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Updating Indicators of Effort Creep in the WCPO Purse Seine Fishery

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Abstract

Effort creep has implications for our understanding of trends in fishing effort and our ability to maintain stocks around target reference points, and can affect vessel profits. Paper SC12-MI-WP-08 reviewed candidate indicators of effort creep in the WCPO purse seine fishery at the request of the PNA. The work was supported by SC12, which noted its relevance for skipjack harvest control rule development (SC12 report para. 645). PNA requested that SPC report annually on trends in effort creep by updating key tables from that paper, and expressed interest in similar work being undertaken so that any adjustment for effort creep would be compatible across the WCPO (SC12 report para. 641).

This paper updates and summarises the latest information available to SPC as of 5th June 2018 (see Table 1). The majority of candidate effort creep indicators have decreased over the recent period when examined both within and outside PNA EEZs, with 2017 in particular having a relatively low annual CPUE based upon current available data. This year drives the trends seen in Table 1. The short term trends shown in that table therefore need to be considered separately to the longer term trends seen.

The number of sets made per day has gradually increased then stabilised over time, reflecting an increase in effective effort within fishing day limits. The trend is different between set types, with free school set frequency increasing notably, while the rate of associated sets per day declined slightly. While catch per set declined slightly over time, setting rate has generally increased at a greater rate leading to increases in catch per day. While recent changes in catch and CPUE may reflect the ultimate consequences of effort creep, we note that purse seine CPUE is considered relatively insensitive to changes in underlying fish biomass. The relationship between trends in purse seine CPUE, the underlying biomass and effort creep remains unclear.

Vessel characteristics, which may better reflect effort creep, all displayed increasing trends over time. A challenge is to identify a limited suite of vessel characteristics that directly (or indirectly) influence effort creep, noting that trends in different characteristics are likely correlated (i.e. larger vessels have greater hold capacities, etc.).

Catchability estimates from stock assessments aggregate the effects of changes in vessel efficiency on fishing mortality when estimating stock size and trends. Trends are presented from the most recent skipjack and yellowfin stock assessments. While trends from the 2016 skipjack assessment indicated general stability or declines in tropical purse seine catchability, those for yellowfin show considerable variability within years, which reduces their utility as an effort creep indicator. Further, practical challenges include the timeliness of estimates. This may limit year-on-year use, but they may be adequate for less frequent adjustments to effort limits and validation of other approaches.

We invite SC14 to:

- note the trends in the purse seine fishery metrics, and the need to ensure related information is available to understand the potential influences on effort creep;
- note the importance of developing consistent and complete information on vessel characteristics, and improved information on the effects of changing FAD technologies.

Table 1: Summary of trends in indicators within and outside PNA EEZs (avg 2016/17 vs 2014/15)

Indicator	PNA 2016/17 vs 2014/15	Non-PNA 2016/17 vs 2014/15
Sets/day	-1%	-8%
Total tuna CPUE(mt/day)	-10%	-35%
Total tuna CPUE(mt/set)	-9%	-29%
Catch(total tuna/skipjack)	-9%/-16%	-21%/-24%
Vessel length	+5%	
Vessel GRT	0%	
Vessel HP	+1%	
Vessel crew nos.	+3%	
MFCL assessment catchability trend (SKJ)	-2%	
MFCL assessment catchability trend (YFT)	-5%	

Introduction

Effort creep describes the situation where fishing vessels improve their ability to catch fish over time within an effort-managed system, and hence catch more per fishing day. This may create economic benefits through increased efficiency. However, effort creep becomes a problem if:

- Adjustments are not made to management systems to take into account the resulting increases in fishing mortality per 'fishing day', in which case stock management targets would not be met (e.g. the skipjack stock would fall below the adopted interim target reference point level[1]; see Scott et al., 2016. In time, this phenomenon will be a key element of consideration for harvest control rules; or
- Incentives created within management systems to increase vessel efficiency distort the patterns of investment in the fleet and lead to vessel designs or operations that are not optimal.

