catches from the domestic fisheries of Indonesia and the Philippines. Reductions in purse seine FAD effort in 2010 has the greatest effect in terms of removing overfishing (67.4% of overfishing removed) followed by the reduction in longline catch in 2010 (34.7% of the overfishing removed). For a scenario approximating 2011 fishery conditions, F/F_{MSY} stabilises at a projected level of 1.29. The difference between 2010 and 2011 fishery outcomes is mainly due to the return to higher levels of FAD-based purse seine effort in 2011.

We present a series of projections specifically for the bigeye tuna stock under a range of future of purse seine associated set effort and longline fishery bigeye catch level combinations. Using this set of projections, we identify the conditions in these fisheries that remove 50% and 100% of overfishing in bigeye tuna in the WCPO by 2018. For each, the relative contribution of the two fisheries to the desired reduction in bigeye overfishing was calculated.

2 Introduction

CMM 2008-01, adopted in December 2008, sought 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 has been pursued though 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 were phased in over the period 2009-2011.

In section 3 of this paper, we review the implementation of the key elements of CMM 2008-01 and its successors. This review covers 2009-2012. The key elements of the CMM reviewed here are purse seine effort levels, the 2009 - 2012 FAD closures, 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 4 reviews results from previous assessments of the impacts of a variety of combinations of catch and effort levels on bigeye tuna overfishing. Given the interim nature of CMM 2012-01, new projections are performed to inform further discussions on management measures for tropical tuna.

3 Implementation of key elements of CMM 2008-01 and its successors

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

3.1 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. In CMM-2011-01, this was adjusted to be no greater than 2010 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 level[2];
- Purse seine fishing is prohibited in the two western high seas pockets (since 1 January 2010).
- 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;
    - Preservation of existing rights under registered regional or bilateral fisheries partnership arrangements or agreements in paragraph 7; and

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

- Exclusion of archipelagic waters from the scope of the CMM;
- Extension CMM 2011-01, allows 36 Philippines catcher vessels to fish in the HSP-1 SMA.

VMS information from purse seine vessels provides the most up-to-date information on effort within the fishery of relevance to the CMM baseline of 2010 (Figure 1). An increase in total effort can be seen between 2009 and 2011. Total effort in 2012 was comparable to the historical high in 2011, and was 8% higher than 2010 levels.

Using raised logsheet data, purse seine effort from 2001 to 2012 can be broken down by various categories of EEZs and high seas (Figure 2). Due to 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, purse seine effort in the WCPFC tropical purse seine fishery increased considerably to 2011, excluding domestic purse seiners based in Indonesia and Philippines. Since that year, raised logsheet data suggest effort has fallen in 2012. In comparison to effort in 2004, this remains an increase of 21%, and in comparison to effort in 2010 an increase of 3% (Figure 2). It should be noted that stock assessment results indicate that the effectiveness of the effort has typically increased on top of the increases in total effort.

Comparison of effort between logsheet fishing days and sets and VMS sources suggested that for some fleets there has been a change in how days are reported; specifically, days that would have previously been reported as days searching (which we count as fishing days) are now reported as days in transit (which we consider non-fishing days), which is inconsistent with effort reported in previous years. Further investigation is required, but if this is a widespread phenomena it has important implications for large scale effort creep under the current fishing day limits.

3.2 FAD closure and overall FAD usage patterns

Information on the implementation of the 2009 and 2010 FAD closures was reported to recent Scientific Committee and Commission meetings (WCPFC-SC7-2011-MI-WP-01; WCPFC-SC8-2012-MI-WP-06; WCPFC8-2011-43 (Rev 1)). This information has been further updated using the latest observer data holdings and extended to cover the 2012 FAD closures. The key findings are:

- The incidence of reported activity related to use of drifting FADs during the FAD closures was considerably lower in 2010, 2011 and 2012 (5.6%, 9.6% and 3.2%, respectively) compared to 2009 (19.2%) (Table 1);
- The observed incidence of vessels drifting at night with fish aggregation lights on increased from 2.4% in 2009 to 4.7% in 2010, but then fell in subsequent years (2.3% in 2011, 1.2% in 2012);
- The proportions of associated sets conducted during the closure periods were substantially lower than other months (Figure 3). Note that some level of associated set fishing is expected in the closure months, mainly in archipelagic waters;
- There was some evidence for a slight decline in total effort (days) during the closures in recent years (Figure 3);
- In 2010, the proportions of effort associated with FAD usage outside the closure period, particularly the months immediately before and after the closure, were lower than is typically the case. In 2011, overall FAD usage returned to more historical levels prior to the

2011 closure, while in the remainder of 2011 and in 2012 the proportion of associated sets stabilised around 40% of total set numbers (Figure 3);

- Several fleets (notably Japan, Philippines, New Zealand) have substantially changed their fishing operations, focusing more on unassociated set fishing in 2010-2012 than they had in the past (Table 2), while other fleets (e.g. Kiribati, Korea) show notable declines in the 2012 data available. These changes, indicated in logsheet data, is generally corroborated by available observer data. It is not known if this is a deliberate strategy or rather a response to the availability of surface schools;
- In spite of this, the total estimated number of FAD sets made in 2011 was a record high, largely due to increased purse seine effort overall, with a slight decline in total FAD sets in 2012 (Figure 4);
- Skipjack, yellowfin and total catches were slightly below average during the 2009 and 2010 closures. Sustained high total catches (particularly skipjack and bigeye) occurred between the 2010 and 2011 closures; however total (and skipjack) catches during the 2011 closure were almost half those seen during the previous closure months. Catches recovered somewhat following that closure, but did not reach the levels experienced earlier that year, primarily due to continued relatively low skipjack catches (Figure 5). Catches recovered in 2012, and catches during that year's closure period were similar to those seen during the 2009 and 2010 closures;
- Catches of bigeye tuna were strongly reduced during closure periods compared to the other months of the year (Figure 5);
- While catches were reduced during the closures, the average size of the fish in the catch was generally higher for all species during the closures (Figure 6) because of the larger average size of fish caught in unassociated sets. These larger average sizes, which have higher unit value, may offset to some extent the loss of revenue that occurs as a result of lower catches during the closures.

3.3 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)[3] given the existing limits on EEZ effort (see Table 7, WCPFC6-2009-IP17).

Figure 7 shows the distribution of purse seine effort during 2012 from three independent sources of data – logsheet, observer and VMS data. The three data sets show similar patterns. There is a relatively small increase in the amount of effort within the HSP, presumably for transiting purposes

[3] For the purpose of this paper, we define the eastern high seas as the high seas areas of the WCPFC convention area between 10ºN and 20ºS and east of 170ºE. 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 170ºE is excluded from this definition.

and/or the effort by the Philippines catcher vessels permitted to fish in the HSP1 according to CMM 2011-01. Historically, the proportion of total purse seine effort occurring in the HSP has been about 10-20% annually; in 2012, on the basis of available logsheet data, it was 0.9%. The occurrence of purse seine effort in the eastern high seas is related to some extent to the ENSO cycle, being higher during *El Niño* events. In 2012 ENSO-neutral conditions dominated, consistent with increased purse seine effort in more easterly waters.

3.4 Longline catch

CMM 2008-01 established certain bigeye longline catch limits for CCMs other than Small Island Developing States and Territories (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[4] 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 Hawaii-based fleet only.

