SCIENTIFIC COMMITTEE
SIXTEENTH REGULAR SESSION

ELECTRONIC MEETING
11-20 August 2020

Developing the monitoring strategy for the WCPFC harvest strategy for WCPO skipjack

WCPFC-SC16-2020/MI-IP-02

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Contents

Executive Summary

A monitoring strategy is a key element of a harvest strategy, as detailed in Annex 1 of Conservation and Management Measure 2014-06. A monitoring strategy has four main components: performance indicators; stock assessment; review of the management strategy evaluation (MSE) simulations; and exceptional circumstances.

This report outlines and describes these components for WCPO skipjack, with a particular emphasis on the calculation of the initial set of candidate performance indicators using current WCPFC databases. Similar monitoring strategies will be developed for the harvest strategies for South Pacific albacore, yellowfin and bigeye tuna.

When developing and testing candidate MPs, performance indicators are calculated from the results of MSE simulations to compare and contrast the expected relative performance of each candidate MP. When monitoring the performance of an adopted MP, performance indicators will be calculated from real-world observations to determine that the actual outcomes are within the range of values predicted by the MSE and are consistent with achieving agreed management objectives. The ability to calculate the desired indicators as part of the monitoring strategy depends on the necessary data being available. It is shown that most of the candidate monitoring strategy indicators for skipjack can be calculated using the current WCPFC databases. However, the indicators for the social objectives may require additional data to be collected. Additionally, some indicators that are expressed in non-specific terms need further development.

To the extent possible, the indicators used to monitor the performance of the adopted management procedure (MP) should be the same as those that were used to compare and select the MP from the results of MSE simulations. Where the monitoring strategy indicator is calculated in the same way as the indicator from the MSE simulations, they can be directly compared to evaluate whether the actual performance of the MP is consistent with that suggested by the simulations. To monitor the performance of the adopted MP using indicators that are different to the MSE indicators it will be necessary to develop ranges of acceptable performance for comparison, perhaps related to past performance. For example, the indicator that considers the level of bycatch will require a range of values to determine if the observed levels of bycatch are acceptable, or trending in an undesirable way.

We invite WCPFC-SC to consider the developments in the monitoring strategy for WCPO skipjack tuna. Specifically we invite SC16 to:

- Note the importance of continuing to develop monitoring strategies for WCPO tuna stocks;
- Consider whether performance indicators 2 and 9 should be retained in the initial candidate set of indicators given their possible overlap with other indicators;
- Decide whether it is necesary to develop ranges of acceptable values for monitoring strategy indicators that are not calculated within the MSE simulations;
- Provide clarification on the calculation of indicator 10 (monitoring of fisheries in CCMs).

1 Introduction

A monitoring strategy is a key element of a harvest strategy, as detailed in Annex 1 of Conservation and Management Measure 2014-06. During the harvest strategy development process a management procedure (MP) is selected and adopted by stakeholders on the basis that it is thought most likely to achieve the agreed management objectives for the fishery (Punt et al., 2014). The selection process is informed by performance indicators calculated from Management Strategy Evaluation (MSE) simulation results (Scott et al., 2019c, 2018; Yao et al., 2019). While the adopted MP is operating, there is a need to monitor the fishery and stock to check that the MP is performing as expected, particularly in relation to how well the agreed management objectives are actually being achieved. This is the role of the monitoring strategy.

For harvest strategies developed by the Western and Central Pacific Fisheries Commission (WCPFC), the adopted MP for each tuna stock will be used to set fishing opportunities at the Western and Central Pacific Ocean (WCPO) regional level based on estimates of the stock status. The revised harvest strategy work plan has scheduled the development of monitoring strategies for each stock (WCPFC, 2019; Scott et al., 2017, 2019a). The monitoring strategies may require the collection of new information and data. For example, monitoring economic objectives may require new economic information to be gathered. Discussions between FFA (Pacific Island Forum Fisheries Agency) and member countries are still ongoing on the guidelines of submitting and reporting the economic data.

A monitoring strategy has four main components (Figure 1):

- **Performance indicators** - to evaluate the actual performance of the MP and to compare the real performance of the fishery and stock to that expected from the MSE simulations;
- **Stock assessment** - to inform some of the performance indicators, particularly the biologically based ones;
- **Review of the MSE simulations** - to ensure that the data and assumptions that underpin the simulations used to select the MP remain appropriate;
- **Exceptional circumstances** - to identify situations that fall outside the range of assumptions over which the adopted MP has been tested.

This report outlines and describes the four main components of the monitoring strategy for WCPO skipjack, with a particular emphasis on the calculation of the initial set of candidate performance indicators using the current WCPFC databases. Similar monitoring strategies will be developed for the harvest strategies for South Pacific albacore, yellowfin and bigeye tuna.

This report:

- Outlines the main components of the skipjack monitoring strategy;
- Describes how the initial set of candidate performance indicators for the monitoring strategy can be calculated from the current WCPFC databases and provides examples where possible;

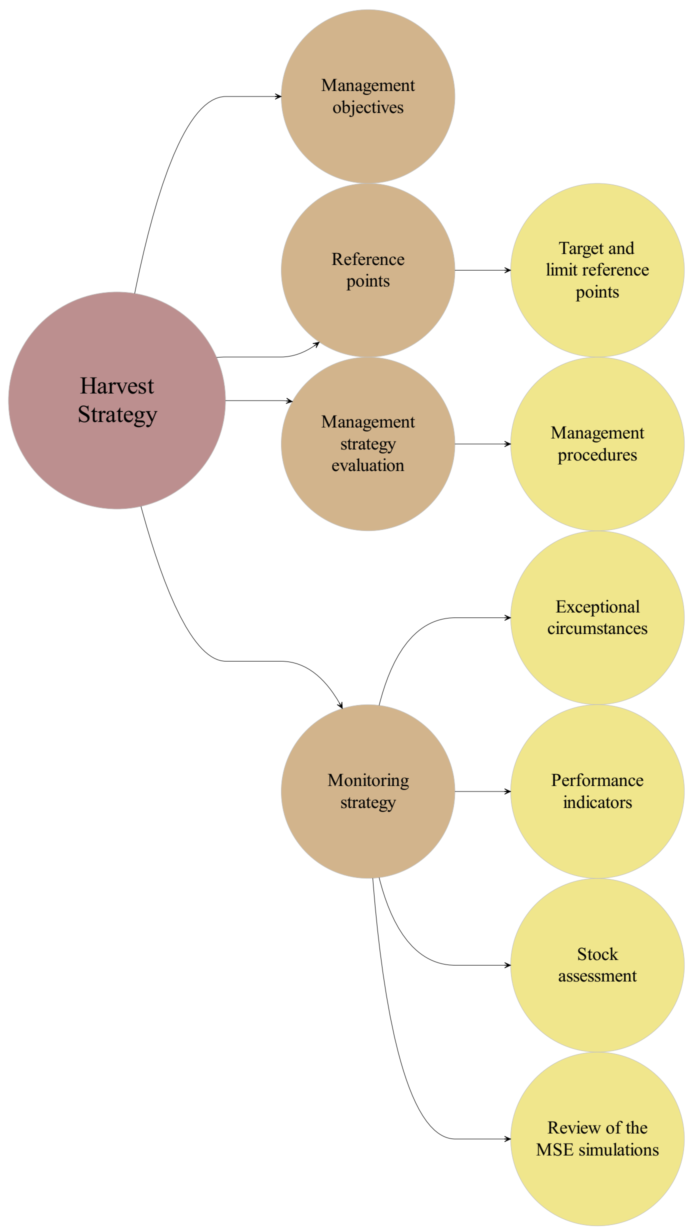

Figure 1: Harvest strategy conceptual diagram, showing how the monitoring strategy fits in with general harvest strategy process.

