A TEMPLATE FOR AN INDICATOR-BASED ECOSYSTEM REPORT CARD FOR THE INDIAN-OCEAN TUNA COMMISSION

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Abstract

As an opportunity to take the lead in moving forward implementing Ecosystem-based Fisheries Management (EBFM) in the IOTC Convention Area, the Working Party on Ecosystems and Bycatch recommended the development of an indicator-based ecosystem report card with the aim of testing a new approach for linking ecosystem science to management and increasing the communication and reporting of the state of the different components of the Indian Ocean ecosystem to the Commission (IOTC–WPEB12 2016). Here, first we aim to initiate a discussion and make the case for the need to develop an indicator-based ecosystem report card in the IOTC Convention Area. Second, we provide a potential template of an indicators-based ecosystem report card which will contribute to the discussion and contribute to the process towards its full development and use. 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.

1 Introduction

Fisheries for tuna and tuna-like species play an important role ecologically, economically and socially in the Indian Ocean. In 2015, these fisheries caught 1.6 million metric tones (IOTC 2015). These fisheries provide important ecosystem services by providing sources of food, employment, income, recreation, and tradition among many others to all the fishing nations and communities exploiting these resources in the Indian Ocean (Rogers et al. 2014). The Indian Ocean Tuna Commission has largely focused on managing fisheries of tuna and tuna-like species, with less effort dedicated to address the ecosystem considerations of these fisheries. Traditionally, the emphasis has been placed on controlling fishing mortality on target stocks to ensure the conservation and optimal utilization of stocks covered by the Convention Agreement (IOTC 2009). Most of the ecosystem based fishery management up to now has been focused on the management of bycatch species, and less emphasis has been given to account for the impacts of fisheries on trophic interactions and food webs.

Over time there has been an increasing recognition for the need to account for significant interactions between fish species and their ecosystems, to account for the wide range of economic and social factors arising from fisheries, and to account and quantify the value all the ecosystems services derived from healthy ecosystems and sustainable fisheries (Larkin 1996, Pikitch et al. 2004). As a result of all these recognitions, a more comprehensive and integrated approach to manage fisheries and their associated ecosystems has emerged referred as ecosystem-based fisheries management (Link 2002, FAO 2003). Accordingly, over the last decades international instruments of fisheries governance 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). Currently there exist multiple binding treaties and agreements such as the UN Fish Stocks Agreement, the FAO Compliance Agreement, and the Convention on Biological Diversity-Aichi targets that set the standard principles to govern and manage highly migratory fish species and associated ecosystems within an ecosystem approach. Consequently, there is increasing expectation for the IOTC to expand its current mandate and fisheries management to ensure the management of its target fish stocks accounts for ecosystem considerations, ecosystem impacts and the wide range of economic and social factors arising from fisheries (Lodge et al. 2007, de Bruyn et al. 2013).

There are multiple approaches and tools for including ecosystem information in fisheries management and making EBFM operational, as well as providing ecosystem advice to the managers and policy-makers. An example of a simple approach would be to synthesize ecosystem information into a synthesis report or an ecosystem report card to provide ecosystem context to inform single-species strategic management advice. More advance approaches would consist in accounting for all the direct and indirect interactions between fisheries and the target and non-target species, as well as accounting for ecosystem processes and environmental pressures using more complex tools with the aim of providing more tactical fisheries management advice (Plagányi et al. 2012, Collie et al. 2016, Skern-Mauritzen et al. 2016). All these continuum of approaches require the development of a variety of tools ranging from 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.

As an opportunity to take the lead in moving forward implementing EBFM in the tunaRFMOs, the Working Party on Ecosystems and Bycatch recommended the development of an indicator-based ecosystem report card with the aim of testing a new approach for linking ecosystem science to fisheries management and increasing the communication and reporting of the state of the different components of the Indian Ocean ecosystem to the Commission (paragraph 86 IOTC–2016–WPEB12). An indicator-based ecosystem report card can be viewed as a qualitative ecosystem assessment that synthesizes and integrates information across the several ecosystem components in question. It is a reporting tool designed to distill information into simpler highly visual form that can be easily understood by the scientific community, managers and policy-makers.

