AN INDICATOR-BASED ECOSYSTEM REPORT CARD FOR IOTC – AN EVOLVING PROCESS

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SUMMARY

To facilitate the implementation of an Ecosystem Approach to Fisheries Management in the IOTC Convention Area, the Working Party on Ecosystems and Bycatch has recommended the development of an indicator-based ecosystem report card. The main purpose of the ecosystem report card is to improve the link between ecosystem science and management and increase the awareness, communication and reporting of the state of IOTC's different ecosystem components to the Commission. Here, we first present the potential uses of an indicator-based ecosystem report card and highlight the different tools available to better link ecosystem science with fisheries management. Second, we present a reporting framework to monitor the impacts of climate and fisheries on the different components of the marine pelagic ecosystem in the IOTC convention area. Third, we present a set of candidate ecosystem indicators to be used to monitor each of the ecosystem components. Fourth, we propose a process to develop the first prototype ecosystem report card for IOTC. Continuing the development and refinement of the report card with the involvement of a diverse group of experts including scientist, managers and other key stakeholders will be pivotal to improve its utility and relevance to the management of tuna and tuna-like species and associated ecosystems in the Indian Ocean.

KEYWORDS

Ecosystem based fisheries management, report card, ecosystem indicators, ecoregions, stakeholders

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1. Introduction

Human activities such as fishing affect marine ecosystems in different ways. The recognition for the need to account for significant interactions between fish species and their ecosystem as well as account for the wide range of economic and social factors arising from fisheries has led to the development of more comprehensive and integrated approach to manage fisheries and associated ecosystems, referred to as the Ecosystem Approach to Fisheries Management (EAFM) or Ecosystem-based Fisheries Management (EBFM) (Link 2002, FAO 2003). In a nutshell, the implementation of EBFM aims to apply the three pillars of sustainable development to the fisheries sector, combining the ecologically sustainability of stocks and associated ecosystems, economic and social viability of the fishing industry and dependent communities through good governance (Garcia et al. 2003, Gascuel et al. 2014). Accordingly, over the last decades international instruments of fisheries governance, such as the UN Fish Stocks Agreement, the FAO Compliance Agreement, and the Convention on Biological Diversity-Aichi targets, have embraced this integrated and more comprehensive approach to fisheries management by setting the core principles and standards for the management of highly migratory fishes such as tunas, billfishes and sharks and associated ecosystems (Meltzer 2009).

Although IOTC does not make reference to EBFM in its Convention Agreement, the Working Party on Ecosystem and Bycatch (WPEB) has added into its Program of Work the development for a plan for ecosystem based fisheries management approaches in the IOTC. The WPEB has requested the development of an indicator-based ecosystem report card (IOTC 2018). The main purpose of the ecosystem report card is to improve the link between ecosystem science and management and increase the awareness, communication and reporting of the state of IOTC's different ecosystem components to the Commission. It could be used to report on the impacts of IOTC fisheries not only on the targeted stocks, but also on bycatch species, the broader ecosystem structure and function and habitats of ecological significance. Similarly, it could report on the effects of natural environmental variation and climate change on the different ecosystem components.

Objectives

Here, we first present the potential uses of an indicator-based ecosystem report card and highlight the different tools available to better link ecosystem science with fisheries management. Second, we present a reporting framework to monitor the impacts of climate and fisheries on the different components of the marine pelagic ecosystem in the IOTC convention area. In this framework we propose a set of broad ecosystem components to be reported and monitored in the ecosystem report card. Third, we present a set of candidate ecosystem indicators to be used to monitor each of the ecosystem components. Fourth, we propose a process to develop the first prototype ecosystem report card for IOTC.

2. Tools to link ecosystem science with fisheries management – the role of ecosystem report cards

The potential roles and uses of an indicator -based ecosystem report card

Below we highlight the main purposes and potential uses of an indicator-based report cards in the IOTC Convention Area:

(1) It is an effective communication tool since it synthesizes large and often complex amount of information into a succinct and visual product. It is could be used to communicate the state (trends and status) of several ecosystem components to the Commission and other interested stakeholders;
(2) It has the potential to increase the visibility and utility of important ecosystem data and research;
(3) It is an opportunity to create a stronger link between the ever-expanding ecosystem research and fisheries management;
(4) It could be used to summarize the status of top indicators that best describe the ecosystem and provide ecosystem context for fisheries managers to inform fisheries management decisions.
(5) It can be used to identify regions or issues of concern in order to direct and focus management actions on specific components or regions.
(6) It can be used as a framework for monitoring and communicating activities and for providing accountability by measuring the success of a particular management measure.
(7) It has the potential to engage the Commission and other stakeholders in the process of incorporating ecosystem considerations into management decisions.

How a report card should look like?

We highlight the importance of producing a succinct highly visual and communicative ecosystem report card. Other regions of the world where they have been implementing the ecosystem approach for at least two decades have learnt that this is an important issue to tackle from the very beginning (Zador et al. 2016). We are seeking to highlight in the report card only the top indicators that best describe the main pressures and the state of the main ecosystem components in one or two pages. The visual presentation and communication of a complex subject such as the dynamics of marine ecosystems and how they respond to anthropogenic and environmental pressures is challenging. Therefore, the card and the indicators should be understandable by multiple audiences with ranging technical abilities and backgrounds. In Figure 1, we provide a visual example of an indicator-based report card produced by the North Pacific Fisheries Management Council in the USA for the Eastern Bering Sea region (Zador et al. 2015). The indicator-based report card consists of a set of multi-year indicators with the objectives of illustrating their long- and short-term trends, and current status of different components of the ecosystem. It summarizes the status of top indicators selected by a team of ecosystem experts that best describes the ecological status of this region. The ecosystem report cards are also supplemented by a short bullet list with a small description of the ecosystem and a detailed ecosystem assessment. Every year the report card is updated by the Ecosystem Committee and it is presented to the Council.