- Identifies where additional data collection may be necessary;
- Identifies where further refinement of candidate monitoring strategy indicators may be required.

2 Performance indicators

Performance indicators translate the high level, and often qualitative, management objectives into quantitative metrics that measure the performance of a harvest strategy in terms of achieving those management objectives. When developing and testing candidate MPs, performance indicators are calculated from the results of MSE simulations to compare and contrast the expected relative performance of each candidate MP (Scott et al., 2018; Yao et al., 2019). When monitoring the performance of an adopted MP, performance indicators will be calculated from real-world observations to determine that the actual outcomes are within the range of values predicted by the MSE and are consistent with achieving agreed management objectives (Scott et al., 2017, 2019a).

The indicators that can be calculated from the MSE simulations, including their level of aggregation, are limited by the operating models used in the simulations, for example the spatial structure and the way that fisheries are represented (Scott et al., 2019c). The monitoring strategy has access to a wide range of real-world data meaning it may be possible to include additional information when calculating performance indicators for the monitoring strategy. However, to the extent possible, the performance indicators used to monitor the performance of the adopted MP should be the same as the performance indicators that were used to compare and select the MP from the MSE simulations.

In this section we:

- Describe the initial set of candidate monitoring strategy indicators for the WCPO skipjack / tropical purse seine harvest strategy;
- Describe the currently available data for calculating these indicators;
- Describe how these indicators can be calculated;
- Identify potential issues for calculating the indicators using the currently available data.

2.1 The initial set of candidate monitoring strategy indicators

For the purpose of developing and testing candidate MPs for skipjack, an initial set of candidate performance indicators, for both the MSE simulations and the monitoring strategy, have been proposed in relation to management objectives for the tropical purse seine fishery (Table 1) (Scott et al., 2018; WCPFC, 2017). This intial set of performance indicators can continue to be developed through the harvest strategy process through stakeholder input, depending on the availability of appropiate data.

PI	Type	Objective	MSE Indicator	Monitoring Strategy Indicator
1	Biological	Maintain SKJ (and YFT and BET) biomass at or above levels that provide fishery sustainability throughout their range	Probability of estimated $SB/SB_{F=0} > 0.2$.	Probability of SB/SBF=0 > 0.2.
2	Economic	Maximise economic yield from the fishery.	Predicted effort relative to EMEY (to take account of multi-species considerations, BET and other spp; may be calculated at the individual fishery level). BMEY and FMEY may also be considered at a single species level.	Observed effort in the fishery relative to EMEY.
3	Economic	Maximise economic yield from the fishery.	Average expected catch (may also be calculated at the assessment region level).	Observed catch information.
4	Economic	Maintain acceptable CPUE.	Average deviation of predicted SKJ CPUE from reference period levels.	Observed CPUE maintained at or greater than specified levels.
5	Economic	Take into account the special requirements of developing states and territories.	Proxy: average value of SIDS/non-SIDS catch.	Observed proportion of SIDS effort / catch to total effort / catch from SIDS waters from logsheet or VMS data.
6	Economic	Catch stability	Average annual variation in catch.	Observed variation in catch from logsheet data.
7	Economic	Stability and continuity of market supply.	Effort variation relative to reference period level (may also be calculated at the assessment region level).	Observed effort levels from log-sheet or VMS data.
8	Economic	Maintain SKJ, YFT, BET stock sizes around TRPs (where adopted).	Probability of and deviation from SB/SBF=0 > 0.5 (SKJ) in the short-, medium- and long-term as determined from MSE (may also be calculated at the assessment region level).	Current median adult biomass, as determined from the reference set of Operating Models.
9	Social	Food security in developing states (import replacement)	Proxy: average proportion of CCMs-catch to total catch for fisheries operating in specific regions.	Ratio of locally marketed fish to imported fish products.
10	Social	Avoid adverse impacts on small scale fishers	MSY of SKJ, BET, YFT. Possible information on other competing fisheries targeting SKJ (may also be calculated at the assessment region level). Any additional information on other fisheries / species as possible.	Monitoring of fisheries in CCMs.
11	Ecosystem	Minimise bycatch	Number of FAD sets; Expected catch of other species.	Ratio of target species catch to catch of non-target species from observer program.

Table 1: Summary of the current working set of performance indicators and associated management objectives for the tropical purse seine skipjack tuna fishery (WCPFC, 2017).

2.2 Data availability

The monitoring strategy indicators that are based on stock status and sustainability (performance indicators 1 and 8) will require estimates of stock status to be determined from a stock assessment (see Section 3). No major data deficiencies have been identified for these indicators (Scott et al., 2017). However, it is noted that it is unlikely that assessments will be performed on an annual basis and instead these indicators may be calculated every two or three years.

Many of the economic monitoring strategy indicators use catch and fishing effort data (indicators 3, 4, 5, 6 and 7). These data can be taken from the WCPFC databases, which includes the integrated regional tuna fishery databases. The sources of data are the SPC member countries, but also the WCPFC countries that are not SPC members (including the distant-water fishing nations). These databases primarily comprise:

- Annual catch estimates;
- Aggregated catch and effort logbook data, stratified by time (Year/Month) and area (1x1 degrees for purse seine and pole and line fisheries and 5x5 degrees for longline fisheries);
- Operational catch and effort logbook data;
- Aggregated size (length and weight frequency) data.

The catch and effort data are considered to be comprehensively recorded meaning that it is possible to calculate these indicators at a variety of levels of aggregation (for example, spatial, temporal and fishing gear) (Scott et al., 2017). For more details on the structure of the database and the levels of aggregation see Appendix A.

It was agreed by WCPFC that performance indicator 2 would not be considered further as an indicator for the MSE simulations (WCPFC, 2018). This was because the MSE simulations do not explicitly consider economics and therefore estimating MEY within the model would be challenging and requires many additional assumptions. Additionally, it was noted that indicator 3 addresses the same management objective (maximise economic yield from the fishery). The use of MEY based indicators for the monitoring strategy considered here may be possible but requires many assumptions to be made (Scott et al., 2017). Given that indicator 2 requires many assumptions to be made and that the management objective is already addressed by performance indicator 3 it may not be necessary to retain it in the suite of monitoring strategy indicators. As such, this indicator is not considered further here.

The two social objectives are concerned with food security in developing states and avoiding adverse impacts on small scale fishers (indicators 9 and 10) (Table 1). Data availability for calculating the monitoring strategy indicators associated with these objectives was summarised as 'data partially available' or 'data absent', depending on the method and the scale at which they are to be calculated (Scott et al., 2017). This means that alternative data sources may be required to monitor these social objectives. It was noted that these social objectives appear to be a key potential gap within the monitoring strategy that will need to be considered in more detail.

The candidate ecosystem objective focuses on minimising the catch of non-target species (indicator 11) (Table 1). Recording catch of key non-target species occurs through logsheet submissions and data collection through the relevant WCPO observer programmes. However, observer coverage can vary substantially between fisheries in the WCPO. Data availability can be summarised as 'data partially available' or 'data absent', depending on the method and the scale at which they are to be calculated (Scott et al., 2017). It is noted that recent developments in e-monitoring and e-reporting may lead to substantial improvements in both the quantity and quality of data collected for key non-target species.