The total average bigeye longline catch for 2001-2004 was 83,923 tonnes[5] (including recent revisions provided by fishing nations). In recent years, bigeye longline catch has increased slightly from 66,441 tonnes in 2010 through 67,557 tonnes in 2011 to 71,148 tonnes in 2012 (79%, 81% and 85% of the average catch for 2001-2004, respectively; Figure 8).

The effectiveness of bigeye catch reductions in reducing fishing mortality depends on whether the reductions occurred because of reduced fishing effort (which would imply reduced fishing mortality) or were simply the result of further declines in the bigeye stock. To evaluate these alternatives, we examined longline effort and bigeye catches in the core area of the tropical fishery (130°E – 150°W, 20°N – 10°S) where bigeye tuna are the target species of the longline fishery. In this core area (which comprises 81% of the total Convention Area longline catch of bigeye during 2001-2012), the bigeye catch declined with a similar pattern as the Convention Area as a whole; however, longline effort showed a different pattern of moderate decline from 2002 to 2006, followed by a stabilisation to 2010 and subsequent increase to 2012 (Figure 9). This implies that the reduction in catch has resulted not from effort reduction but from declining CPUE (Figure 9, bottom panel and see also Harley et al. 2012). If CPUE is an indicator of bigeye tuna abundance, the conclusion would be that

[4] Chinese bigeye longline catch limits were updated for 2012 in CMM 2011-01

[5] Compared to numbers in WCPFC9-IP09, major changes to the calculation behind these figures and other figures in this working paper include the exclusion of catches from the Vietnam fleet and the Indonesia fleet in archipelagic waters.

recent catch declines have occurred in response to further declines in adult bigeye tuna abundance and have therefore been ineffective in reducing fishing mortality.

CMM 2008-01 also limited longline catches of yellowfin tuna to their 2001-2004 average levels for each CCM, excluding SIDS. Total annual yellowfin catch in 2001-2004 averaged 75,712 tonnes (see footnote no. 4). In 2010 and 2011, the provisional total longline catch of yellowfin was 75,582 tonnes and 75,393 tonnes respectively, and fell below the 2001-2004 average level in 2012 to 65,582 tonnes.

3.5 Gear types other than tropical 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. The average bigeye catch for 2001-2004 was 9,557 tonnes, while the reported catch in 2010 was 7,510 tonnes, in 2011 was 6,675 tonnes, and in 2012 was 9,789 tonnes. For yellowfin, the average catch in 2001-2004 was 74,779 tonnes, while the reported catch has fluctuated from 87,080 tonnes in 2010 to 62,590 tonnes in 2011 and up to 79,863 tonnes in 2012. Therefore, in 2012 catches for both species were slightly greater than the average level for 2001-2004.

4 Evaluating management impacts on bigeye overfishing

4.1 Effectiveness of previous measures

In previous papers to meetings of the Scientific Committee (e.g. Hampton et al., 2012; MI-WP-06), Technical and Compliance Committee (OFP, 2011; WCPFC-TCC7-2011/31) and the Commission (OFP, 2012; WCPFC9-2012-IP15_rev1), stock projections have been undertaken using the 'reference case' models for each key tropical tuna stock to assess the implications of *status quo* conditions, the potential effectiveness of CMM 2008-01 measures, and identify changes within the fisheries required to remove overfishing on the WCPO bigeye stock. The reader is referred to the papers for specific issues. Below we summarise the general findings of the projection analyses.

Analysing fishery levels relative those in recent years provides a guide for actions required to remove bigeye overfishing. Maintenance of observed 2009 bigeye tuna catch and fishery effort levels results in F/F_{MSY} remaining high, with a projected level of F/F_{MSY} = 1.40 in 2021 (Figure 10). Under a scenario best approximating reported fishery catch and effort in 2010, F/F_{MSY} declines and is at a projected level of 0.96 in 2021. This is driven by several factors: the lower than usual FAD use in 2010, the lower longline catches, and a large (30%) reduction in reported catches from the domestic fisheries of Indonesia and the Philippines. For a scenario approximating 2011 fishery conditions, F/F_{MSY} stabilises at a projected level of 1.29. The difference between 2010 and 2011 fishery outcomes is mainly due to the return to higher levels of FAD-based purse seine effort in 2011.

The individual impacts on bigeye tuna F/F_{MSY} of observed levels of catch or effort for the longline, purse seine and domestic Philippines and Indonesia fishery groups were examined relative to a 2004 baseline. The reduction in purse seine FAD effort in 2010 has the greatest effect in terms of removing overfishing (67.4% of overfishing removed) followed by the reduction in longline catch in 2010 (34.7% of the overfishing removed).

Scenarios have also examined a total purse seine closure (i.e., where FAD effort is not transferred to unassociated fishing). These result in a relatively small incremental reduction in F/F_{MSY} compared to that achieved by a FAD closure, at a cost of substantial reductions in total catch, particularly in the purse seine fishery.

4.2 Evaluation of future conditions required to remove BET overfishing

Here we present a series of projections for the bigeye tuna stock to inform discussions regarding new CMMs for the management of tropical tunas. These comprise a set of 'generic' projections of various combinations of purse seine associated set fishery effort levels (20°N – 20°S) and (grouped) longline fishery catch levels only. Using this set of projections, we identify the conditions in these fisheries that remove 50% and 100% of overfishing in bigeye tuna in the WCPO by 2018.

Similar assumptions were made in the current projections as in previous analyses (e.g. WPCFC-SC8/MI-WP-06). The main assumptions were:

- The reference case model from the 2011 bigeye (WCPFC-SC7-2011-SA-WP-02) stock assessment was used - this model was adopted by SC7 for the provision of management advice in 2011;
- Projections were deterministic in that no process or estimation error was assumed;
- Projections were run for seven years from 2012, i.e. the goal was to reach the specified levels of bigeye overfishing removal by 2018. This final year was selected on the basis of discussions underpinning the Chairman's draft CMM on tropical tuna (WCPFC9-2012-12);
- A "base year" was chosen in order to express catch and effort values for 2012 - 2018, defining the particular fishing strategy or management option being projected into the future, in relative terms. These relative catch or effort values are referred to as scalars; a scalar of 1.0 would mean a catch or effort level for a particular fishery group equivalent to that which occurred in 2011. **At the request of SC9, scalars relative to alternative baseline years were also calculated and included within the Tables.**
- 'Actual' conditions in 2010 and 2011 of PS associated fishery effort and LL catch were used to project through those years, and scalars then applied to the corresponding levels in 2011 for 2012 onwards. This assumption impacts the short-term post-2011 projections of biomass and catches, but does not significantly impact the main performance measures, which are the equilibrium outcomes at the end of the projection period;
- Scalars were applied on the level of effort within the purse seine associated fishery. This is the current approach to managing this fishery (e.g. PNA VDS). While projections were also run implementing scalars on purse seine bigeye catch levels (not presented), results are highly sensitive to changes in catch level. Under effort based projections, catches are scaled by the underlying stock size. In catch-based projections, scalar combinations can result in

stock collapse in specific model regions as the population falls below levels required for specified catches to be taken.

