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Multi-fishery management options analyses for bigeye and yellowfin tuna

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At the third meeting of the Western and Central Pacific Fishery Commission (WCPFC 3), the WCPFC Secretariat tabled a paper entitled *Proposal in respect of Paragraph 11 of Conservation and Management Measure 2005-01* (WCPFC3-2006/16). The purpose of the paper was to investigate the potential for closure of purse-seine fishing grounds to reduce the fishing mortality on bigeye and yellowfin tuna in the WCPO.

The paper considered four specific options for area closures, specifically:

Scenario 1: A 12-month closure of high seas enclaves to all purse seine fishing (and no effort transfer to waters under national jurisdiction).

Scenario 2: Closure on FAD and floating objects sets on the high seas and in waters under national jurisdiction (except archipelagic waters) in the last two quarters of the year.

Scenario 3: Closure on FAD and floating objects sets in the third quarter of the year and total purse seine effort closure on high seas in the last quarter of the year.

Scenario 4: High seas purse seine closure, closure on FAD and floating objects sets in waters under national jurisdiction (except archipelagic waters) in the last quarter of the year, and a quota on bigeye longline catch on the high seas**.**

The predicted outcome of these scenarios was investigated within the framework of the 2006 stock assessment models for yellowfin and bigeye tuna (Hampton et al 2006a, 2006b). These assessments included stock projections that were based on levels of fishery-specific effort that were considered to represent the most likely levels of effort over the short-term. The effort levels incorporate decisions by WCPFC2 relating to both the purse-seine and longline fisheries (i.e. catch and effort levels established under Conservation and Management Measure 2005-01).

The **base-line** level of fishing effort was defined as follows.

- Purse seine effort levels for 2004 were assumed for the projection period. The distribution of effort among regions, quarters and set types was specified according to the average distributions for the period 2001–2004. The use of a multi-year average distribution reduces the risk of anomalous results arising from unusually high or low effort occurring in one of these strata in an individual year.
- Longline effort levels averaged over 2001–2004 were assumed for the projection period.
- Relative effort levels for the Philippines and Indonesian domestic fisheries were assumed to continue through the projection period at 2004 levels (due to increases in estimated effective effort for those fisheries during 2001–2004).

Following SC 2, a more comprehensive range of stock projections was undertaken for yellowfin and bigeye tuna (Langley & Hampton 2006, included as Appendix 2). The latter analysis incrementally varied the fishery-specific effort levels for three key method fisheries (longline, purse-seine associated sets, and purse-seine unassociated sets) as a proportion of the base-line level of fishing effort. The outcome of each stock projection was assessed in relation to the equilibrium biomass level ($B_{project}/B_{MSY}$) and the associated exploitation rate ($F_{project}/F_{MSY}$). The projected catch from each component of the fishery was also computed.

A comparable approach was applied to assess the four scenarios identified by the WCPFC Secretariat. This necessitated deriving an effort series, relative to the base-line effort, that was consistent with the reduction in effort associated with each scenario. The analysis was necessarily limited to the spatial (six-region) and temporal (quarterly) structure and the fishery definitions of the stock assessment models. Consequently, it was not possible to explicitly model relatively fine-scale spatial closures, such as the closure of the areas of international waters. Conversely, it was not possible to explicitly model the maintenance of recent levels of purse-seine fishing in archipelagic waters.

Instead, it was necessary to make a number of simplifying assumptions to develop an effort series for inclusion in the stock assessment model that best represented the change in effort (from the base-line) of each scenario. The effort reductions were approximated, as follow.

i. The closure of International Waters to purse-seine was approximated by reducing the total effort in a region (3 or 4) by a specific gear type (associated/unassociated) by the proportion of the effort in the International Waters that occurred within that region during 2001-2004 (Scenarios 1–4, Table 1).
ii. The exemption providing for FAD and floating object (associated) sets in archipelagic waters was accounted for by assuming all associated sets in archipelagic waters were conducted on anchored FADs. Levels of fishing on anchored FADs were maintained at 2004 levels (Scenarios 2 and 4).
iii. Unless explicitly noted in the scenario, a range of increases in the number of unassociated sets was considered to account for the potential transfer of effort from associated sets to unassociated sets following the introduction of a measure to prohibit associated sets (Scenarios 2–4).
iv. The bigeye longline (flag based) catch limit, excluding the “2000 mt provision”, was modeled based on an overall effort limit (i.e., assumes longline CPUE remains constant) (Scenario 4).

These approximations assume that the catchability and selectivity of each of the method fisheries are comparable throughout a MFCL model region, for example, that the selectivity and catchability of purse-seine associated sets is equivalent between national and international waters within MFCL regions 3 and 4.

