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Estimating potential tropical purse seine fleet sizes given existing effort limits and candidate target stock levels

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Abstract

Concern has been noted over the size of WCPO fishing fleets relative to available fishing opportunity levels during discussions at WCPFC11; there was a CCM proposal on capacity limits to that meeting; and a capacity management work plan within CMM 2014-01.

To provide an example process to identify whether there is indeed over-capacity within WCPO fisheries, this paper estimates purse seine fleet sizes within the tropical WCPO compatible with current effort management limits, and with candidate skipjack target reference point levels. Fleet sizes are expressed in terms of 'full time equivalent' vessels (FTEs), being a vessel assumed to fish for 250 days per annum. This provides a common currency for the evaluation. Noting that particular 'fleets' may operate for part of the year outside the WCPO (and hence not all current vessel activity reflects 'full time' fishing), we attempt to adjust for this. Finally, noting that purse seine fleet productivity is suspected to have increased over time, we examine the potential implications of this phenomenon on future fleet capacity.

FTE purse seine fleet sizes compatible with limits allowed under CMM2014-01 and tropical CCM nominated effort limits were 281-289 vessels (dependent upon whether vessels fishing for part of the year within the EPO were taken into account within calculations). FTE fleet sizes compatible with candidate TRP effort levels were generally lower, with 50% or 60%$SB_{F=0}$ TRPs (as focused upon during discussions at SC10 and WCPFC-MOW3) equating to 142-220 vessels. We note alternative assumptions of purse seine fleet dynamics relative to skipjack abundance would affect the fleet sizes compatible with these TRPs. This analysis also assumes all vessels have equal performance. In practice, the 'worst' performing (less profitable) vessels would likely be removed from the fishery first to achieve fleet size reductions. This would imply that catch levels would remain higher than expected, and reductions in vessel numbers would need to be greater than evaluated here. This phenomenon is akin to the scenario where purse seine vessel productivity increases over time.

To compare the estimated limits against current levels of effort, preliminary estimates of 2014 tropical purse seine effort indicate that 57,138 days were fished in that year. This is equivalent to 229 FTE purse seine vessels (ignoring EPO 'part-time' vessels). This represents 19% less vessels than estimated compatible with the CMM limits, but 8-61% more vessels than estimated as compatible with TRPs of 50% or 60%$SB_{F=0}$. It implies current purse seine effort levels (and fleet sizes) are likely in excess of those required to achieve these two TRP levels.

To maintain effective effort at CMM limits where purse seine productivity increased by 3% per annum for 5 years, an 8% reduction in the number of FTEs was required, to 258 vessels. Under TRP levels, the number of compatible FTEs ranged from 122 FTE vessels (60% $SB_{F=0}$) through to 274 vessels (40% $SB_{F=0}$), though these numbers should be viewed as preliminary until further work examining the relationship between purse seine CPUE and abundance is completed.

We invite WCPFC-SC to:

- consider the importance of this field of research and its prioritisation within the SC work plan;
- propose further work to identify patterns of participation by vessels within the fishery;
- consider expansion of the approach to longline and other fisheries;

- suggest specific analyses that assist the Commission's consideration of fleet capacity; and
- consider the implications of these analyses when providing advice to WCPFC12.

Introduction

Within the tropical Western and Central Pacific Ocean, the level of purse seine fishing is currently managed through effort limits, with additional area and gear management interventions. These effort limits are in terms of fishing days. However the unit of effort production is ultimately the purse seine vessel, as they need to have a specific number of fishing days during a year to remain profitable. This raises the issue of balancing the capacity of a fleet of vessels to produce effort, with the fishing opportunities available over time.

Fishing capacity can be described as: "The amount of fish or fishing effort that can be produced by a vessel or a fleet if fully utilised and for a given resource condition". Overcapacity exists where the maximum harvest level that a fisher could produce with the existing level of effort exceeds the desired level of harvesting. The WCPFC Convention text (Article 5) notes that the Commission should "take measures to prevent or eliminate over-fishing and excess fishing capacity and to ensure that levels of fishing effort do not exceed those commensurate with the sustainable use of fishery resources". Potential over-capacity within WCPO fisheries was noted repeatedly during discussions at WCPFC11 (WCPFC, 2014a), capacity limits were the subject of a CCM proposal (WCPFC11-2014-DP16), and a capacity management work plan is indicated within CMM 2014-01 (e.g. para 53).