We note that FFA or SPC has not been tasked by the WCPFC or associated bodies to collect economic data. Our understanding is that FFA would be assisting members to facilitate agreement by CCMs to the establishment of guidelines that could be used if they wished to submit economic data to the Commission. With regard to this work on developing guidelines, we are informed by the FFA that at SC15 the proposed guidelines developed based on agreed principles were not accepted and the SC "recommended that further intersessional work be undertaken to further develop such guidelines and any associated documents required with regard to the confidentiality and use of any economic data provided under this process". There has been no further progress on this, and as such explicit economic performance indicators cannot be included at this stage, however we note that proxies such as CPUE and size frequencies could be utilised based on equating these to specified economic objectives.

2.3 Calculating monitoring strategy indicators

When monitoring the performance of the MP it is important to be able to compare the expected outcomes from the MSE simulations to the real-world observations. To the extent possible, the performance indicators in the monitoring strategy should be the same as the indicators from the MSE simulations. For many of the indicators in Table 1, the monitoring strategy indicator is identical or very similar to the MSE simulations indicator (indicators 1, 3, 4, 6, 7 and 8).

The monitoring strategy indicators 1 and 8 can be calculated using results from stock assessment (see Section 3). It is possible to derive the same information from the MSE simulations allowing direct comparison. These indicators are not calculated here but can be obtained from the most recent stock assessment.

Indicators 3, 4, 6 and 7 can be calculated for both the MSE simulations and the monitoring strategy (see Appendix B). The geographical resolution and structure of fisheries in the MSE simulations are the same as those in the 2019 skipjack stock assessment (Vincent et al., 2019). This limits the level of aggregation (spatial, temporal and fishery) that the MSE simulation indicators can be presented at. For the monitoring strategy, these indicators may be calculated at finer levels of aggregation, depending on the availability of data. For example, it would be possible to calculate these monitoring strategy indicators at a finer resolution of spatial aggregation. However, this would mean that the indicators in the monitoring strategy and MSE simulations do not directly correspond making comparison difficult. In this report the example calculations for the monitoring strategy indicators 3 and 4 are carried out over the same regions and fisheries as the MSE simulations (See Appendix B). Indicators 6 and 7 are based on variability of catch and effort which have additional considerations when calculated for the monitoring strategy, as discussed below.

Where the indicators for the monitoring strategy and MSE simulations are not the same, the MSE simulation indicators are proxies for their monitoring strategy counterpart. This is because the necessary information required for their calculation is not included in the models used for the MSE simulations. The management strategy and MSE simulation indicators may measure different things but both are attempting to reflect the associated management objective.

When proxies are used it is not possible to directly compare the monitoring strategy indicators to those from the MSE simulations. It may therefore be necessary to develop a range of acceptable values for the monitoring strategy indicators to evaluate whether the performance of the MP is acceptable. For example, performance indicator 11 for the monitoring strategy calculates the ratio of target species catch to catch of non-target species. The same indicator for the MSE simulations calculates the number of FAD sets (it is not possible to get the catch of bycatch species from the MSE simulations)(Scott et al., 2018). The MSE simulations indicator contributes towards the MP selection process but is clearly different to the monitoring strategy indicator. For the monitoring strategy indicator to be useful, an acceptable range of values will need to be developed (e.g. what ratio of target species catch to non-target species catch is too small?).

When the monitoring strategy indicator is different to the MSE simulations indicator, it may still be worth calculating the MSE simulations indicators with real data as a further check on the actual performance of the MP.

The MSE simulation indicators 5 and 9 are proxies for their monitoring strategy counterparts (Table 1). It is not currently possible to calculate indicators 5 and 9 for the MSE simulations as the information for attributing catches to Exclusive Economic Zones (EEZs) or CCMs is not available in the modelling framework (Scott et al., 2018).

Calculating indicator 5 for the monitoring strategy requires identifying the total catches and effort inside SIDS EEZs and also identifying what proportion of that catch and effort is from SIDS fishing activity. To attribute the catches and effort to SIDS EEZs requires the data to be reported at an appropriate spatial scale. The purse seine data are currently reported at 1x1 degrees which means it is possible to attribute this WCPO wide data to individual EEZs. In the example indicator calculated in Appendix B.3, flag data are used to attribute the SIDS EEZ catches and effort to SIDS fishing activity. The flag data takes into account data from country flagged vessels fishing inside SIDS EEZs and takes into account the attribution of catch and effort to the chartering nation.

The management objective for indicator 5 takes into account the special requirements of developing states and territories. An alternative indicator for the MSE simulations that focuses on this objective will be developed in the future and will become increasingly important when mixed fishery interactions are considered (Scott et al., 2020a). It is worth noting that some of the concerns about the disproportional impact of the harvest strategy on SIDS will be considered by allocation processes which are outside of the harvest strategy process. It is anticipated that the MP for skipjack will apply to the WCPO region. The current MSE simulations operate under the assumption that the MP will affect all fisheries in this region equally, through proportional changes to catch or effort, relative to a base period (Scott et al., 2019d,c). In this way, the actions of the MP will not be directly responsible for any disproportionate burden of conservation actions on SIDS.

Indicator 9 is specifically concerned with food security in developing states. In the monitoring strategy it is measured as the ratio of locally marketed fish to imported fish products. Food security in developing states is a very important issue. However, there is possible overlap between indicator 9 and other indicators. For example, if current estimated level of $SB/SB_{F=0}$ is considered to be sustainable (as measured by indicators 1 and 8) then it could be assumed that impacts on food security are minimised. This means that it may not be necessary to retain this indicator in the suite of monitoring strategy indicators and is not considered further here.

Performance indicator 10 focuses on avoiding adverse impacts on small scale fishers and is measured in different ways for the monitoring strategy and the MSE simulations. The indicator for the MSE simulations uses MSY of the different stocks as a proxy (Table 1). The monitoring strategy indicator is currently very vague ("Monitoring of fisheries in CCMs."). Ideally this indicator should be more specific in terms of what is actually being calculated, as well as a range of acceptable values. As such, an example monitoring strategy indicator has not been calculated here. As mentioned above, alternative data sources may be required to monitor the social objectives.

Performance indicator 11 is concerned with the minimisation of bycatch. As a proxy, the MSE simulations indicator measures the number of FAD sets (an output from the model). This is because the MSE simulations do not include information on other species. The monitoring strategy indicator looks at the catches of non-target species from the observer program. As with other monitoring indicators that are calculated differently to the MSE simulations indicators, it will be necessary to develop a range of acceptable values that can be used to evaluate the performance of the MP. Although non-target species are included in the WCPFC databases, the historical data are poorly reported and so is not presented here. There have been recent improvements in reporting of bycatch species (e.g. key shark species) from observer programs and some other common bycatch species (e.g wahoo and mahi-mahi) from logbook reporting which is highly variable and fleet dependent. As noted above, the recent developments in e-monitoring and e-reporting may lead to substantial improvements in both the quantity and quality of data collected for key non-target species This means that this indicator can be calculated for the monitoring strategy in the future.

For the monitoring strategy to be useful it is necessary that the data are collected and considered in a timely manner. The indicators for the MSE simulations are presented in different ways, including as averages over three different periods (short-, medium- and long-term) and as time series (Scott et al., 2018, 2019b). Although the monitoring strategy indicators can be calculated in the same way, this would be of limited use as monitoring information needs to be presented in a timely manner. Instead considering the recent time series of the indicators will be more important. However, for some indicators, calculating time series are less appropriate, in particular, indicators 6 and 7 which are based on the variability of catches and effort respectively. This means that additional methods for calculating and presenting these indicators should be considered. For example, observed absolute changes in catches or effort can be compared to some average value in the past. It is worth noting that it is possible to include additional rules with the MP that limit the variability of the output, for example, by restricting the MP output to be no more than 15% different from the previous output.

