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ECOSYSTEM AND CLIMATE INDICATORS FOR CONSIDERATION WITHIN THE WCPO

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EXECUTIVE SUMMARY

Background

1. SC16 is reminded that both SC12 and SC15 considered the development of ecosystem indicators as low to medium priority within the SC work schedule.
2. This Information Paper outlines candidate ecosystem and climate indicators that can be established using existing data sources and collection programmes, rather than proposing new activities that may need additional resources.
3. The indicators proposed are in addition to those already used by the SC to report on target stocks.
4. The selection criteria for candidate indicators proposed applied a modified approach to that described in SC15-EB-WP-12.
5. Several of the indicators recommended in SC15-EB-WP-12 are not progressed in this Information Paper as they would require additional information gathering in the WCPFC (i.e. they could not be developed using existing data sources and collection programmes).

Recommendations

The SC16 is invited to consider the following **advice:**

1. The candidate ecosystem indicators proposed be tested with the results reported to SC17. This will include a framework for indicator evaluation.
2. The candidate climate indicators proposed be tested in parallel with the ecosystem indicators given the co-dependence between ecosystem and climatic conditions.
3. Note that the results of the proposed work should help facilitate the capacity of the SC to provide future advice on Resolution 2019-01 to the Commission.
4. Note that the SC may need to re-evaluate the priority of this work once these candidate indicators have been tested.

Introduction

Ecosystem indicators are a regular agenda item for the WCPFC Scientific Committee (SC). At SC12 a general work schedule to progress the SC's work towards design and testing of ecosystem indicators was agreed (Annex 1). The discussion at SC12 noted that the process for selecting indicators should include the determination of appropriate reference levels and testing of their predictive performance. SC15-EB-WP-12 provided a list of potential ecosystem indicators of relevance to tuna RFMOs that can be used to track the impacts, on the broader pelagic ecosystem, of fisheries targeting tuna and tuna-like species (Annex 2). SC15-EB-WP-12 also provided a general framework based on a rule-based decision tree to provide guidance on how reference points could be set and used for diverse types of ecosystem indicators.

Noting the SC15 discussion that past WCPFC studies could inform future work, this Information Paper outlines candidate ecosystem indicators that can be established using existing data sources and collection programmes across the categories of environment, fishing effort, catch assemblage and trophic structure.

The adoption of the WCPFC Resolution on Climate Change as it relates to the Western and Central Pacific Fisheries Commission (Resolution 2019-01) in 2019 may result in the Commission requesting further advice from the SC on climate impacts. In recognizing this potential future request, the Information Paper also outlines candidate climate indicators that can be established using existing data sources and collection programmes.

Criteria for Ecosystem and Climate Indicators

The criteria applied to select candidate indicators for testing included:

1. science and data based;
2. characterize the states and trends of WCPFC marine ecosystems with respect to fishing activity and/or climate;
3. reflect well-defined processes underlying fishing activity and fishery responses to climate;
4. responsive to changes attributable to fishing pressure and climate (ie. minimal time-lags and capability to provide early warning);
5. estimable on a routine basis with a historical data time-series available;
6. cost-effective;
7. scalable across national, sub-regional and regional scales;
8. linked to existing WCPFC models and decision making processes (for inclusion in MSE scenarios, validation of predictions and testing of model assumptions);
9. can be routinely estimated by members without reliance of the Science Service Provider.

Candidate Indicators

Environmental variables

Consistent monitoring of environmental variables is important not only for the assessment of climate change patterns, but also to provide the oceanographic context to the observed changes in other indicators. A continual inspection of how environmental variables may or may not be supporting climate change predictions over three to five year timescales should be a standard component of WCPO ecosystem reporting, supporting decision making and adaptive management (Smith et al. 2007).

Both data from physical ocean model analyses (providing the most up-to-date, physically realistic model outputs), and ocean model reanalyses (typically delayed but informed by more observational data) will be used, and several alternative ocean products will be explored for the potential to provide an ensemble.

Descriptor	Metric	Feature	Data required
Position of the eastern boundary of the warmpool	5 yr rolling average most recent ENSO positive/neutral/negative	Validate climate projections of increasing prevalence and/or changing nature of El Nino type conditions	Satellite/model derived SST
Occurrence of marine heatwaves	SST anomalies	Spatial occurrence, duration and intensity of extreme ocean temperatures	Satellite/model derived SST
Strength of east Australian current	Annual and 5 year rolling average	Occurrence of seasonal tropical species along Australian coast	Ocean model derived currents data
Central tendency of annual and seasonal sea surface temperature	Yearly and 5-yearly rolling	Validate climate projections of eastward shift of key habitat indicators	Satellite/model derived SST
Longitudinal variability in thermocline depth	Yearly and 5-yearly rolling	Potential effects on catchability	Model derived temperature at depth
Chlorophyll	Annual central tendency and variability by region	Potential indicator of tuna habitat	Satellite ocean color/ocean model derived
Regional eddie kinetic energy	Annual and seasonal by region	Potential indicator of tuna habitat and drifting FAD density	Model derived ocean current data
Sea-surface height variability	Annual and seasonal by region	Potential indicator of tuna habitat	Satellite derived ocean model data
Spatial extent of the oligotrophic waters	Annual and seasonal centroid and extent	Expansion of poor tuna habitat	Satellite ocean color/model derived
Large scale climate indices	Annual and seasonal indices	Provide oceanographic context to other indicators. Validate increased prevalence of strong ENSO events	Oceanic Niño Index, Pacific Decadal Oscillation