- Levels of activity in other fisheries were kept constant. Changes in unassociated purse seine effort have minimal impacts on the bigeye stock (see the results of previous projections where the implications of a total purse seine closure and a FAD closure were compared) but do have implications for the status and level of other tropical tuna species. Other fisheries (Indonesia-Philippines domestic fishery, other fisheries) were also held constant, given current uncertainties within the data available for these fisheries.
- Recruitment was assumed to occur at the average of the level estimated over the period 2000-2009, as recommended by SC6;
- Catchability (which can have a trend in the historical component of the model) was assumed to remain constant in the projection period at the level estimated in the terminal year of the assessment model.

We stress that the choice of base year is not critical for the projections, as a wide range of catch/effort levels are explored in the various scenarios. As stated above, the choice of 2011 as the base year simply means that all other catch or effort levels used in the projections are expressed relative to their respective levels in 2011.

A grid of projections was developed, across a range of associated purse seine effort and longline catch scalars. To help identify those conditions that achieved the -desired reduction in overfishing, a regression approach was used; the reduction in bigeye overfishing was modelled as a function of associated purse seine fishery and longline fishery scalars. Predictions using this model interpolated - across a finer grid of scalars than feasible to compute with individual projections - were used to identify those scalars that achieved the approximate removal of 100% (Table 3) and 50% (Table 4) of bigeye fishing by 2018. For each of these conditions, the relative contribution of the two fisheries to the desired reduction in bigeye overfishing was also calculated using the regression model. Relative fishery contribution to reductions in overfishing was estimated by setting one fishery to a scalar of 1 and identifying the reduction in F/F_{MSY} resulting from the scalar applied to the other fishery (and *vice versa*).

The purse seine associated set fishery scalars that removed overfishing (in combination with those scalars for the longline fishery) were converted into an equivalent FAD closure period. The required reduction in 2011 total FAD days outside the FAD closure period corresponding to the scalar was divided by the corresponding average monthly FAD days (excluding archipelagic waters activity). Three months (corresponding to the existing closure) were then added to identify the total FAD closure period required.

5 References

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Table 1. Summary statistics for various vessel behaviours documented by observers during the CMM 2008-01 FAD Closures in 2009, 2010, 2011 and 2012. Archipelagic waters, which are outside the scope of CMM 2008-01, are not included in the summary statistics. Based on processed observer data available as at 11 Jul 2013.

	2009 (Aug – Sep)	**2010 (Jul – Sep)**	**2011 (Jul – Sep)**	**2012 (Jul – Sep)**
Number of observer trips processed to date	182	315	268	102
Number of observed fishing and searching days processed to date (Coverage rate)	3,473 *(54.3%)*	6,254 *(67.0%)*	6,323 *(62.9%)*	1,899 *(21.3%)*
Number of observed sets processed to date (Coverage rate)	3,480 *(55.2%)*	7,196 *(64.8%)*	5,138 *(59.5%)*	1,970 *(18.3%)*
Number of nights drifting with fish aggregation lights (activity = 14) (% of total)	85 *(2.4%)*	295 *(4.7%)*	144 *(2.3%)*	77 *(1.2%)*
Number of days setting or investigating Drifting FADs (SCH_ID = 4) (% of total)	204 *(5.9%)*	176 *(2.8%)*	227 *(3.6%)*	98 *(1.5%)*
Number of days reported as "No fishing, drifting with floating object" (Activity = 12) (% of total)	187 *(5.4%)*	115 *(1.8%)*	147 *(2.3%)*	39 *(0.6%)*
Number of days reported with any activity related to a drifting FAD (Activity = 9,10,12,23,24,25,26) (% of total)	667 *(19.2%)*	349 *(5.6%)*	607 *(9.6%)*	202 *(3.2%)*

Table 2. Estimated annual proportions of total sets that are associated sets, by flag, for 2005 – 2009, 2010, 2011 and 2012. Shaded rows indicate fleets for which the proportion of logsheet-reported sets is substantially lower than the observer-reported estimates, noting 2012 observer data are provisional.

Flag	Proportion of total sets that are ASSOCIATED						
	2005 - 2009	2010		2011		2012	
	Logsheet	Logsheet	Observer	Logsheet	Observer	Logsheet	Observer
China	0.54	0.25	0.28	0.59	0.58	0.62	0.68
Ecuador	0.74	0.93	0.98	0.91	0.94	0.98	0.98
El Salvador	0.88	0.98	0.99	0.98	1.00	0.98	
FSM	0.63	0.41	0.51	0.63	0.61	0.63	0.59
Indonesia		0.27	0.32				
Japan	0.52	0.13	0.11	0.18	0.21	0.25	0.20
Kiribati	0.45	0.30	0.24	0.41	0.46	0.25	0.26
Korea	0.25	0.15	0.16	0.32	0.30	0.16	0.14
Marshall Is	0.79	0.34	0.33	0.74	0.75	0.63	0.61
New Zealand	0.67	0.33	0.43	0.54	0.47	0.35	
PNG	0.52	0.32	0.25	0.43	0.41	0.40	0.41
Philippines	0.51	0.24	0.26	0.25	0.29	0.26	0.34
Solomon Is	0.78	0.79	0.88	0.86	0.74	0.88	0.96
Spain	0.83	0.85	0.81	0.94	1.00	0.89	
Tuvalu	0.25	0.12	0.09	0.17	0.01	0.27	0.18
Chinese Taipei	0.49	0.23	0.21	0.39	0.40	0.41	0.44
USA	0.49	0.28	0.27	0.54	0.55	0.38	0.50

Table 3. Projection conditions that remove 100% of BET overfishing by 2018, relative to status quo 2011 conditions (F/FMSY = 1.421) and the contribution to this reduction made by purse seine associated effort and longline catch reductions. Effort and catch in other fisheries assumed constant. Scalars for longline (catch) and purse seine Associated effort (days) are also related to CMM baseline years. Note these scalars are approximate. Equivalent total FAD closure period estimated from conditions in 2011. This assumes no change in FAD effort within archipelagic waters, and includes the existing three month closure period.

% BET overfishing removed relative to status quo (2011)	LL catch level			PS ASS effort level			Total equivalent PS FAD closure period	Contribution to reduction (%, 2011 scalars)	
	Scalar on 2011	Scalar on 2001/04 avg	Scalar on 2004	Scalar on 2011	Scalar on 2010	Scalar on 2004		LL	PS ASS
100.12	1.19	1.10	1.00	0.47	0.76	0.45	8.4	-8.93	108.93
100.04	1.14	1.05	0.96	0.49	0.79	0.47	8.2	-5.10	105.10
99.96	1.09	1.01	0.92	0.51	0.82	0.49	8.0	-1.27	101.27
99.89	1.04	0.96	0.88	0.53	0.85	0.51	7.8	2.56	97.44
99.81	0.99	0.91	0.83	0.55	0.89	0.53	7.6	6.40	93.60
100.18	0.96	0.89	0.81	0.56	0.90	0.54	7.5	8.67	91.33
100.1	0.91	0.84	0.77	0.58	0.93	0.56	7.3	12.50	87.50
100.03	0.86	0.79	0.72	0.60	0.97	0.58	7.1	16.34	83.66
99.95	0.81	0.75	0.68	0.62	1.00	0.60	6.9	20.19	79.81
99.87	0.76	0.70	0.64	0.64	1.03	0.62	6.7	24.04	75.96
100.16	0.68	0.63	0.57	0.67	1.08	0.64	6.4	30.09	69.91
100.09	0.63	0.58	0.53	0.69	1.11	0.66	6.2	33.94	66.06
100.01	0.58	0.53	0.49	0.71	1.14	0.68	6.0	37.79	62.21
99.93	0.53	0.49	0.45	0.73	1.18	0.70	5.8	41.65	58.35
99.86	0.48	0.44	0.40	0.75	1.21	0.72	5.6	45.52	54.48
100.15	0.40	0.37	0.34	0.78	1.26	0.75	5.3	51.52	48.48
100.07	0.35	0.32	0.29	0.80	1.29	0.77	5.0	55.38	44.62
100	0.30	0.28	0.25	0.82	1.32	0.79	4.8	59.25	40.75
99.92	0.25	0.23	0.21	0.84	1.35	0.81	4.6	63.13	36.87
99.84	0.20	0.18	0.17	0.86	1.38	0.83	4.4	67.01	32.99

