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Evaluation of activities within the purse seine fishery through time

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Rev1: Corrected an error in the tabulation of fishing days, detailed in Table 2, along with the associated text.

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Executive summary

This paper presents an initial investigation into changes in fishing strategy and reporting behaviours in the tropical purse seine fishery, in response to questions raised by Members on the topic (e.g., including during the 20th Regular Session of the WCPFC Commission (WCPFC20-Summary Report, paras 180-186)).

We evaluated logsheet, observer, and VMS data to explore apparent changes in fishing-related activities compared to non-fishing activities (e.g., transiting) through time. Notable increases in reported non-fishing activities during fishing trips have been observed, suggesting a reduction in searching behaviours and an increase in transiting between fishing locations. This behaviour may in part be due to increased reliance on instrumented drifting FADs, providing more real-time information to fishers on the location and size of tuna schools, thus mitigating the need for traditional searching techniques.

To explore the potential impact on overall fishing effort (in days) in the purse seine fishery, under different assumptions of how a day spent at-sea is or is not related to fishing activities, we developed a suite of scenarios to test. In each scenario we reclassified some of the daily activities reported in logsheet data from non-fishing to fishing activity, based on certain criteria. For each scenario, we recalculated the total effort that would have been expended in the fishery relative to the baseline reporting. We found that using total days at sea (neglecting the details of day-to-day activities) increased the estimate of fishing days by approximately 32%, on average, since 2010, whereas more conservative scenarios associated with reclassifying daily activities suggested that fishing effort would be 2-6% higher under the assumptions made.

We invite the SC to review this paper and to offer insight around their understanding of how purse seine fishing and/or reporting has changed through time. The Science Services Provider welcomes suggestions on additional analyses to be undertaken in the coming year to better inform the discussion on this important topic. Similarly, if there are identified needs for improving upon the reporting requirements in the purse seine fishery, these suggestions would be valuable to explore.

1 Background

The tuna purse seine fishery in the Western and Central Pacific Fisheries Commission Convention Area (WCPFC-CA) is the largest in the world, with approximately 79% of the total tuna harvest from the Pacific Ocean (∼3.3 million mt in 2023) coming from the WCPFC-CA (∼2.6 million mt) (WCPFC, 2023; SPC-OFP, 2024). The purse seine sector accounts for the majority of the tuna catches from the WCPFC-CA (70% in 2023). CMM 2023-01 (preceded by CMM 2021-01, 2020-01, 2018-01, etc.) details provisions for the management of the tropical fisheries for bigeye, skipjack, and yellowfin tuna in the Convention Area. One of the key provisions for the management of stocks targeted with purse seine gear is a limit on fishing days in coastal CCM EEZs and the high seas.

In recent fora, including the 20th Regular Session of the WCPFC Commission, the patterns of increasing catch in association with decreasing effort in the purse seine fishery (Vidal et al., 2024) have been noted by Members (WCPFC20-Summary Report, paras 180-186). These observations highlight the need to more closely evaluate the fishing activities within the purse seine fishery to better understand whether: (i.) technological changes are continuing to increase purse seine efficiency, (ii.) the relative abundance has continued to increase, thus increasing nominal CPUE, or (iii.) if there have been changes in fishing strategy and/or reporting of effort that may influence the perception of changes in effort over time. This paper aims to evaluate the reporting of vessel activities in the purse seine fishery over time to identify whether changes in behaviour may be influencing the perception of fishing effort.

To support the monitoring of effort, the WCPFC requires minimum Scientific Data to be provided to the Commission (SciData) for the managed fisheries of the WCPFC-CA. Among these submissions include operational (i.e., logsheet) data for the key fisheries, including purse seine. One component of the operational data is a requirement for daily activity reporting during fishing trips (see Annex 2 of the SciData). Among the selection of activities to be reported each day, there are two that are considered fishing activities (i.e., a [fishing] set, and a day searched, but no sets made). There is a suite of additional codes to describe non-fishing activities while at sea (e.g., transiting, gear breakdown, and bad weather) and to indicate when a vessel is in port. In addition to the logsheet data, information from Vessel Monitoring Systems (VMS) and observer-reported data are also submitted to the Commission and may help to corroborate/add context to activities reported in the logsheet data.

In this paper, we take a preliminary look at the available data sets to evaluate how activities and/or the reporting of activities in the purse seine fishery may have changed over time, evaluate how those changes could be influencing the assessment of fishing effort each year, and propose additional analyses to more fully investigate these patterns in purse seine activity over the coming year.