Effort creep can result from improvements to existing vessels with investment in better fishing technology and more powerful engines, or the addition/substitution of newer vessels. Removing less effective vessels from the fishery means available days can be fished by more efficient vessels, thereby increasing the overall fleet efficiency and also leading to effort creep. Policy and regulatory changes can also affect the rate of effort creep. For example, FAD closure periods within the WCPO may have reduced fishing power in recent years, although increased FAD fishing and FAD deployment outside the closure period may have negated that. Separating these influences is not straightforward.

At SC12, paper MI-WP-08 reviewed candidate indicators of effort creep in the WCPO purse seine fishery at the request of the PNA to inform consideration of adjusting the Vessel Day Scheme TAE for effort creep. The work was supported by SC12, which noted that it was also directly relevant to the development of a harvest control rule for skipjack (SC12 report, para 645, see also discussion in MI-WP-08). PNA requested that SPC report annually on trends in effort creep by updating key tables from that paper, and expressed interest in similar work being undertaken so that any process of adjustment for effort creep would be compatible across the WCPO (SC12 report, para 641).

This paper updates and summarises the latest information available to SPC as of 5^{th} June 2018. Three potential groups of proxies for effort creep are examined here:

- Trends in tuna catch levels, catch rates, and alternative fishing effort values;
- Estimates of trends in vessel characteristics;
- Trends in estimated 'catchability' from WCPFC stock assessment models.

Examination of trends in catch, catch rate effort

Examining trends in overall catch, catch rates and effort levels provides a simple indicator of effort creep. These values were estimated within and outside PNA EEZs (where for the purposes of this paper, PNA refers to PNA Parties + Tokelau) using aggregate (1°x1°) raised logsheet data, summarised by approximate EEZ/high seas area for the WCPFC Convention Area within the latitudinal range 20°N-20°S. Effort and catch within archipelagic waters were included within estimates due to the nature of the aggregate data used. Trends are examined over the last 10 years (2008-2017). Recent trends are summarised by taking ratios between average effort, CPUE, and catch in 2016-17 and 2014-15.

Fishing days in the WCPO tropical fishery are generally limited through the PNA VDS, EEZ-nominated effort and skipjack catch levels, and high seas effort limits (e.g. Pilling and Harley, 2015). In cases where fishing days are limiting, however, effective effort could increase through changes in activity within a fishing day, such as an increase in the number of sets made per fishing day (Figure 1). The number of sets made per fishing day has increased over the recent 10 year period for unassociated (free school) sets while the number of associated (FAD) sets decreased. The average sets/day inside PNA waters over

[1] We note that a challenge in effort control systems is managing an individual species to a desired level within a multispecies fishery.

2016-2017 relative to 2014-2015, increased by 3% for free school sets while FAD sets decreased by 10% (-1% combined). Outside PNA waters free school setting rates increased by 7% while FAD sets decreased by 30% (-8% combined).