Further, it also necessary to assume a high degree of mixing of the stock between these areas within a region; i.e., there is no accumulation of biomass within the closed area and fish density (and catchability) is equivalent inside/outside the closed area (within the MFCL region).

For each scenario, the reductions (and increases) in fishing effort, relative to the base-line level, are presented in Table 1. It is important to note the reductions outlined in each of the scenarios were not applied to the longline and purse-seine fisheries operating within Indonesian and Philippine domestic waters.

Approximately 16% of associated purse-seine sets are conducted within International Waters. In 2001–05, catch rates of both yellowfin and bigeye tuna from associated sets were comparable between waters of national jurisdiction and International Waters (Figure 1). This indicates that the assumption of comparable catchability between the two areas is valid for both species.

Prior to 2002, catch rates of yellowfin and bigeye from purse-seine sets associated with anchored FADs were comparable to catch rates from drifting FADs and log sets (combined). However, in more recent years, anchored FADs have yielded higher catch rates for both species, particularly for yellowfin (Figure 2).

This indicates that the assumption of comparable catchability between these two categories of set types is not completely valid, at least for recent years. Consequently, the reduction in fishing mortality related to reductions in associated sets outside of archipelagic waters is likely to be smaller than predicted for the various scenarios. Nevertheless, given that anchored FAD sets account for only 20% of the associated sets in MFCL region 3 in 2002–2005, the bias introduced in applying the assumption of constant catchability of associated sets is likely to be small and unlikely to substantially alter the key conclusions presented in WCPFC3-2006/16.

The outcome of the four scenarios described in Table 1 was presented in WCPFC3-2006/16. Appendix 2 documents a large number (several thousand for each species) of other management options based on simple changes in the level of the base-line effort. These results are available for consideration by SC and have been provided in electronic form (Excel file) to the Secretariat. However, the results for yellowfin are no longer directly relevant as the assessment model dynamics and the resulting point estimate of the fishing mortality based reference point ($F_{current}/F_{MSY}$) have changed between the 2006 and 2007 assessments.

The results for bigeye tuna remain current as there has been no update of the stock assessment in 2007. The key conclusion from the bigeye analysis was that to achieve an exploitation rate of F_{MSY} would require a large (>50 per cent) reduction in effort of either longline or purse-seine associated, particularly in the absence of any reduction in the effort from the composite Indonesian/Philippines fishery. Smaller fishery-specific reductions in effort would be required if effort reductions were shared between key fishery groups.

References

Hampton J., Langley A., Kleiber P. 2006a. Stock assessment of yellowfin tuna in the western and central Pacific Ocean, including an analysis of management options, WCPFC SC2 SA WP-1, Manila, 7–18 August.

Hampton J., Langley A., Kleiber P., 2006b. Stock assessment of bigeye tuna in the western and central Pacific Ocean, including an analysis of management options, WCPFC SC2 SA WP-2, Manila, 7–18 August.

Langley A., Hampton J. 2006. Management options for yellowfin and bigeye tuna in the WCPO fishery. Pacific Economic Bulletin Volume 21 Number 3.

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Table 1. Percentage of base-line levels of fishery-specific applied to approximate effort levels under each of the four scenarios. Definitions of the fisheries are provided in Appendix 1.

	FISHERY				
	PS ASSOC 3,4	PS UNS 3,4	LL ALL	PHID MISC 3	PH HL 3
Scenario 1					
Q1	84%	84%	100%	100%	100%
Q2	84%	84%	100%	100%	100%
Q3	84%	84%	100%	100%	100%
Q4	84%	84%	100%	100%	100%
Annual	84%	84%	100%	100%	100%
Scenario 2					
Q1	100%	100% (also 110%, 120%....160%)	100%	100%	100%
Q2	100%	100% (also 110%, 120%....160%)	100%	100%	100%
Q3	0% + Anchored FAD sets (2004 level)	100% (also 110%, 120%....160%)	100%	100%	100%
Q4	0% + Anchored FAD sets (2004 level)	100% (also 110%, 120%....160%)	100%	100%	100%
Annual	57%	100% (also 110%, 120%....160%)	100%	100%	100%
Scenario 3					
Q1	100%	100% (also 110%, 120%....150%)	100%	100%	100%
Q2	100%	100% (also 110%, 120%....150%)	100%	100%	100%
Q3	0%	100% (also 110%, 120%....150%)	100%	100%	100%
Q4	84%	84% (also 100%, 110%, 120%....150%)	100%	100%	100%
Annual	56%	96% (also 100%, 110%, 120%....150%)	100%	100%	100%
Scenario 4					
Q1	100%	100% (also 110%, 120%, 130%)	65%	100%	100%
Q2	100%	100% (also 110%, 120%, 130%)	65%	100%	100%
Q3	100%	100% (also 110%, 120%, 130%)	65%	100%	100%
Q4	0% + Anchored FAD sets (2004 level)	84% (also 100%, 110%, 120%, 130%)	65%	100%	100%
Annual	77%	96% (also 100%, 110%, 120%, 130%)	65%	100%	100%