2 Logsheet activity reporting

The strategies used to carry out the purse seine fishery have evolved over time to leverage technology and tuna behaviour to potentially increase efficiency, economic rents, and profitability. One of the key changes in fishing strategy has been the increased reliance on man-made drifting FAD (dFAD) sets over the more traditional approach of targeting schools of tuna unassociated with floating objects (e.g., free schools). Within the scope of dFAD sets, the technology continues to improve where the contemporary fishery is largely reliant on satellite-tracked FAD buoys mounted with multi-frequency echo-sounders to convey in-situ information to the vessel/fishing company about the presence and size of tuna schools associated with individual buoys (e.g., Lopez et al., 2014; Pons et al., 2023). As a result, time spent searching for tuna schools is expected to decrease, as fishers will, in theory, have more reliable and precise information about where and when tuna schools may be available. Figure 1 shows that as the proportion of reported fishing sets (relative to all reported activities) has gradually decreased over time along with searching activities, the relative proportion of transiting (a non-fishing activity) has been increasing (noting a slight decline from 2021 - 2023).

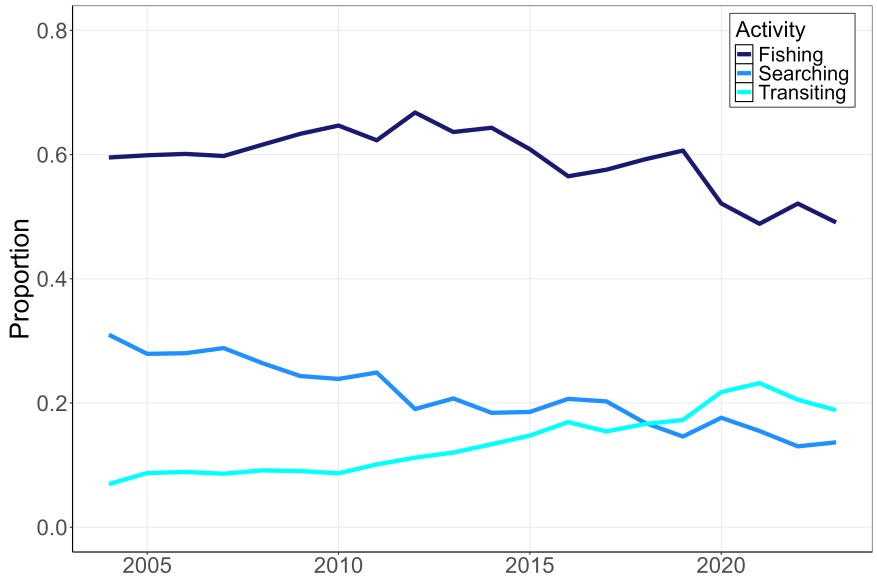

Figure 1: Time series of the proportion of the three main logsheet reported at-sea activities: fishing, searching, and transiting from 2004-2023

To investigate why transiting may be increasing while searching for tuna schools is decreasing, we further evaluated the sequence of reported fishing activities within fishing trips, using unraised logsheet data. Specifically, we evaluated the activities or set types following transiting activities. Figure 2 indicates that in the early part of the time series, fishing-related activities (i.e., fishing and searching combined) made up around 80% of the activities that followed transiting, with searching accounting for approximately 30-35%. In 2023, fishing-related activities account for 66% of the activities that follow transiting, with only 15% of those activities considered searching.

There also appears to be improved reporting of returning to port, whereas historically transiting was often the last reported activity in a trip. There is a notable increase in the non-fishing maintenance/breakdown category from 2010-2021, but that category appears to have dropped off considerably in the last two years. Lastly, there has been a notable increase in the 'Other' category, to account for ∼15% of the post-transit activities in 2023. The nature of the 'Other' category is further detailed in Table A2.