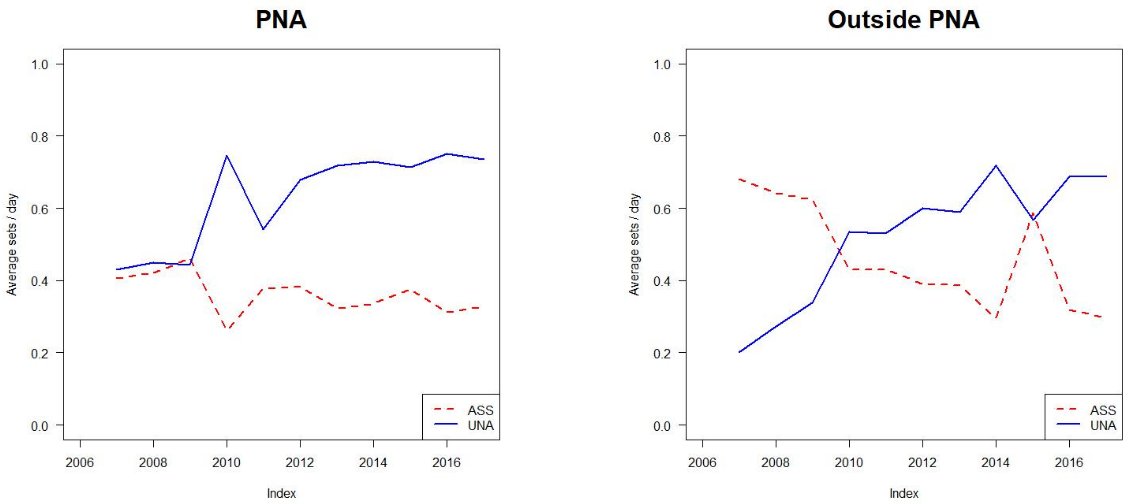

Figure 1: Time series of setting rate (sets per fishing day) for associated and unassociated set types, for inside (left) and outside (right) PNA EEZs.

Trends in the nominal CPUE were measured as total tuna (mt) caught per day fished, and per set. The latter was calculated to account for increases in sets made per day which were shown above, and both metrics are presented in Figure 2. The majority of the catch (69-79%) was comprised of skipjack (Figure 4) which drives these trends.

CPUE within PNA EEZs has been consistently higher than outside. The drop in CPUE outside the PNA EEZs in 2010 appears consistent with closure of key high seas areas, implying that the remaining fishing areas were of lower suitability to purse seine fishing. CPUE inside and outside PNA EEZs have shown similar trends in the recent period. Comparing average CPUE over 2016-17 to the average over 2014-2015, these have decreased by 9% (per set) and 10% (per day) inside PNA EEZs, and by 29% and 35% respectively outside PNA EEZs, strongly influenced by 2017, which available data suggests had notably low catch rates. While catch per day inside PNA EEZs has generally increased marginally, the catch per set has declined slightly in the longer-term, corresponding with increases in the number of sets made per day (Figure 1). The increased set rate per day therefore appears to have compensated for any reduced catch rate per set. Outside PNA EEZs, the overall trend in CPUE has been downwards, significantly influenced by the closure of the high seas and relatively poor fishing in 2011, with some recovery in CPUE in the most recent period, in particular 2015.

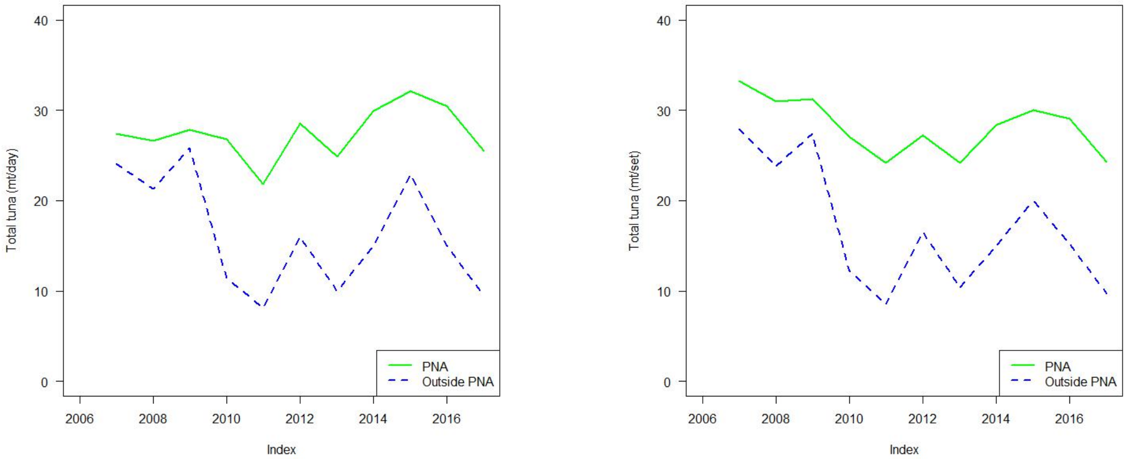

Figure 2: Time series of nominal purse seine total tuna CPUE in terms of mt/day (left) and mt/set (right) inside and outside PNA EEZs.