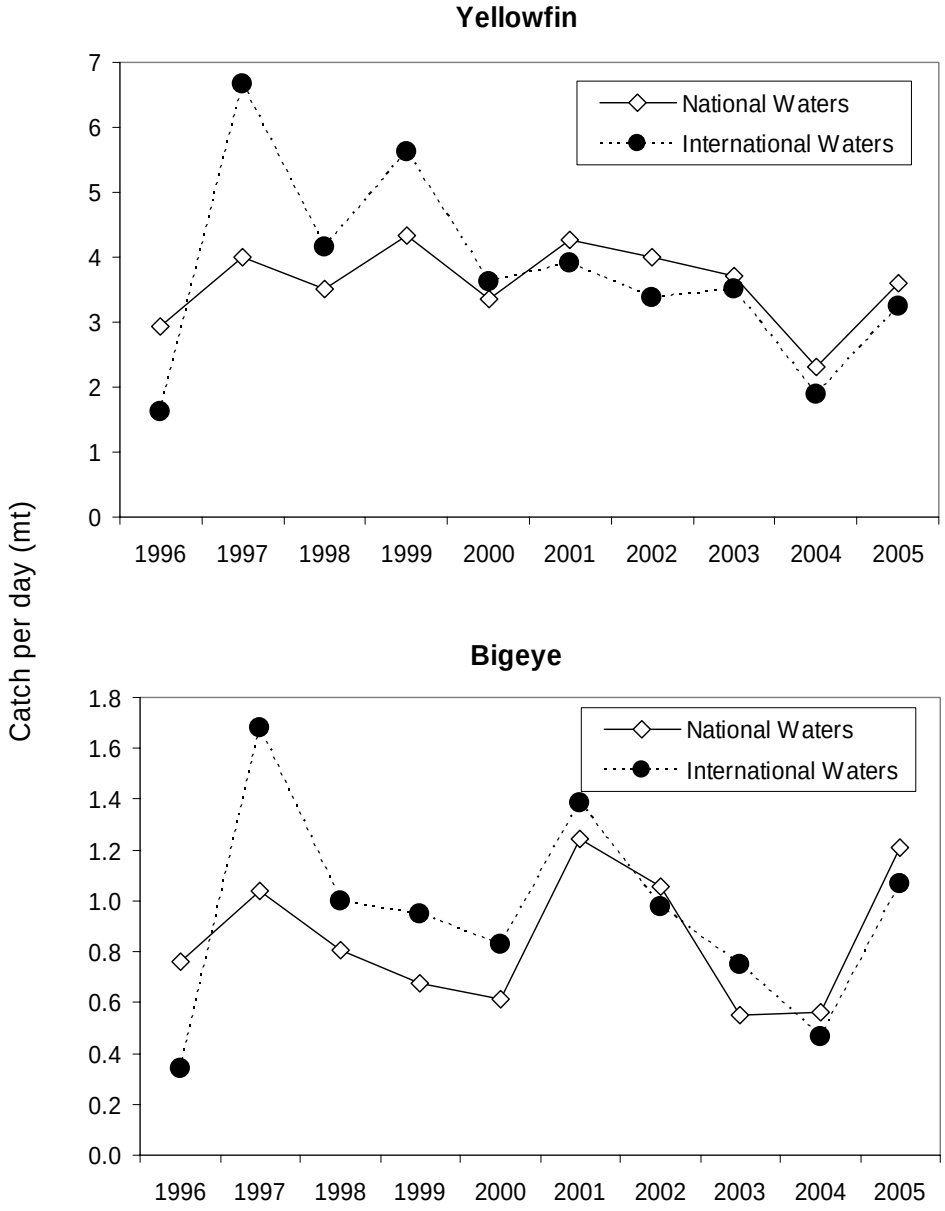

Figure 1. Annual average catch rate (mt per day) of yellowfin (top) and bigeye (bottom) from purse-seine associated sets (anchored FAD, drifting FAD, and log sets) conducted in national waters and international waters within MFCL region 3. The figures exclude purse-seine sets in the national waters of Indonesia and the Philippines.