A report card does not stand by it self

An ecosystem report card usually does not stand by itself (Figure 2). Unquestionably a succinct ecosystem report card with a limit of one, two pages restricts the amount of information that can be conveyed in such a reduced space. So, a succinct highly visual ecosystem report card might be too short to portray a complete representation of major ecosystem pressures and the state of key ecosystem components, and at the same time capture the scientific rigor and credibility required in management and decision-making processes. To resolve these shortcomings, the ecosystem report card in order to be self-standing, credible and scientifically rigorous must be also accompanied by an ecosystem assessment (Zador et al. 2016). The ecosystem assessment should include all the details about the ecosystem indicators portrayed in the ecosystem report card and include other additional ecosystem indicators which might also be deem necessary to monitor the main pressures and the state of the ecosystem. The ecosystem assessment could include a detailed description of each indicator, including how it is calculated, data sources and data requirements, a description and interpretation of its trends and current state capturing the uncertainty of the indicators, factors causing the observed trends and a final section with its implications and link to fisheries management. Both the ecosystem report card and the ecosystem assessment report could be used to report on and monitor the impacts of IOTC fisheries and the effects of environment and climate change on the different components of the ecosystems, not only on the targeted stocks, but also on bycatch species, the broader ecosystem structure and function and habitat of ecological significance.

Many tools exist to link ecosystem science with fisheries management

An indicator-based ecosystem report card is one of many tools commonly used to better communicate ecosystem science and link it with fisheries management (ICES 2013, Zador et al. 2016). Since EBFM started to be implemented around the world, multiple approaches and tools varying in complexity and with different degrees of data requirements have been developed and are being tested to better link ecosystem information into fisheries management, as well as providing ecosystem advice to the managers and policy-makers.

Another example of a simple approach would be to synthesize current knowledge and ecosystem information into an ecosystem synthesis report (or ecosystem overview report) (Figure 2). These ecosystem synthesis reports are another tool which aim to bring together and summarize many ecosystem related research efforts into one document to spur new understanding of the connections between ecosystem components (ICES 2013, Zador et al. 2015). These ecosystem synthesis reports are many times used to provide the context and directions for the development of ecosystem assessment and ecosystem report cards. Another useful tool is the development on an ecosystem plan, which is can be used to guide the operationalization of EBFM within a region (Figure 2). An ecosystem plan creates a transparent process that may help the Commission to formalize a clear vision and objectives centered on the ecosystem and not by objectives centered on one individual species or stock. The ecosystem plans are many times used as a framework of strategic planning to guide and prioritize activities of all them to better link ecosystem science and management, and also to spin off other initiatives such as the aforementioned ecosystem synthesis reports, ecosystem assessments, and ecosystem report cards.

More advance tools and approaches would consist of developing Ecosystem Integrated Assessments utilizing a blend of data analysis and modeling to communicate not only the current status of ecosystems but also possible future scenarios that account for the effects of climate change and fishing (Zador et al. 2015, Zador et al. 2016).

Using more complex tools such as end-to-end ecosystem and multispecies models can provide more tactical fisheries management advice (Plagányi et al. 2012, Collie et al. 2016, Skern-Mauritzen et al. 2016). Therefore, these continuum of approaches require the development of a variety of tools ranging from simpler ecosystem synthesis reports to ecosystem risk assessments, indicator-based ecosystem report cards, indicator-based assessments, ecosystem models, management strategy evaluation and the formalization on an ecosystem fishery plan (Garcia and Cochrane 2005, Smith et al. 2007, Fletcher et al. 2010, Link 2010, Fogarty 2014, Zador et al. 2016). These tools vary in complexity, data needs, expertise, and time and resources for their development.

3. What ecosystem components should be monitored? An assessment framework to monitor the impacts of fisheries and climate change on the ecosystem

For monitoring purposes, we need to identify the full range of interactions between IOTC fisheries and the different components of the pelagic ecosystem pelagic, and identify indicators best suited to monitor these effects and the linkages among them. This requires prior identification of the main pressures impacting the state of the marine ecosystem, and identification of what ecosystem components are being affected and impacted by these pressures. We identify two major *drivers* and associated *pressures* that may be influencing the *state* of the ecosystem in the IOTC Convention Area. The first driver, human population growth and a rising demand for fish protein, places fishing as the most important anthropogenic *pressure* impacting the *state* of fish species and associated ecosystems in the ICCAT Area (Collette et al. 2011). Second, the changing oceanographic conditions in the Indian Ocean as well as the emerging climate change (and their associated environmental changes in the ecosystems) are also generating pressures influencing the *state* of the ecosystem that also need to be accounted for (Bell et al. 2013). Assessing the state of the ecosystem would also require to monitor the impacts of pressures on the following ecosystem components (1) the productivity of the system (plankton communities), (2) fishes, (3) seabirds, (4) sea turtles, (5) marine turtles, as well as (6) the community structure and foodwebs and finally (7) habitats of ecological significance. For practical reasons, when monitoring the state of the different taxonomic groups, it is important to distinguish between those species retained and non-retained by IOTC fisheries, since many species interact by IOTC fisheries but not all of them are retained, including some fishes and other vulnerable taxa such as seabirds, sea turtles and marine mammals. Therefore, we propose to monitor the state of the following ecosystem components (Figure 3):

1) **State of retained species:** The state of fish species retained by IOTC fisheries include the main commercial tunas, billfishes and some sharks as well as the small tunas and other bony fish species caught by IOTC fisheries. Each fishery preferentially targets and retains a set of species but may also catch other fish species, that although not primarily targeted, are also retained for commercial reasons. Some of the retained species are regularly assesses and other not which is also an important factor to consider when choosing indicators for monitoring purposes.
2) **State of non-retained species:** The state of species incidentally caught and non-retained by IOTC fisheries either because of their low commercial value or the non-retention measures in place. This include some shark species and bony fishes, but also sea turtles, seabirds, sea turtles and marine mammals.
3) **State of foodweb and biodiversity:** The state of the ecosystem structure and functioning of pelagic food webs.
4) **State of habitats of ecological significance:** The state of knowledge on habitats of special ecological significance for the species interacting with IOTC fisheries and how these fisheries and changing environment might be impacting them. Habitat of ecological significance might include areas used by species for spawning grounds and migration corridors, productive areas for feeding, or areas of with a large aggregation of species and high biodiversity.
5) **State of productivity**: Both changes in oceanographic conditions (due to natural variability of the system and/or to climate change) and human activities can affect the productivity of the system producing bottom up effects in the foodweb, ultimately impacting the productivity of species.