Here, we first aim to initiate a discussion and make the case for the need to develop an indicator-based ecosystem report card in the IOTC Convention Area. Second, we provide a potential template of an indicator-based ecosystem report card which will contribute to the discussion and contribute to the process towards its full development and use. In doing so, we propose a set of broad ecosystem components to be reported and monitored in the ecosystem report card, and provide examples of potential candidate ecosystem indicators to monitor each of the ecosystem component. However, we recommend convening a team of ecosystem experts with a wide variety of expertise to review and refine the proposed template as well as select a short list of ecosystem indicators to populate the template before it is endorsed to convey the advice on Ecosystem Matters (See recommendation section). Ultimately, we aim to build familiarity with this approach and seek to start a process to lead the way to an adaptive product that will suit the needs of fisheries managers and Commissioners to ensure ecosystem considerations is used in management decisions in the IOTC Convention Area.

2 Initiating a discussion on the need for an ecosystem report card for the IOTC convention area

An indicator-based ecosystem report card can have multiple purposes and uses. Below we highlight six main purposes and utilities to make the case for the need to develop an indicator-based ecosystem report card in the IOTC Convention Area:

(1) It synthesizes and summarizes multiple and complex ecosystem information from different sources into smaller and simpler number of grades to characterize the state of the different components of the ecosystem in question;
(2) It increases 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 establishes an ecosystem context within which management decisions can take place;
(5) It is an effective communication tool since it synthesizes multiple ecosystem information into a succinct summary product to effectively communicate the state (trends and status) of several ecosystem components to the Commission and other interested stakeholders;
(6) It has the potential to engage the Commission and other stakeholders in the process of incorporating ecosystem considerations into management decisions.

3 A potential template for an indicator-based ecosystem report card

First, we use the Driver-Pressure-State-Ecosystem services-Response (DPSER) tool to build a conceptual ecological model for the ecosystem where IOTC fisheries take place and use it to identify major structuring themes and the ecosystem components which we aim to report on and monitor. Based on this conceptual ecological model for the ecosystem in the IOTC area, we develop an Ecosystem Report Card to monitor and report on the state (trends and current status) of each major ecosystem component. Last, we provide examples of potential candidate indicators for each ecosystem components in the ecosystem report card.

3.1 The DPSRI framework as a tool to build a conceptual ecological model for the ecosystem in the IOTC Convention Area

An indicator-based ecosystem report card requires of a short list of indicators to describe and monitor the trend and status of the major components of the ecosystem in question. Therefore it is important to identify *a priori* what are the major structuring themes and ecosystem components that should be monitored, as well as identify what are the best indicators to characterize the trends and current status of each ecosystem component. Multiple tools exist to assist in the identification of ecosystem components, examine how the different component interact and select for relevant indicators. Here, we use the Driver-Pressure-State-Ecosystem services-Response (DPSER) framework, derived from the more familiar Driver-Pressure-State-Impact-Response (DPSIR) framework (Figure 1a) to construct a conceptual ecological model of the ecosystem for the IOTC convention area (Figure 1b). We use this conceptual ecological model of the ecosystem to assist in the identification of the major structuring themes and the ecosystem components which we aim to report on and monitor in the ecosystem report card. The DPSER conceptual framework is commonly used as a planning tool that allows identifying the full range of interaction between humans and the ecosystem including the main *drivers* and *pressures* influencing the *state* of the ecosystem, their ecological effects, and identify indicators best suited to monitor these effects and the linkages among them. Then, based on the state of the ecosystem, it allows identifying *responses* or management strategies to ensure sustainable levels of the *ecosystem services* desired by society (Kelble et al. 2013).