The potential size of fishing fleets (a measure of capacity) consistent with existing and candidate effort limits needs to be understood in order to judge whether there is indeed over-capacity within WCPO fisheries. In this paper we examine tropical purse seine fleet capacity within the WCPO (20°N to 20°S) in terms of the days fished by that fleet. We relate total effort levels defined under different Commission processes to 'full time equivalent' purse seine fleet sizes. Noting that particular 'fleets' may operate for part of the year outside the WCPO (and hence not all vessel activity reflects 'full time' fishing), we attempt to adjust for this. Finally, noting that purse seine fleet productivity is suspected to have increased over time (WCPFC, 2014b; see also SC11-2015-MI-IP-01), we examine the potential implications of this phenomenon on future fleet capacity.

Methods

To estimate purse seine fleet sizes consistent with specific total fishing effort limits, we defined total effort levels from two sources: those defined within WCPFC Conservation and Management Measures; and fishing effort levels generally consistent with candidate Target Reference Point levels for skipjack. We related these totals to the number of 'full time equivalent' (FTE) vessels (vessels operating at maximum capacity during the year) that could be accommodated within those total days. The use of FTEs provides a 'common currency' for the analysis. We examined three scenarios to define the number of days fished annually by an FTE.

Total effort levels

We examined purse seine fleet capacities consistent with four alternative future effort levels: those defined under the CMM 2014-01 process, and those generally consistent with the three candidate Target Reference Point levels for skipjack (being 40%, 50% and 60% $SB_{F=0}$; MOW3-WP03). Throughout,

we assume that specified purse seine effort levels represent fishing days (i.e. a day spent searching or on which a set was made) within the tropical region of the WCPO (20°N to 20°S).

For the calculations, effort limits were grouped into four 'geographic areas' within the tropical region 20°N to 20°S (Table 1). No attempt was made to segregate the high seas waters in this analysis. Purse seine effort levels within the Indonesian and Philippine EEZs were not included within fleet size calculations, due to a general lack of effort information for these fleets.

Effort levels consistent with WCPFC CMM 2014-01

Total tropical purse seine effort limits defined under WCPFC management measures and through the PNA purse seine Vessel Day Scheme (the Total Allowable Effort) were developed for the different geographic regions considered (Table 1).

EEZ-based estimates were derived from the PNA's Total Allowable Effort, and from the additional purse seine effort limits nominated by CCMs (WCPFC10-2013-DP19 to WCPFC10-2013-DP28; see Appendix 1).

High seas effort limits were derived from flag-based effort levels defined within CMM 1214-01. In addition, permissible effort by Philippine vessels operating within high seas pocket #1 was included, as specified limits of days and vessel numbers. Within calculations of fleet capacity, the Philippine vessel number limits specified within CMM 2014-01 were used.

For archipelagic waters, it was assumed that available effort estimates for 2013 would continue into the future (see WCPFC11-2014-IP02_rev3, Table 1).

Effort levels consistent with candidate skipjack TRP levels

WCPFC MOW3-WP-03 identified levels of purse seine effort consistent with candidate target reference points (TRPs) for skipjack tuna, relative to the level of effort in 2012 (see Table 4 of that paper). To approximate effort levels consistent with each candidate TRP, actual purse seine effort in 2012 for the different geographic areas was taken from WCPFC11-2014-IP02_rev3 (Table 1 of that paper), and adjusted using the corresponding effort scalar relative to 2012 for each TRP (Table 2).

The assumption is that the geographic distribution of total effort between the four geographic areas would remain consistent with that estimated in 2012. We note that this would be influenced by, for example, management measures defining the level of effort permissible on the high seas. We also note that the stock status resulting from specific effort levels will be influenced by the dynamics of purse seiners (see SC11-MI-WP-04). The implications of this for the results are examined further within the discussion.