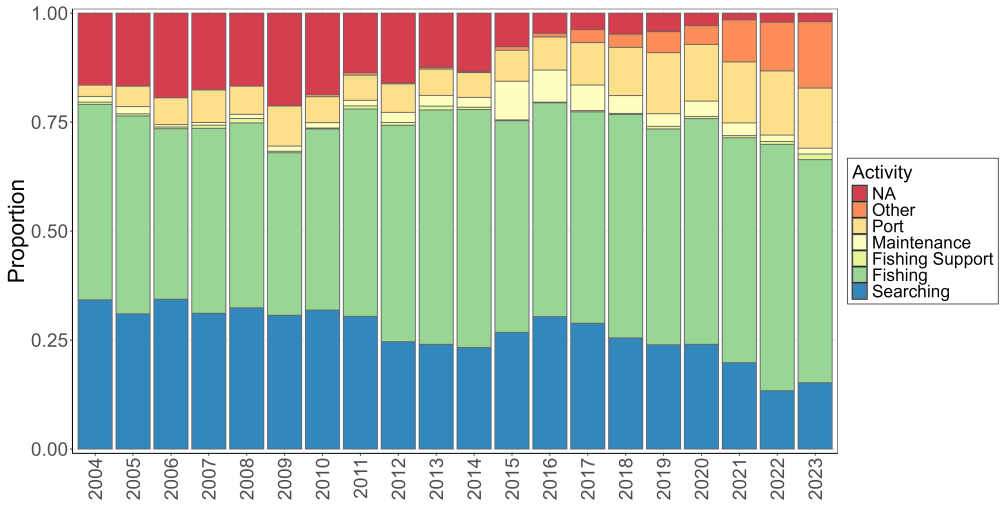

Figure 2: The proportion of activities reported after transiting from 2004-2023

For situations where a fishing set directly followed transiting, we evaluated the type of set that was made. The assumption is that in the contemporary fishery, free-school sets still require searching as compared to dFAD sets which may be informed by remote sensing technologies as opposed to searching in the more traditional sense. Figure 3 further breaks down the set type (i.e., FAD, Free school, Log, Animal, Other) associated with setting activities identified as 'Fishing' in Figure 2 and shows a few notable trends. Specifically, i. the proportion of FAD sets immediately following transiting has generally increased over time from ≤12% between 2004-2010 to 20-30% in the last five years; ii. the proportion of free-school sets immediately following transiting activities modestly increased around 2010 from generally below 20% to between 25-35% (of activities that follow a transiting activity) ever since. Log sets have generally declined through time (see Vidal et al., 2024), so it is not surprising that this set type has decreased following transiting as well. The 'No set' category is the sum of non-fishing activities, and has remained fairly stable at ∼50% (shown also in Table A2).

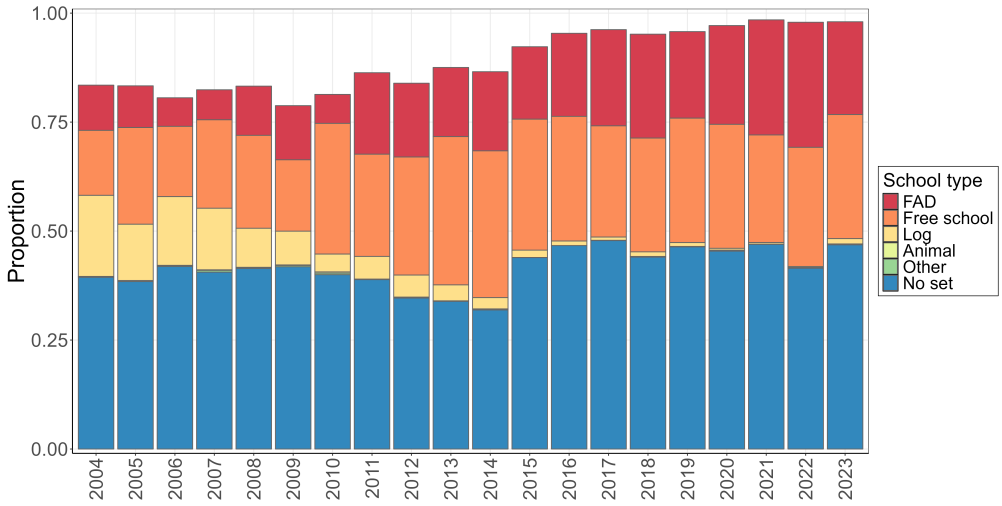

Figure 3: The proportion of set types reported after transiting, from 2004-2023

If we instead explore the activities that precede the main types of fishing sets (e.g., free school and FAD sets) we see that, on average, searching has decreased by almost 50% when comparing the average searching from 2004-2009 to that of 2020-2023 for FAD sets, whereas for free school sets, searching has decreased by about 33% when comparing the two time periods (Figure 4).