Based on the DPSER conceptual framework, we build a conceptual ecological model for the ecosystem where IOTC fisheries take place. We identify two major *drivers* and associated *pressures* that may be influencing the *state* of the ecosystem in the IOTC Convention Area (Figure 1b). 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 IOTC Area. Second, the natural environmental variability in the Indian Ocean as well as the emerging climate change (and their associated environmental changes in the ecosystems) are also generating several pressures influencing the *state* of the ecosystem that also need to be accounted for. Potentially the *state* of the ecosystem could be characterized or described with multiple ecological elements and attributes that would need to be monitored. For practical reasons Regional Fisheries Management Organizations around the world intending to apply an ecosystem approach in managing their main fisheries have categorized the ecological state of their ecosystem into four different operational components that can be assessed and monitored over time. These include: (1) target species (2) bycatch species, (3) ecosystem properties and trophic interactions and (4) habitats (Lodge et al. 2007). If monitored over time these components taken together would characterize and describe the overall state of tunas and tuna-like species and associated ecosytems in the IOTC Convention Area. Another major element in the Conceptual Ecological Model of the IOTC ecosystem is the *response,* which consists of a set of fisheries management responses to account for the impacts of fishing and the influence of environmental variation and climate change in the state of tuna and tuna-like species and associated ecosystem. Ultimately, it is also important to illustrate that a sustainable managed and healthy *state* of the ecosystem can deliver multiple *ecosystem services* including provisioning, regulating, cultural and habitat services.

3.2 A potential template for an indicator-based ecosystem report card

The conceptual ecological model for the ecosystem where IOTC fisheries take place provides a framework to develop an Ecosystem Report Card to monitor and track each major ecosystem component. Accordingly, we present an ecosystem report card with two major structuring themes (Figure 2a). The first theme devoted to monitor the trends and current status of the relevant *pressures* affecting the state of the ecosystem. A second theme devoted to monitor the trends and current status for the different ecological components describing the *state* of tuna and tuna-like species and associated ecosystems, which include target species, bycatch species, ecosystem-properties and trophic relationships, and habitats. For this ecosystem card we focused on developing a template or framework mainly to report and monitor the different components and attributes characterizing and describing the ecological state of the marine ecosystem where IOTC fisheries interact. Yet this proposed template or framework should be seen as a living document. All the contrary, it should be seen as a first step to initiate discussions, as this will need to be further refine and adapted to the needs of the managers and decision and policy makers. For example, if deem relevant, an additional structural theme capturing the socio-economic importance of fisheries in the IOTC area could be easily added in the report card.

This ecosystem report card would need to be populated with a series of ecosystem indicators in order to monitor trends and characterize the current status of the different ecosystem components in question. Ideally, relevant indicators for each component must be associated to pre-establish operational objectives and thresholds to activate specific management responses to ensure the objectives are met. The aim of having an indicator is to monitor and portray the long-term trend of the indicator in question. The long-term trend of the indicators could also be accompanied by a summary of the most recent trend within a specific time window and the current status (Figure 2b). Furthermore, it is also important to capture in the report card how confident we are on the indicators (trend and current status) and therefore the level of evidence (or uncertainty) in each indicator should also be illustrated.

We highlight the importance of producing a succinct highly visual and communicative ecosystem report card. The card should be understandable by multiple audiences with ranging technical abilities and backgrounds. 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 but an important issue to tackle from the very beginning, an important lesson learned in other regions of the world (Zador et al. 2016). Unquestionably a succinct ecosystem report card with a limit of one or 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 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 a more in depth-ecosystem assessment (for example an Integrative Ecosystem Assessment, see recommendations section below) (Zador et al. 2016). The ecosystem assessment should include all the details about the ecosystem indicators portrayed in the ecosystem report card, detail indicator descriptions including data sources, methods and interpretation as well as capture the uncertainty of the indicators. The in-depth assessment could also include analysis of factors influencing trends, implications of fisheries management, other observations, etc.

3.3 Potential ecosystem indicators to populate the ecosystem-report card

We would recommend working with a diverse group of experts on ecosystem indicators and management to refine the proposed template for the ecosystem report card and select a short list of indicators to populate the ecosystem card **(**see recommendation section below**)**. However, in the mean time, we provide examples of potential candidate indicators for each broad structuring theme and ecosystem components of the ecosystem report card **(**Table 1). In the examples, we highlight how each indicator should be associated to a pre-established operational objective, thresholds and management and conservation measures to ensure that those thresholds are not exceeded. We make a distinction between natural and anthropogenic drivers and pressures. Natural drivers such as environmental variability and to some extent climate change result to unmanageable pressure (at least by IOTC) and anthropogenic drivers such as demand for fish protein lead to manageable pressures such as fisheries extractions which it is under the purview of IOTC. It is also important that the selected ecosystem indicators 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 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 criteria to guide the identification of useful ecosystem indicators (Rice and Rochet 2005, Shin et al. 2010), which should be used by the ecosystem experts to guide their selection process. Furthermore, indicators can be developed based on empirical data or model-derived data from existing ecosystem models. We also advised to identify desired indicators that cannot be currently developed given the available data and knowledge but that potentially could be developed in the future.