Accordingly, we envision an ecosystem assessment (and associated ecosystem report card) to report on the relevant *pressures* affecting the state of the ecosystem, and report on the ecological *state* of the pelagic ecosystem interacting with IOTC fisheries. The proposed assessment framework should be seen as a living document and treated as a first step to initiate the process in IOTC. It could be further refined as new information becomes available and adapted to the needs of the managers and decision and policy makers. For example, in the future, if deem relevant, additional themes capturing the main management responses, ecosystem services delivered by sustainable stocks and fisheries as well as the socio-economic importance of fisheries in the IOTC area could be easily added in the ecosystem assessment and report card.

4. Candidate ecosystem indicators to track each of the ecosystem components

The ecosystem assessment and report card framework need to be populated with a series of ecosystem indicators in order to monitor trends and the current status of the different components. Furthermore, relevant indicators for each component must be associated ideally to pre-establish operational objectives and thresholds to activate specific management responses to ensure the objectives are met (Figure 4). We also recommend establishing a diverse group of experts with experience on IOTC fisheries, fisheries management and ecosystem indicators to develop and routinely update the indicators to populate the assessment and report card (see recommendation in section 5). However, until a group of ecosystem experts is established to lead formally the process, we propose operational objectives, provide potential candidate indicators for each broad structuring theme and ecosystem components, and describe the risk of not monitoring them.

Climate and environment

Management objectives -Monitoring the potential impacts of changing oceanographic conditions and climate change on the broader ecosystem with a special focus on IOTC species.
Candidate indicators • Sea surface temperature • Water column descriptions (e.g. mixed layer depth) • Chlorophyll concentrations/primary production • Chlorophyll concentration and seas surface temperature gradients (fronts) • Sea level anomaly • Eddie kinetic energy • Dissolved oxygen concentration
Risks of not monitoring this component The abundance/biomass, horizontal and vertical distribution and reproductive capacity of species most vulnerable to environmental variability might change due to natural variability in the marine environment, that can be aggravated by climate change. This might lead to a dangerous decrease of IOTC species abundance and/or a horizontal migration of tropical species to more temperate waters for example, that could end up having socio-economic impacts on the fisheries.

Fishing pressure and effort

Management objectives Monitoring the spatio-temporal patterns of fishing pressure and effort to minimize the impacts of fishing on the different components of the ecosystem from species to communities to foodwebs.
Candidate indicators • Number of active ICCAT vessels operating in the area annually • Total number of logline hooks spatially and over time • A measure of purse seine pressure spatially and over time • Total catch spatially and over time • Total fishing activity as hours fished per square km by vessels with AIS systems • Vessel track intensity measured with AIS systems • Mean trophic level indicators (catch data)
Risks of not monitoring this component Not considering the spatio-temporal patterns of fishing activity limits the potential of defining area-based plans to minimize impacts of fishing on main target species, as well as protect vulnerable taxa.

State of retained and assessed fish species

Management objectives
-Prevent overfishing of IOTC species.
-Rebuild overfished IOTC species.

Candidate indicators*

- Single species spawning stock biomass relative to a reference level (e.g. Bmsy or proxies)
- Single species fishing mortality relative to a reference level (e.g. Fmsy or proxies)
- 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)
- Single species age-based indicators
- Fish condition (length-weight residuals)
- Distributional range (including extent, center of gravity, pattern within range at different depths, and pattern along environmental gradients)
- Species size at first sexual maturation and whether it changes over time
- Population genetic structure
- Ichthyoplankton abundance indices

*It is recommended to identify priority species of bony fishes, sharks and rays to develop the indicators.

Risks of not monitoring this component
Not monitoring the impacts of fisheries on main commercial species can lead to overfishing of the stocks which can drive stocks bellow acceptable levels of productivity and risk (overfished status), followed by depletion and collapses if overfishing is not addressed.

State of retained and non-assessed fish species

Management objectives
-Minimize and reduce the impact of fishing retained species.
-Monitor and prevent overfishing of retained species most at risk.

Candidate indicators *

- Total catches of retained and non-assessed IOTC species
- Total catches of retained and non-assessed species interacting with IOTC fisheries (this includes other non-IOTC fish species interacting with fisheries)
- Single species catch and catch rate indicators
- 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)
- Distributional range (including extent, center of gravity, pattern within range and pattern along environmental gradients)
- Fish condition (length-weight residuals)
- Species size at first sexual maturation and whether it changes over time

*It is recommended to identify priority species of bony fishes, sharks and rays to develop the indicators.

Risks of not monitoring this component
The abundance of species most vulnerable to IOTC fisheries, those being highly susceptible to being caught by IOTC fisheries and well as having low intrinsic productivity values, might decline to low levels jeopardizing their reproductive capacity if not properly monitored.