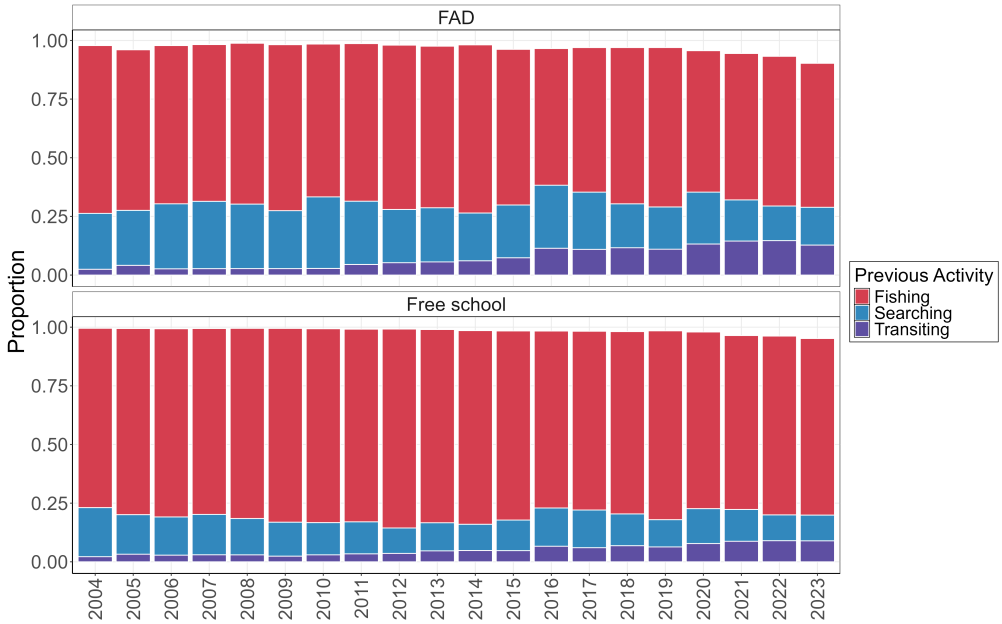

Figure 4: The proportion of the key activities (fishing, searching, and transiting) that preceded a free school or FAD sets, from 2004-2023. The missing portion of the plot accounts for Other activities.

These patterns highlight changes in reported behaviors leading up to a fishing set, but there have also been notable changes in setting activity through time. Specifically, around 2010, the year the

VDS was implemented, there is a marked change in the number of free school sets made; however, only a portion of these sets have been successful (approximately 40% throughout the time series). Figure 5 shows a step change in free school sets in 2010, but from 2010-2023, the total number of sets for both free school and FAD sets has remained fairly stable, albeit with inter-annual variability. Catches, however, have steadily increased since the beginning of the time series. The explanation for this apparent increase in free school sets is not clear but there are two hypotheses that may explain this change, at least in part: i. due to the FAD closure period, additional vessels (perhaps formerly FAD-oriented) shifted to free school sets for a portion of the year, and ii. given the implementation of effort controls on the fishery, perhaps additional opportunistic sets were made on days where some level of fishing activity had already been carried, to maximize effort within a fishing day (see Hamer et al., 2024 for additional detail).