Fishing effort shift

Under the assumption that the spatial distribution of commercial fishing effort approximates where fish are, or were, with some time-lag, empirically-derived indicators that capture temporal shifts in effort distribution might help us benchmark the impacts of fishing-climate interactions on fish spatial distribution at defined points in time. Importantly, development of empirical indicators also enables comparisons with model-based predictions of species' distribution shift, for e.g. under SEAPODYM.

Below, we propose a series of indicators of effort shift in the WCPO tuna purse-seine (PS) and longline (LL) fisheries. These indicators, capturing central tendency and dispersion of

fishing effort, among other metrics, are easily calculated and based on datasets already available in house at SPC.

Descriptor	Metric	Feature	Data required
Central tendency of annual and seasonal PS and LL effort	5 yr rolling average Centre of gravity (of fishing effort) Inertia (of fishing effort)	Validate climate projections of shifting distribution of PS and LL effort	WCPFC PS and LL fishing data
Distributional spread of annual and seasonal PS and LL effort	As above	As above	WCPFC PS and LL fishing data
Central tendency of annual and seasonal PS FAD fishing effort	As above	Tracks fishing effort but provides more nuanced information on vessel activity	WCPFC PS fishing data – associated sets
Distributional spread of annual and seasonal PS FAD fishing effort	As above	As above	WCPFC PS fishing data – associated sets

Bycatch and target species distribution and assemblage changes

The geographic distribution of fisheries catch can be interpreted as a proxy of both target and bycatch species' distributions, acknowledging biases linked to the non-random distribution of fishing effort, and issues of gear selectivity. Hence, spatial metrics that monitor the central tendency, spread and microstructure of the catch distribution through time may constitute useful candidate indicators for tracking species' responses to ecosystem and climatic variability (Woillez et al. 2007; Rice et al. 2015; Vidal et al. 2020).

Moreover, temporal trends in species' abundance seem ideal indicators of fishing and management impacts and environmental variability over time. Based on fisheries data, catch-per-unit-effort (CPUE) is a commonly used index of abundance, though with several caveats (e.g. changes in fishing technique, seasonal variability) that usually prevent the use of nominal catch rates and require CPUE standardization to obtain more representative abundance trends. Integrating CPUE-based indicators for target tuna species with the aforementioned spatial indicators (e.g. Vidal et al. 2020), in addition to those based on shifts in catch composition and species' biological parameters (e.g. age and size structure) may provide valuable multi-source inference on ecosystem and climate change effects. We outline some of these below.

Descriptor	Metric	Feature	Data required
SPATIAL DISTRIBUTION			
Distribution shifts in target and bycatch species	5 yr rolling average Centre of gravity Inertia Area occupied Gini Index	Captures spatial shifts in climate and/or fisheries-sensitive species distributions through time.	WCPFC PS and LL fishing data; observer data; stock assessment data
CPUE TRENDS			
Target species and bycatch CPUE trends	5 yr rolling average, by region	Provides indices of abundance	WCPFC PS and LL fishing data; observer data; stock assessment data
SPECIES COMPOSITION			
Proportion of rare bycatch species in catch	5 yr rolling average, by region	Insight into temporal patterns in bycatch composition (including SSIs); short and long-term ecosystem changes	WCPFC PS and LL fishing data; observer data
Proportion of large predatory fish species in catch	5 yr rolling average, by region	Indicative of short and long-term ecosystem changes	WCPFC PS and LL fishing data; observer data
Change in species assemblages (target and bycatch species composition)	5 yr rolling average, by region	Indicative of temporal patterns in target and bycatch species composition	WCPFC PS and LL fishing data; observer data
Diversity of the catch (target and bycatch)	5 yr rolling average, by region	Species richness; indicative of ecosystem changes	WCPFC PS and LL fishing data; observer data
BIOLOGICAL PARAMETERS			
Population size structure	5 yr rolling average, population wide, by region	Demographic information can complement / provide alternative indicators to biomass- and composition-based metrics	WCPFC PS and LL fishing data; fbserver data; port sampling data; ftock assessment data
Population age structure	5 yr rolling average, population wide, by region	As above	WCPFC PS and LL fishing data; observer data; port sampling data; stock assessment data

