SCIENTIFIC COMMITTEE

TWELFTH REGULAR SESSION

Bali, Indonesia

3–11 August 2016

Ecosystem indicators: moving forward to design and testing

WCPFC-SC12-2016/EB WP-02

Neville Smith[1], Valerie Allain[1], and Graham Pilling[1]

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[1] Oceanic Fisheries Programme, Pacific Community (SPC), Noumea, New Caledonia

ABSTRACT

Ecosystem indicators have been previously discussed and identified by the SC. This paper proposes that the SC begin design and testing of ecosystem indicators. The ecosystem indicators need to be clear metrics easily incorporated into advice and using the best scientific information available. Even in their simplest implementation ecosystem indicators should enable more precise specification of the range of decisions leading to desired or effective outcomes, and reduce the risk of bad outcomes from those decisions. Previous work within WCPFC and elsewhere provides guidance on the nature and extent of ecosystem indicators needed. A range of existing indicators are available for the WCPO and many more can be developed readily. The substantive work is in design of appropriate indicators and then testing them.

Accordingly, we invite the Scientific Committee to:

- Note the proposed approach for the design and testing of ecosystem indicators for WCPO for use by WCPFC;
- Consider the importance of this work programme and its prioritisation within the SC work plan;
- Provide direction on the scope of the work, timing, and the implementation; and
- Consider funding from the SC budget or other sources to resource the work.

1. INTRODUCTION

Ecosystem indicators have been discussed previously by the Scientific Committee (SC), including in 2015 (Anon 2015a). The SC sought guidance from the Commission on this matter in 2015. This paper proposes that we, the SC, move to a stage where ecosystem indicators are in design and testing so that we can provide better advice to the Commission on the topic, and receive direct guidance in response.

1.1 The Convention

Our Convention is clear that part of the conservation and management of highly migratory fish stocks includes in Article 5 ecosystem and bycatch considerations:

> *"…(c) apply the precautionary approach in accordance with this Convention and all relevant internationally agreed standards and recommended practices and procedures;*
>
> *(d) assess the impacts of fishing, other human activities and environmental factors on target stocks, non-target species, and species belonging to the same ecosystem or dependent upon or associated with the target stocks;*
>
> *(e) adopt measures to minimize waste, discards catch by lost or abandoned gear, pollution originating from fishing vessels, catch of non-target species, both fish and non-fish species, (hereinafter referred to as non-target species) and impacts on associated or dependent species and promote the development and use of selective, environmentally safe and cost-effective fishing gear and techniques;*
>
> *(f) protect biodiversity in the marine environment;…".*

There is of course a clear mandate in Article 12 for the Scientific Committee to plan, co-ordinate, review, report upon and make recommendations about such science to the Commission.

The WCPFC science community has made progress on several of these matters. This paper seeks to address how we might move forward to deliver on the full range of these obligations in a more explicitly measurable manner. There is no question that much is known already, and that much science and research continues to occur on such ecosystem matters. What appears generally missing are clear metrics to incorporate such advice into our day-to-day business in a way that uses the best scientific information available and balances the at times competing principles in our Convention.

1.2 Strategic Research Plan

The SC Strategic Research Plan (Anon 2011) includes a section on monitoring and assessment of the ecosystem. That section includes reference to: "*establishing ecosystem indicators to monitor the effects of fishing, other anthropogenic effects and natural variability on ecosystem structure, function and biodiversity*".

1.3 Why ecosystem indicators?

Fisheries management decisions are, at their simplest, informed risk management. Data describing fisheries are collected. Scientists, economists, compliance analysts, and the like derive information from the data and bring their respective knowledge to bear to put that in front of fisheries managers. Those managers are then able to use that knowledge and make wise decisions which minimise risk –

on many issues including for example stock sustainability, the population status of species of special interest, and fishers' incomes.

In stock assessment we are constantly striving – through obtaining better data, developing a greater understanding of the ecology of the target species, and improving our modelling approaches – to develop greater precision as to stock status and at the same time reduce the biases in our predictions of stock status. With greater precision we are able to both better specify the range of plausible outcomes resulting from decisions, and reduce the risk in those decisions.