The long-term trend in associated CPUE has fluctuated without trend, while unassociated catch rates tended to decline, particularly outside PNA EEZs (Figure 3). When evaluated over the most recent period, catch rates by set type and region have all decreased, except for associated sets outside PNA EEZs which increased slightly (3%). Associated sets within PNA EEZs decreased by 5% while unassociated sets decreased by 9% and 51%, within and outside PNA waters, respectively.

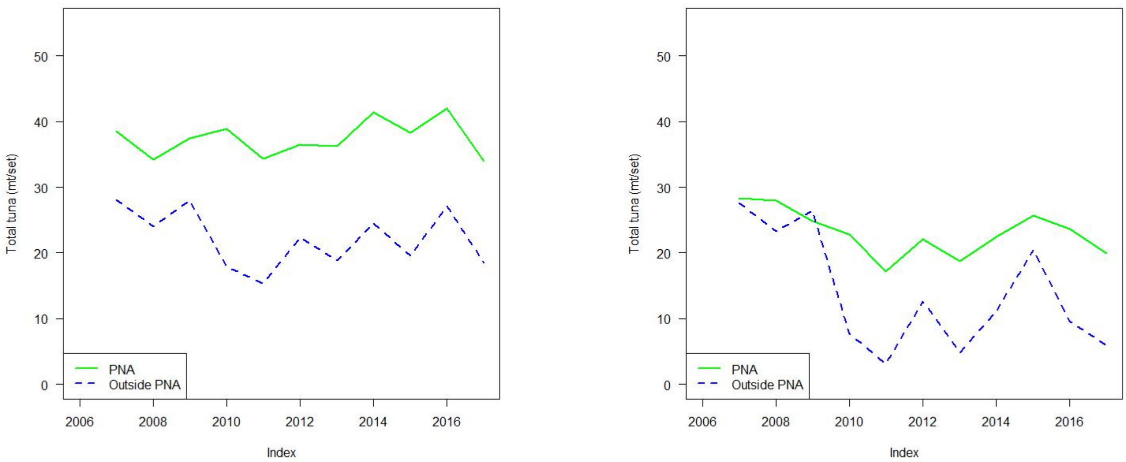

Figure 3: Time series of nominal purse seine total tuna CPUE (mt/set) for associated (FAD) sets (left) and unassociated (free school) sets (right) inside and outside PNA EEZs.

The potential for new FAD technology (e.g. increased use of sonar-equipped FADs), and the suspected increase in the number of FADs deployed, will influence the CPUE trends in the associated set time series. If we presume an artificial operational ceiling of 1 FAD set per day, the increased use of FADs equipped with sonars may allow effort creep to continue through the more efficient use of the improved selection of FAD fishing opportunities that exist and the 'optimisation' of FAD fishing, with vessels being directed to the most productive FADs (those that have larger aggregations beneath them, based upon acoustic information provided by the FADs sonar system) to maximise catch. This may also influence the increasing trend in associated set CPUE seen in recent years (e.g. Figure 3) despite the slight decline in associated set rates. However, this is an area that needs to be further examined.

More detailed information of FAD deployments, in particular the proportion of sonar-associated FADs, FAD technology, the influence of the FAD closure period, and related CPUE changes is needed. In particular, the number of deployed and actively monitored FADs could be a key characteristic of vessel fishing strategy responsible for effort creep. A project proposal arising from the WCPFC FAD IWG was provided to SC13 on this (SC13-EB-WP-05) and related analyses are presented in paper SC14-MI-WP-10.

Total tuna catch over the 10 year period within PNA EEZs first increased and then stabilised after 2010 (Figure 4). Catch outside PNA EEZs fell notably in 2010, consistent with closure of key high seas areas, and has generally increased since that time towards pre-closure levels. Within PNA EEZs, average 2016-2017 total tuna catch decreased by 9% relative to the 2014-2015 average. Outside PNA EEZs, 2016-2017 catch decreased by 21%, this value being strongly influenced by the high 2015 catch associated with a strong *El Nino* event, and the corresponding shift in fishing effort to the east.

