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REVIEW OF T-RFMO ECOSYSTEM RESEARCH TO INFORM A WORKPLAN ON ECOCARDS FOR THE EPO

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EXECUTIVE SUMMARY

IATTC's *Ecosystem Considerations* document was created to support implementation of the Ecosystem Approach to Fisheries Management (EAFM) by incorporating ecosystem considerations into fisheries management decisions. The *Ecosystem Considerations* document is a complementary report to the annual *Fishery Status Report* and focuses on reporting on incidental catches of species other than the target tuna and tuna-like species (e.g., billfish), environmental and oceanographic conditions, as well as highlighting ecosystem dynamics in the eastern Pacific Ocean (EPO). With the Antigua Convention entering into force, IATTC's responsibilities have increased to ensure long-term sustainability of not only tunas and tuna-like species, but also other associated species of fish and the broader ecosystem. In parallel, IATTC's Strategic Science Plan (SSP) identifies a plethora of ecosystem-related research projects that facilitate a better understanding to support operationalization of EAFM. Due to this increase in ecosystem-related research, much of which is summarized in the *Ecosystem Considerations*, the length and complexity of the document has increased over time. Consequently, it now exists in a form that is not optimal for conveying key information to IATTC's Cooperating Members and Non-Members (CPCs) and the wider public. Therefore, the staff aimed to review ecosystem research conducted by other tuna-Regional Fisheries Management Organizations (t-RFMOs), and how this research is delivered to their respective Commissions, with the ultimate goal of developing a useful product for tracking and monitoring the status of EPO ecosystems and effectively inform decision making. This review is used, as a first step, to inform a proposed workplan to replace the *Ecosystem Considerations* with two complementary ecosystem-advice products. The first consists of a summarized indicator-based Ecosystem Report Card or "*EcoCard*" that highlights a selected set of key indicators recommended by the staff and through stakeholder consultation to best represent ecosystem status. The second consists of a more extensive (reference document), "*Ecosystem Status Assessment"* that details a full suite of indicators to describe the annual status of marine ecosystems as well as changes in indicator values over time. The overarching goal is to improve ecosystem-related effective communication, operationalization and decision making for IATTC.

As a result, the staff propose a transition to the *EcoCard* concept based on the following workplan, including:

(1) development of a conceptual framework for determining the main drivers (e.g., fishing, climate) and ecosystem elements to monitor (e.g., state of non-retained species, habitats) and the potential spatial extent of an *EcoCard* (i.e., "*ecoregions*");

(2) development of tools and indicators, including establishment of criteria for selecting, calculating, assessing, validating and interpreting candidate indicators for monitoring ecosystem components;

(3) development of pilot ecosystem-advice products ("*EcoCard*" and "*Ecosystem Status Assessment*") to support the decision-making process and improve communication tools for visualizing ecosystem status.

When developing the *EcoCard* and proposed workplan, the IATTC staff plan to provide recommendations and seek feedback regularly from the EBWG, the SAC, the Commission and other relevant stakeholders throughout the process.

1. BACKGROUND

The IATTC's *Ecosystem Considerations* document has been published as a section in IATTC's *Fishery Status Report* since 2003 and presented annually to the Scientific Advisory Committee (SAC). The purpose of the document is to provide information on the potential ecological effects of the eastern Pacific Ocean (EPO) tuna fisheries to guide the development of conservation and management measures (CMMs) for tuna and tuna-like fishes [1], and most recently for non-target species and the habitats and ecosystems these species inhabit. The document was created in response to development of the ecosystem approach to fisheries management (EAFM) prompted by the 2001 Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem, which sought to implement the FAO Code of Conduct and to incorporate ecosystem considerations and sustainable fishing practices into fisheries management strategies (FAO 2001, Garcia *et al.* 2003). Furthermore, the Antigua Convention strengthened IATTC's responsibility to ensuring long-term ecological sustainability—officially entering into force in 2010—through its various articles (Article IV 3; Article VII 1a,f, g; Article XV 3).