Table 4. Projection conditions that remove 50% of BET overfishing by 2018, relative to status quo 2011 conditions (F/FMSY = 1.421) and the contribution to this reduction made by purse seine associated effort and longline catch reductions. Effort and catch in other fisheries assumed constant. Scalars for longline (catch) and purse seine Associated effort (days) are also related to CMM baseline years. Note these scalars are approximate. Equivalent total FAD closure period estimated from conditions in 2011. This assumes no change in FAD effort within archipelagic waters, and includes the existing three month closure period.

% BET overfishing removed relative to status quo (2011)	LL catch level			PS ASS effort level			Total equivalent PS FAD closure period	Contribution to reduction (%, 2011 scalars)	
	Scalar on 2011	Scalar on 2001/04 avg	Scalar on 2004	Scalar on 2011	Scalar on 2010	Scalar on 2004		LL	PS ASS
50.05	1.17	1.08	0.99	0.72	1.16	0.69	5.9	-14.01	114.01
49.97	1.12	1.03	0.94	0.74	1.19	0.71	5.7	-6.77	106.77
49.9	1.07	0.99	0.90	0.76	1.22	0.73	5.5	0.49	99.51
49.82	1.02	0.94	0.86	0.78	1.26	0.75	5.3	7.77	92.23
50.19	0.99	0.91	0.83	0.79	1.27	0.76	5.2	12.05	87.95
50.11	0.94	0.87	0.79	0.81	1.30	0.78	4.9	19.31	80.69
50.04	0.89	0.82	0.75	0.83	1.34	0.80	4.7	26.59	73.41
49.96	0.84	0.77	0.71	0.85	1.37	0.82	4.5	33.88	66.12
49.88	0.79	0.73	0.67	0.87	1.40	0.84	4.3	41.20	58.80
49.81	0.74	0.68	0.62	0.89	1.43	0.86	4.1	48.53	51.47
50.17	0.71	0.65	0.60	0.90	1.45	0.86	4.0	52.55	47.45
50.1	0.66	0.61	0.56	0.92	1.48	0.88	3.8	59.86	40.14
50.02	0.61	0.56	0.51	0.94	1.51	0.90	3.6	67.20	32.80
49.94	0.56	0.52	0.47	0.96	1.55	0.92	3.4	74.55	25.45
49.87	0.51	0.47	0.43	0.98	1.58	0.94	3.2	81.92	18.08
50.16	0.43	0.40	0.36	1.01	1.63	0.97	2.9	93.07	6.93
50.08	0.38	0.35	0.32	1.03	1.66	0.99	2.7	100.44	-0.44
50.01	0.33	0.30	0.28	1.05	1.69	1.01	2.5	107.83	-7.83
49.93	0.28	0.26	0.24	1.07	1.72	1.03	2.3	115.24	-15.24
49.85	0.23	0.21	0.19	1.09	1.76	1.05	2.1	122.67	-22.67

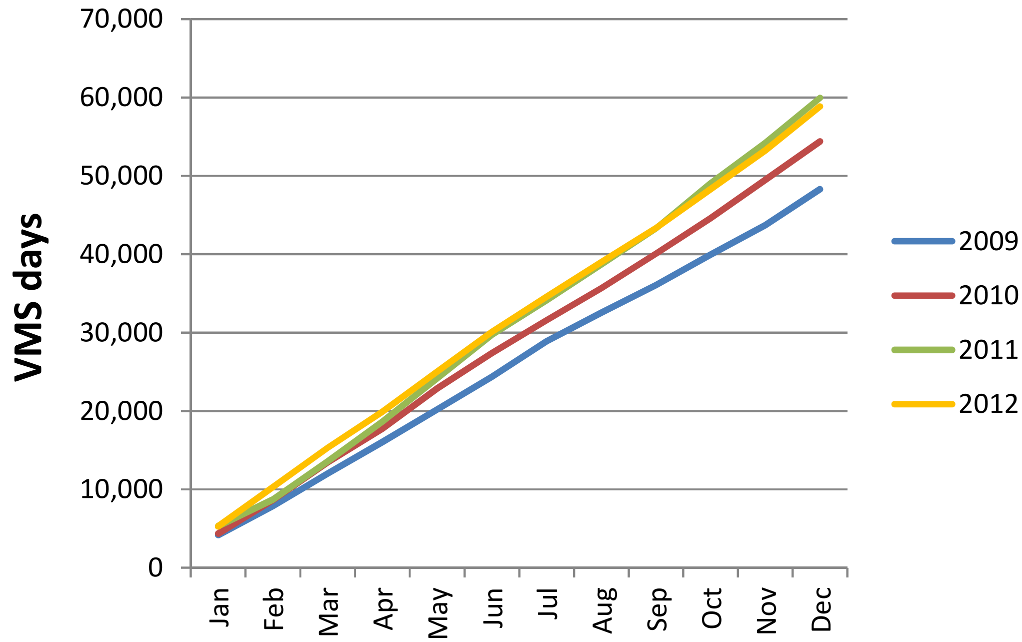

Figure 1. Cumulative purse seine effort by month, 2009-2012, as measured by VMS (days in port and end-of-trip transit days omitted).

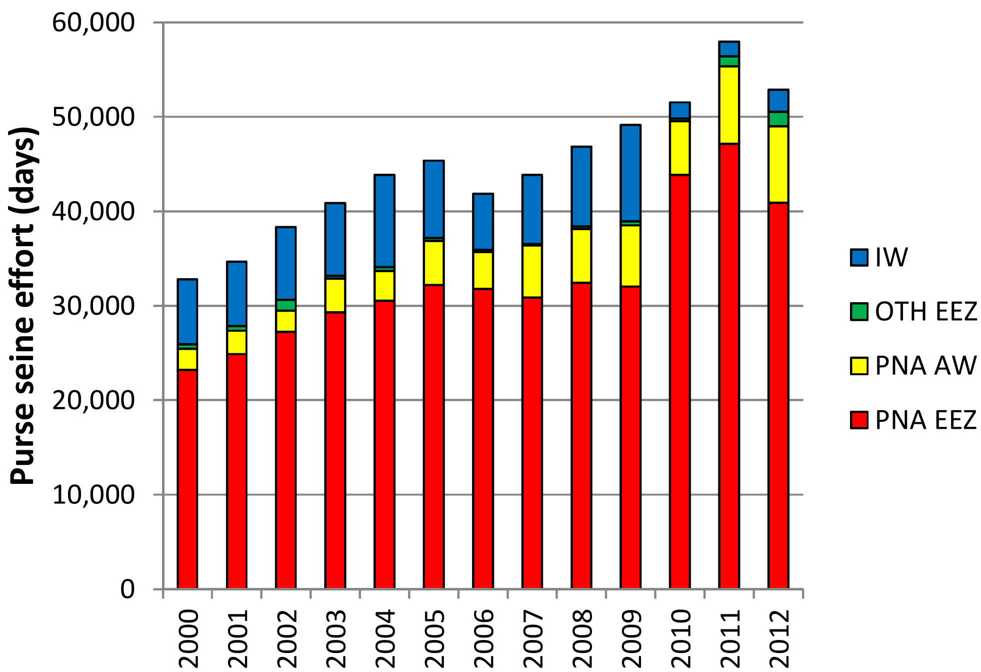

Figure 2. Purse seine effort (days fishing and searching) in the WCPFC Convention Area between 20^{o}N and 20^{o}S, excluding domestic purse seine effort in Philippines and Indonesia. Estimates are based on raised logsheet data.