State of non-retained vulnerable taxa

Management objectives
-Minimize and reduce the number of interactions of fishing on non- retained vulnerable taxa
-Increase the post-release survival of non-retained vulnerable species
-Monitor and prevent overfishing of non- retained vulnerable species

Candidate indicators*

- Bycatch per unit effort
- Frequency of bycatch or total number of interactions of bycatch species
- Discard survival of bycatch species (total number of individuals killed per fleet)

- For bony fish and sharks - 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)
- For bony fish and sharks -Single species catch
- Population level biomass/abundance
- Population level mortality of bycatch species
- Population genetic structure
- Distributional range (including extent, center of gravity, pattern within range and pattern along environmental gradients)

*It is recommended to identify priority vulnerable species of bony fishes, sharks, rays, sea turtles, marine mammals and seabirds to develop the indicators.

Risks of not monitoring this component

The abundance of species most vulnerable to IOTC fisheries, those being highly susceptible to being caught by IOTC fisheries and well as having low intrinsic productivity values, might decline to low levels jeopardizing their reproductive capacity if not properly monitored.

State of the community structure, foodweb and biodiversity

Management objectives

-Increase existing knowledge on ecosystem structure, trophic interactions and biodiversity in order to maintain the species interactions sustaining energy flow in the ecosystem and avoid crossing thresholds that might rapidly move the ecosystem into a new, unknown state.

-Develop ecosystem-level risk assessments for balancing tradeoff apparent from an understanding of different ecosystem interactions.

Candidate indicators

- Group spawning stock biomass relative to a reference level (e.g. Bmsy or proxies)
- Biomass indicators (total, guild/community)
- Proportion of non-declining exploited species
- Recovery in the Population Abundance of Sensitive Species
- Group Fishing mortality relative to a reference level (e.g. Fmsy or proxies)
- 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)
- Proportion of predatory fish or "Large Species Indicator" (catch based)
- Abundance-Biomass Comparison (ABC) curve
- Mean Trophic Level Indicators (catch based)
- Mean maximum length of community (catch based)
- Species diversity indices (Shannon/Simpson/Evenness/Richness) (catch based)
- 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)
- Mean Trophic Level Indicators (model based)
- Size spectra (total, by guild/community) (model based)
- Mean maximum length of community (model based)
- Species diversity indices (Shannon/Simpson/Evenness/Richness) (model based)
- Proportion of predatory fish or "Large Species Indicator" (model based)

Risks of not monitoring this component

Ignoring the indirect effects of fishing due to the existing trophic relationships and ecological processes between ecosystem components might cause unintended and non-easily understandable (but manageable if they were understood) consequences in ecosystems functioning and communities composition, and energetic structure, affecting the goods and services that societies obtain from marine ecosystems.

State of productivity

Management objectives -To explore the interaction between primary and secondary production and IOTC species dynamics. -Use integrated methods that could produce scenarios of low and high productivity and help forecasting their potential bottom up effects on the foodweb.
Candidate indicators • Primary production • Zooplankton biomass and/or abundance • Zooplankton biomass and size structure
Risk of not monitoring this interaction A reduction in primary production could negatively affect the production of the commercially important IOTC species and might be linked to a non-intended overfishing of stocks before the signal is completely clear. Bottom-up changes are likely to favor some species over others in competition for shared resources, potentially resulting in economic tradeoffs.

State of habitats of ecological concern

Management objectives -Reduce or avoid impacts of fishing on habitats of ecological significance. -Maintain biodiversity. -Mitigate and adapt to climate change.
Candidate indicators • Mapping areas of special importance for life history stages of species (e.g. spawning areas, migratory corridors) • Mapping areas for vulnerable, threatened, declining species • Mapping areas of high biological diversity • Mapping habitat suitability of species and changes in habitat suitability due to climate change • Percent overlap of habitat of ecological significance by high fishing pressure • Percent area close to a specific gear
Risk of not monitoring this interaction Not having a good understanding of habitats of ecological significance hinders the potential use of marine spatial planning to inform management strategies to minimize and avoid fishing impacts and mitigation strategies to adapt to climate change.

Other aspects of indicator selection and development

It is important that the ecosystem indicators eventually developed have a clear understanding of what they intend to represent in each of the ecosystem components (Link 2010). Sometimes the intent of the indicator may aim to describe the state of the ecosystem component without a clear management link; other times it may be directly link to a relevant management response. Therefore, the purpose of each indicator should be early clarified. The ecosystem indicators chosen should also be responsive and reflective of the system-wide impacts of fishing and the environment. There exist multiple criteria to guide the identification of useful ecosystem indicators (Rice and Rochet 2005, Shin et al. 2010, Queirós et al. 2016), which could be used by the ecosystem experts to guide their selection process.

Some indicators can be developed relatively easily based on empirical data collected routinely by IOTC Member States and other might require the use of external sources of data (e.g. remote sensing data). Other indicators would need to be developed based on model-derived data from ecosystem models. We advised to consider also desired indicators that cannot be currently developed given the current data availability in IOTC but that potentially could be developed in the future with external sources or new collections protocols.

Additionally, we also need to resolve how we want to communicate the trends and current status of each indicator to the Commission (Figure 4). We might choose to illustrate what it is the long-term trend of the indicators or choose to summarize what it is the most recent trend within a specific time window (e.g. using the last five years of data) and the current status (e.g using also the last five years of data). We might want to visualize the current status of the indicator against a selected reference point(s) as well as to capture in the report card how confident we are on the indicator therefore show the level of evidence (or uncertainty) in each indicator. All these aspects of the indicator visualization need to be predetermined and discussed by the group of ecosystem experts leading the process to make the ecosystem report card highly visual and communicate.

5. A process proposal to develop the first prototype ecosystem report card in IOTC

We propose the following process, activities and research tasks to be conducted by the WPEB to support the operationalization of EBFM in the IOTC region. First, we propose a series of activities to be carried out during the WPEB13 and inter-sessionally until the WPEB14 to facilitate the development of the first prototype ecosystem report card in IOTC:

(1) Establish and engage a **Group of Ecosystem Experts** to contribute in the development of the ecosystem assessment and ecosystem report card. We encourage that the team of ecosystem experts be composed of a group of diverse stakeholders including both IOTC scientists and managers with a diverse scientific, fisheries management, and ecosystem background. The potential list of ecosystem indicators to be monitored within IOTC should be determined following vetted criteria and selected by consensus. We expect all aspects of the process to be influenced by the extent of scientific knowledge, the data, as well the particular expertise of the ecosystem team.