But tuna do not live in isolation from the ecosystem which supports them. At its simplest, if the system in which they live is sick, the tuna population cannot thrive despite the wisest decisions based on single-species stock assessment. To make truly wise decisions we need to consider the ecosystem with the stock. Even in their simplest implementation ecosystem indicators should enable more precise specification of the range of decisions leading to desired or effective outcomes, and reduce the risk of bad outcomes from those decisions through better understanding of the cause of potential stock assessment biases. Especially for the longer lived tunas, ecosystem indicators should increasingly provide early warning of when issues may arise. Such forecasts allow time for management response in near real-time rather than trying to catch up years later. This will be particularly important as we move to making decisions in a Management Strategy Evaluation (MSE) framework (Scott et al., 2016a).

1.4 Additional external drivers

Apart from the obligations arising in the Convention, there are other external factors which mean this issue – implementing meaningful and useful ecosystem indicators - has become a priority for action. The two core external drivers are the degree of transparency and accountability required from civil society, and the market certification of sustainable fisheries and the degree to which such certifications hinge on ecosystem considerations as much as the status of the target species.

The degree of accountability and transparency required by civil society has two major facets. One is simply to know that governance is good and the oceans are well. The extent to which the WCPFC engages in such conversations is beyond the remit of the SC. However, it is clear that increasingly the Commission will request science to support its work in this area, as evidenced by the developing MSE work (Scott et al., 2016a; Scott et al., 2016b). The other facet, and clearly a role for science, is in the provision of information which allows competing uses of marine resources to be managed. The competing use of the oceans for mineral resources through sea bed mining is just one example (Moore and Squires, 2016). The degree of pre-activity impact assessment required for those activities is likely to change expectations with respect to reporting on the fisheries ecosystem.

Increasingly, market certification has high expectations of the performance of fisheries, especially with respect to the effects of fishing on the environment and the status of the fishery with respect to the ecosystem in which it is embedded (Bellchambers et al., 2016). Factors such as the traceability of catch remain in the remit of the Technical and Compliance Committee (TCC), but the arising improvements in information about catch are of course very beneficial for the fisheries science which underpins ecosystem indicators. Topics such as the bycatch of species of special interest are increasingly important in market certifications, as is the general health of the ecosystem in which the fishery is occurring. Within the main market certification frameworks, ecosystem considerations become increasingly more important and with continued audits and re-certification there is an expectation of increasingly better performance over time (MSC, 2016).

1.5 Why this paper?

In the absence of direct guidance from the Commission, this paper draws on work by the SC to date to explore ecosystem indicators, briefly examines the current state of ecosystem indicator development in the Western and Central Pacific Ocean (WCPO) and identifies options for a process to move forward and design and test ecosystem indicators for the tuna fisheries in the WCPO. Recommendations for design and testing of ecosystem indicators for the WCPO are provided in the context of a medium term work plan. Work in other RFMOs and more generally has not been reviewed, but would be a key task for the proposed 2016-18 working process.

2. MOVING FORWARD

The SC has directly and indirectly done considerable work in the area of ecosystem indicators over time. Apart from work on sharks, very little, if any, of that work has evolved into formal indicators which are used in fisheries management.

Capturing the breadth of indirect work to date would provide a suite of ecosystem indicators which could be developed relatively simply. Moving further and developing additional indicators from existing data sources is also immediately tractable. Putting these together in a framework which meets the needs of WCPFC is also feasible, although it will require some time and resources. At the other extreme, designing a complete ecosystem framework for the WCPO and within that designing a range of ecosystem indicators on which to begin data collection would be a substantial undertaking.

2.1 Some WCPFC ecosystem indicator research to date

Kirby et al. (2005) presented the Pressure-State-Response framework for the development of quantitative ecosystem indicators. They indicated that univariate and multivariate data analyses are appropriate methodologies to identify ecosystem indicators. The need for developing indicators allowing stakeholders to identify and better understand natural and fishery induced changes in marine ecosystems was expressed. They also highlighted that continuous monitoring and long-time series are necessary to ensure quality and accuracy of indicators. They concluded that system-level indicators of ecosystem state should be developed to monitor stability, diversity and 'ecosystem health'.