Scenarios for converting effort 'limits' to purse seine vessel numbers

The four examined effort limits were converted into estimates of the total number of vessels, using the number of days fished by a full time equivalent (FTE) vessel each year. Three scenarios were used to examine the sensitivity of results to the assumed FTE level.

Estimation of full time equivalent vessels

The simplest scenario was that all days fished within the tropical WCPO would be by FTE vessels.

To develop candidate estimates of the number of days per year fished by an FTE, the distribution of fishing days per vessel per year over the recent period was examined from logsheet data. Following removal of those vessels identified as fishing within the eastern Pacific Ocean and hence known to not represent FTEs, annual recorded fishing days by each vessel ranged from only a limited number of days to vessels recorded as actively fishing for 350 days per year (Figure 1). The mode of the data lay at 210 fishing days per year, while the median was just over 200 days per year. Noting issues with effort reporting within logsheets in recent years, which would bias the number of fishing days downwards (see discussion), we also examined annual tropical purse seine vessel activity (estimated fishing days[1]) from VMS information (2010-2014). The mode of these data lay at 260 fishing days per year, while the median was at 233 days per year. The annual maximum was comparable to that identified from logsheets (350 days per year).

Using these results as guidance, within this analysis an FTE purse seine vessel was assumed to actively fish for 250 days per year (approximately 21 days fishing per month). This was considered plausible given necessary periods of steaming to and from fishing grounds and offloading/transhipment at the end of fishing trips, and the need for longer periods of refit during a year. The fleet size compatible with a total effort level (TE) was therefore = TE/250.

Incorporation of 'part time' fishing vessels

Two purse seine vessel operational patterns were assumed to constrain the days spent fishing per year by 'full time equivalents' within the tropical WCPO. These were:

- Vessels spending part of their time fishing within the Eastern Pacific Ocean;
- Vessels spending part of their time fishing within the archipelagic waters of some CCMs.

These two 'groups' of vessel were dealt with separately, as they had different implications for the calculation. FTEs for all geographic areas unaffected by the two calculations below were estimated as for full time equivalent vessels (above).

Nineteen vessels were identified in the most recent three years of data as having operated within the EPO for part of the year ('EPO vessels'; these vessels fished 56% of a 250 day FTE within the WCPO on average in the last four years). The days fished by these vessels within the WCPO were 'quarantined' within the subsequent calculations using the following procedure:

- The average total days spent fishing by these vessels within the WCPO by geographic area were removed from the total effort levels for those areas;
- the remaining fishing days within each effort limit scenario in each area were then assigned to FTE vessels to estimate the total vessels compatible with the remaining effort;
- the nineteen EPO vessels were then added on to the total FTE vessels estimated in step 2.

We therefore assumed that the average operating pattern seen by the 'EPO' vessels in the recent past would continue into the future. Alternative scenarios for this future EPO fishing pattern could be investigated.

Data indicated that vessels fishing within archipelagic waters of CCMs spent a proportion of their time fishing within neighbouring EEZs. Calculated as the average relative proportion of an FTE, vessels that fished in archipelagic waters spent the majority of their fishing time within neighbouring EEZs (75% of

[1] Calculated as a day in which one or more of the speeds calculated between any two sequential hourly VMS positions on that day fell below 9 knots.

the FTE was within EEZs). There was considerable variability around this average. Within the calculations:

- The FTE proportion for archipelagic waters was first used to define the number of vessels that could fish within archipelagic waters given the total effort for that area;
- that number of vessels was used to define how many fishing days would also be used on average by them within neighbouring EEZs. These days were 'quarantined' (taken off the EEZ total);
- remaining days within the EEZ limit were used to calculate the permissible FTEs for that area.

Impact of changes in purse seine productivity on capacity

Increases in purse seine productivity increase the impact of a day of fishing on the stock; i.e. the effective effort increases. Limiting fishing impacts on the stock to a particular level (e.g. a TRP) would therefore require a reduction in fishing days, and hence the number of vessels, to compensate.