4 Connecting ecosystem science to management advice

As a first step, we envisage an indicator-based ecosystem report card to be a tool to synthesize ecosystem information in order to be able to communicate and inform to the Commission about the current state (trends and status) of the different components of the ecosystems. 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 in-depth 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 can 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 emerges and fit new emergent management needs. 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 had lead to better incorporation of ecosystem considering into fisheries management advice and decisions (Zador et al. 2016). While there are amply 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, moreover the development and testing of Management Strategy Evaluation for achieving fishery ecosystem objectives are also slowly emerging (Sainsbury et al. 2001, Large et al. 2013, Skern-Mauritzen et al. 2016, Zador et al. 2016).

5 Recommendations and future work in support of the development of the ecosystem report card

We propose the following activities and research venues to facilitate the development of an indicator-based ecosystem report card:

(1) Prepare an **Ecosystem Synthesis Report** with the aim of describing main physical and ecological components of the ecosystem and their interactions and relevance with IOTC fisheries. Moreover, the report could review what it is known about the direct and indirect impact of the fisheries on the different components of the ecosystems, as well as review known links between the environment and fisheries productivity in the region. The Ecosystem Synthesis Report can provide the context for the development of the ecosystem report card.

(2) Engage a **Group of Ecosystem Experts** in the Working Party on Ecosystem and Bycatch to review and refine the proposed template of the ecosystem report card and select a short list of indicators to populate the ecosystem card. The team of ecosystem experts should also include a group of stakeholders with a diverse scientific, management and fishing experience of the ecosystems. Indicators should be selected following a well establish criteria and by consensus and the final list of indicators should be presented as candidate indicators to be included in the report card. We expect the selection of indicators to populate the ecosystem report card will be influenced by the extent of scientific knowledge and data, as well the particular expertise of the ecosystem team.

(3) The ecosystem report card and indicators within should be supplemented by an in-depth **Ecosystem Assessment** or **Integrative Ecosystem Assessment.** The ecosystem assessment should include all the details about the ecosystem indicators portrayed in the ecosystem report card, with detail indicator descriptions including data sources, methods and interpretation as well as capture the uncertainty of the indicators. The in-depth assessment could also include analysis of factors influencing trends, implications of fisheries management, other observations, etc. This assessment will increase the credibility of the report card as well as provide managers with the scientific rigor needed to make management decisions.

(4) To start a **Formal Dialogue with the Commission**, the ecosystem report card could be presented to the Commission once developed, so the Commission can provide inputs and suggestions on the content and design of the report card that could be incorporated in further versions of the card. 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 integrative ecosystem assessment is used in management decisions.

(5) Investigate what would be the **Ideal Scale(s) of the Ecosystem Report Card**. A management area could be related to known ecological boundaries but also political and traditional fishing ground boundaries. To initiate the progress we recommend that an ecosystem report card be developed for the whole IOTC convention area but we anticipate that it might be more meaningful to streamline and synthesize the ecosystem information to ecologically meaningful based regions or ecoregions. This could be investigated by the Working Party on Ecosystem and Bycatch.

(6) The proposed template for the ecosystem report card while it captures the major ecological components of the ecosystems and their interactions with the environment and fisheries, it does not capture the main socio-economic components of fisheries and ecosystems. We also recommend exploring venues to link the **Human Component (Social, Economic and Cultural)** to the ecosystem report card.