Sibert (2005) mentioned the size spectrum of the biota as a measure of the ecosystem effects of fishing and referred to the ensemble size spectrum of the principle tuna stocks in the WCPO using estimates of the size composition of MFCL stock assessment tuna populations (Hampton, 2004). He also noted that implementing an ecosystem approach to fisheries requires the management area to be identified.

Allain et al. (2012) reported on longline bycatch catch rates and demonstrated significant increasing or decreasing trends according to the species considered. It was concluded that using those bycatch rates as informative indicators for longline would require a higher observer coverage rate and long-term time series of data. Three ecosystems indicators were also calculated for longline fisheries: mean trophic level of the catch, annual proportion of apex predators and annual proportion of predators with high turn-over. They provided various trends according to the fisheries considered and note that appropriate interpretation of these indicators requires a good knowledge of the underlying ecosystem functioning.

Allain et al. (2015) presented a set of ecosystem scale indicators related to monitoring the pelagic ecosystem effects of different levels of fishing effort on the western Pacific Ocean warm pool. The indicators were based on exploration of different scenarios of fishing effort, including approaches designed to reduce and/or increase the amount of bycatch taken, and decrease and/or increase the amount of tuna harvested. That modelling showed warm pool ecosystem structure to be relatively resilient due in part to the high diversity of predators in food webs, each consuming a wide range of prey (Allain et al., 2015). The work identified some key indicators: the catch level of bycatch species; the size of catch in the fishery; and the diversity and biomass at higher trophic levels.

Rice et al. (2015) presented, for seven of the fourteen key shark species, a range of indicators, including trends in the indicators over time where data were available. The indicators reported include changes in species occurrence through space and time, changes in species composition in catch data through space and time, catch per unit of effort trends over time and fisheries and a range of biological indicators (sex ratios in catch, maturity status of catch, and trends in measured size of catch). In addition to identifying several recommendations for improving data collection and analysis of shark data, they recommended future indicator analyses for relevant key shark species.

Collectively these papers and the others available in the SC archives highlight the key issues and some existing data and analyses for the WCPO that could be used for the development of ecosystem indicators.

2.2 A range of indicators

One of the key debates around ecosystem indicators appears to be which ones to use. There are of course several responses to that question, all of them potentially correct. Maybe most important for SC to resolve is which ones we need to meet our mandate under the Convention. This is a core piece of work which needs to be completed.

What is clear from outside the WCPO (Fulton et al., 2005) and from within the WCPO (Kirby et al., 2005; Allain et al., 2012; Allain et al., 2015; Rice et al., 2015), is that all work to date strongly recommends a range of ecosystem indicators, and that some are simple whilst others need to be more complex. What is also clear from work within the WCPO and outside is that to support the design, testing and future use of ecosystem indicators we need to maintain our efforts to improve currently held data (Williams et al., 2016), collect better data (Clarke and Gilman, 2015), and to continue to collect a broad range of data (e.g., Williams, 2016; Smith et al., 2016). All of this will be needed to support the implementation of indicators. At the same time, the design and testing of indicators can occur independent of those developments.

2.3 Status of indicator availability

Some candidate indicators are clearly already available for the WCPO – for sharks (Rice et al., 2015) and for monitoring the pelagic ecosystem effects of different levels of fishing effort on the western Pacific Ocean warm pool (Allain et al., 2015). The spatial population and ecosystem dynamics model SEAPODYM is well advanced (Senina et al., 2016) and is able to be used in a variety of ways with respect to design and testing of ecosystem indicators (Nicol et al., 2016). For example, the capacity of SEAPODYM to include alternate oceanographic states (e.g. ENSO phases and climate change projections) would allow testing of candidate ecosystem indicators such as micronekton distribution under different future climate scenarios. The SC is also able to call on summary observer data through BDEP (Williams et al., 2016), fish length frequency, age and growth data through various studies (Nicol et al., 2011; Harley and Williams, 2013; McKechnie, 2014) through to external data streams such as satellite imagery of phytoplankton production through time.

There are also a range of indicators which will be able to be developed from existing data (but which have not been analysed in an indicators context to date). One example is changes in the catch length frequency of fish species over time (Figure 1). In this case, it might be assumed that the truncation of the maximum size over time and left-shift of the population structure is negative for the stock. Scott et al. (2016b) suggest this approach as one potential performance indicator of the ecosystem objectives in MSE for the tropical purse seine fishery. Such indicators can be derived from existing data, can be analysed retrospectively to consider system changes to date, and are relatively intuitive. However, one of the challenges with such an indicator is that a reduction in average size could be good with respect to stock-scale recruitment and thus a good thing for the fishery. The key point being that understanding what is going on behind indicators – cause and effect – is a core part of assessing their utility.