To illustrate the impact of increases in purse seine productivity, we estimated the equivalent number of FTE vessels for each total effort level at the end of a 5 year period, under a scenario where vessel productivity increased by 3% per annum over that period (Alex Tidd, *pers comm*; see also analyses in SC11-MI-IP-01). In this evaluation, the effect of a 3% annual increase was compounded (i.e. it represents an increase in effective effort of 1.03^5, or 16%, over 5 years).

Results

We examine the number of full-time equivalent purse seine vessels that could operate within the tropical WCPO relative to different effort 'limits' (CMM limits and TRP limits). Within each, the consequences under the three FTE calculations are examined.

Effort levels consistent with WCPFC CMM 2014-01

Combining effort limits described within CMM 2014-01 and recent effort levels estimated within archipelagic waters, 65,867 fishing days were 'permitted' in the tropical WCPO. This equates to 281 FTE purse seiners (fishing 250 fishing days per annum; Table 3).

Taking into account the 'part time' fishing patterns of EPO vessels (and the pattern of fishing between archipelagic waters and neighbouring EEZs) increased the number of FTE vessels compatible with CMM limits. The compatible number of FTEs increased to 289 vessels.

Maintaining the effective effort at CMM limits where purse seine productivity increased by 3% per annum for 5 years would require an 8% reduction in the number of FTEs to 258 vessels. Under this scenario, each day of fishing in 5 years time had 1.16 times the impact of a current fishing day.

Effort levels consistent with candidate skipjack TRP levels

The alternative candidate TRP levels for skipjack implied a wide range of effort levels, and hence compatible number of total FTE vessels. Total FTEs ranged from 142 vessels with a TRP of 60% $SB_{F=0}$, through 212 vessels at a target of 50% $SB_{F=0}$, to 318 vessels at a 40% $SB_{F=0}$ target. It is worth noting that the CMM limits therefore implied a stock size below that at the TRP of 50% $SB_{F=0}$.

Taking into account the non-FTE nature of vessels fishing part-time within the EPO (and archipelagic waters) implied an additional 8 'FTE' vessels were compatible with each TRP effort limit.

Increases in purse seine productivity again reduced the number of FTEs compatible with each TRP effort level. FTE numbers were reduced by 14% and ranged from 122 FTE vessels (60% $SB_{F=0}$) through to 274 vessels (40% $SB_{F=0}$), though these numbers should be viewed as preliminary until further work examining the relationship between purse seine CPUE and abundance is completed.

Discussion

This paper estimates purse seine fleet sizes within the tropical WCPO compatible with current management limits, and with candidate skipjack target reference point levels. These fleet sizes are expressed in terms of 'full time equivalent' vessels, representing a vessel assumed to fish for 250 days per annum, to provide a common currency for the evaluation. The FTE fleet sizes compatible with current CMM 2014-01 and related purse seine effort limits were 281-289 vessels (dependent upon whether the part-time nature of vessels fishing for part of the year within the EPO was taken into account). FTE fleet sizes compatible with candidate TRP effort levels were generally lower, with 50% or 60%$SB_{F=0}$ TRPs (as focused upon during discussions at SC10 and WCPFC-MOW3) equating to 142-220 vessels – considerably less than implied by the management limits.

To compare the estimated limits against current levels of effort, preliminary estimates of 2014 tropical purse seine effort indicate that 57,138 days were fished in that year (using the same geographic regions evaluated here). This is equivalent to 229 FTE purse seine vessels (ignoring 'part-time' vessels). This is 19% fewer vessels than estimated compatible with CMM limits, but 8-61% more vessels than estimated as compatible with TRPs of 50% or 60%$SB_{F=0}$. This implies current purse seine effort levels (and fleet sizes) are likely in excess of those required to achieve these two TRP levels.

The calculation relative to current management limits provides an indication of the maximum effort levels 'permissible' for the tropical WCPO. It should be noted that for some EEZs, effort levels in the recent past have been far lower than nominated, and hence these EEZ values represent aspirational limits. In turn, effort levels estimated based upon nominated EEZ skipjack catch limits (e.g. Australia and New Caledonia) are calculated using assumed catch rates. Where data exist, those catch rates have shown considerable variability over time, and these effort levels are therefore uncertain.