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7 Figures

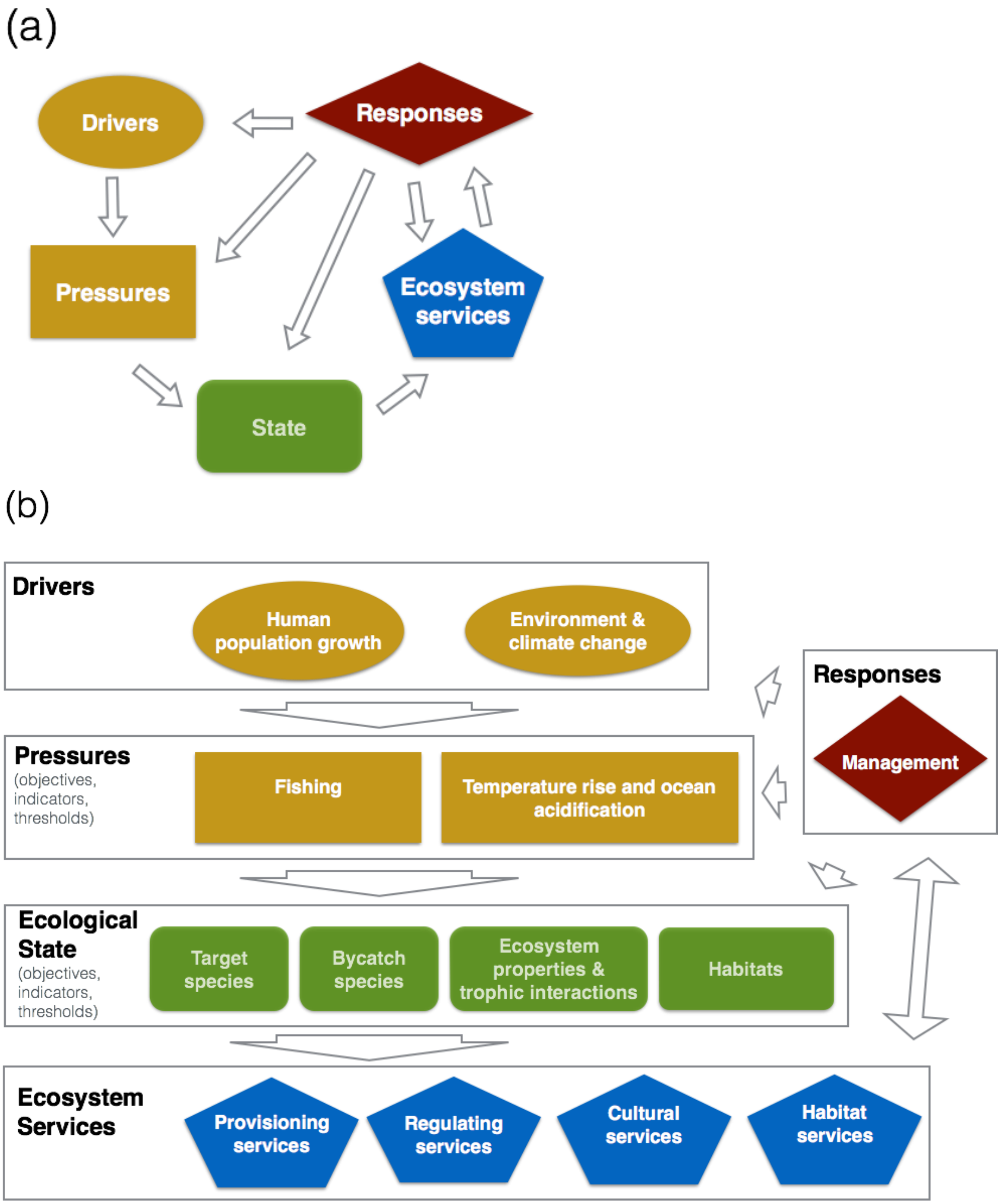
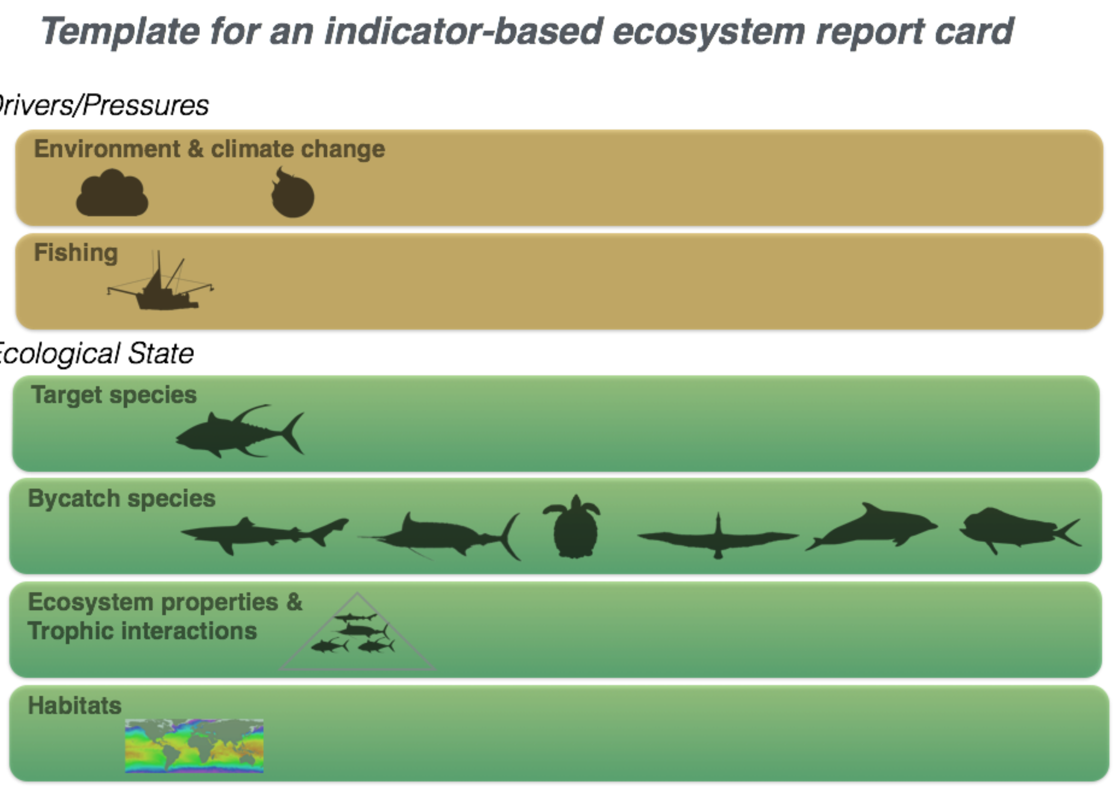