A critical part of finding meaningful indicators, the trend or change of which reflects our best understanding of changes in the ecosystem, is whether the SC feels we have that knowledge. The best extant advice is that we do. For instance the results of the most recent implementation of SEAPODYM is very close to what we might expect from Multifan-CL (Senina et al., 2016).

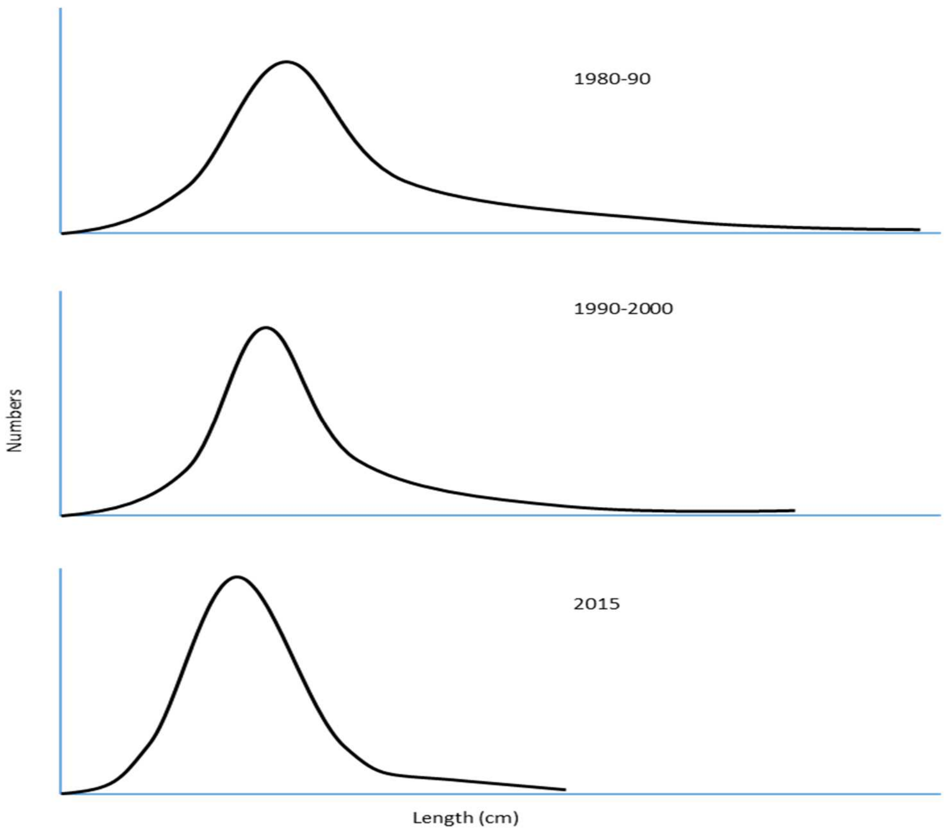

Figure 1: Size structure the catch of a hypothetical fish population Z, as might be derived from observer sampling data, 1980-90, 2000-2010, and 2014.

Additionally the WCPFCs Bycatch Management Information System (BMIS) already provides a source of highly relevant information on aspects of ecosystem indicator availability and will be an important resource in this work (Fitzsimmons et al., 2015).

In summary, a range of existing indicators are developed for the WCPO across a broad range of ecosystem facets, and many more can be developed readily. The substantive work is in design of appropriate indicators and then testing them.

2.4 Designing and testing indicators

The suite of indicators selected needs to be designed so as to meet the SC mandate under the Convention, in particular Article 5 (d), (e) and (f) as identified in section 1.1. We need to develop metrics which can readily be used to provide advice in our day-to-day business. Designing indicators needs to carefully consider those that make most sense given the way the WCPFC works, the data that are already available, and the practicality of collecting new data and maintaining the various types of monitoring already in place.