(2) During the WPEB13 identify a **teams of volunteering individuals** (which will be part of the **Group of Ecosystem Experts)** to lead the development of candidate indicators for each ecosystem component to be presented and reviewed during the WPEB14 meeting. Each team will prepare a small assessment document to document the development of the indicators (including data sources, methods, interpretation, management implications, challenges). Instructions will be provided on how to structure the assessments and the developing and reporting of the indicators. It is intended that these assessment documents for each ecosystem component will form the basis of a future ecosystem assessment of the IOTC region.

(3) Present the first ecosystem assessments and candidate indicators to be reviewed during the WPE14 meeting in order to prepare and present the **first prototype ecosystem report card and ecosystem assessment** to the 22nd Scientific Committee (SC22) and the 24th session of the Indian Ocean Tuna Commission (IOTC24).

(4) Get funds to organize a **workshop with the participation of a wide range of stakeholders** (IOTC scientists and managers with a diverse scientific, fisheries management, and ecosystem background) to contribute in the process of developing the ecosystem assessment and report card.

Second, we propose a series of activities to be carried out in the short-medium term by the WPEB to support the operationalization of EBFM in the IOTC region:

(1) Develop a **Fisheries Ecosystem Plan** for the IOTC region to guide the operationalization of EBFM within the IOTC convention area. Ecosystem plans are considered a tool that can serve as a framework to identify and formalize ecosystem goals and objectives, plan actions and research based on priorities, measure performance of the whole fishery system and address trade-offs, and incorporate them in fisheries management (Levin et al. 2018).

(2) Prepare an **Ecosystem Synthesis Report** (sometimes also referred as an Ecosystem Overview) to synthesize and integrate existing research and knowledge of the main pressures and drivers that contribute to the state, and changes in the state, of the different ecosystem components. Ideally, the Ecosystem Synthesis Report should provide the context and directions for the development of the ecosystem assessment and report card.

(3) Prepare a full **Ecosystem Assessment and complementary Ecosystem Report Card** to report to the Commission on the main pressures and the state of the IOTC ecosystem. In order to support the interpretation of the ecosystem report card and to demonstrate the credibility and scientific rigor of its indicators, the ecosystem report card should be developed in association with an Ecosystem Assessment. The ecosystem assessment should include all the details about the top ecosystem indicators portrayed in the ecosystem report card, and include other additional ecosystem indicators that are deemed necessary to monitor the main pressures and the state of the ecosystem. The Ecosystem Assessment could include a detailed description of each indicator, including how it was calculated, data sources and data requirements, a description and interpretation of its trends and current state capturing the uncertainty of

the indicators, factors causing the observed trends and a final section with its implications and link to fisheries management. An ecosystem assessment would increase the credibility of the report card as well as provide managers with the scientific rigor needed to make management decisions.

(4) Establish of a **Formal Dialogue with the Commission** on the implementation of EBFM in IOTC. The prototype ecosystem assessment and ecosystem report card could be presented to the Commission once developed, so that the Commission can provide inputs and suggestions on the content and design of the report card that could be incorporated in future versions. A frequent dialogue between all interested stakeholders will lead to adaptive products to better suit the needs of fisheries managers to ensure the ecosystem report card and associated ecosystem assessment are used in management decisions.

(5) Investigate what would be the **Ideal versus Practical Spatial Units** for the use and development of the Ecosystem tools and proucts including the fisheries ecosystem plan, ecosystem synthesis report, ecosystem assessment and ecosystem report card. The identification and delineation of area-based management units or ecoregions with meaningful ecological boundaries is a key element of any ecosystem approach. Potential area-based management units or ecoregions within the IOTC convention area could be related to known ecological boundaries but also political and traditional fishing ground boundaries to ensure fisheries management advice can be implemented. We recommend the WPEB to investigate what would be the ideal vs practical spatial scales to develop a suitable framework that could allow IOTC to effectively operationalize EBFM tailored to the needs and characteristics of the organization. An area-based ecosystem framework would allow monitoring the pressures and the ecological state of the different components of the ecosystem and focus management action on an area basis since the environmental drivers and species composition and fisheries impacts on them would be presumably different.

(6) Develop the **Socio-Economic and Governance Component** to fully implement EBFM in IOTC. The proposed framework for the ecosystem assessment and report card captures the major ecological components of the ecosystems and their interactions with the environment and fisheries but it does not capture the main socio-economic and governance components of fisheries and ecosystems. We recommend that the WPEB explore opportunities to link the socio-economic and governance components to the ecosystem report card and other ecosystem-related initiatives.