Trophic changes

Monitoring the trophic structure of the ecosystem can be conducted at different levels of the complex pelagic ecosystem: from monitoring a single parameter for a unique species that can reflects the state of the ecosystem (e.g. fat content of tuna inform on quality and quantity of prey available in the environment) to monitoring the predator's stomach content that inform on changes in prey composition and size-spectrum that could be linked to climate variability (Olson et al., 2014)

Based on the Pacific Marine Specimen Bank which includes the WCPFC Tuna Tissue Bank (Macdonald et al., 2020), a large number of samples and analyses from 2000 to present are available to start trialling some candidate trophic indicators to inform on changes in the ecosystem.

Descriptor	Metric	Feature	Data required
TROPHIC LEVEL			
Trophic Level of landings / total catch (landings+discards)	Nitrogen isotopes	Decreasing total trophic level is indicative of heavily fished systems	Nitrogen isotope analyses of muscle tissue (PMSB)
FISH CONDITION			
Fish condition	Fat content Length-weight relationship	Lower fish condition is indicative of unfavourable ecosystem conditions for the species tested	Fatmeter data (PMSB) WCPFC PS and LL port sampling data
CHANGES IN ECOSYSTEM COMMUNITIES			
Seasonal and annual shifts in diet composition	Proportion of epipelagic versus mesopelagic species SKJ prey proportion Trophic level of the preys Apparition of new prey items Diversity of prey	Ecosystem structure change (related to climate variability) SEAPODYM validation	Tuna stomachs database (PMSB)
Size-spectrum of prey	Size range, average	Ecosystem structure change (related to climate variability)	Tuna stomachs database (PMSB)
Stomach microbiomes	Shifts to warm conditions community	First indicator of changes in community composition Directly related to fish stress	Tuna stomachs (PMSB) & metagenomics analyses

REFERENCES

Macdonald, J., Allain, V., Roupsard, F., Sanchez, C., Vourey, E., 2020. Tuna Tissue Bank: Annual Report. 16th Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, WCPFC-SC16, 12-20 August 2020 RP-P35b-01.

Olson, R.J., Duffy, L.M., Kuhnert, P.M., Galván-Magaña, F., Bocanegra-Castillo, N., Alatorre-Ramírez, V., 2014. Decadal diet shift in yellowfin tuna *Thunnus albacares* suggests broad-scale food web changes in the eastern tropical Pacific Ocean. Marine Ecology Progress Series 497, 157–178.

Annex 1

Table 1: Proposed approach for the design and testing of WCPO ecosystem indicators for use by WCPFC (note that the last two columns are indicative only and intended to be developed over time).

Task	Timeframe	Concurrent SC Work	Concurrent Activities
Conduct a technical review of other RFMO ecosystem indicator work, and broader development in ecosystem indicators	Jan-Apr 2017	Improving quality of observer data Improving quality and comprehensiveness of fisheries data Expanding range of data collected Developing MSE for the tropical tuna species and albacore Implementation of the shark research plan Implementation of the Strategic Research Plan Biological and ecological studies of the tuna species	Improving the use of ecosystem models to advise management Increasing the monitoring of catch and discards for bycatch species Expanding fisheries monitoring programmes to include prey species Adding spatial components to ecosystem models Exploring changes in tuna biology over time Exploring changes in tuna diet through time Developing SEAPODYM and in particular management applications Enhancing biological data collection and the tuna tissue bank
Expert workshop to develop a range of candidate ecosystem indicators for the WCPO	May 2017		
SC discussion on the range of candidate ecosystem indicators for the WCPO from the expert workshop	Aug 2017		
Engage broader stakeholder base in discussion on the range of candidate ecosystem indicators	Sep – Dec 2017		
Compilation of data and analyses to inform testing of ecosystem indicators	Oct 2017-Jan 2018		
Expert workshop to test the refined range of candidate ecosystem indicators for the WCPO	Jan-Feb 2018		
Review indicators and data requirements and integrate into WCPFC fisheries and ecosystem monitoring programme	Feb 2018-Apr 2018		
SC review of the range of candidate ecosystem indicators for the WCPO	Aug 2018		