A current and specific example of design and testing of an indicator which make sense in the way that WCPFC works is how stock range might be monitored over time – are environmental factors influencing stock distribution? One potential driver of perceived range changes is the availability of prey. It may be that ecosystem studies which examine changes in transient pelagic habitat, the broader environment and changes in climate might be better at detecting factors influencing the distribution of prey. As such, indicators of forage fish distribution and changes over time may be particularly useful.

The design also needs to consider the external drivers impacting on their use as identified in section 1.4. Fulton et al. (2005) provide design attributes which will be important given the drivers identified, including indicators which characterise the system and its current state, and indicators which provide early signal detection for changes in state. The other critical source of external information will be work done in other tuna RFMOs to date and more broadly regionally and globally on ecosystem indicators. One such example is the work conducted by the Indiseas project (Shin et al., 2010; Shin and Shannon, 2010; Coll et al., 2015). They have tested ecological and biodiversity indicators, climate and environmental indicators and human dimension indicators in about 30 ecosystems (http://www.indiseas.org). Examining the current state of ecosystem indicator development elsewhere, and collating information on work relevant to the WCPO is a key activity moving forward.

One specific example where there remain extant contradictory views is with regard to balanced versus selective harvesting, i.e. in regards to managing the target species size/age of capture and the same for bycatch. There is yet little consensus on which may be most appropriate. With respect to the design of indicators, it may be that dual indicators are needed until such debates are resolved (e.g. indicators which capture the broader ecosystem context of the selected harvesting strategy, and more simplistic indicators which simply report what was harvested and changes therein). This example also clearly highlights the need for objectives for management of impacts on the ecosystem. Such work has already begun under the MSE process (Scott et al., 2016a; Scott et al., 2016b).

Considering the desirable attributes of indicators, the internal and external drivers identified, and the broad data sets available to WCPFC, current work globally, and the concurrent development of ecosystem objectives through MSE, it is timely and feasible for SC to assess a potential suite of ecosystem indicators for the fisheries for highly migratory species in the Western and Central Pacific Ocean and then test them.

2.5 A future work plan – next steps

Experience in similar work shows that a combination of collaborative detailed technical work, targeted analyses, and broader stakeholder inclusion are critical to the development of robust new science work programmes in WCPFC (e.g., Scott et al., 2016a). This work plan should of course draw on other SC and WCPFC work and resources to the greatest extent possible (e.g. the use of BMIS (Fitzsimmons et al., 2015).

Accordingly, to progress the design and testing of ecosystem indicators, the following approach is proposed for SC to consider (Table 1). If the work is to proceed, it will need resourcing. This programme of work is ambitious but achievable in the timeframes indicated.

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).

<table>
<tr><th>Task</th><th>Timeframe</th><th>Concurrent SC Work</th><th>Concurrent Activities</th></tr>
<tr><td>Conduct a technical review of other RFMO ecosystem indicator work, and broader development in ecosystem indicators</td><td>Jan-Apr 2017</td><td rowspan="8">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</td><td rowspan="8">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</td></tr>
<tr><td>Expert workshop to develop a range of candidate ecosystem indicators for the WCPO</td><td>May 2017</td></tr>
<tr><td>SC discussion on the range of candidate ecosystem indicators for the WCPO from the expert workshop</td><td>Aug 2017</td></tr>
<tr><td>Engage broader stakeholder base in discussion on the range of candidate ecosystem indicators</td><td>Sep – Dec 2017</td></tr>
<tr><td>Compilation of data and analyses to inform testing of ecosystem indicators</td><td>Oct 2017-Jan 2018</td></tr>
<tr><td>Expert workshop to test the refined range of candidate ecosystem indicators for the WCPO</td><td>Jan-Feb 2018</td></tr>
<tr><td>Review indicators and data requirements and integrate into WCPFC fisheries and ecosystem monitoring programme</td><td>Feb 2018-Apr 2018</td></tr>
<tr><td>SC review of the range of candidate ecosystem indicators for the WCPO</td><td>Aug 2018</td></tr>
</table>

3. CONCLUSIONS

Ecosystem indicators have been previously discussed and identified by the SC since its inception in 2005. This paper proposes that the SC begin design and testing of ecosystem indicators so that we can provide better advice to the Commission on the topic. The ecosystem indicators need to be clear metrics easily incorporated into advice and using the best scientific information available. Even in their simplest implementation ecosystem indicators should enable more precise specification of the range of decisions leading to desired or effective outcomes, and reduce the risk of bad outcomes from those decisions through better understanding of the cause of potential stock assessment biases. Especially for the longer lived tunas, ecosystem indicators should increasingly provide early warning of when issues may arise.