The results relative to the candidate TRPs are influenced by assumptions of purse seine fleet dynamics relative to skipjack abundance (see also SC11-MI-WP-04). The analyses presented here, and those underlying WCPFC MOW3-WP-03, assume a direct relationship between skipjack biomass and skipjack CPUE (and hence its relationship with effort). However, hyper-stability in purse seine skipjack CPUE has been hypothesised for the WCPO. While we do not know the nature and extent of this phenomenon, it may imply that for the 60%$SB_{F=0}$ TRP we are overstating the reduction in vessels required to achieve that TRP, and under-stating the effort increase required to achieve the 40%$SB_{F=0}$ TRP.

The results relative to candidate TRPs also assume all vessels have equal performance. In practice, if reductions in vessel numbers were required to achieve levels consistent with TRPs, the 'worst' performing (less profitable) vessels would likely be removed from the fishery first. This would imply that resulting levels of catch would remain higher than expected, and reductions in vessel numbers would need to be greater than evaluated here. This effect would be akin to the scenario where purse seine vessel productivity increases over time (see below).

The use of an 'average' FTE vessel within this analysis does not capture the potential variability seen in the number of days fished per annum by vessels. The actual days fished per annum by each purse seine vessel within the WCPO from logbook returns ranged considerably above and below the FTE value used here. A notable proportion of these indicated annual fishing periods of less than 100 days, despite those vessels known to be fishing 'part time' within the EPO being removed from these data. This pattern was still seen, but to a reduced level, within available VMS data. The implication for the economic profitability of vessels is unclear. A proportion of the annual activities that do not match the expected 'FTE' duration would be related to the misreporting of fishing activity on logsheets by some fleets in recent years (SPC, 2013; see also SC11-MI-IP-01), which reduces the number of days reported as actively fished per year. They may also represent vessels spending some time outside the tropical region and in EEZs excluded from this analysis (e.g. fleets flagged to the Philippines, New Zealand, Japan; Figure 2). In turn, a lack of complete operational data for some vessels, the inability of some domestic vessels to fish in poor weather, and vessels that enter or leave the fishery part way through the year, may also skew distributions below the assumed FTE.

Potential increases in the productivity of purse seine vessels over time due to improved technical developments (e.g. faster vessels, new net technology, smart FADs, etc.) and resulting increases in total effective effort implies notable reductions in the number of FTEs over time may be needed to control overall fishing impact. There is a need to understand the driving factors behind productivity increases in order to understand how it may change in the future, and hence allow the development of plans to adjust fishing capacity over time to maintain stocks around TRPs, for example (see also SC11-MI-IP-01). In this sense, alternative metrics for fishing effort other than a fishing day may become appropriate to more effectively capture those changes driving improved fleet productivity (Pascoe et al., 2003). This is discussed further in SC11-MI-IP-01.

This paper provides a preliminary analysis of tropical WCPO purse seine fleet capacity levels consistent with four potential effort limit levels. We invite WCPFC-SC to:

- consider the importance of this field of research and its prioritisation within the SC work plan;
- propose further work to identify patterns of participation by vessels within the fishery;
- consider expansion of the approach to longline and other fisheries;
- suggest specific analyses that assist the Commission's consideration of fleet capacity; and
- consider the implications of these analyses when providing advice to WCPFC12.

References

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Table 1. Effort limits (days) within four geographic groups of the WCPO, as defined by limits within CMM 2014-01 and nominated nationally.

Area	Effort limit (days)	Notes
PNA	44,033	As defined in http://www.pnatuna.com/VDS, without vessel length adjustment.
Archipelagic waters	7,846	Not limited, assumed to remain at 2013 levels (WCPFC11-2014-IP02_rev3, Table 1)
Nominated EEZs within 20N20S	7,047	See Appendix 1
High seas	2,282 + 4,659	CMM 2014-01, Attachment D + PH limit within HSP1 (Attachment C, para 10; 4,659 days and 36 fishing vessels)
Total	**65,867**	

Table 2. Estimated purse seine effort levels approximated from the effort scalars that achieved each candidate skipjack TRP.