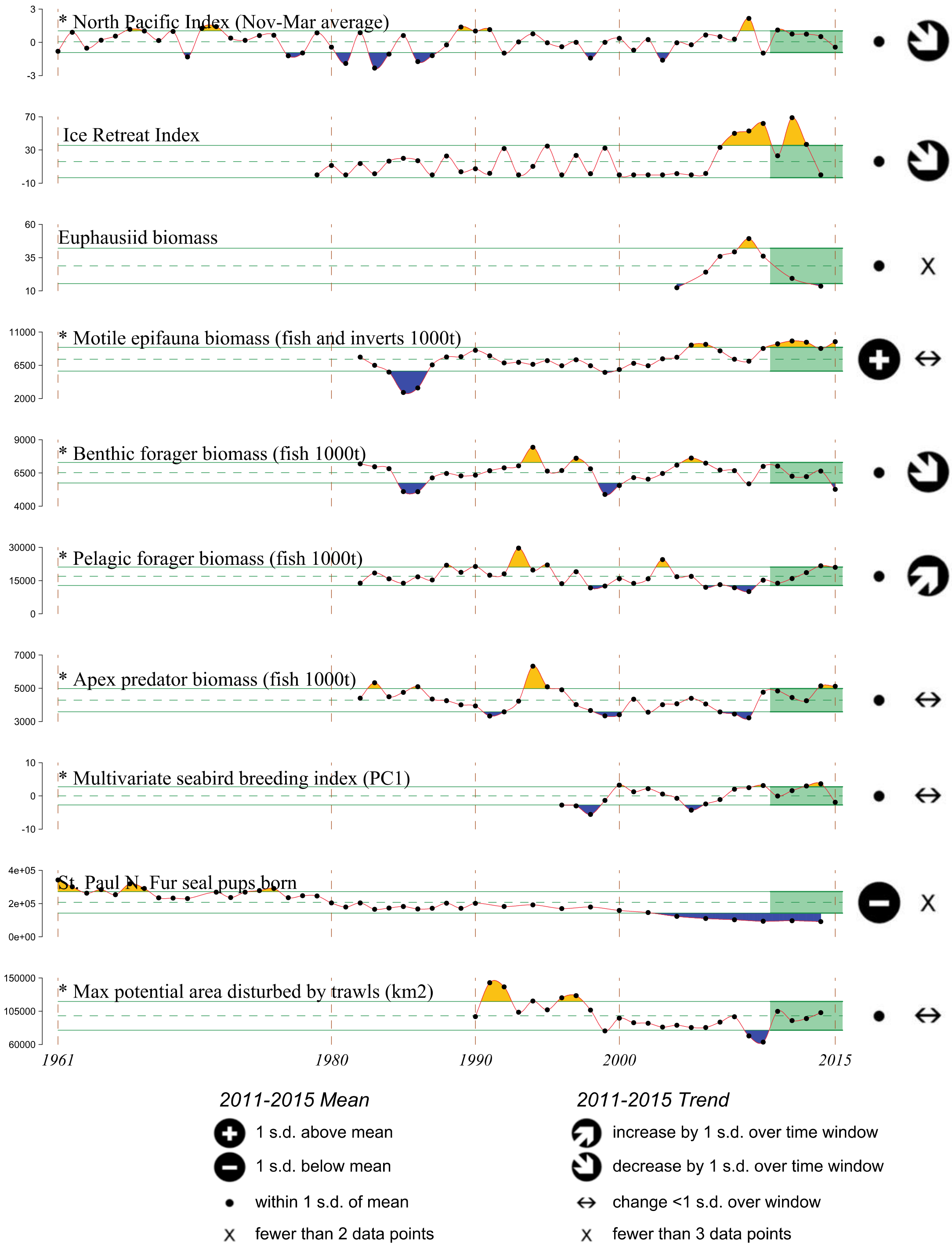
(7) For all the activities proposed above, we further recommend to the WPEB to incorporate them in their Work Plan as well as to identify roles, responsibilities and timelines for each of them to further advance these initiatives.

6. Conclusions

We foresee the indicator-based ecosystem report card to be a tool to synthesize ecosystem information in order to be able to communicate and inform the Commission about the current state (trends and status) of the different components of the ecosystem. The ecosystem report card has the potential to increase the visibility of ecosystem data and research as well as identify data and research gaps and limitations. Once it starts to be refined and adapted to the needs of managers, it could be used to provide ecosystem context for the deliberations of management advice and decisions. Therefore, by providing ecosystem context for management advice, the ecosystem report card with its associated ecosystem assessment can be seen as a tool to support strategic management advice and decision-making. For example, the single species management advice could be evaluated in the context of its interactions with other species and other components of the ecosystem and their current status, so the single-species advice could be adjusted to account for ecosystem considerations if deemed necessary. The ecosystem report card should be treated as a living tool to be adapted as new ecosystem information and management needs emerges.

It is important to establish from the very beginning of the process a frequent dialogue with managers and other interested stakeholders, so they become part of the process to ensure the products produced are adapted to their needs. Frequent communication between scientist and managers, and flexible products that can be adapted easily to the user needs are two key practices that have led to better incorporation of ecosystem considering into fisheries management advice and decisions in other areas of the world (Zador et al. 2016). While there are ample examples worldwide where ecosystem considerations are being used to provide context for strategic management advice, there are few cases worldwide where ecosystem information is being used to provide tactical or practical management (Plagányi et al. 2012, Collie et al. 2016, Skern-Mauritzen et al. 2016). This limited use of tactical management is in part due to the lack of clear operational objectives for many of the ecosystem indicators as well as the lack of quantitative thresholds to link indicators to management responses. Yet this is an active area of research with encouraging future perspectives. Furthermore, the development and testing of management strategy evaluation for achieving fishery ecosystem objectives are also slowly emerging which should further advance the implementation of an ecosystem approach to ensure sustainable fisheries and ecosystems (Sainsbury et al. 2001, Large et al. 2013, Skern-Mauritzen et al. 2016, Zador et al. 2016).