Previous work within WCPFC and elsewhere provides guidance on the nature and extent of ecosystem indicators needed, and highlights the importance of current SC work to improve existing stored data, collect better data, and to continue to gather a broad range of data. A range of existing indicators are available for the WCPO and many more can be developed readily. The substantive work is in design of appropriate indicators and then testing them.

Accordingly, we invite the Scientific Committee to:

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REFERENCES

Anon. 2011. Strategic Research Plan of the Scientific Committee 2012–2016. Seventh Regular Session of the Scientific Committee of the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean. 9–17 August 2015, Pohnpei, Federated States of Micronesia. Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia.

Anon. 2015a. Report of the Eleventh Regular Session of the Scientific Committee of the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean. 3–8 August 2015, Pohnpei, Federated States of Micronesia. Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia.

Allain, V., Griffiths, S., Polovina, J., and S. Nicol. 2012. WCPO ecosystem indicator trends and results from ecopath simulations. SC8 EB-IP-11. Eighth Regular Session of the Scientific Committee of the WCPFC. Busan, Republic of Korea. 7–15 August 2012.

Allain, V., Griffiths, S., Bell, J. and S. Nicol. 2015. Monitoring the pelagic ecosystem effects of different levels of fishing effort on the western Pacific Ocean warm pool. Issue-specific national report. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Nouméa, New Caledonia.

Bellchambers, L. M., Phillips, B.F., and M. Perez-Ramierez, M. (2016). From certification to recertification the benefits and challenges of the Marine Stewardship Council (MSC): A case study using lobsters. *Fisheries Research*, 182: 88-97.

Clarke, S., and E. Gilman. 2015. Changes to WCPFC Longline Observer Bycatch Data: Proposals in Response to a Minimum Suite of Harmonized Fields for Tuna RFMOs. SC11 EB-IP-05. Eleventh Regular Session of the Scientific Committee of the WCPFC. Pohnpei, Federated States Micronesia. 5–13 August 2015.

Coll, M., L. J. Shannon, K. M. Kleisner, M. J. Juan Jordà, A. Bundy, A.G. Akoglu, D. Banaru, J. L. Boldt, M.F. Borges, A. Cook, I. Diallo, C. Fu, C. Fox, D. Gascuel, L.J. Gurney, T. Hattab, J.J. Heymans, D. Jouffre, B.R. Knight, S. Kucukavsar, S. I. Large, C. Lynam, A. Machias, K. N. Marshall, H. Masski, H. Ojaveer, C. Piroddi, J. Tam, D. Thiao, M. Thiaw, M.A. Torres, M. Travers-Trolet, K. Tsagarakis, I. Tuck, G.I. van der Meeren, D. Yemane, S. G. Zador, and Y.J. Shin. (2015). Ecological indicators to capture the effects of fishing on biodiversity and conservation status of exploited marine ecosystems. *Ecological Indicators* 60: 947-962.

Fitzsimmons, L., S. Clarke, S. Caillot, and S. Nicol. 2015. Redevelopment of the Bycatch Information Management System (BMIS). SC11 EB-IP-07. Eleventh Regular Session of the Scientific Committee of the WCPFC. Pohnpei, Federated States Micronesia. 5–13 August 2015.

Fulton, E. A., Smith, A. D. M., and Punt, A. E. (2005). Which ecological indicators can robustly detect effects of fishing? *ICES Journal of Marine Science*, 62: 540-551.

Harley, S., and P. Williams. 2013. A compendium of fisheries indicators for bigeye, skipjack, yellowfin, and south Pacific albacore tunas. SC9 SA-WP-06. Ninth Regular Session of the Scientific Committee of the WCPFC. Pohnpei, Federated States Micronesia. 6–14 August 2013.