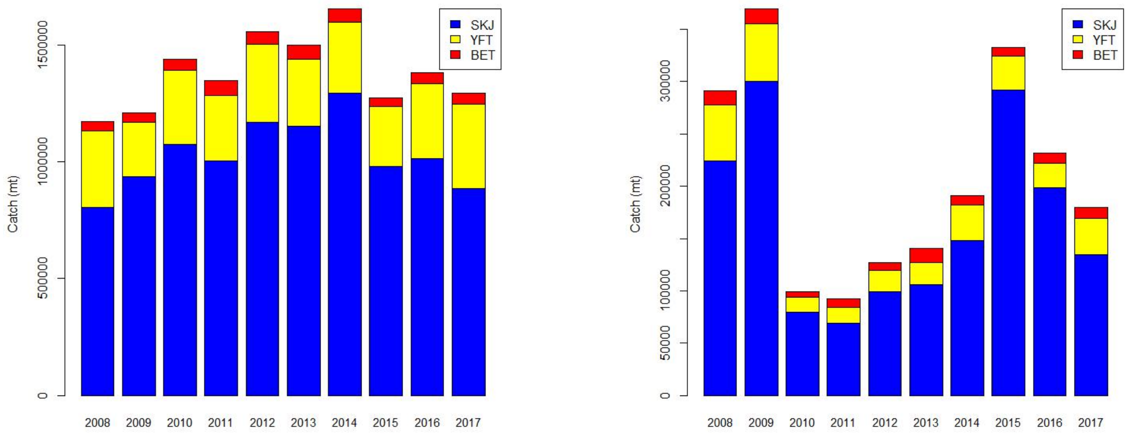

Figure 4: Time series of purse seine catches inside (left) and outside (right) PNA EEZs (2008-2017). Note different y-axis scales.

To monitor and adjust overall fishing effort levels for effort creep, recent changes in CPUE provide perhaps the most obvious starting point for an indicator. However, purse seine CPUE is felt to be relatively insensitive to changes in underlying fish biomass compared to that from the longline fishery, due to the schooling behaviour of fish. Separating effort creep effects from this hyperstablity is challenging. CPUE is also influenced by the effect of oceanographic conditions and ENSO cycles; improved use of new technology (rather than technology-based effort creep *per se*); improved knowledge of good fishing areas; communication between vessels (cooperation versus competition); and the influence of market forces and management regulations (e.g. FAD closure period, increasing fuel costs, fluctuations in market prices, which may have both positive and negative outcomes for productivity). Similar challenges are identified for the use of catch levels, although changes in that indicator perhaps present the ultimate impact of effort creep. A combination of these indicators may be appropriate.

Changes in vessl characteristics within the purse seine fishery

To the extent that effort creep is driven by the size of vessels or other specific vessel characteristics, changes in these features are a possible indicator of effort creep. There are three potential sources of vessel characteristic data which may cover different components of the tropical purse seine fishery: the WCPFC Record of Fishing Vessels; the FFA Vessel Register; and the PNA VDS Register. Information is also available from observer records of vessel characteristics.

The accuracy of information in these vessel registers still need to be verified and standardised, to ensure consistency in measurements used, submitted characteristic values, and completeness of information for some fields. Based upon the information currently available, Figure 5 shows the evolution of average length, GRT, engine power and number of crew of vessels on the FFA Register. A long-term increase is seen in characteristics, and more recently they have grown by around 0-5% (see Table 1 for details). We note that estimates reflect vessels that may operate in specific tropical WCPO areas.