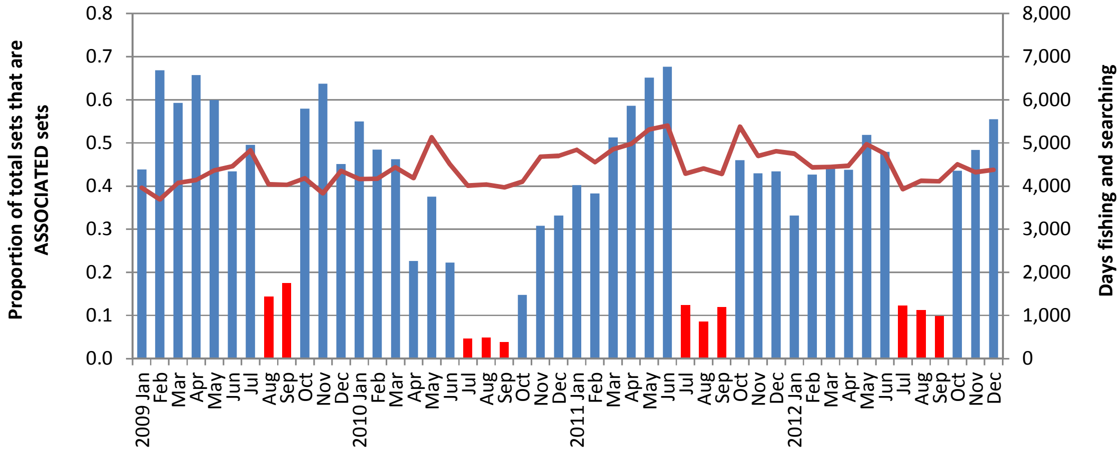

Figure 3. Proportion of the total purse seine fishing activity comprising associated sets, as indicated by logsheet data. Red bars indicate the FAD closure months. Total effort in days is shown by the plotted line. Activities in the domestic purse seine fisheries of Indonesia and Philippines are excluded.

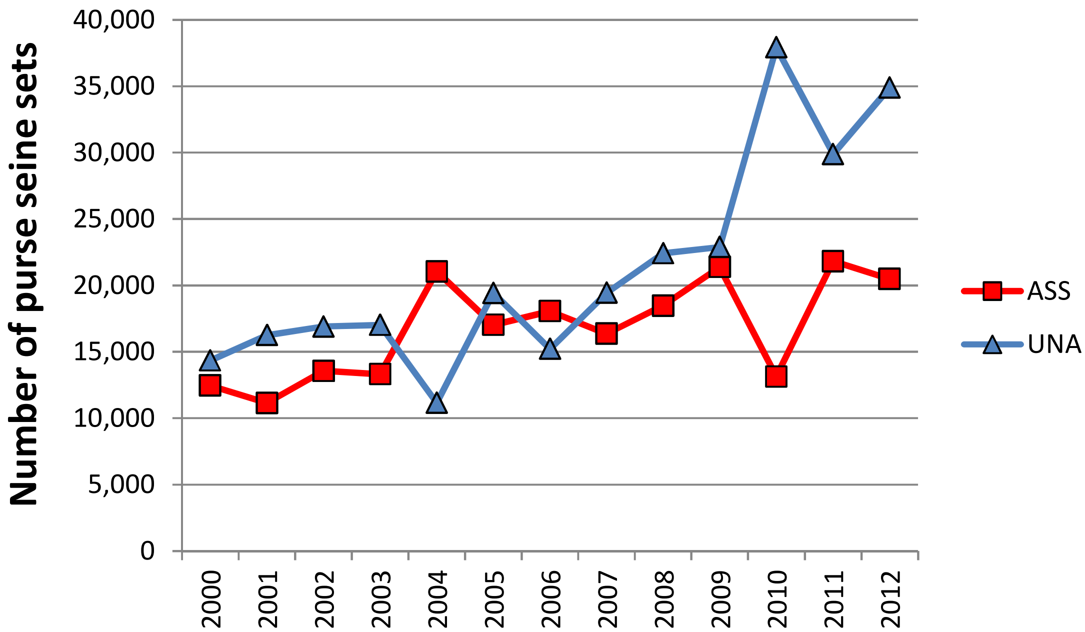

Figure 4. Number of associated (ASS) and unassociated (UNA) sets made in the WCPO tropical purse seine fishery, 2000 – 2012. Activities in the domestic purse seine fisheries of Indonesia and Philippines are excluded.