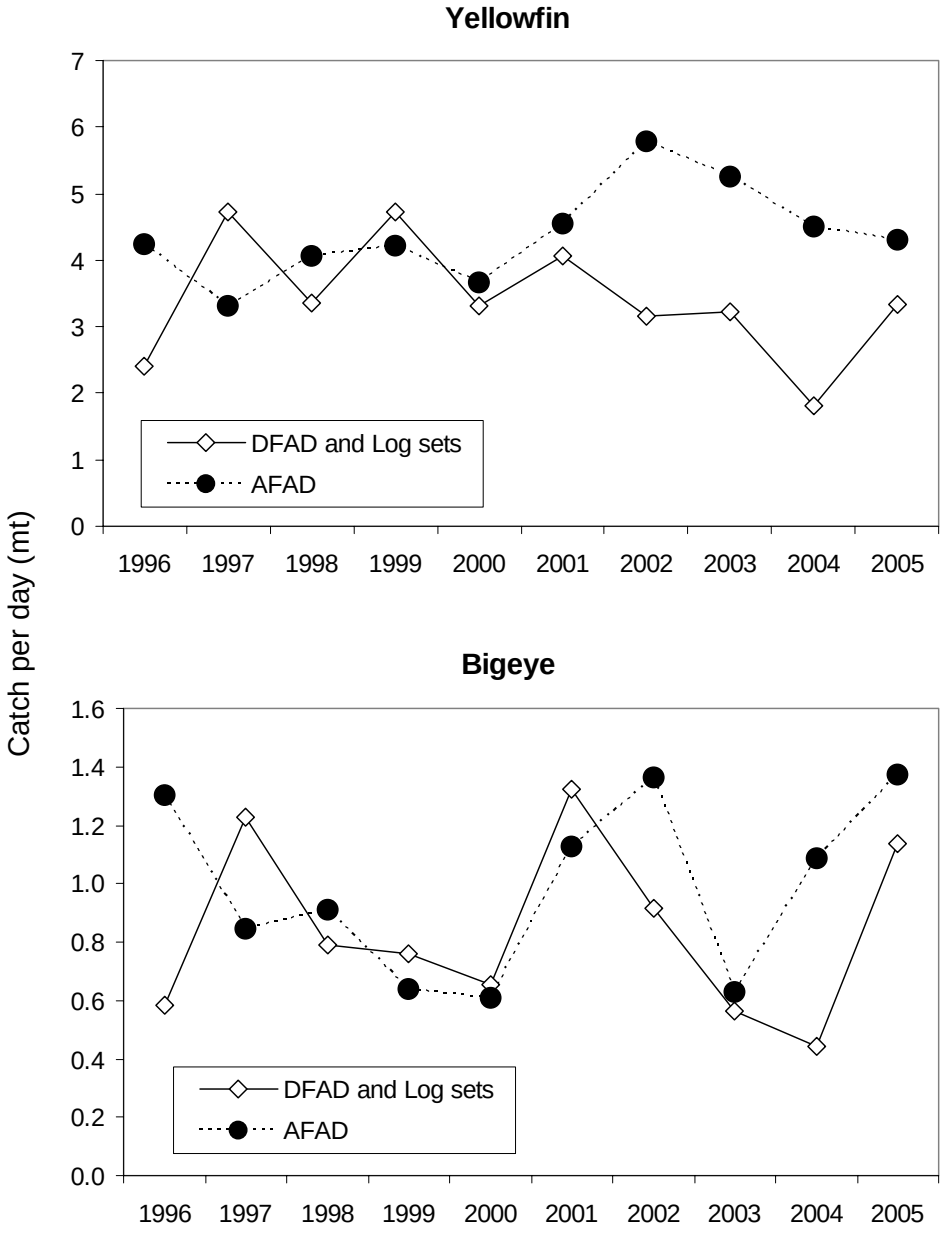

Figure 2. Annual average catch rate (mt per day) of yellowfin (top) and bigeye (bottom) from purse-seine anchored FAD sets and drifting FAD and log sets combined within MFCL region 3. The figures exclude purse-seine sets in the national waters of Indonesia and the Philippines.

Appendix 1. Definition of fisheries for the six-region MULTIFAN-CL analysis of yellowfin and bigeye tuna.

Fishery	Nationality	Gear	Region
1. LL ALL 1	Japan, Korea, Chinese Taipei	Longline	1
2. LL ALL 2	Japan, Korea, Chinese Taipei	Longline	2
3. LL HW 2	United States (Hawaii)	Longline	2
4. LL ALL 3	All excl. Chinese Taipei & China	Longline	3
5. LL TW-CH 3	Chinese Taipei and China	Longline	3
6. LL PG 3	Papua New Guinea	Longline	4
7. LL ALL 4	Japan, Korea	Longline	4
8. LL TW-CH 4	Chinese Taipei and China	Longline	4
9. LL HW 4	United States (Hawaii)	Longline	4
10. LL ALL 5	All excl. Australia	Longline	5
11. LL AU 5	Australia	Longline	5
12. LL ALL 6	Japan, Korea, Chinese Taipei	Longline	6
13. LL PI 6	Pacific Island Countries/Territories	Longline	6
14. PS ASS 3	All	Purse seine, log/FAD sets	3
15. PS UNS 3	All	Purse seine, school sets	3
16. PS ASS 4	All	Purse seine, log/FAD sets	4
17. PS UNS 4	All	Purse seine, school sets	4
18. PHID MISC 3	Philippines, Indonesia	Miscellaneous (small fish)	3
19. PH HL 3	Philippines, Indonesia	Handline (large fish)	3