2.4 Summary of calculating monitoring strategy indicators

The monitoring strategy indicators and whether they can be calculated using the current WCPFC databases are summarised in Table 2.

PI	Monitoring strategy indicator	Possible to calculate	Comments
1	Probability of estimated SB/SBF=0 > 0.2	Yes	Estimated using stock assessment.
2	Observed effort in the fishery relative to EMEY.	May require additional economic data and assumptions	Not calculated for MSE simulations and may not be needed for monitoring as indicator 3 covers the same objective.
3	Observed catch information	Yes	Can be calculated at same or alternative levels of aggregation as MSE indicator.
4	Observed CPUE maintained at greater than specified levels	Yes	Can be calculated at same or alternative levels of aggregation as MSE indicator.
5	Observed proportion of SIDS effort / catch to total effort / catch from SIDS waters	Yes	Requires identifying catches and effort of SIDS and in SIDS EEZs.
6	Observed variation in catch from logsheet data.	Yes	Requires definition of acceptable range of variability.
7	Observed effort levels from log-sheet or VMS data.	Yes	Can be calculated at same or alternative levels of aggregation as MSE indicator.
8	Current median adult biomass	Yes	Estimated using stock assessment.
9	Ratio of locally marketed fish to imported fish products.	May require alternative data sources	Overlaps with other indicators so possibility of dropping.
10	Monitoring of fisheries in CCMs	May require alternative data sources	More specific indicator is required.
11	Ratio of target species catch to catch of non-target species from observer program.	In the future	Possible to calculate in the future given increase in monitoring.

Table 2: Summary of the initial set of monitoring strategy indicators and whether they can be calculated using the current WCPFC databases.

3 Routine stock assessment

While the MP is operating, the status of the stock will still be routinely assessed. These stock assessments will be performed using the most up-to-date stock assessment models and data and represent the best available science. It is important to note that these stock assessments are not the same assessments that may be part of a model-based MP (such as the one proposed for the skipjack MP) which provide inputs to the harvest control rule.

The routine stock assessments serves two purposes within the monitoring strategy:

- Check whether the grid of operating models used to generate the MSE simulation results is still valid (see Section 4);
- Provide data to calculate the performance indicators that require a stock assessment (indicators 1 and 8 in Table 1).

4 Reviewing the MSE simulations

The selection process of the MP will have been informed by performance indicators calculated from the MSE simulation results. While the adopted MP is operating it is necessary to periodically review the validity of the MSE simulations. This is to ensure that the data and assumptions (e.g. the distribution of fishing effort across the model regions) that were used to test and select the MP remain appropriate (Scott et al., 2019d). As new data become available or as the dynamics of the fishery change over time it may be necessary to revise the design and assumptions of the modelling framework, including the sources of uncertainty.

As mentioned above, routine stock assessments will continue to be performed while the MP is operating. As such, they may be different from the grid of operating models that were used in the MSE simulations. The grid of operating models represents the range of uncertainties that the candidate MPs are tested against and it is important that all plausible sources of uncertainty are considered. The routine stock assessments will also be conducted over a grid of uncertainty (for example, see Vincent et al. (2019)). As the routine stock assessments represent the best available science, it is important that the range of uncertainty they cover is also covered by the grid of operating models. If not, it means that the operating models do not sufficiently cover the full range of plausible uncertainties and it may be necessary to review the MSE simulations. This includes possibly reconditioning the operating models and rerunning the MSE simulations to see if the adopted MP is still the most appropriate choice.

For example, the range of $SB/SB_{F=0}$ covered by the proposed grid of operating models for the skipjack MSE evaluations is equal to the range from the 2019 stock assessment, suggesting that the proposed grid of operating models adequately covers the range of uncertainty (Figure 2) (Scott et al., 2020b).

5 Exceptional circumstances

A key part of the monitoring strategy is the identification and agreement by stakeholders of situations within the fishery or stock that are termed ‘exceptional circumstances’ (Scott et al., 2019a). In general terms, exceptional circumstances are events that fall outside the range of assumptions

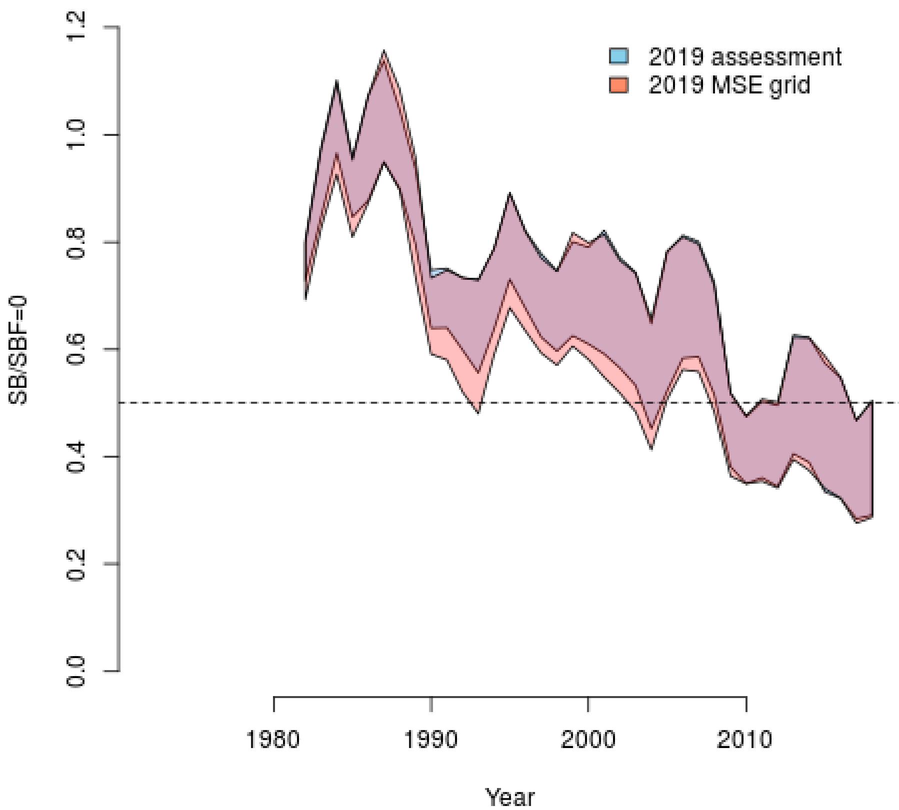

Figure 2: Comparing the range of estimated depletion from the 2019 skipjack operating model grid to that from the 2019 stock assessment.

over which the adopted MP has been tested. They may also include situations where the trajectory of the stock has not responded as expected to management action, for example, if biomass has fallen below the limit reference point, catches continually exceed some upper threshold, or general behaviour of the fishery is substantially different to that expected from the simulation testing.

The monitoring strategy should outline, in broad terms, the process for determining whether exceptional circumstances exist and the necessary action that should be taken in the event that they do exist. Exceptional circumstances should be agreed prior to implementation of the selected MP and be defined in broad terms. The MSE expert consultation workshops have stressed the importance of discussing exceptional circumstances throughout the consultation process and to highlight that in spite of our best predictions the future remains uncertain and that the MSE should not be considered a crystal ball (Scott et al., 2016).