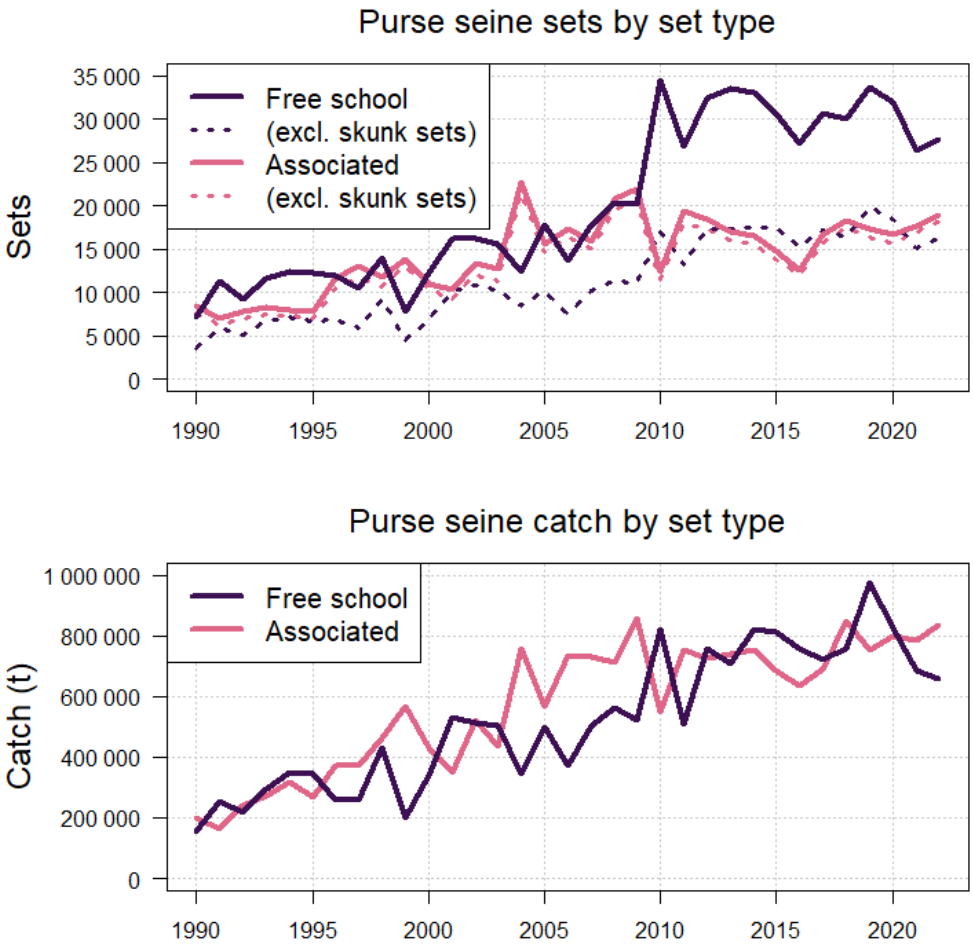

Figure 5: Purse seine sets and catch from 1990-2023

3 Observer data

Observer coverage in the tropical purse seine fishery is mandated to be 100%, and therefore the data collected by observers offers a robust source of independent information to compare to the logsheet-reported data. Observer data are more detailed and comprehensive than what is reported in the logsheet data; however, we can consolidate the observer data to a similar level (e.g., fishing/searching versus transiting or other non-fishing activities) to assess whether there is evidence of bias in what fishers are calling a fishing day versus what observers report as fishing-related activities.

When matched observer and logsheet trips were evaluated, 83-91% of days at-sea were reported consistently by both the logsheet and observer data as either a fishing day or a non-fishing day. However, there were some discrepancies where between 7-15% of the fishing days reported by observers were under-reported in the logsheet data, all fleets combined. There is also an indication of relatively minor over-reporting of fishing days in the logsheet data as compared to observer data but, generally less than 2% (noting some exceptional years during COVID when observer coverage was very low).

For the days where the observer activity log indicated activities associated with fishing but a non-fishing day was reported in the logsheet data, the observer-reported activities were dominated by searching (>50%). There was a suite of other less common activities reported, including investigating free schools or FADs, helicopter or drone use for searching for tuna schools, transhipping/bunkering, etc. There may not be consensus, however, on which activities reported by observers are considered fishing activities and which are not (see Table A1 for a full breakdown of activities reported and those considered as 'fishing' in this paper). This analysis is simply an initial exploration into activities reported to identify where potential changes in behaviour and/or reporting might be evident.

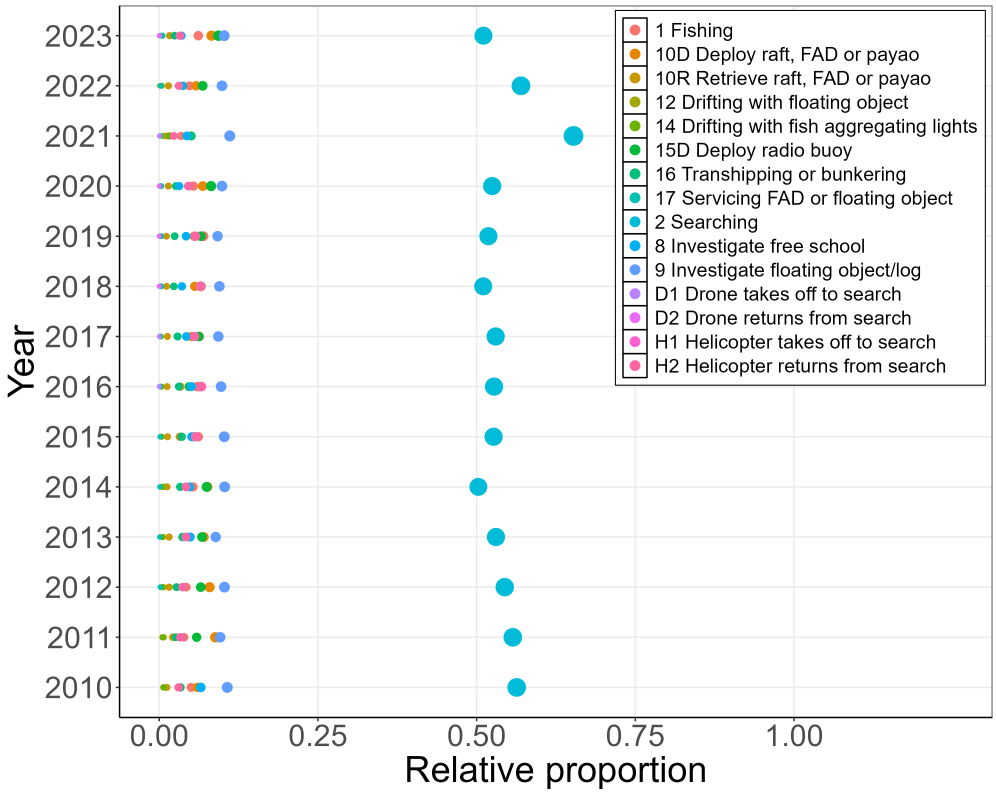

Figure 6: Proportion of fishing-associated activities reported by observers when the logsheet data suggested a non-fishing day, by year