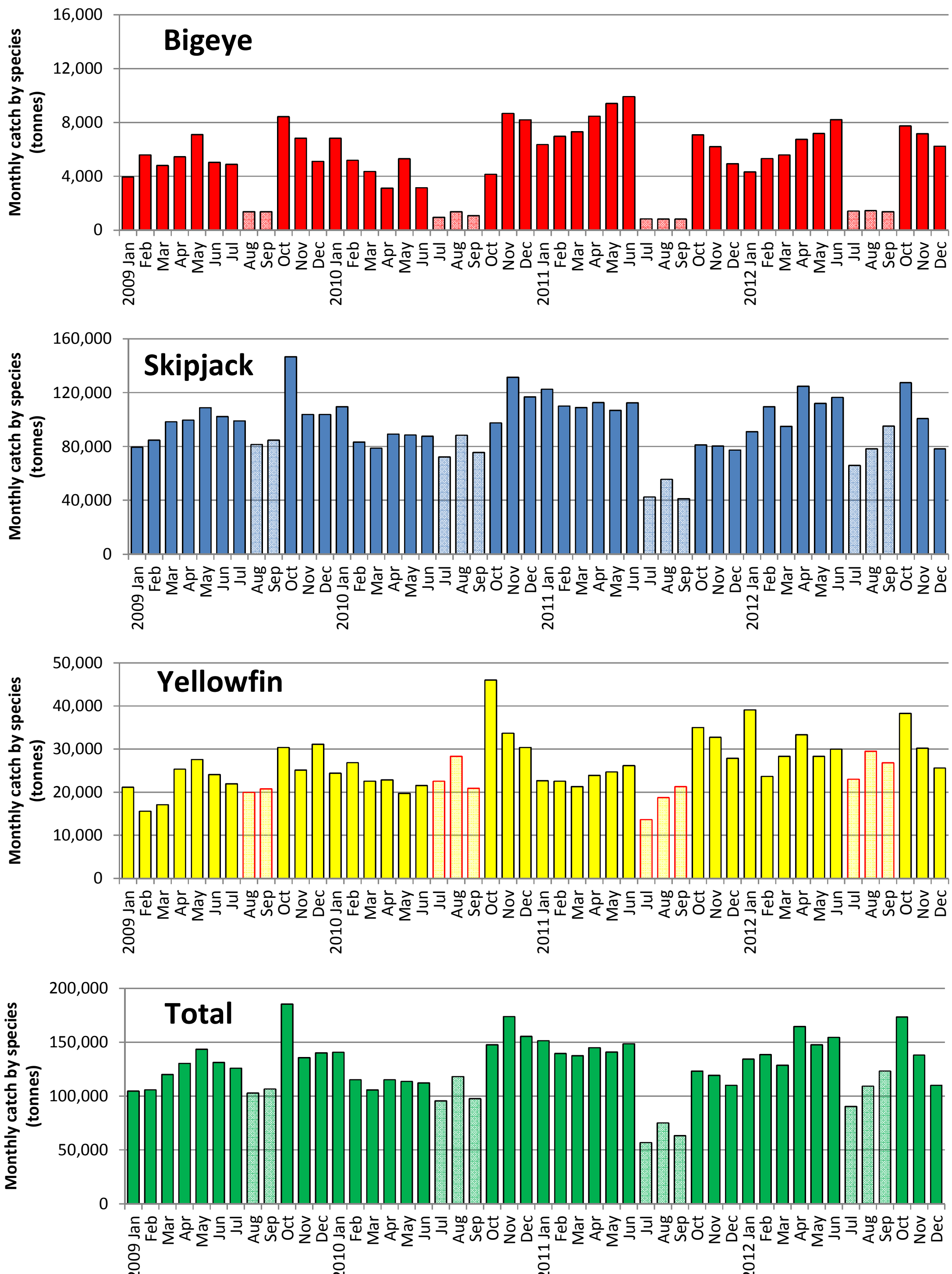

Figure 5. Monthly catch by species (raised logsheet data with species composition adjusted using observer sampling with grab sample bias correction). FAD closure months are shaded in lighter colour. Data excludes the domestic fisheries of Indonesia and Philippines.

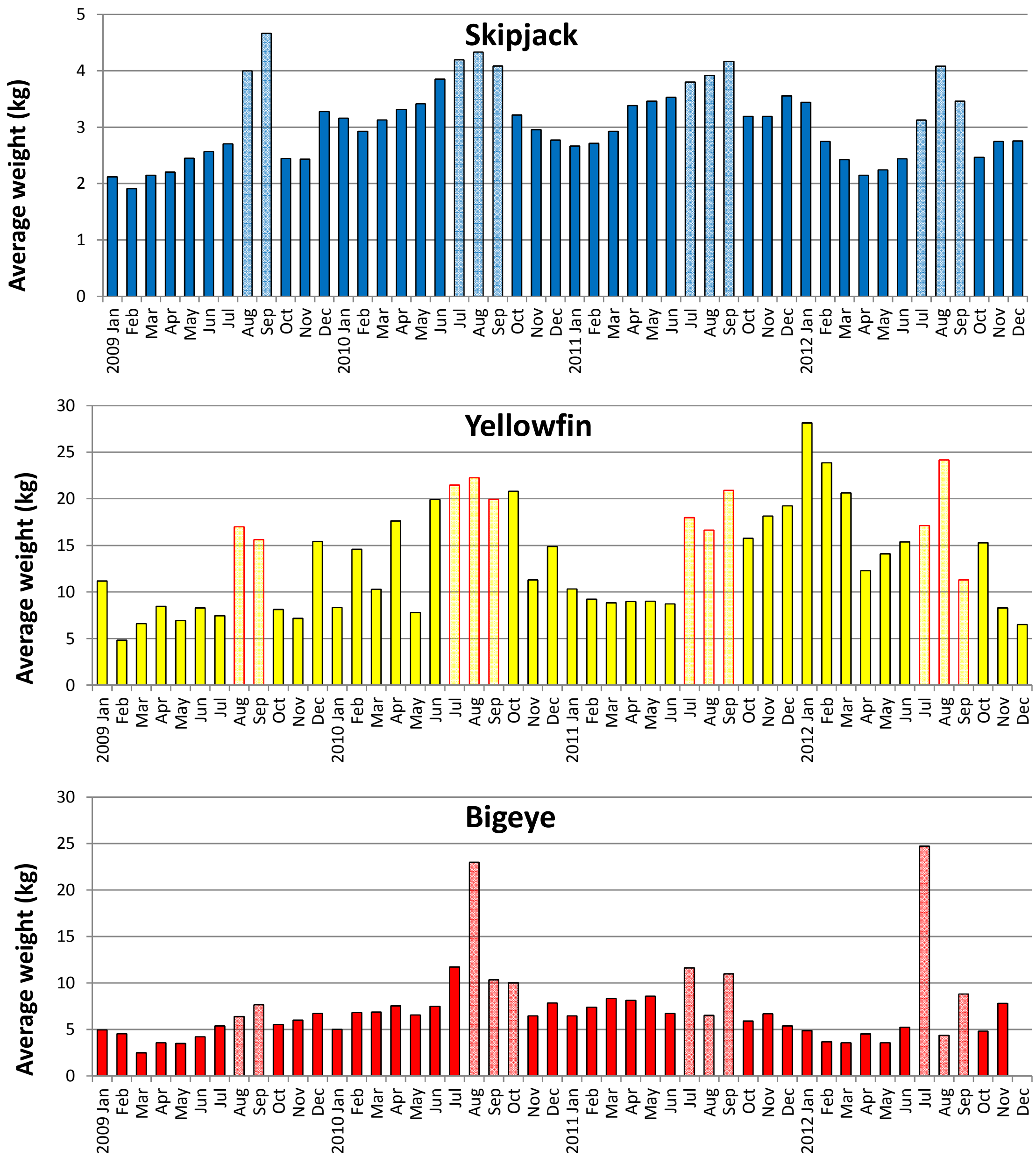

Figure 6. Average weight of bigeye, skipjack and yellowfin tuna, estimated from observer sampling data, during 2009, 2010, 2011 and 2012.