Focus

TUNA RESOURCE MANAGEMENT

Management options for yellowfin and bigeye tuna in the WCPO fishery

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Secretariat of the Pacific Community

At the second meeting of the Scientific Committee (SC2) of the Western and Central Pacific Fisheries Commission (WCPFC), the stock assessments for yellowfin tuna and bigeye tuna in the Western and Central Pacific Ocean (WCPO) were presented (see Hampton et al. 2006a, 2006b). On the basis of these assessments, SC2 provided the following management advice to the Commission.

- In order to maintain the bigeye stock at a level capable of producing the maximum sustainable yield the Scientific Committee recommends a 25 per cent reduction in fishing mortality from the average levels for 2001–2004.
- In order to maintain the yellowfin stock at a level capable of producing the maximum sustainable yield the Scientific Committee recommends a 10 per cent reduction in fishing mortality from the average levels for 2001–2004.

The SC2 did not provide any direction as to how these reductions in fishing mortality should or could be implemented. The simplest interpretation would be to implement the advice by a direct reduction of fishing effort in all fisheries to 75 per cent of the average level of effort in 2001–2004. However, this approach is overly simplistic as it unduly impacts those fisheries that are not causing a significant impact on either the bigeye or yellowfin stocks, particularly the fisheries outside of the equatorial regions where fishing mortality rates are low.

There are a wide range of potential management measures that could be introduced to achieve the recommended reductions in fishing mortality in these two stocks. The simplest approach is to identify the main fisheries responsible for these impacts and explore the range of effort reductions required to achieve the fisheries management target. For the purpose of this analysis, the target reference point was considered to be an overall fishing mortality rate equivalent to F_{MSY} (that is, the level of fishing mortality that will produce the maximum sustainable yield). However, the SC2 also recognises that the Commission may decide to maintain stocks at a level

higher than B_{MSY} (that is, the equilibriumlevel of total biomass for a stock fished at the F_{MSY} level) and this would require fishing mortality to be at a corresponding level below F_{MSY}. Under that management objective, a larger reduction in overall fishing mortality would be required.

Methods

A wide range of potential management options for yellowfin and bigeye were investigated within the framework of the stock assessments presented at SC2. The analysis involved varying the fishing effort for four main fishery groups (longline, purse-seine associated sets, purse-seine unassociated sets, and Indonesian and Philippines fisheries) relative to a base-line level of effort ('base-line scenario'). The baseline effort was comparable to the effort series formulated for the projections undertaken in the two stock assessments (see Hampton et al. 2006a, 2006b). The projections also assumed equilibrium conditions, that is, long-term average recruitment, mediated by the stock recruitment relationship (SRR).

The outcomes of each management scenario were summarised by determining $F/F_{MSY,}$ the change in fishery specific catch (and catch per unit effort, or CPUE) relative to the base-line scenario, the change in maximum sustainable yield (MSY), and the corresponding (equilibrium) biomass level relative to the B_{MSY} level.

For the analysis, the base-line levels of fishing effort are defined as follows.

- Total purse-seine effort levels (days) equivalent to the 2004 level. The distribution of effort (days) among regions, quarters and set types was specified according to the average distributions for the period 2001–2004.
- Longline effort levels equivalent to the average of 2001–2004.
- Relative effort levels for the Philippines and Indonesian domestic fisheries at 2004 levels (due to increases in estimated effective effort for those fisheries during 2001–2004).
- For fisheries with estimated time-series variation in catchability, the estimated catchability for the last data year (2005) was assumed.

Projections were undertaken using multiples of the levels of effort for the four fishery groups: longline (LL), purse-seine associated sets (PS ASSOC), purse-seine unassociated sets (PS UNASSOC), and the Philippines/Indonesian fisheries (ID/PH).

Table 1 **Multiples of base-line effort**

Fishery group	Multiples of base-line effort
LL	0.50, 0.55, 0.60,0.65,0.70,0.75, 0.80, 0.85, 0.90, 0.95, 1.0, 1.1*, 1.2*
PS ASSOC	0.50, 0.55, 0.60,0.65,0.70,0.75, 0.80, 0.85, 0.90, 0.95, 1.0, 1.1*, 1.2*
PS UNASSOC	0.50, 0.55, 0.60,0.65,0.70,0.75, 0.80, 0.85, 0.90, 0.95, 1.0, 1.1*, 1.2*
ID/PH	0.75, 1.0

* only undertaken for runs with ID/PH effort at 0.75.
This resulted in a total of 3,528 (11*11*11*1 + 13*13*13*1) different scenarios of effort in the projection period. Each scenario was undertaken for both bigeye and yellowfin.