If exceptional circumstances occur it will be necessary to revisit the MP and determine future action. In the event that the MP deviates significantly from expected performance it may be necessary to re-evaluate the adopted MP or, in severe cases where there is considered to be a risk to the stock, take remedial action.

6 Summary

This paper summarises the main components of a monitoring strategy. There is particular emphasis on whether the initial proposed set of indicators for the skipjack monitoring strategy can be calculated using the current WCPFC databases. It is important that the monitoring strategies for the WCPO tuna stocks continue to be developed as other work on the harvest strategies progresses.

7 Acknowledgments

We gratefully acknowledge funding for this work from the New Zealand Ministry of Foreign Affairs and Trade (MFAT) funded project “Pacific Tuna Management Strategy Evaluation”.

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A Structure of the WCPFC databases

The WCPFC databases are essentially integrated into a single database called LogMaster. Inside this database, catch and effort data is available by several factors including time, gear and location. The database uses codes to refer to different gear types (Table 3).

Table 3: Gear codes used in the LogMaster data.

Gear code	Gear
A	All gears
S	Purse seine
P	Pole & line
L	Longline
G	Driftnet
T	Troll
R	Ringnet
H	Handline
O	Unclassified
K	Hook & line

The purse seine and pole and line tables provide catch and effort data at 1x1 degrees of geographic resolution. This level of resolution means that it is possible to approximately attribute these data to individual Exclusive Economic Zones (EEZs).

The purse seine data is further broken down by an association code which ranges from 0 - 9, depending on the type of Floating Aggregation Device (FAD) (Table 4).

Table 4: FAD association codes used in the LogMaster data.

Schass Code	Association
0	No code
1	Unassociated
2	Feeding on baitfish
3	Drifting log, debris or dead animal
4	Drifting raft, FAD
5	Anchored raft, FAD
6	Live whale
7	Live whale shark
8	Other
9	No tuna associated

For this analysis we aggregate the purse seine data into two categories: associated (codes: 0 and 3 to 9) and unassociated (codes: 1 and 2). In LogMaster purse seine effort is reported as number of sets and number of days. For this analysis we use number of sets.

The all gear tables include catch and effort data for all gear types. The purse seine data in these tables is not broken down by association code. The data in the all gear tables is only available on a 5x5 degrees of geographic resolution which means it is not possible to directly attribute these data to individual EEZs.

To allow comparison with the results of the MP evaluations, the data has been attributed to the different stock assessment model areas, based on the 8 area model from the 2019 stock assessment (Vincent et al., 2019). The area outside the stock assessment areas is excluded from the analysis. At the time of writing, the 2019 LogMaster data is still provisional, hence it is not included in this analysis.

For some of the performance indicators it is necessary to identify which catches are from Small Island Developing States (SIDS), Non-SIDS and High Seas (Table 5). These categories are only available for the purse seine and pole and line data due to the geographic resolution.

Table 5: Designation of SIDS in the LogMaster data.

SIDS	Non-SIDS
Cook Islands	Indonesia
Fiji	El Salvador
Tuvalu	Howland & Baker
Tonga	Philippines
Tokelau	Palmyra
Nauru	Vietnam
Niue	Australia
Solomon Islands	China
Vanuatu	Japan
Kiribati Islands	Wake Atoll
Federated States of Micronesia	Hawaii
Samoa	New Zealand
Marshall Islands	Korea
Papua New Guinea	USA
Palau	Taiwan
Gilbert Island	Ecuador
Phoenix Island	European Union
Line Island	
New Caledonia	
French Polynesia	
Wallis and Futuna	
American Samoa	
Guam	
Northern Mariana Islands	

B Example calculations of performance indicators for the monitoring strategy

Here we demonstrate how performance indicators can be calculated for the monitoring strategy using the currently available data in the LogMaster database.

As mentioned in the main text, the performance indicators from the MSE simulations are sometimes presented as the averages over three periods. This method of presentation is not appropriate for indicators from the monitoring strategy as it requires the most up-to-date information to monitor the performance of the adopted MP.

Most of the calculated monitoring strategy indicators are presented as time series. However, indicators 6 and 7 consider the variability of catch and effort and it is less useful to present these as a time series. Instead, the average absolute annual change in catch and effort is calculated over a recent average. As future monitoring data is collected it can be compared to this recent average.

Performance indicators 1 and 8 are calculated using information from the most recent stock assessment and are not included here. As mentioned in the main text, we do not calculate example indicators for performance indicators 2, 9, 10 or 11 here.

All calculations were carried out using R (R Core Team, 2020).

B.1 Performance indicator 3: Expected average catch

Performance indicator 3 (average expected catch) can be calculated across the whole stock assessment region, as well as for each of the individual stock assessment areas. The catches can also be disaggregated by gear type, with the catches from purse seine being further disaggregated as either associated or unassociated.

The results from the MSE simulations are currently being presented as:

- Total catch from all gears in all regions;
- Total catch from all gears by stock assessment model region;
- Purse seine catches in stock assessment model regions 6, 7 and 8.

It is possible to calculate the monitoring strategy indicator in the same way to allow direct comparison with the expected results from the MSE simulations (Figure 3).