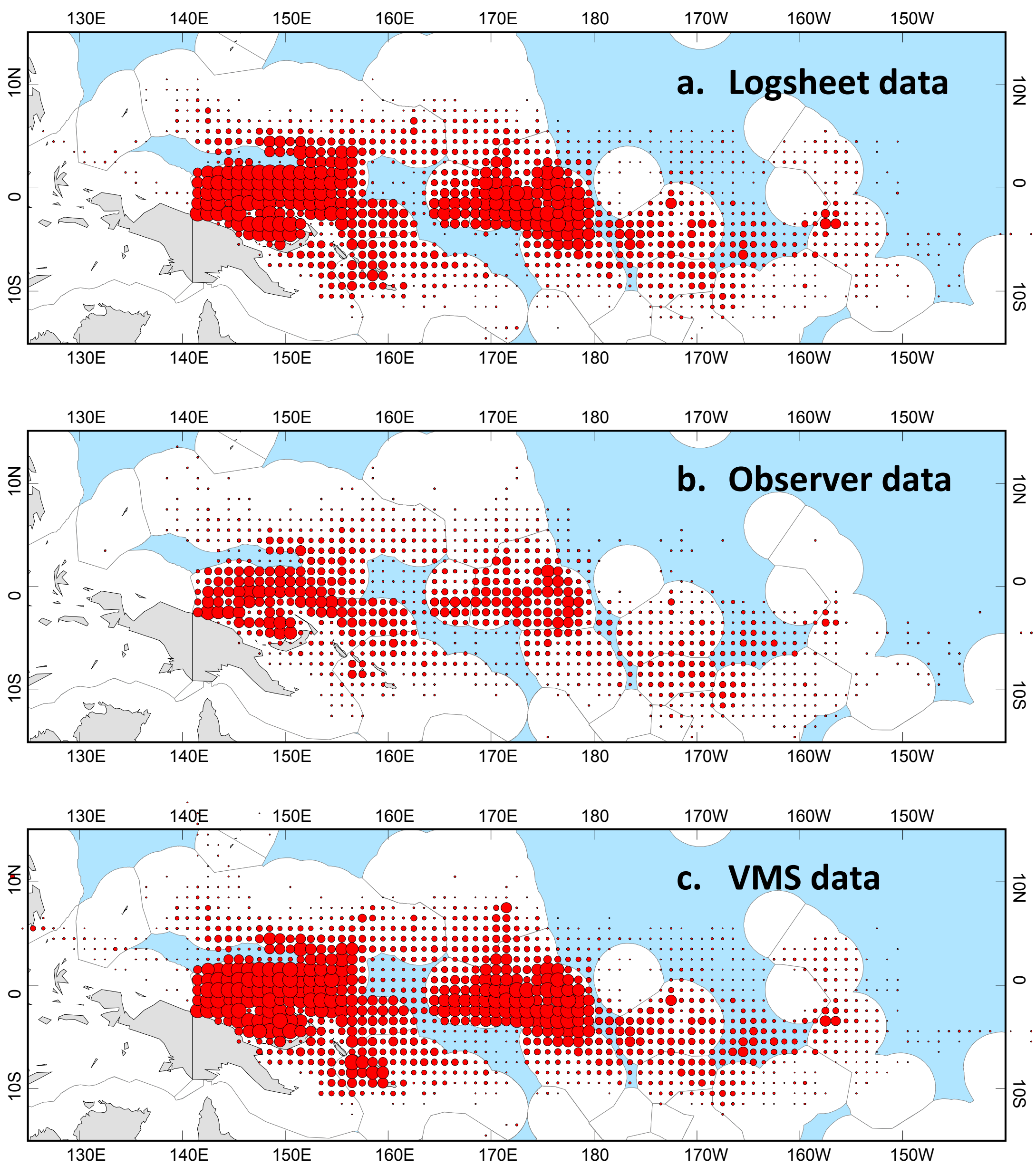

Figure 7. Distribution of purse seine effort (days) during 2012 from a. logsheet data, b. observer data, and c. VMS data.

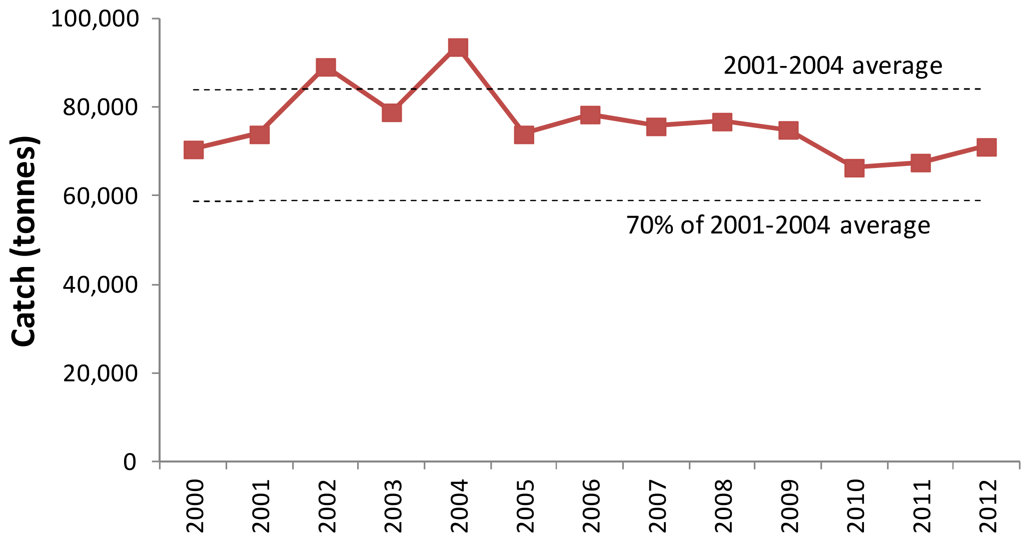

Figure 8. Estimates of bigeye tuna catch by longline in the WCPFC Convention Area, 2000 – 2012. Excludes catches from Vietnam and Indonesian archipelagic waters.