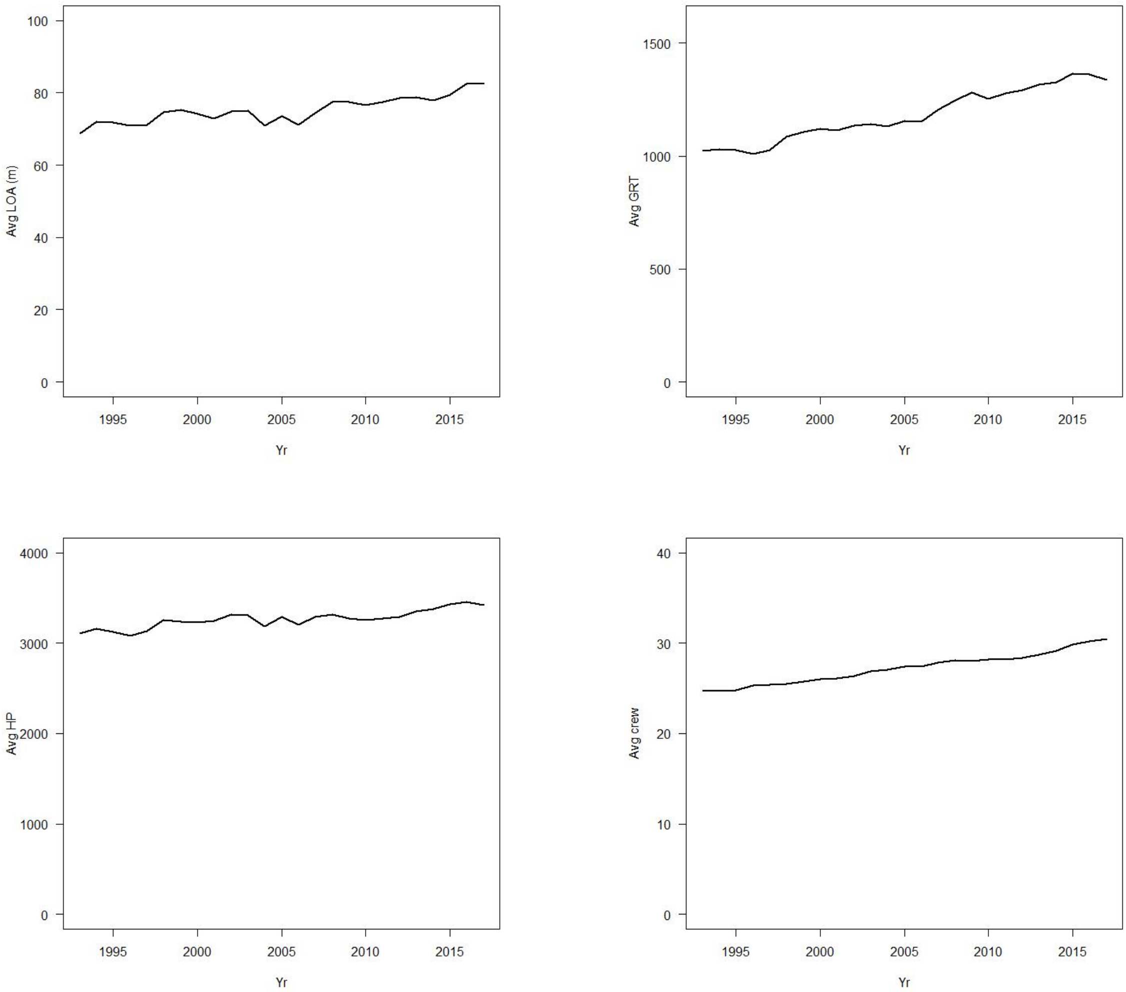

Figure 5: Average vessel size characteristics of purse seine vessels registered annually on the FFA Vessel Register in terms of length overall (m) (top left); gross registered tonnage (GRT) (top right); engine horsepower (bottom left); and number of crew (bottom right).

The notable increase in GRT in the most recent years is influenced in part by missing data. Calculations based upon the median characteristics over time, which reduces the influence of for example the addition of one or two very large vessels, showed comparable percentage trends to those indicated here.

Monitoring vessel characteristics may allow the technical drivers of effort creep to be identified. These may be specific to set types; e.g. more powerful blocks, larger net mesh, and knotless mesh may increase the effectiveness of free school fishing, while adoption of echo-sounders on FADs may increase the effectiveness of FAD fishing. A challenge is to identify a limited suite of characteristics that directly (or indirectly) influence effort creep. The relationship between the change in a characteristic and the level of effort creep is not necessarily linear, nor may that effect continue through time. In turn, efficiency may have increased at a higher rate than the growth in an individual characteristic, as the combined impact on efficiency of changes in different characteristics may be greater. Identifying characteristics that influence CPUE, and then modelling their combined effects where data allow, taking the stock size into account, may help identify the overall level of effort creep and whether a single characteristic such as vessel length, or a suite of characteristics in a simple combination, can act as a suitable proxy.