	Candidate skipjack TRP		
	$40\%SB_{F=0}$	$50\%\ SB_{F=0}$	$60\%SB_{F=0}$
Scalar on 2012 effort:	1.5	1	0.67
PNA	62,027	41,351	27,705
Archipelagic waters	11,925	7,950	5,327
EEZs within 20N20S	2,247	1,498	1,004
High seas	3,314	2,209	1,480
Total	79,512	53,008	35,515

Table 3. Number of full-time equivalent (FTE) purse seine vessels consistent with the effort levels under each scenario, and each FTE assumption.

Scenario	CMM limits	Effort consistent with candidate SKJ TRPs		
		$40\%SB_{F=0}$	$50\%SB_{F=0}$	$60\%SB_{F=0}$
All FTEs	281	318	212	142
FTE with EPO/AW proportion	289	326	220	150
FTEs in 5 years with 3% effort creep	258	274	183	122
Approximate days	65,867	79,512	53,008	35,515

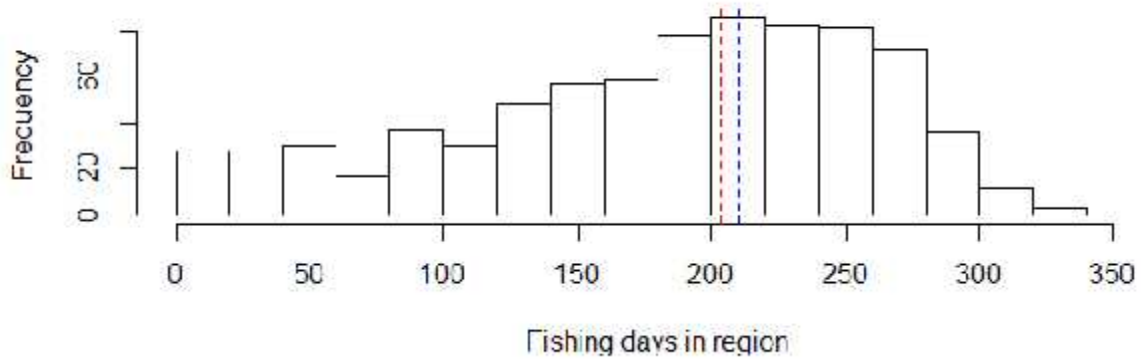

Figure 1. Histogram of frequency of fishing days per year per purse seine vessel within the tropical WCPO, over the period 2010-2013. Red vertical line represents median of distribution (203 days). Blue vertical line represents the mode of the distribution (210 days). Source: logbook data.