Figure 1. Frameworks to inform the indicator-based ecosystem report card. (a) The Driver-Pressure-State-Ecosystem services-Response (DPSER) framework and (b) a conceptual ecological model for the ecosystem where IOTC fisheries operate.

(a)


Template for an indicator-based ecosystem report card
Drivers/Pressures
Environment & climate change
Fishing
Ecological State
Target species
Bycatch species
Ecosystem properties &
Trophic interactions
Habitats

(b)

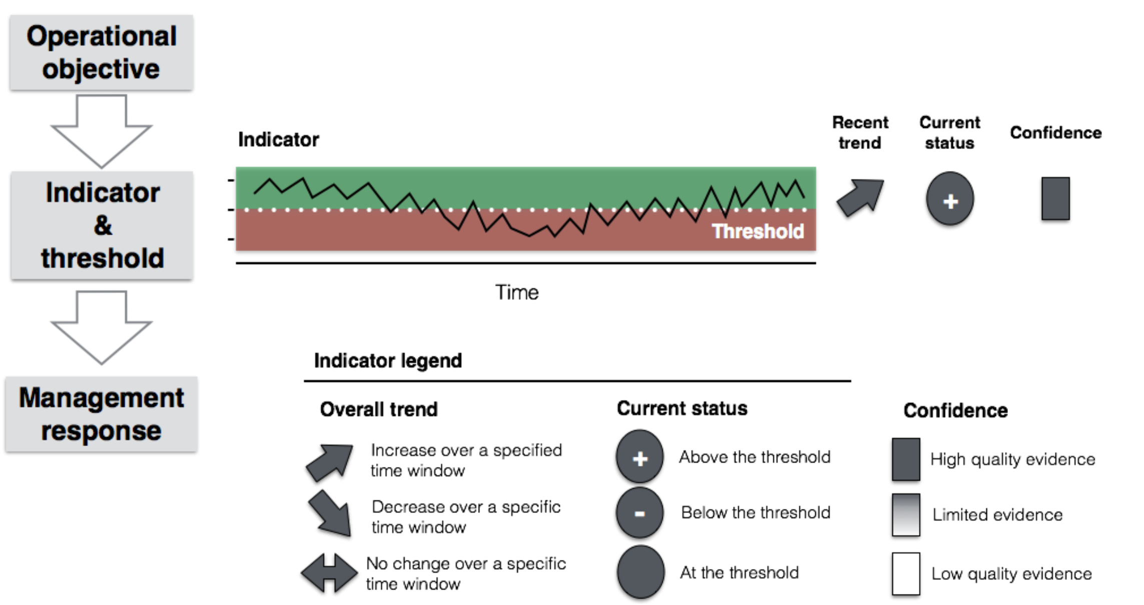

Operational objective
Indicator & threshold
Management response
Indicator
Threshold
Time
Recent trend
Current status
Confidence
Indicator legend
Overall trend
Increase over a specified time window
Decrease over a specific time window
No change over a specific time window
Current status
Above the threshold
Below the threshold
At the threshold
Confidence
High quality evidence
Limited evidence
Low quality evidence

Figure 2. A template for an indicator-based ecosystem report card for the IOTC convention area to monitor and report on the state (trends and current status) of each major ecosystem component.

8 Tables

Table 1. Examples of potential candidate indicators for each broad structuring theme and ecosystem components of the ecosystem report card. Note how each indicator is associated to a pre-established operational objective, thresholds and management and conservation measures to ensure that those thresholds are not exceeded. A distinction is made between natural drivers (such as environmental variability) leading to unmanageable pressures, and anthropogenic drivers (such as demand for fish protein) leading to manageable pressures such as fisheries extractions.

DRIVERS/PRESSURE				
	Operational objectives	**State indicators**	**Thresholds**	**Management response**
Environment & climate change	Monitor average sea surface temperature	Average sea surface temperature over time	-not applicable	Pressure unmanageable by the IOTC
Fishing	Landings do not exceed global fishery yields of the IOTC area Fishing capacity does not exceed total productivity of the stocks	-Landing over time -Total number of vessels	-Global fishery yields estimated for the IOTC area -Capacity levels of 2006/2007	-Adjustment of total allowable catches -Adjustment of capacity.
ECOLOGICAL STATE				
Target species	Maximize sustainable harvest of target species applying the precautionary approach.	-Biomass trends relative to B_{MSY} -Fishing mortality rate trends relative to F_{MSY} -Proportion of stocks above sustainable levels	-Target and limit reference points are defined for population biomass and fishing mortality (B_{MSY} and F_{MSY} or proxies)	-Harvest control rule -Recovery plans -Capacity-reduction plans - Catch quotas

Bycatch species	Maintain and restore populations of bycatch species above levels at which their reproduction may become seriously threatened	-Population size trends -Size/age structure trends -Catch trends -Vulnerability of a species to overfishing	-Bycatch limits allocated to vulnerable species -In absence of information apply the precautionary approach	-Bycatch limits or caps for species or groups -Gear modifications and practices to reduce bycatch -Adoption of good practices by crews and release of capture life animals following protocol
Ecosystem properties and trophic relationships	Maintain viable trophic interactions and interdependencies involving species that are affected by fishing	-Species composition of the catch -Size based indicators -Trophic level based indicators -Diversity indices -Relative catch of a species or groups -Trophic links and biomass flows	-Limit reference point for the impacts of fishing on key stone predators and preys in the ecosystem -In absence of knowledge, precautionary reference point values based on general expectations	- Multispecies management plans (e.g. one bycatch specie limiting the catch of other target species) - Mitigation measures - Safe release practices
Habitats	Describe, identify and protect habitats of special concern and habitat utilization of species	-Identification and mapping of habitats of special concern (e.g. reproduction, migration, feeding, hotspots) -Habitat shifts and range contractions -Habitat suitability index -Habitat size (e.g. O2 minimum zones)	-Minimum habitat needs for population viability	-Restriction or limit fishing on habitats of special concern such as spawning and nursery habitats.