Hampton, W. J. 2004. Tuna Meta-Population Abundance and Size Structure as Indicators of Ecosystem Impacts of Fishing. SCTB17/ECO-3. 12pp. Standing Committee on Tuna and Billfish.

Kirby, D., Allain, V., and B. Molony. 2005. Potential ecosystem indicators for the WCPO. First Regular Session of the Scientific Committee of the WCPFC. Noumea, New Caledonia. 8–19 August 2005.

McKechnie, S. 2014. Analysis of longline size frequency data for bigeye and yellowfin tunas in the WCPO. SC10 SA-IP-04. Ninth Regular Session of the Scientific Committee of the WCPFC. Majuro, Republic of the Marshall Islands. 6–14 August 2014.

Moore, S., and D. Squires. (2016). Governing the Depths: Conceptualizing the Politics of Deep Sea Resources. *Global Environmental Politics*, 16:2, 101-109.

MSC, 2016. Marine Stewardship Council: Global Impacts Report 2016. MSC, London, UK. 64 pp. ISSN 2052-8876.

Nicol, S., S. Hoyle, J. Farley, B. Muller, S. Retalmai, K. Sisior, and A. Williams. 2011. Bigeye tuna age, growth and reproductive biology (Project 35). SC7 SA-WP-01. Seventh Regular Session of the Scientific Committee of the WCPFC. Pohnpei, Federated States Micronesia. 9–17 August 2011.

Nicol, S., P. Lehody, I. Senina, and N. Smith. 2016. SEAPODYM review with an update about ongoing developments and preliminary results. SC12 EB-IP-14. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.

Rice, J., Tremblay-Boyer, L., Scott, R., Hare, S., and A. Tidd. 2015. Analysis of stock status and related indicators for key shark species of the Western Central Pacific Fisheries Commission. SC11 EB-WP-04-Rev1. Eleventh Regular Session of the Scientific Committee of the WCPFC. Pohnpei, Federated States Micronesia. 5–13 August 2015.

Scott, R., Pilling, G., M., Hampton. J., Reid, C., and N. Davies. 2016a. Report of the Expert Consultation Workshop on Management Strategy Evaluation. SC12 MI-WP-05. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.

Scott, R., Pilling, G., M., and J. Hampton. 2016b. Performance statistics and monitoring strategies for skipjack and South Pacific albacore commensurate with: candidate management objectives for the Tropical Purse Seine and Southern Longline Fisheries. SC12 MI-WP-04. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.

Senina, I., P. Lehodey, B. Calmettesa, S. Nicol, S. Caillot, J. Hampton, and P. Williams. 2016. Predicting skipjack tuna dynamics and effects of climate change using SEAPODYM with fishing and tagging data. SC12 EB-WP-01. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.

Shin, Y. J., Shannon, L. J., Bundy, A., Coll, M., Aydin, K., Bez, N., and J. L. Blanchard. (2010). Using indicators for evaluating, comparing, and communicating the ecological status of exploited marine ecosystems. *ICES Journal of Marine Science*, 67: 692–716.

Shin, Y. J., and Shannon, L. J. 2010. Using indicators for evaluating, comparing and communicating the ecological status of exploited marine ecosystems. *ICES Journal of Marine Science*, 67: 686–691.

Sibert, J. R. 2005. Ecosystem Boundaries and Indicators: getting started with the ecosystem approach. SC1 EB-SWG-WP-6. First Regular Session of the Scientific Committee of the WCPFC. Noumea, New Caledonia. 8–19 August 2005.

Smith, N., C. Sanchez, F. Roupsard, S. Calliot, V. Allain, D. Brogan, J. Farley, S. Fukufoka, M. Hosken, B. Leroy, S. Nicol, T. Park, T. Peatman and E. Vourey. 2016. Project 35: Bigeye biology, and Project 35b: WCPFC Tuna Tissue Bank. SC12 RP-P35-01. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.

Williams, P. 2016. Scientific data available to the Western and Central Pacific Fisheries Commission. SC12 ST-WP-01. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.

Williams, P., Smith, N., Tuiloma, I., Falasai, C., and S. Clarke. 2016. Trial Application of the BDEP Template for Summarizing Bycatch Data. SC12 EB-WP-12. Twelfth Regular Session of the Scientific Committee of the WCPFC. Bali, Indonesia. 3–11 August 2016.