4 VMS

Logsheet data is predicated on the interpretation and reporting of various activities by fishers, while at-sea (or in-port). VMS data on the other hand represents objective, standardized and automated reporting of vessel positions and activities, and serves as a valuable source of information to compare to the self-reported logsheet data. VMS data are largely available from 2010 onward, so the time series is shorter than those presented for logsheet data. It should be noted that the evaluation of VMS activity is based upon an algorithm that uses vessel speed ($<$ 9kt = fishing/searching; $\geq$ 9kt = transiting), and therefore, does not provide conclusive evidence of when a vessel is fishing versus when it is not, but given the polling frequency of VMS for the purse seine fishery, we have reasonably high confidence in the performance of the algorithm.

Figure 7 indicates that based on vessel activities recorded by VMS, there have not been notable changes in transiting activities for most fleets over the times for which VMS data are available. When we compare the VMS trends in transiting days to the same from logsheet data (Figure 8), there are some inconsistencies. Specifically, for some fleets, there has been an increasing trend in transit days since approximately 2010. In the most recent years, there appears to be a slight decline in transit days for the fleets that have shown an increasing trend over much of the time

series. This decline may be related to La Niña conditions in recent years when the fishery was more concentrated in the western region of the WCPO, potentially requiring less transit time to reach the fishing grounds.

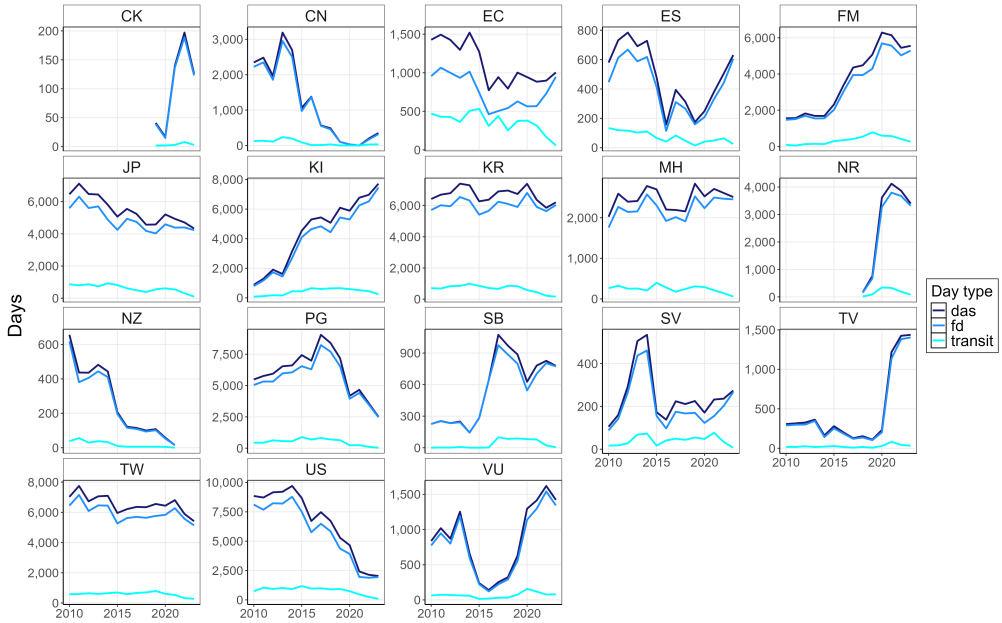

Figure 7: Days estimated from VMS using the purse seine effort algorithm, by year and fleet (das = day at sea; fd = fishing day; transit = a transit day). Note: total days at sea is the sum of fishing and transit days.