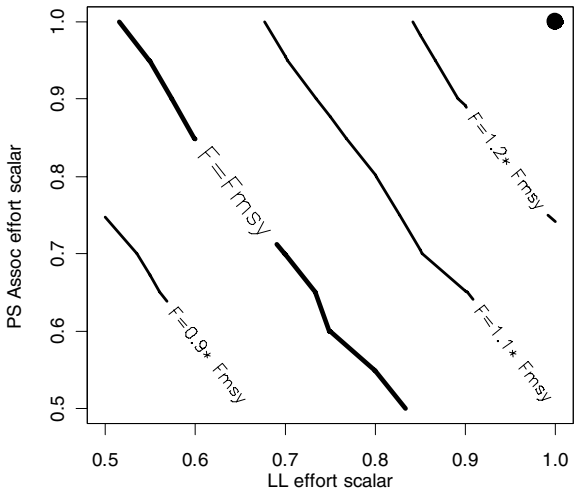
Summary and conclusions

The analysis generates a large amount of output and the results of individual runs can be examined in detail. However, this report focuses on the key outcomes of the analysis, in particular the performance of the various model scenarios were assessed relative to the main (assumed) fisheries management objective; that is, achieving a level of overall fishing mortality equivalent or below the F_{MSY} level.

Bigeye

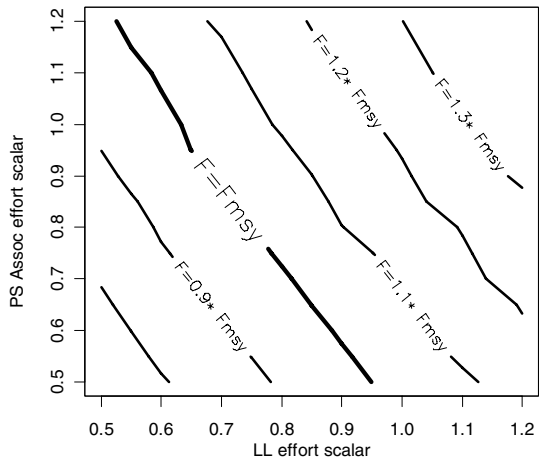
- Bigeye tuna are not caught in purse-seine unassociated sets and, consequently, the level of purse-seine unassociated effort does not affect the overall level of fishing mortality for bigeye.
- For scenarios without a reduction in Indonesian/Philippines effort (effort scalar 1.0), a large (50+ per cent) reduction in effort of either longline or purse-seine associated effort is required to reduce exploitation rates to the F_{MSY} level (Figure 1).
- Considerably smaller reductions (30+ per cent) in effort for these two fishery groups are required to achieve F_{MSY} if effort in the Indonesian/Philippines fisheries is reduced by 25 per cent (effort scalar 0.75) (Figure 2).
- A wide range of effort scenarios applied to both the longline and purse-seine associated fisheries will achieve the F_{MSY} level. For example, at current levels of effort for the Indonesian and Philippines fishery, F_{MSY} can be achieved by effort

Figure 1 **Total WCPO bigeye tuna fishing mortality rates relative to F_{MSY} for differing levels of longline and purse-seine (associated sets) fishing effort and recent Philippines and Indonesian effort levels.**



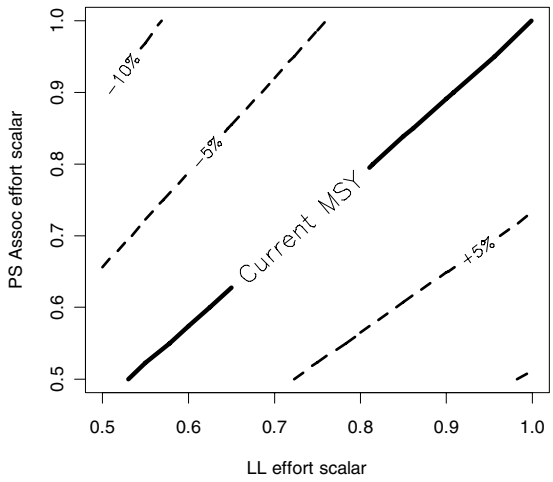
Note: Effort is expressed as multiples of the baseline effort. Effort levels for the Philippines and Indonesian fisheries are held at the baseline level (1.0). The lines represent contours of fishing mortality relative to the F_{MSY} level of effort. The point represents the current effort level.