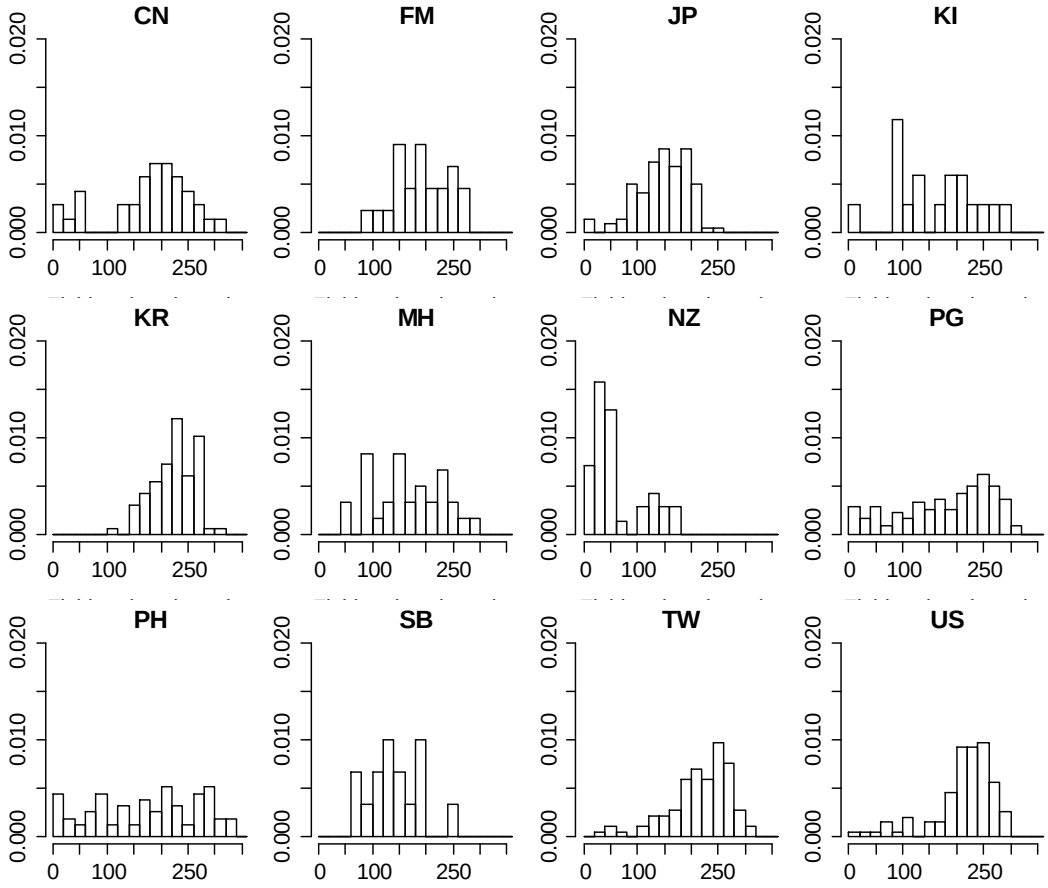

Figure 2. Histogram of proportions of total fishing days (per year per purse seine vessel) within the tropical WCPO over the period 2010-2013, by flag. Only fleets with more than 3 vessels presented. Source: logbook data.

Appendix 1. Nominated national purse seine effort limits for those CCMs with EEZs.

Source of effort limits: WCPFC11-2014-14_rev2, Table 4.

CCM	Proposed effort limit (days)	Notes
Australia	1,579	WCPFC10-DP-19; Australia specified a skipjack catch of 30,000 mt. This was converted into effort (days) taking a recent average purse seine CPUE of 19 mt/day. All effort assumed to be within the region north of 20°S.
Cook Islands	1,250	WCPFC10-DP-20
Fiji	300	WCPFC10-DP-21
Indonesia	(3,374)	Taken from WCPFC11-2014-IP02_rev3, Table 1 as CMM2012-01 limits. Effort for this EEZ not included within the analysis (see main text).
Japan	(1,500)	Not included within the calculations as EEZ is outside the tropical region (20°N 20°S)
Korea	(4,298)	Not included within the calculations as EEZ is outside the tropical region (20°N 20°S)
New Caledonia	800	Nominated limit of 20,000 mt. In the absence of purse seine catch rates for the New Caledonian EEZ, an average CPUE from neighbouring EEZs in recent years was developed (25 mt/day) and applied to estimate the equivalent number of days.
New Zealand	(1,049)	WCPFC10-DP-18. Not included within the calculations as EEZ is outside the tropical region (20°N 20°S). New Zealand specified a skipjack catch of 40,000 mt. This was converted into effort (days) taking a recent average purse seine CPUE of 38 mt/day.
Niue	200	WCPFC10-DP-25
Philippines	(4,623)	Taken from WCPFC11-2014-IP02_rev3, Table 1 as CMM2012-01 limits. Effort for this EEZ not included within the analysis (see main text).
Samoa	150	WCPFC10-DP-22
Tokelau	1000	WCPFC10-DP-28
Tonga	250	WCPFC10-DP-27
USA	1,318	WCPFC10-DP-23; US specified limits of 2588 days across EEZs and high seas. Limit of 1270 high seas days specified in CMM2014-01 Attachment D. Remaining days were assumed to be in-zone.
Vanuatu	200	WCPFC10-DP-24
Total	**7,047**	