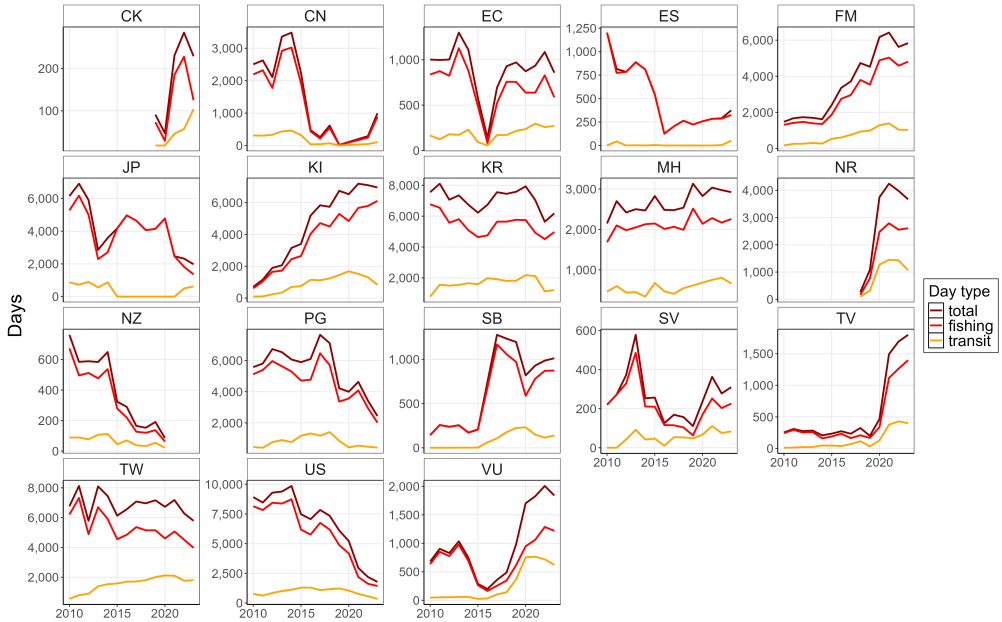

Figure 8: Unraised days calculated from purse seine logsheet data based on reported activities (i.e., a set and searching combined into fishing and other activities grouped into transiting). Note: total days at sea is the sum of fishing and transit days.

5 Management implications and considerations

The data summaries presented here suggest there has been some level of change in the reporting of searching versus transiting days; a change that may reflect the interpretation of 'searching' relative to modern fishing strategies (e.g., utilizing instrumented FAD buoys). To explore the potential implications for this apparent reduction in overall time classified as 'fishing' during fishing trips (with potential implications for the effort limits in CMM 2023-01), we have carried out an exercise to reclassify activities in the logsheet data, as detailed below, and recalculate fishing days. This is a simplistic approach to support the dialogue on this topic, recognizing that additional investigation and attention to the complexities associated with fishing strategy and reporting behaviors is warranted.

For illustrative purposes, if we assume that in fact, there are activities associated with 'searching' behaviour that may be under-reported in the logsheet time series, we can reclassify these activities and explore the potential impact that has had on overall effort. Similarly, we can assume that the VMS analysis is robust and use the estimated fishing days from the purse seine algorithm to compare to reported fishing days.

Table 1: A suite of scenarios highlighting potential changes in effort, in fishing days, based on different criteria to classify fishing activity. Descriptions of the logsheet-reported activities that have been reclassified as 'fishing' based on the sequence of activities are included along with the scenario for which those activities were included as fishing days in the calculation of total effort.

Activity	Explanation	Scenario
Baseline reporting	Sum of effort as reported as a set or searching	0
All days at sea	Consider all days minus the day of departure and day of return to port, as days fishing, unless the sum of reported fishing days is higher, in which case the higher value is used	1
Fish - Fish	Assume that if a vessel goes from one fishing set to another with only transiting activity in between, this activity is in fact searching, as it may be unrealistic to make a set without any searching	2,3,4
Transit - Fish	Similar to the logic for Fish - Fish, the assumption here is that it may be unrealistic to make a set without searching, direct from transiting behaviour	3,4
Boundary - Fish	For these records, it appears that fishing or searching activity has been declared just prior to or just after crossing a boundary. This may be a case of licensing. For example, if a vessel is not authorised to fish in a given area, they do not search nor fish there as a result. Even so, for this exercise (and in some scenarios), we will assume if a vessel was searching prior to crossing a boundary it is likely searching after crossing the boundary. Similarly, if a fishing set is made after crossing a boundary, the transiting prior to the boundary crossing is assumed ot be searching.	4

Table 2 details the estimated days of fishing effort from the tropical purse seine fishery under the

baseline reporting, and the four scenarios described above. Scenario 1 showed an increasing trend, relative to the baseline, with high inter-annual variability in estimated fishing days, potentially due to changing fleet dynamics, chartering arrangements, and environmental conditions. In addition, this scenario applied a fairly coarse procedure for estimation of days (total trip days - 2 to discount for the departure and return days, unless the sum of reported fishing days was higher, in which case that value was used). This approach is likely to introduce some bias with respect to vessels fishing closer to the departure and return ports as compared to those that are traveling longer distances to reach the fishing grounds. Further refinements could be made by incorporating the VMS data to better differentiate travel to the fishing grounds from subsequent transiting within a fishing trip. On average, the total days at sea have been approximately 32% higher than the reported logsheet fishing days since 2010 (approximately 26% higher in 2010 and 42% higher in 2023).