Estimated 'catchability' trends in skipjack and yellowfin stock assessments

Within the MULTIFAN-CL stock assessment model, the fishery-specific parameter 'catchability' measures the impact of a single unit of effort of a given fishery on the stock over time; i.e. it translates the level of fishing effort into the level of fishing mortality. Catchability is allowed to vary over time for some fisheries such as purse seining to adjust the impact of fishing on stocks due to processes such as effort creep. The resulting pattern for the four main tropical purse seine fisheries within the 2016 skipjack stock assessment is shown in Figure 6.

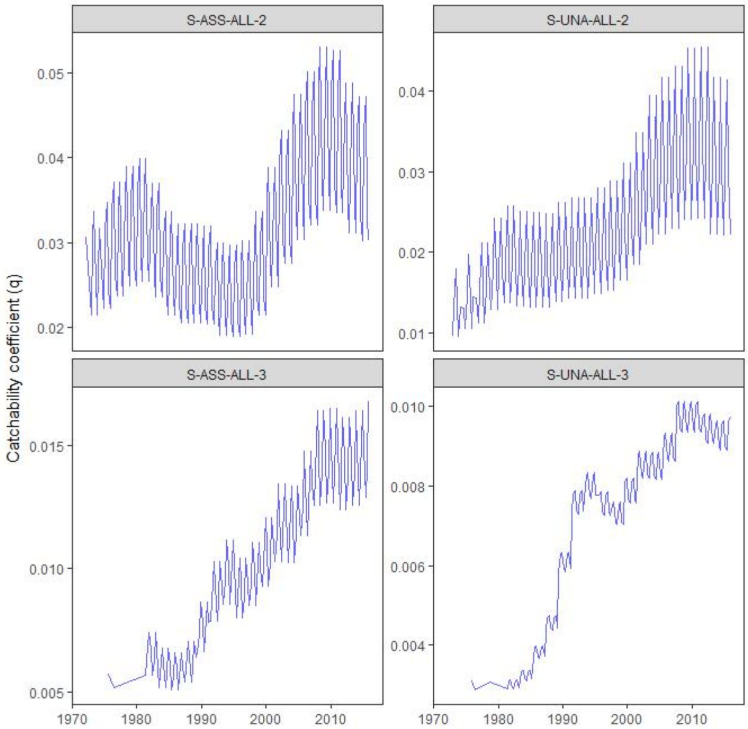

Figure 6: MULTIFAN-CL quarterly time series estimates of tropical purse seine fishery catchability within 2016 skipjack assessment (model regions 2 and 3).