7. FIGURES



Eastern Bering Sea 2015 Report Card

- The **eastern Bering Sea in 2015 was characterized by warm conditions** that were first seen in 2014, and continued through the winter, during which the **PDO reached the highest winter value seen** in the record extending back to 1900.
- The extent of **sea ice during winter was reduced, as was as the size of the cold pool of bottom water** relative to the long term mean during the summer.
- While there was no acoustic survey of euphausiids during summer, rough counts of zooplankton during spring indicated that **small copepods were more prevalent than either lipid-rich large copepods or euphausiids**.
- **Jellyfish remained abundant** during summer, following a new peak fall biomass recorded in 2014.
- **Survey biomass of motile epifauna has been above its long-term mean** since 2010, with no trend in the past 5 years. There has been a unimodal increase in brittle stars since 1989 and for sea urchins, sea cucumbers and sand dollars since 2004-2005.
- **Survey biomass of benthic foragers decreased substantially in 2015, which contributed to the change in their previously stable recent trend to negative.** Recent declines could possibly be related to the consecutive years of springtime drift patterns that have been linked with poor recruitment of flatfish.
- **Survey biomass of pelagic foragers has increased steadily** since 2009 and is currently above its 30-year mean. While this is primarily driven by the **increase in walleye pollock** from its historical low in the survey in 2009, it is also a result of **increases in capelin during the cold years**, which have remained high during the past two warm years.
- **Fish apex predator survey biomass is currently above its 30-year mean**, although the increasing trend seen in recent years has leveled off. **The increase from below average values in 2009** back towards the long term mean is driven primarily by increases in Pacific cod from low levels in the early 2000s.
- **The multivariate seabird breeding index is below the long term mean**, indicating that seabirds bred later and less successfully in 2015. This suggests that **foraging conditions were not favorable for piscivorous seabirds**, a hypothesis further supported by large numbers of dead, emaciated birds observed at sea.
- **Northern fur seal pup production for St. Paul Island remained low** in 2014, indicating that fewer pups were produced in 2014 than during the year of the last survey in 2012.
- The maximum potential **area of seafloor habitat disturbed by trawl gear has remained stable since 2011**.

Figure 1. Example of an indicator-based ecosystem report card. This is the Eastern Bering Sea report card prepared and updated annually by the North Pacific Fisheries Management Council in the USA. The time series depict the long-term mean (dash-line), 1 SD (solid lines). The last 5 years are shaded. The 5 years of data are used to calculate the symbols. The report card also comes with a summary text that highlights the main issues and information to be communicated to managers.

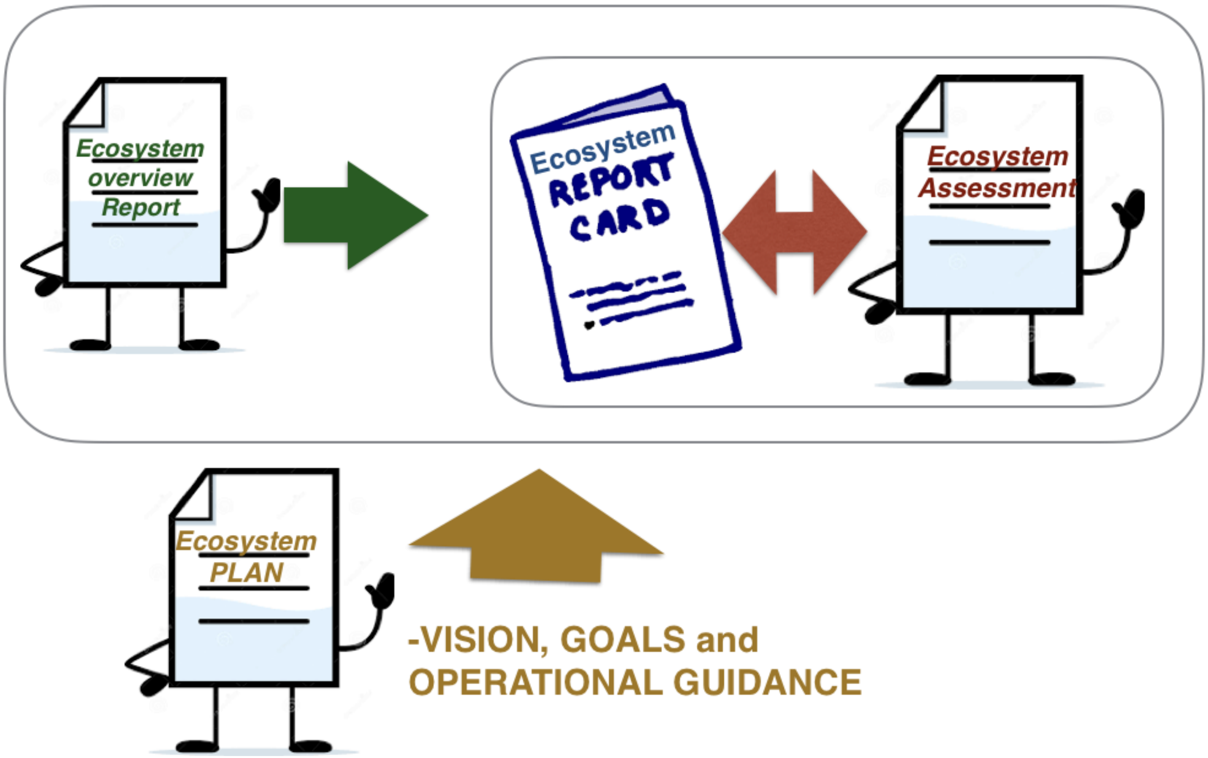


Figure 2. Multiple tools and products to communicate ecosystem science and link ecosystem science with fisheries management.