For the remaining scenarios 2-4, naturally there was an additive effect on the number of estimated fishing days with the subsequent inclusion of activities considered as fishing. All scenarios showed an increasing trend over time, relative to the baseline. In the last few years (2021-2023) purse seine effort under scenario 2 was estimated to be about 2% higher than reported under the baseline. There was negligible difference between scenarios 3 and 4 indicating that although boundary crossings are reported, it doesn't appear that a change in activity reporting (e.g., from transiting to searching) occurs when EEZ and/or EEZ/high seas boundaries are crossed. Together, scenarios 3 and 4 have shown a steady, but modest, increase over time, relative to the baseline reporting. In the most recent years, reporting as for scenarios 3 and 4 would have resulted in about a 5-6% increase in fishing days.

Table 2: Estimated fishing days under the baseline reporting conditions alongside the four proposed scenarios to reclassify purse seine fishing effort, by year from 2004-2023, using unraised logsheet data (excludes Indonesia, Philippines, and Vietnam)

Year	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2004	38,691	45,924	38,970	39,421	39,422
2005	38,996	47,792	39,378	40,103	40,103
2006	36,153	44,412	36,461	37,044	37,044
2007	39,123	48,115	39,472	40,126	40,126
2008	40,250	50,590	40,605	41,321	41,321
2009	41,768	54,061	42,043	42,754	42,754
2010	43,362	54,634	43,745	44,573	44,573
2011	48,065	58,586	48,666	49,738	49,738
2012	44,049	55,444	44,683	45,919	45,919
2013	44,707	58,585	45,440	46,915	46,915
2014	42,359	55,183	43,049	44,569	44,569
2015	36,016	48,736	36,524	37,665	37,665
2016	36,847	48,256	37,437	38,664	38,664
2017	43,013	54,067	43,782	45,022	45,043
2018	41,888	53,540	42,830	44,099	44,116
2019	38,940	51,501	39,671	40,950	40,990
2020	43,364	57,916	44,135	45,593	45,629
2021	40,749	56,483	41,669	43,110	43,192
2022	38,746	55,898	39,640	41,036	41,121
2023	38,097	54,250	38,875	40,037	40,150

The scenarios in this paper have been evaluated at a relatively coarse level, aggregating across fleets and spatiotemporal dynamics. Even so, there are indications of changes in fishing strategies used for the tropical purse seine fishery as well as changes in reporting of activities; the two are unlikely to be mutually exclusive. As with all effort-based management frameworks, continuous monitoring of effort is necessary to understand how efficiency of the effort metric upon which management measures are predicated changes through time. If, for whatever reason, the fishing mortality associated with a unit of fishing effort (here, days) evolves over time, re-evaluation of the effort limits, using contemporary information would be warranted. Failure to account for such changes in effective effort pose risks for achieving management objectives through effort controls.

6 Recommendations

This paper represents an initial approach to assess purse seine effort using reported and observed activities within the fishery. Further work to enhance our understanding of how contemporary fishing behaviors and strategies in conjunction with reporting requirements and behaviours may be influencing effective purse seine fishing effort is recommended. It is critical to understand how potential changes may be impacting the efficacy of the management framework.

- Review the logsheet reporting requirements to bring into alignment with how the fishery has evolved through time

- Further develop the VMS algorithms to improve upon the differentiation of fishing activities
- Explore how the FAD closure periods (including vessel exemptions) have influenced changes in fishing behaviour and reporting through time
- Evaluate if changes in behaviour and reporting vary between high seas and EEZ activity

7 References

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Appendix

Table A1: Summary of reported fishing activities in observer data from 2004-2023, with the Fishing column indicating which activities were considered as fishing days for these analyses

Activity	Frequency	Fishing
No code	218	
1 Fishing	822645	Fishing
2 Searching	284701	Fishing
3 Transit	203076	
4 No fishing - breakdown	16853	
5 No fishing - bad weather	10134	
6 In port	27051	
7 Net cleaning set	1093	
8 Investigate free school	308	
10D Deploy raft, FAD or payao	4429	
10R Retrieve raft, FAD or payao	15	
11 Drifting at day's end	2	
12 Drifting with floating object	25	
13 Other	18	
15R Retrieve radio buoy	237	
16 Transhipping or bunkering	77	
H1 Helicopter takes off to search	291	
23/24 Unknown	12	
51 Repairing net	655	
52 Enter EEZ	15563	
53 Exit EEZ	14723	
94 Confidential	27	
95 Bunkering	584	
96 At-sea transhipment	115	
97 In port - not unload or transhipment	720	
98 Searching (outside of EEZ)	177	
99 Outside EEZ	604	

Table A2: Description of activities included in the 'Other' category when evaluating activities that follow a transiting activity

Frequency	Activity
No code	57
12 Drifting with floating object	1
13 Other	1
16 Transhipping or bunkering	2
52 Enter EEZ	1428
53 Exit EEZ	2643
94 Confidential	6
95 Bunkering	162
96 At-sea transhipment	9
97 In port - not unload or transhipment	141
99 Outside EEZ	33