Figure 2 **Total WCPO bigeye tuna fishing mortality rates relative to F_{MSY} for differing levels of longline and purse-seine (associated sets) fishing effort and 75 per cent of recent Philippines and Indonesian effort levels**



Note: Effort is expressed as multiples of the baseline effort. Effort levels for the Philippines and Indonesian fisheries are at 75 per cent of the recent level. The lines represent contours of fishing mortality relative to the F_{MSY} level of effort.

Figure 3 **Changes in maximum sustainable yield (MSY) for the WCPO bigeye tuna fishery for differing levels of longline and purse-seine (associated sets) fishing effort and recent Philippines and Indonesian effort levels**

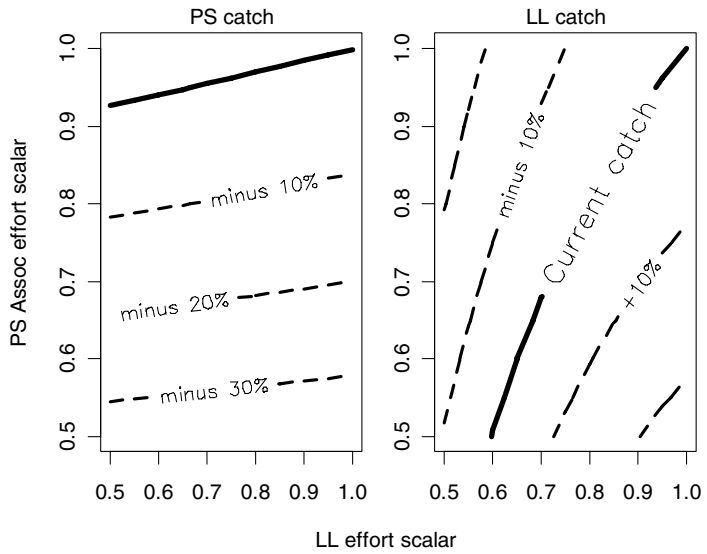


Note: Expressed as the percentage difference from the MSY from the base-case assessment ('current MSY'). Effort is expressed as multiples of the baseline effort. Effort levels for the Philippines and Indonesian fisheries are held at the baseline level (1.0).

reductions of 45 per cent and 20 per cent in the purse-seine associated and longline fisheries, respectively. Alternatively, the same target can be achieved by effort reductions of 15 per cent and 40 per cent, respectively.

- At current levels of effort for the Indonesian and Philippines fishery, the level of Maximum Sustainable Yield (MSY) from the bigeye stock would be marginally increased by an increase in the total effort that is apportioned to the longline fishery, at the expense of the purse-seine associated fishery. This is evident from scenarios that include an effort reduction in the purse-seine associated fishery (Figure 3). Conversely, a proportional shift to purse-seine associated effort will result in a marginal reduction in MSY from the stock.
- At current levels of effort for the Indonesian and Philippines fishery, the level of bigeye catch from the purse-seine fishery is predicted to decline with reduced levels of purse-seine unassociated effort (Figure 4). Declines in longline effort do not result in a significant increase in bigeye purse-seine catch.
- At current levels of effort for the Indonesian and Philippines fishery, decreases in longline effort result in declines in bigeye longline catch at current levels of purse-seine associated effort (Figure 4). However, current levels of bigeye longline catch are predicted to be achieved at lower levels of longline

Figure 4 **Estimated change in purse-seine (left) and longline (right) catch for the WCPO bigeye tuna fishery at differing levels of longline and purse-seine (associated sets) fishing effort and recent Philippines and Indonesian effort levels**



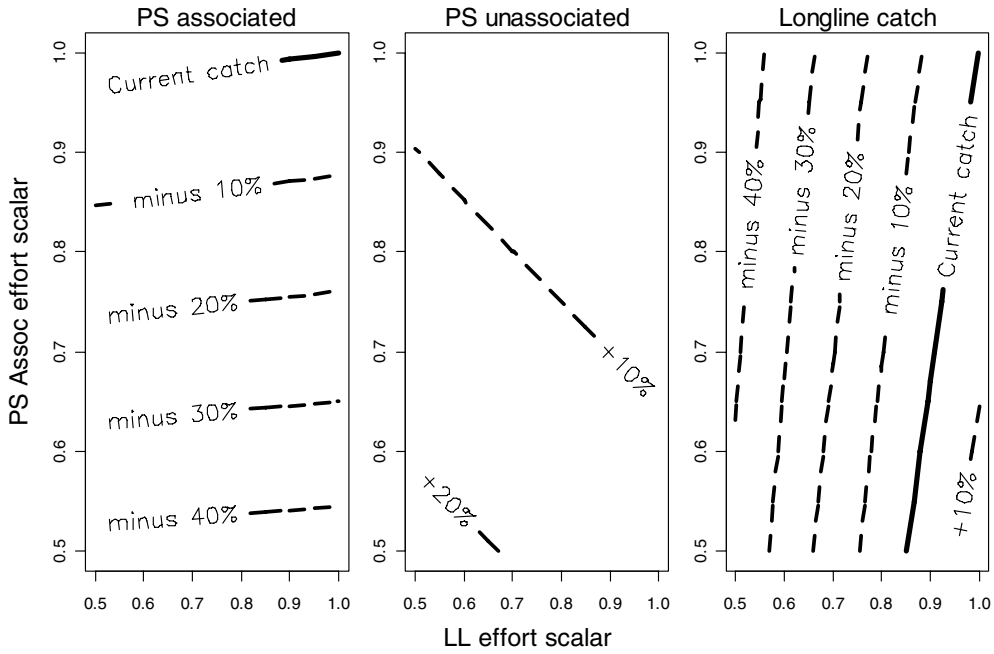
Note: Expressed as the percentage difference from the catches at obtained at the baseline level of fishing effort ('current catch'). Effort is expressed as multiples of the baseline effort. Effort levels for the Philippines and Indonesian fisheries are held at the baseline level (1.0).