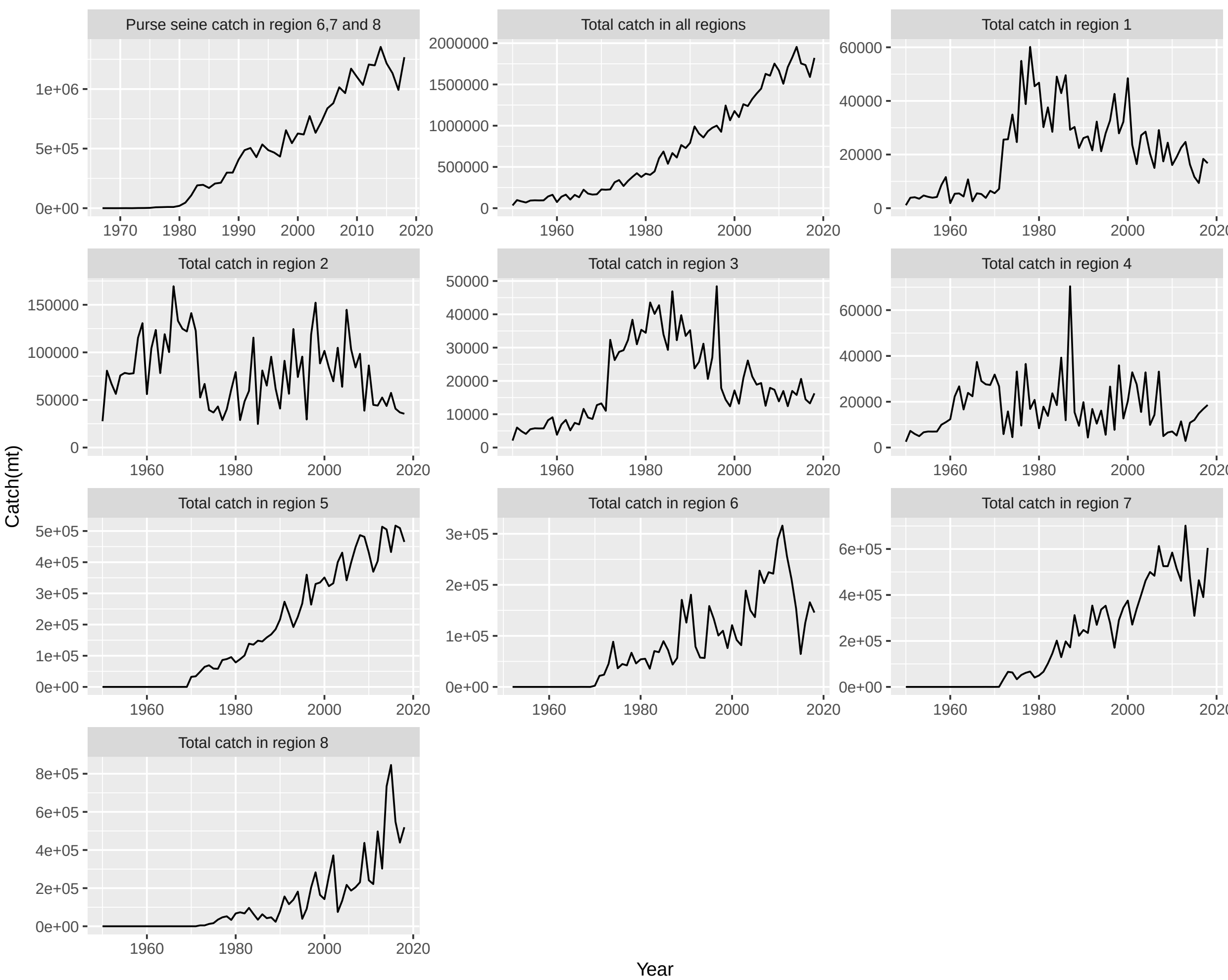

Figure 3: Performance indicator 3. Catches for different combinations of stock assessment areas and gears.

B.2 Performance indicator 4: Average deviation of predicted SKJ CPUE from reference period levels

This indicator calculates the catch per unit effort (CPUE) relative to the reference period. The reference period here is the year 2012, as used in the skipjack MSE simulations.

For the MSE simulations, this indicator is only calculated for the purse seine fisheries operating in stock assessment regions 6, 7 and 8 (excluding the associated purse seines in region 6, which has standardised effort for modelling purposes). For the monitoring strategy it is possible to calculate this indicator in the same way to allow for direct comparison. In LogMaster, the purse seine effort is recorded as the number of sets as well as fishing days. Here we use number of sets, which is also used in the MSE simulations.

As an example, here the indicator is calculated for regions 6, 7 and 8 in each year excluding the associated fishery in region 6 to replicate the MSE simulation performance indicator (Figure 4). A similar calculation could also be performed for the pole and line fishery in region 2.

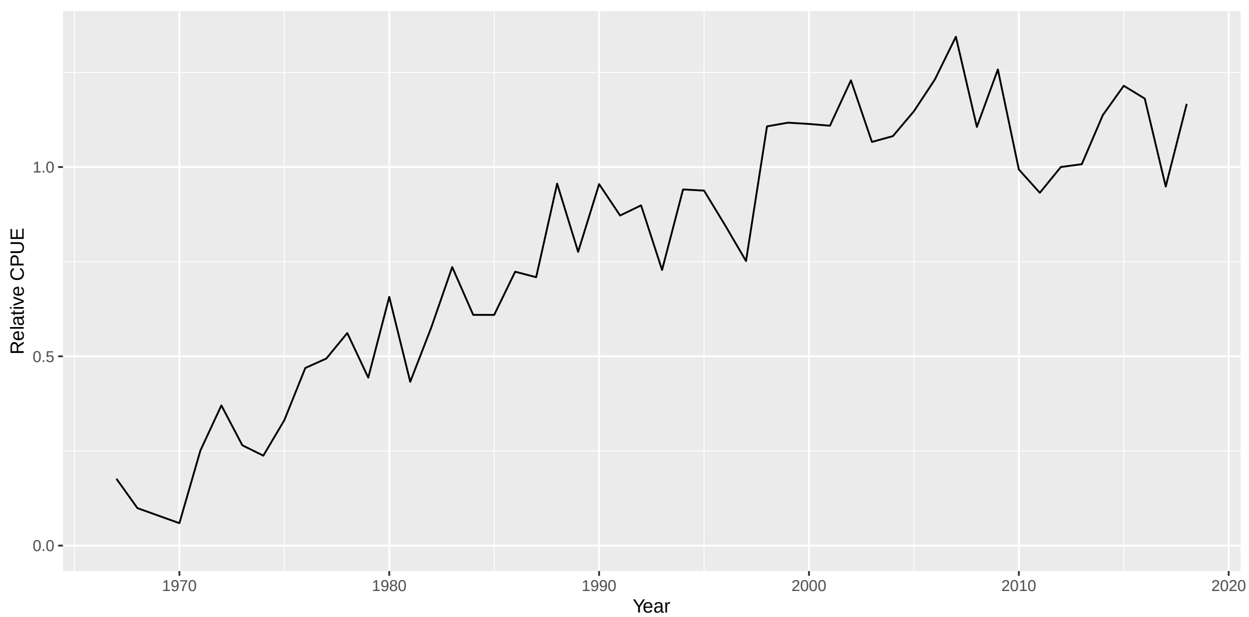

Figure 4: Performance indicator 4. CPUE relative to the CPUE in 2012 for purse seines in stock assessment regions 6, 7 and 8, excluding the associated purse seine in region 6.

B.3 Performance indicator 5: Maximise SIDS revenues from resource rents

This indicator is related to CMM 2014-06 which considers special requirements of developing states. The developed harvest strategies should not have a disproportionate burden of conservation actions on SIDS. As noted in the main text, the monitoring strategy indicator is different to the MSE simulations indicator (Table 1).

The monitoring strategy indicator is based on the observed proportion of SIDS effort and catches to the total effort and catches from SIDS EEZs. To calculate this indicator it is necessary to extract only the effort and catches in SIDS EEZs from the LogMaster database. As noted above, it is possible to approximately attribute purse seine effort and catches to EEZs.

The proportion of total skipjack catch caught in SIDS EEZs, Non-SIDS EEZs and High Seas by the purse seine fishery can be seen in Figure 5 and the proportion of purse seine effort (measured as number of sets) can be seen in Figure 6.