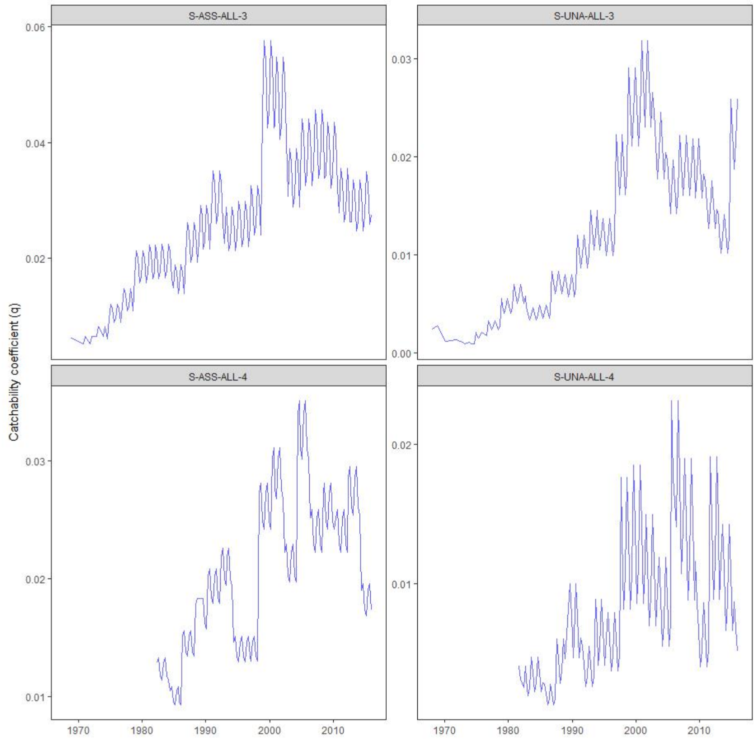

Figure 7: MULTIFAN-CL quarterly time series estimates of tropical purse seine fishery catchability within 2017 yellowfin assessment (model regions 3 and 4).

Catchability estimates for skipjack within tropical purse seine fisheries have increased across the time period up to the mid to late 2000s. Examining more recent trends, catchability estimates have generally stablised or declined, with only the eastern free school fishery showing an increase of just under 2% (Table 2). It should be noted that estimates in the final years of the assessment are considered the most uncertain as they have limited information available to estimate catchability and hence estimates are more strongly influenced toward the 'prior mean' for the catchability parameter.

In contrast to skipjack, the annual average tropical purse seine catchability trends estimated within the 2017 yellowfin assessment showed notable variability in the final years, which led to considerable relative percentage changes estimated within the most recent period (Figure 7, Table 2). This may reflect the less targeted nature of the purse seine fishery when catching yellowfin, but also indicates that the estimates from the 2017 assessment are less helpful in evaluating effort creep within the purse seine fishery for this stock and less strongly influenced by the 'prior mean' of the catchability parameter than skipjack.

Table 2: Average annual increase in purse seine vessel efficiency estimated from the 2016 skipjack and 2017 yellowfin stock assessments.

Fishery	2014-2015/2012-2013	
	Skipjack % change	**Yellowfin** % change
Western free school	-3.2%	0.0%
Western FAD	-3.8%	+41.9%
Eastern free school	1.9%	-28.7%
Eastern FAD	-1.1%	-32.3%

In theory, catchability estimates should be the best indicators of effort creep among the options considered in this paper, as they measure the aggregate effect of changes in vessel efficiency on fishing mortality which for example vessel length indicators do not, and they take into account changes in underlying stock sizes which catch and catch rate indicators cannot do easily. However, model-based estimates will also integrate over fleets, depending on how fisheries are defined in the assessment model. They will also include effects related to the distribution of effort in relation to the distribution of fish at a spatial scale finer than that being modelled. In turn, the utility of catchability estimates for monitoring the fishery for effort creep and adjusting effort limits must be considered, with practical challenges including:

- Timeliness: catchability estimates are only updated when assessments are performed. Estimates in the final years of the assessment are considered the most uncertain as those years have limited information available to estimate catch and hence estimates are more strongly influenced toward the 'prior mean' for the catchability parameter. Combined, in the worst case and where assessments are performed every 3 years, these issues may mean the recent usable estimates may be five or more years old.

- Accuracy: catchability estimates assume that the assessment is completely correct with respect to recent trends in abundance.

The utility of catchability estimates for year-on-year use is therefore limited. Less frequent changes to effort limits based on catchability estimate trends may be more appropriate. In turn, the values may offer a useful validation of other approaches.

Summary

We note that the majority of candidate effort creep indicators have shown decreases over the recent period within the WCPO when examined both within and outside PNA EEZs. The link between trends in these indicators, underlying stock biomass, and the ultimate level of effort creep within the tropical WCPO purse seine fishery remains unclear. Ultimately, the effectiveness of any adjustment approach can be tested within Management Strategy Evaluation (e.g. Scott et al., 2016) to ensure that any proposed management approach is robust to this uncertainty.

We invite SC14 to:

- note the trends in the purse seine fishery metrics, and the need to ensure related information is available to understand the potential influences on effort creep;

- note the importance of developing consistent and complete information on vessel characteristics.

References

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