effort (for example, 80 per cent of baseline effort) if corresponding reductions in effort are applied to the purse-seine associated fishery. This would result in a corresponding increase in bigeye longline CPUE. Significant (greater than 10 per cent) increases in longline catch (and CPUE) are achieved at current levels of longline effort if higher (greater than 40 per cent) reductions were applied to the purse-seine associated fishery.

Yellowfin

- Unlike bigeye, significant catches of (large) yellowfin are taken by purse-seine unassociated sets. Accordingly, this element of the fishery also needs to be considered in the range of effort scenarios considered for yellowfin tuna.
- A range of effort reductions were considered for the three fishery groups—longline, purse-seine associated, and

Figure 5 **Change in yellowfin catch by purse-seine associated (left), purse-seine unassociated, and longline (right) from the WCPO yellowfin tuna fishery at differing levels of longline and purse-seine (associated sets) fishing effort and recent levels of purse-seine unassociated, Philippines, and Indonesian effort**



Note: Expressed as the percentage difference from the catches obtained at the baseline level of fishing effort ('current catch'). Effort is expressed as multiples of the baseline effort. Effort levels for the purse-seine unassociated, Philippines and Indonesian fisheries are held at the baseline level (1.0).

purse-seine unassociated sets—at two levels of effort for the Indonesian and Philippines fisheries (0 per cent and 25 per cent reduction). For the scenarios with no effort reduction in Indonesia and Philippines, the target level of fishing mortality (F_{MSY}) is estimated to be achieved from a wide range of different effort scenarios. Compared to the two purse-seine fisheries, the reduction of longline fishing effort makes a smaller contribution to the overall fishing mortality for the WCPO stock.

- For scenarios that reduce Indonesian and Philippines effort by 25 per cent (0.75 of recent effort), the F_{MSY} for yellowfin is achieved at current levels of effort for the other three fisheries.
- An example of the change in yellowfin catch by fishery group for a range of effort scenarios is presented in Figure 5. The scenarios include the range of longline and purse-seine associated sets, while maintaining recent (base-line) effort levels for purse-seine unassociated sets and Indonesian and Philippines fisheries. Catches from both the purse-seine associated sets fishery and the longline fishery decline in proportion to the level of effort reduction. Declines in effort for both these fisheries result in an increase in predicted catch from the purse-seine unassociated set fishery.

Summary

The various scenarios included in the analysis enable a wide range of potential management options to be considered. The details of individual scenarios can be examined in further detail to assess the impact on individual fisheries as well as on the four fishery groupings. The various scenarios can also be applied to consider the impact of effort reductions achieved via a range of mechanisms such as time and area closures. More complex scenarios can also be explored through this approach, although, as with all these analyses, it is assumed that there is no compensatory behaviour by the individual fisheries that may result in an increase in the effectiveness of the fishing effort.

Overall, all the management measures investigated that achieved the F_{MSY} for bigeye also resulted in levels of fishing mortality for yellowfin that were below the F_{MSY} level. Nevertheless, more sophisticated effort scenarios, such as those that divert purse-seine effort from associated to unassociated sets, may achieve the F_{MSY} target for bigeye, but may not result in a significant reduction in the overall level of fishing mortality for yellowfin.

References

Hampton, J., Langley, A., Kleiber, P., 2006a. *Stock assessment of yellowfin tuna in the western and central Pacific Ocean, including an analysis of management options*, WCPFC SC2 SA WP-1, Manila, 7–18 August.

——, 2006b. *Stock assessment of bigeye tuna in the western and central Pacific Ocean, including an analysis of management options*, WCPFC SC2 SA WP-2, Manila, 7–18 August.

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