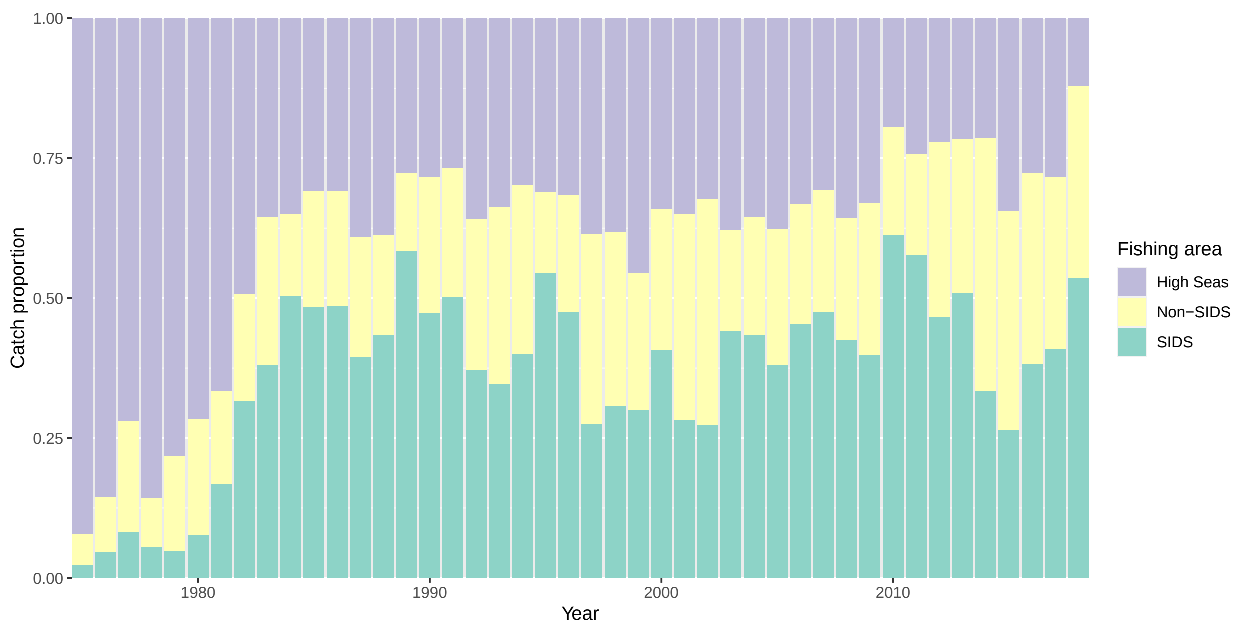

Figure 5: Proportion of total skipjack catch caught in SIDS EEZs, Non-SIDS EEZs and High Seas by the purse seine fishery.

To calculate the monitoring strategy indicator, the effort and catches in SIDS EEZs need to be attributed to those that came from SIDS and non-SIDS fishing activity. Here we use the *Flag* column of the LogMaster database to identify which of the vessels fishing in SIDS EEZs have SIDS flags.

The flags are split into SIDS and non-SIDS according to Table 5. The proportion of skipjack catches taken by SIDS and non-SIDS flags in SIDS EEZs can be seen in Figure 7 and the proportion of purse seine effort (number of sets) made by SIDS and non-SIDS flags in SIDS EEZs can be seen in

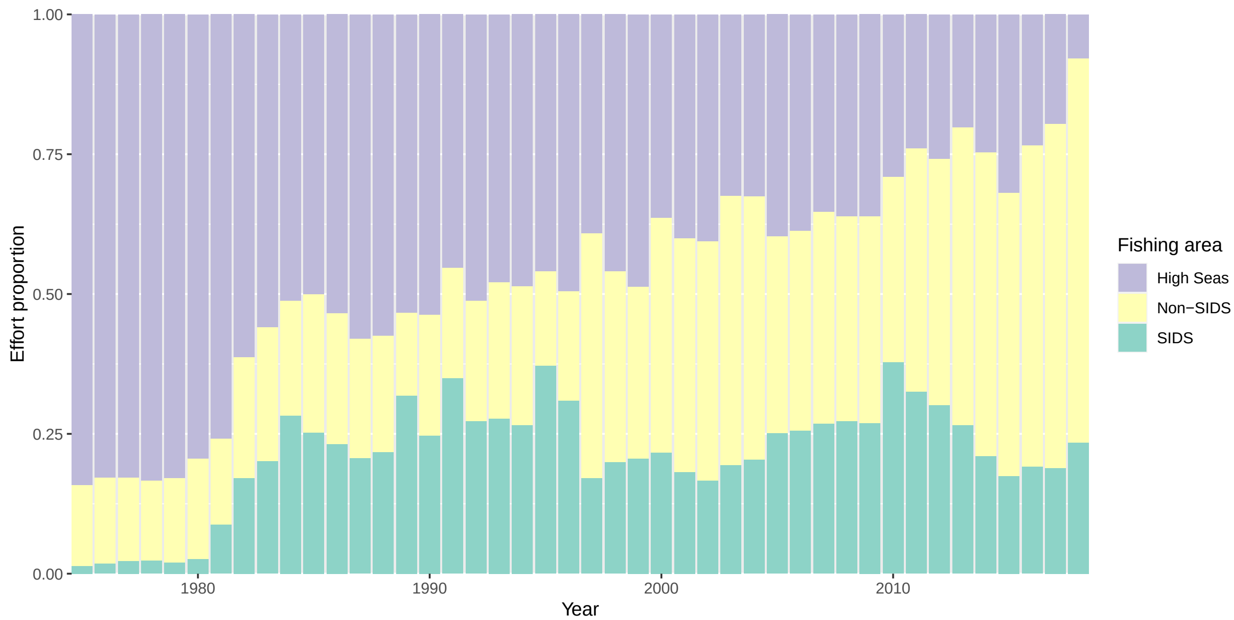

Figure 6: Proportion of total purse seine effort (number of sets) in SIDS EEZs, Non-SIDS EEZs and High Seas.

Figure 8. Any disproportionate burden would be reflected by the proportion in each year attributed to SIDS and non-SIDS flags.

This type of calculation is currently only possible for purse seine and pole and line fishery because their data can be approximately attributed to EEZs given the 1x1 degrees geographical resolution of the data. A similar calculation can also be done for other target species, including bigeye and yellowfin tuna.

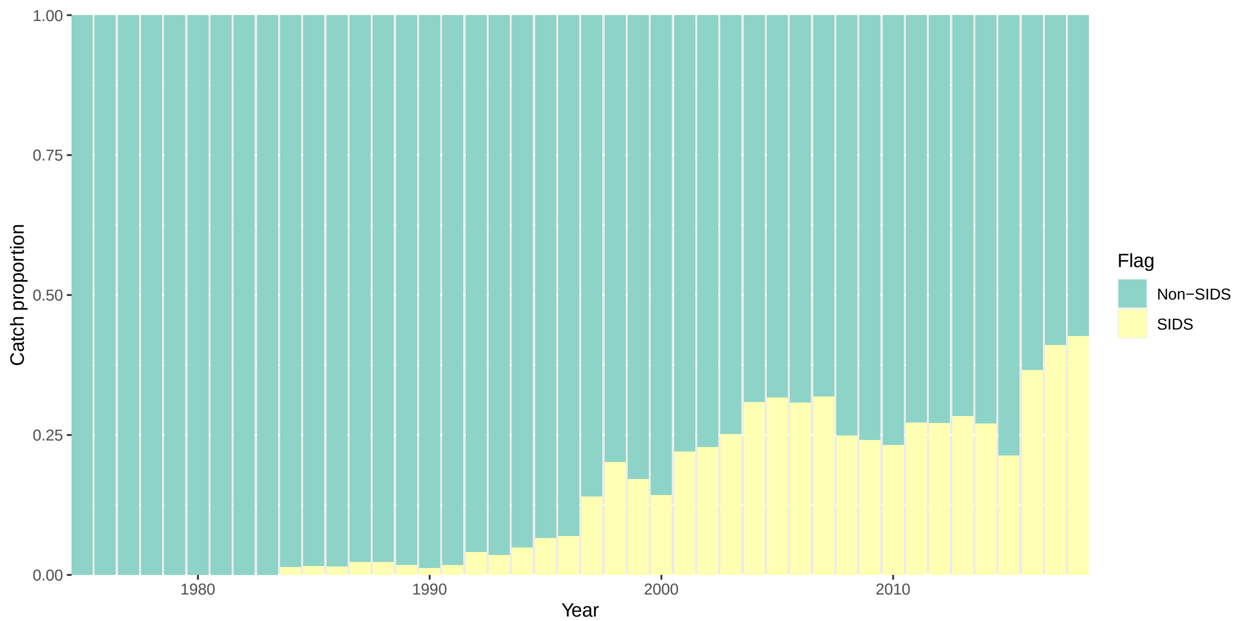

Figure 7: Proportion of total skipjack catch in SIDS EEZs by purse seine fishery, attributed to SIDS and non-SIDS flags.