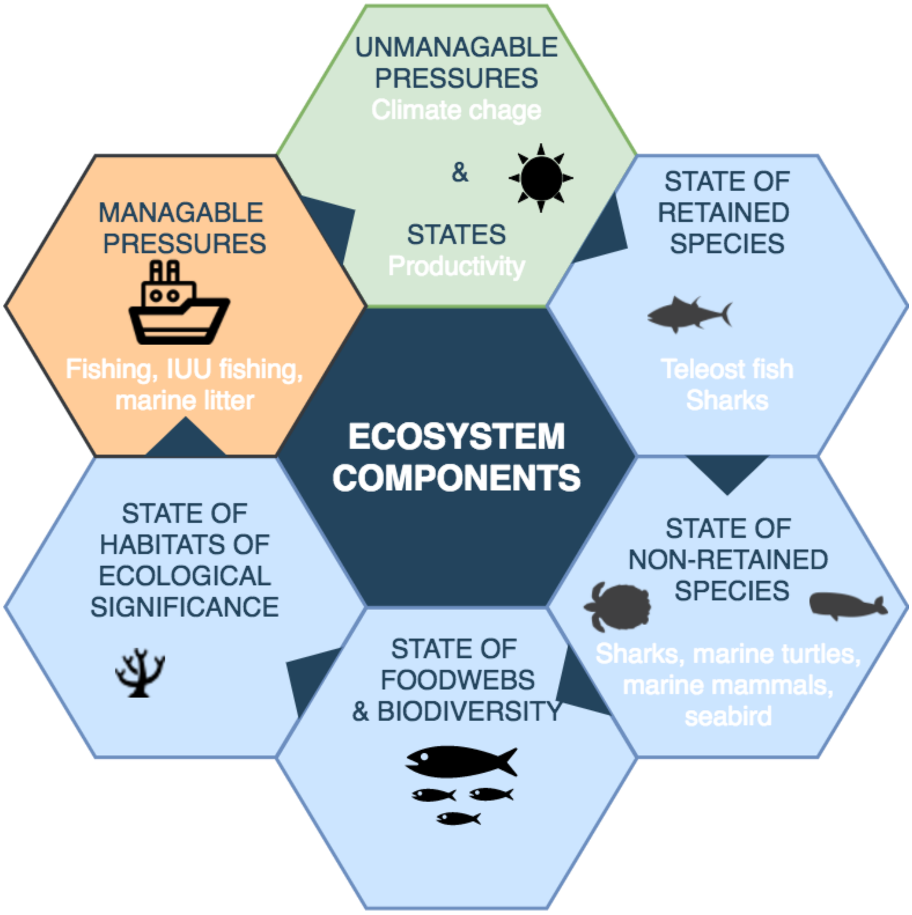


Figure 3. Ecosystem components to be monitored in the IOTC Convention area

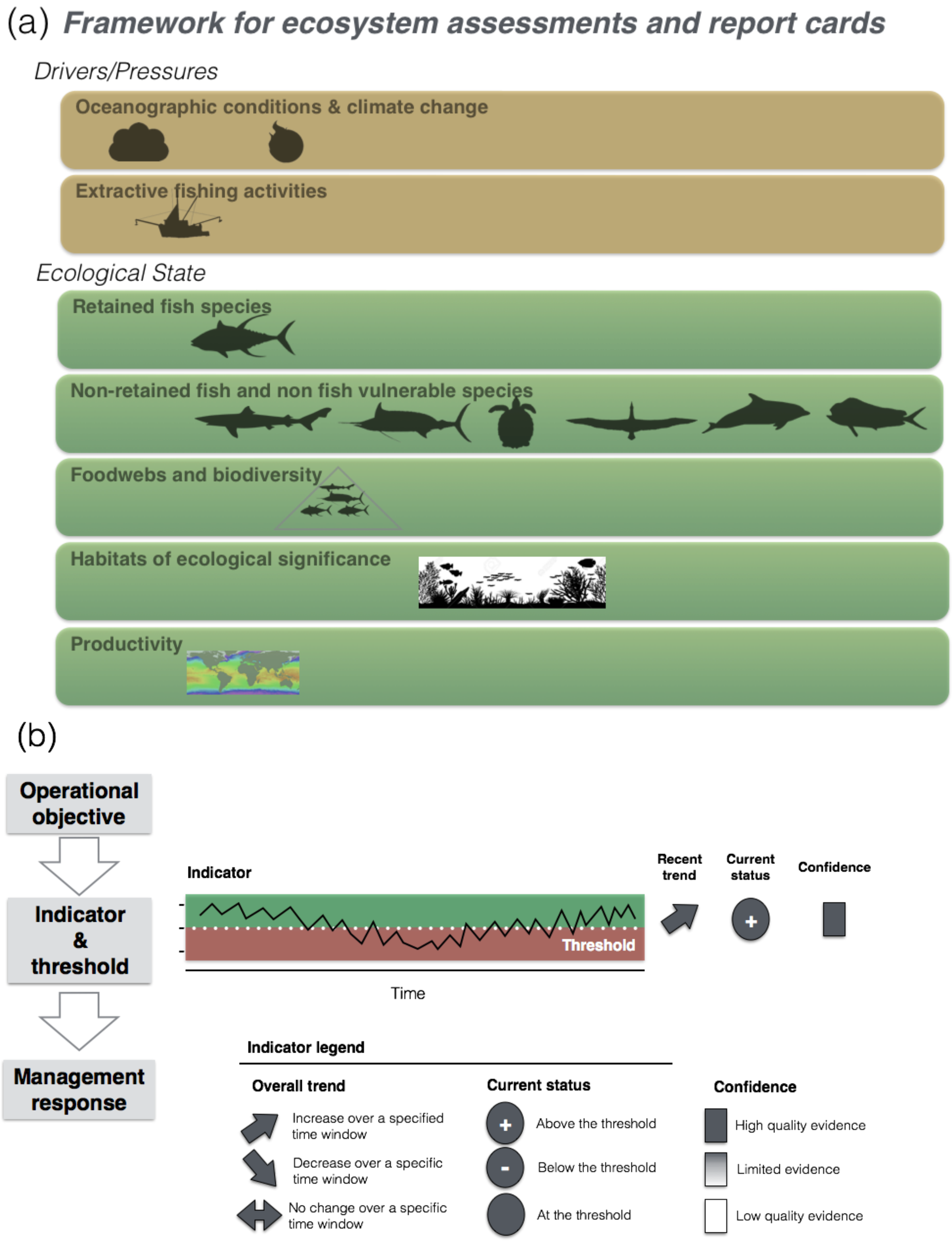


Figure 4. Framework for ecosystem assessments and report cards for the IOTC convention area to monitor and report on the pressures and the state of the pelagic ecosystem to the Commission.

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