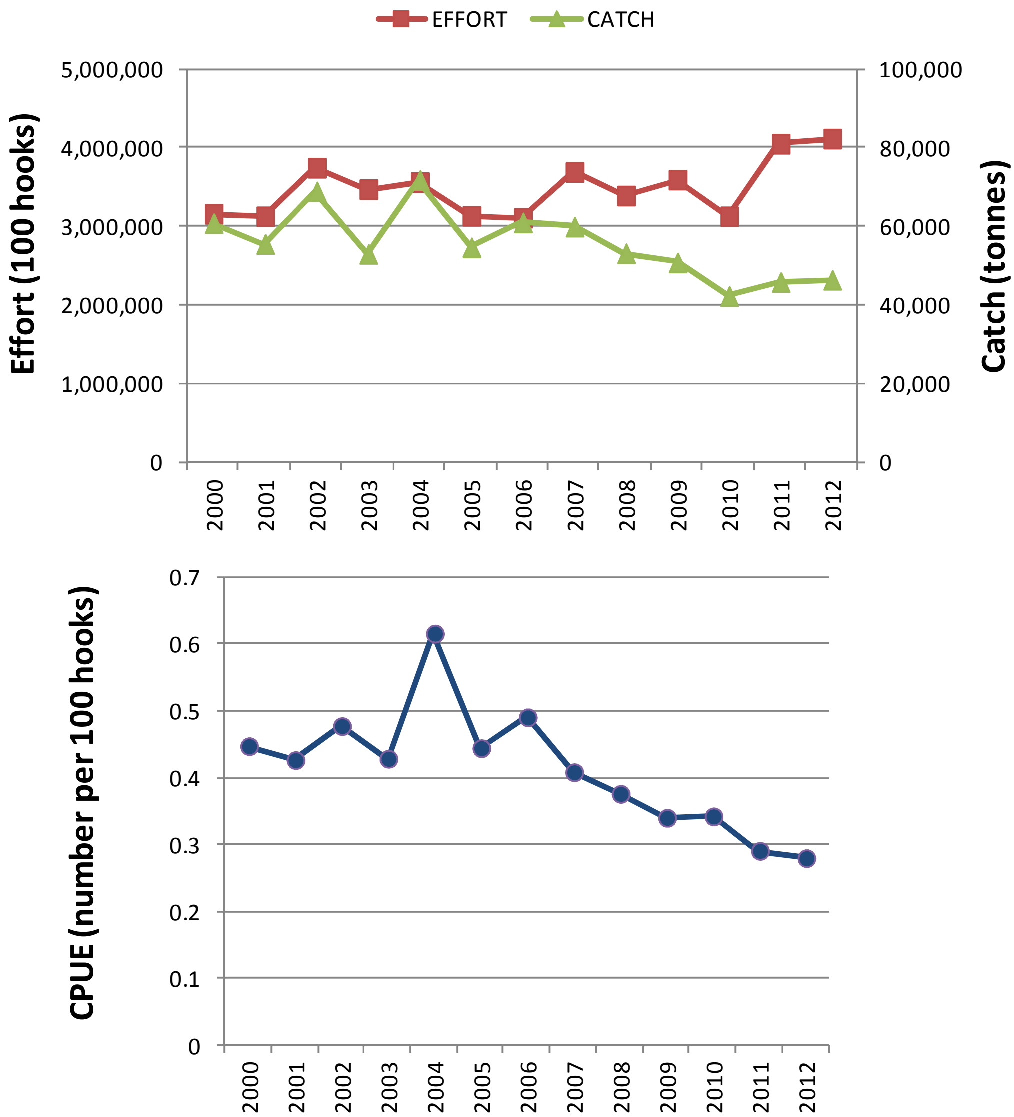

Figure 9(a). Estimates of longline effort and bigeye catch (upper panel) and bigeye CPUE (lower panel) for the CORE area of the tropical longline fishery (130°E - 150°W, 20°N - 10°S).

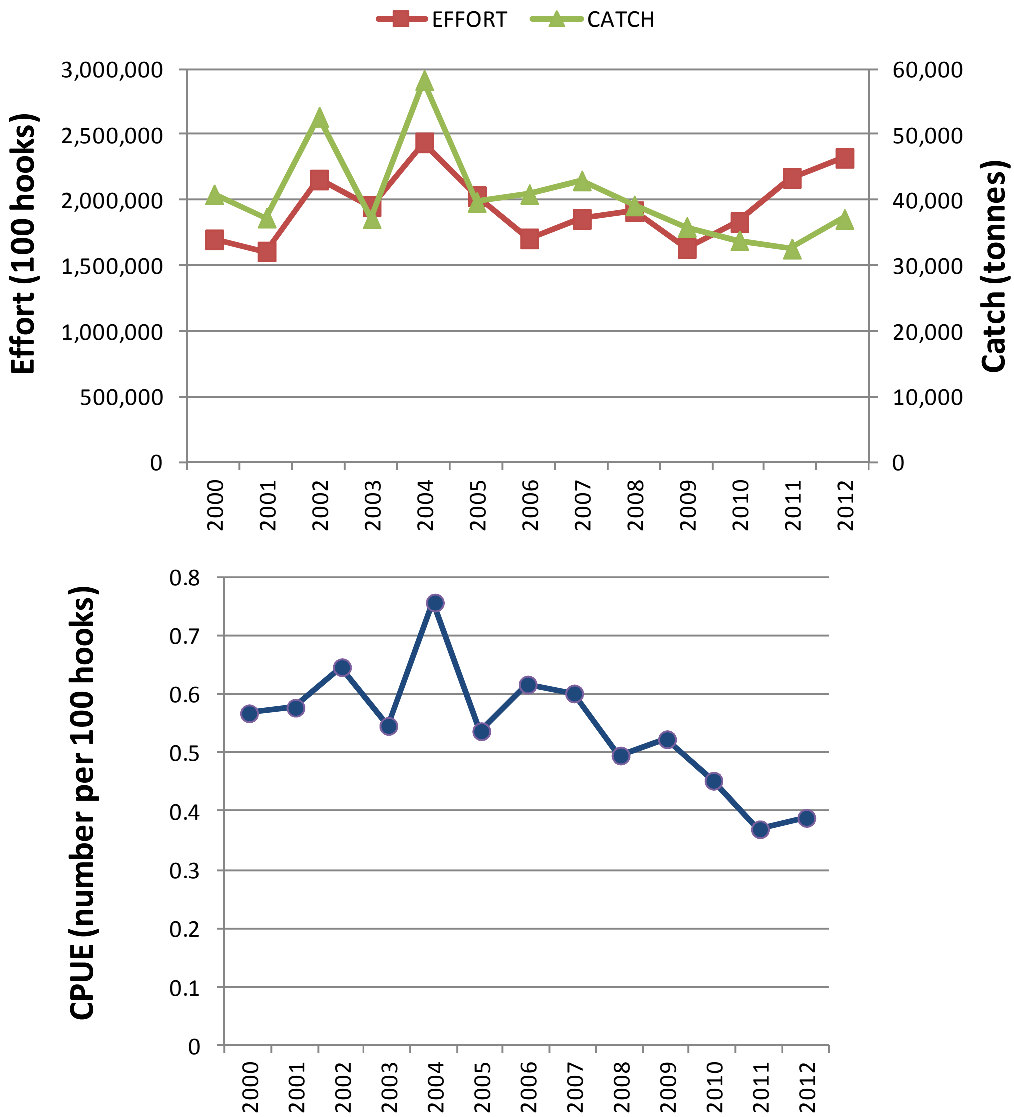

Figure 9(b). Estimates of longline effort and bigeye catch (upper panel) and bigeye CPUE (lower panel) for the EASTERN area of the tropical longline fishery (170°E - 150°W, 20°N - 10°S).

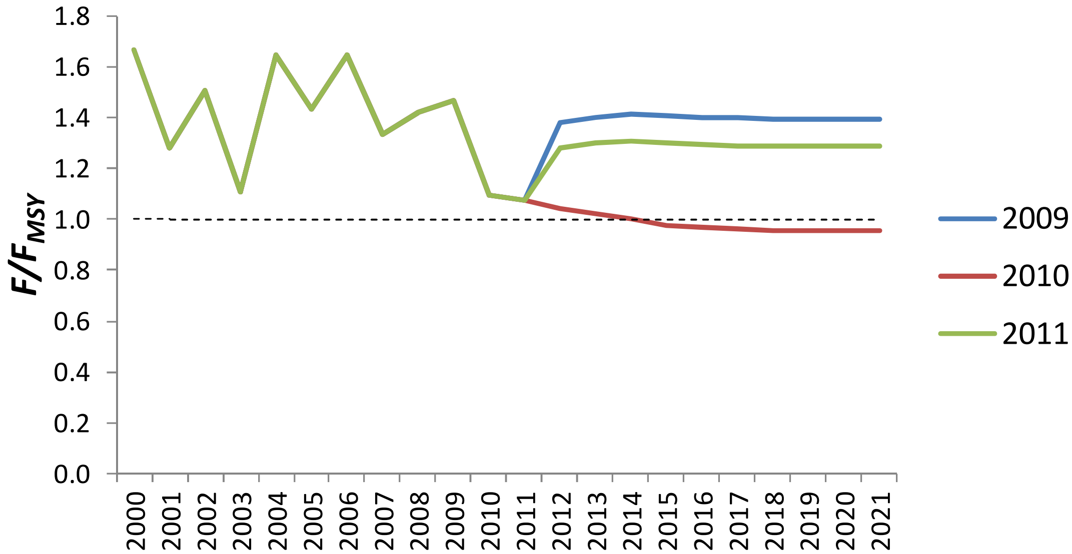

Figure 10. Recent historical and projected F/F_{MSY}, for BIGEYE tuna under the 2009, 2010 and 2011 fishing patterns, assuming that future recruitment is constant at its average 2000-2009 level.