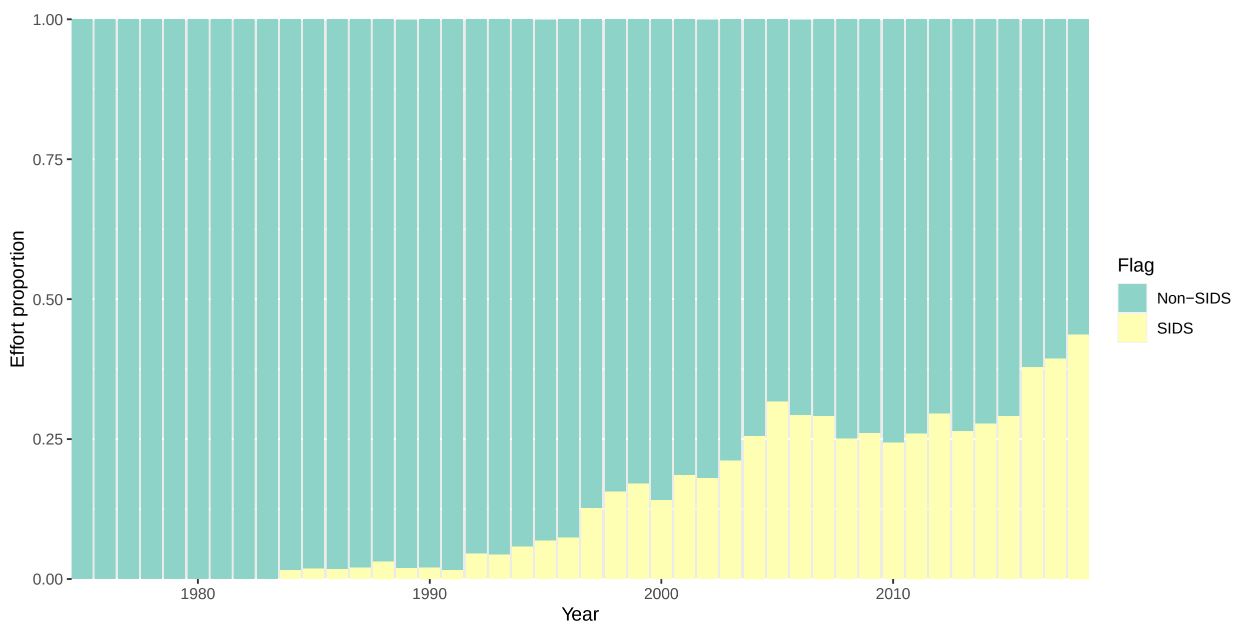

Figure 8: Proportion of total purse seine effort (number of sets) in SIDS EEZs, attributed to SIDS and non-SIDS flags.

B.4 Performance indicator 6: Average annual variation in catch

This indicator explores the absolute annual change in catches. It is possible to examine the catches over different groupings of fishery and area (Figure 3). The annual absolute change in catches can also be calculated over the same groupings.

For the MSE simulations this indicator is calculated as the average value of the variability over different time periods. As mentioned above, this may be of limited use for the monitoring strategy because it is preferred that the collected data is used in a timely manner. An alternative is to compare the current variablity in catches to a period in the past. For example, Table 6 shows the average absolute annual change in skipjack catch over different fishery and region groupings over the years 2009 to 2018. This average change could be used as a base line when comparing the observed data.

Fishery and area grouping	Change in catch (Mt)
Purse seine catch in region 6,7 and 8	131294
Total catch in all regions	143494
Total catch in region 1	4991
Total catch in region 2	20261
Total catch in region 3	3275
Total catch in region 4	3426
Total catch in region 5	48029
Total catch in region 6	47020
Total catch in region 7	125775
Total catch in region 8	192580

Table 6: Average absolute annual change in skipjack catch over the years 2009 to 2018.

B.5 Performance indicator 7: Effort variation relative to the reference period level

This indicator is concerned with the variability of effort. As with performance indicator 6, the MSE simulation indicator is calculated as the average value of the variability over different time periods. As described above, this is of limited use for the monitoring strategy because it is preferred that collected data is used in a timely manner. It will therefore be necessary to develop alternative methods for using this indicator in the monitoring strategy.

As with the catch variability indicator, an alternative is to compare the current variablity in effort to a period in the past. In line with the MSE indicator, here we take the effort (number of sets) of purse seine fisheries operating in stock assessment regions 6, 7 and 8 (excluding the associated purse seines in region 6, which has standardised effort for modelling purposes) (Figure 9). For the monitoring indicator, other combinations of areas and fisheries would be possible.

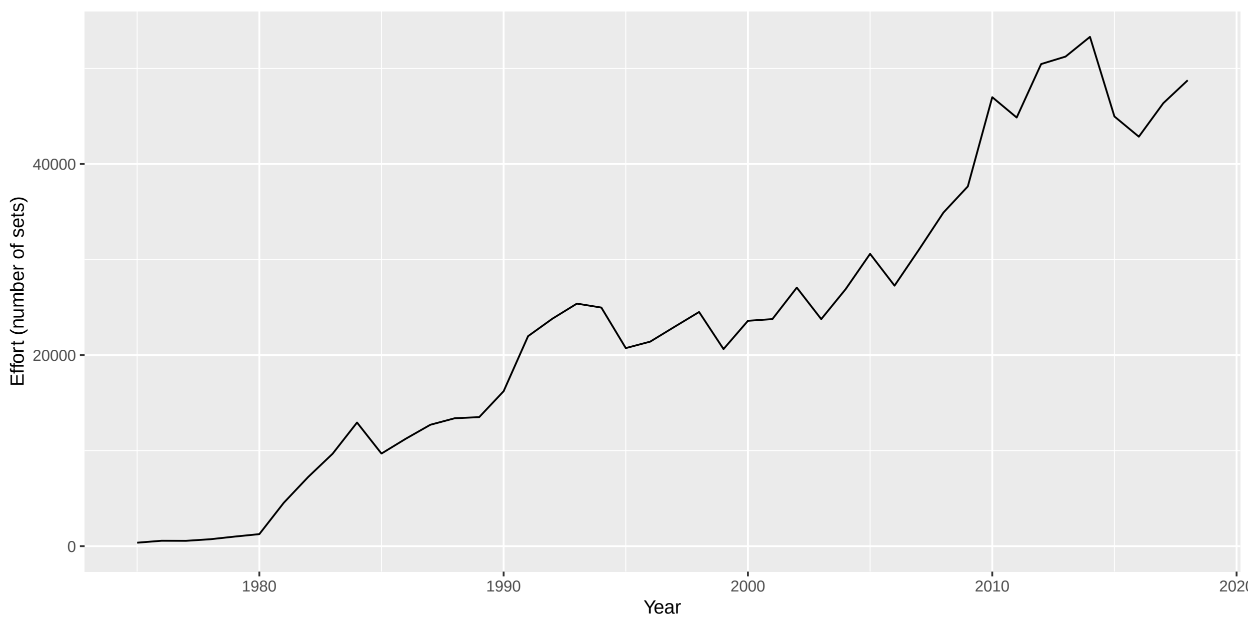

Figure 9: Fishing effort (number of sets) of purse seine fisheries in stock assessment regions 6, 7 and 8 (excluding the associated purse seines in region 6).

The average absolute change in fishing effort over the period 2009 to 2018 is 3901. This value could be used as a base line for the indicator when investigating the observed data.