Annex 2

Candidate ecosystem indicators

INDICATOR NAME	SCORE (max = 8)	Scientific Basis IQ1	Ecosystem Relevance IQ2	Responsivenes IQ3	Targets? IQ4	Early-warning IQ5	Concrete IQ6	Cost-effective IQ7	Data available IQ8	Ecological component
Group Spawning Stock Biomass relative to a reference level (e.g. Bmsy or proxies)	8	1	1	1	1	1	1	1	1	target species
Group Fishing mortality relative to a reference level (e.g. Fmsy or proxies)	8	1	1	1	1	1	1	1	1	target species
Single species biomass/abundance/catch rate indicators	7.5	1	1	1	1	1	1	1	0.5	target and non-target species
Total catch (total, by guild)	7	1	1	1	0.5	1	1	1	0.5	target and non-target species
Mean Trophic Level Indicators (model derived)	7	1	1	1	1	1	1	0.5	0.5	trophic relationships
Community size based indicators (mean length, 95th percentile of the length distribution, Proportion of fish larger than the mean size of first sexual maturation) (model based)	7	1	1	1	1	1	1	0.5	0.5	target and non-target species/trophic relationships
Size spectra (total, by guild/community) (model based)	7	1	1	1	1	1	1	0.5	0.5	trophic relationships
Frequency of bycatch and total number of interactions	6.5	1	1	0.5	1	1	1	0.5	0.5	non-target vulnerable species
Population level mortality (non target species)	6.5	1	1	1	1	1	1	0	0.5	non-target species
Community size based indicators (mean length, 95th percentile of the length distribution, Proportion of fish larger than the mean size of first sexual maturation) (catch based)	6.5	1	1	0.5	1	0.5	1	1	0.5	target and non-target species
Mean Trophic Level Indicators (catch)	6.5	1	1	1	1	0.5	0.5	1	0.5	trophic relationships
Predation mortality from multispecies models	6.5	1	1	1	0.5	1	1	0.5	0.5	trophic relationships
Distributional range (including extent, centre of gravity, pattern within range and pattern along environmental gradients)	6	1	1	0.5	0	1	1	1	0.5	target and non-target species
Proportion of non-declining exploited species	6	1	0.5	1	1	0.5	1	0.5	0.5	target and non-target species
Recovery in the Population Abundance of Sensitive Fish Species	6	1	0.5	1	1	0.5	1	0.5	0.5	target and non-target species
Single Species Spawning Stock Biomass relative to reference level (e.g. Bmsy or proxies)	6	1	0	1	1	1	1	0.5	0.5	target and non-target species
Single species fishing mortality relative to a reference level (e.g. Fmsy or proxies)	6	1	0	1	1	1	1	0.5	0.5	target and non-target species
Single species size based indicators (mean length, 95th percentile of the length distribution, Proportion of fish larger than the mean size of first sexual maturation)	6	1	0	0.5	1	1	1	1	0.5	target and non-target species
Zooplankton biomass and/or abundance	6	1	1	0	1	1	1	0.5	0.5	pelagic habitats/trophic relationships
Primary production	6	1	1	0	1	1	1	0.5	0.5	pelagic habitats/trophic relationships
Biomass indicators (total, guild/community) including fish, marine mammals and seabirds	5.5	1	0.5	1	1	1	1	0	0	target and non-target species/trophic relationships
Mean maximum length of fish and elasmobranchs (catch data)	5.5	1	0.5	1	0.5	0	1	1	0.5	target and non-target species
Mean maximum length of fish and elasmobranchs (model derived)	5.5	1	1	1	0.5	0	1	0.5	0.5	target and non-target species
Single species catch (Length-frequency; Catch sex and maturity composition)	5.5	1	0	0.5	0.5	1	1	1	0.5	target and non-target species
Proportion of predatory fish or "Large Species Indicator" (model derived)	5	1	0.5	1	0.5	0.5	0	1	0.5	target and non-target species
Proportion of predatory fish or "Large Species Indicator" (catch data)	5	1	0.5	1	0.5	0.5	0	1	0.5	target and non-target species
Fish condition (length-weight residuals) for main commercial species	5	1	1	0.5	0	0	1	1	0.5	target and non-target species/trophic relationships
Single species age-based indicators	5	1	0	0.5	0.5	1	1	0.5	0.5	target and non-target species
Zooplankton biomass and size structure	5	1	1	0	1	1	1	0	0	pelagic habitats/trophic relationships
Abundance-Biomass Comparison (ABC) curves	4.5	1	1	1	0	1	0.5	0	0	target and non-target species
Species diversity indices (Shannon/Simpson/Evenness/Richness) (model derived)	4.5	1	1	0	0.5	0	1	0.5	0.5	target and non-target species
Ichthyoplankton abundance indices	4.5	1	1	0	0.5	1	1	0	0	target and non-target species
Species size at first sexual maturation	4	1	0	0	0.5	1	1	0.5	0	target and non-target species
Species diversity indices (Shannon/Simpson/Evenness/Richness) (catch data)	3.5	1	0.5	0	0.5	0	0	1	0.5	target and non-target species
Discard survival	2.5	0	1	0	1	0	0.5	0	0	non-target vulnerable species
Population genetic structure (single species)	0	0	0	0	0	0	0	0	0	target and non-target species