Initially, the *Ecosystem Considerations* document was focused on describing developments in IATTC research or published studies pertaining to ecosystem topics that occurred during the previous year, sometimes including relevant work from scientists external to the IATTC. Although its contents have varied over time (e.g., see SAC-01-15, SAC-14-11), four topics have remained a primary focus: (1) tuna fishery impacts in the form of direct effects including incidental catches of species other than the target tuna and tuna-like species (i.e., "bycatch"), and indirect effects including trophic interactions (e.g., studies of stomach contents of tuna and tuna-like species), (2) environmental or oceanographic conditions (e.g., El Niño Southern Oscillation, ENSO, events) that impact the catches of tropical tunas, for example through shoaling or deepening of the thermocline (Bayliff 1989), (3) ecosystem modeling, and more recently, (4) ecological risk assessments (e.g., Ecological Assessment of Sustainable Impacts of Fisheries, EASI-Fish: SAC-09-12, BYC-09-01, BYC-10 INF-B, BYC-11-02, SAC-13-11, SAC-14-12) to prioritize conservation and data collection efforts of potentially vulnerable bycatch species interacting with the tuna fisheries.

Over the last decade, the scope of the staff's research has expanded as a result of increasing requests by CPCs to explicitly address ecological components of the Antigua Convention (see IATTC Strategic Science Plan (SSP), IATTC-101-02a). This increase in the number and nature of ecosystem-related research projects undertaken by the staff is also a reflection of the broadening array of ecological, environmental and fishery issues that are required to be understood to pursue support of EAFM implementation in the EPO ecosystem. As a result, the length and complexity of the all-encompassing *Ecosystem Considerations* document has increased significantly in recent years. Consequently, it may now exist in a form that is not optimal for succinctly conveying key information and messages to IATTC's Cooperating Members and Non-Members (CPCs) and the wider public. Adding to the growing needs for more efficiently communicating the staff's scientific work to the Commission, including ecosystem research, is a possible transition to shortened agendas of scientific meetings. Specifically, at its 14th Meeting in 2023, the IATTC SAC recommended *that the Commission and the SAC reconsider the way in which the Committee conducts its work, so that future SAC meetings are more oriented towards responding more effectively to the needs of the Commission.* Given that increased costs have made longer meetings prohibitive, this implies the need for reduced and shorter staff documents and presentations that are more focused on the immediate needs of the Commission (e.g., background work directly related to the staff's recommendations for

[1] As defined in IATTC's specifications for data provision under Resolution C-03-05 as tunas and billfishes (see Table 1 in the specifications).

management and/or any other action), and more time for discussion. This new format of the SAC and potentially the meetings of the Working Groups (WG) on Ecosystem and Bycatch and Fish-aggregating devices (FADs), respectively, has introduced challenges to present detailed descriptions of research activities to the SAC and the WGs.

Therefore, the staff now aim to restructure the *Ecosystem Considerations* document into two complementary ecosystem-advice products aligning with the FAO roadmap towards EAFM implementation (Figure 1). The first ecosystem-advice product includes a summarized indicator-based Ecosystem Report Card or "*EcoCard*" serving as a condensed visual tool for conveying a suite of relevant bycatch, ecosystem, and climate indicators, among potential others, selected by expert opinion to best represent the state of the ecosystem. The framework presented in Figure 2 and the National Oceanic and Atmospheric Administration's (NOAA) visualization of marine ecosystem status provide examples of the *EcoCard* concept and depiction of indicators. The second ecosystem-advice product includes a more extensive (for consultation only as needed) complementary "*Ecosystem Status Assessment*" detailing a suite of indicators to describe the annual status of EPO marine ecosystems as well as changes in indicator values over time. The overarching goal is to improve communication regarding complex ecological aspects of the ecosystem, IATTC's efforts towards pursuing ecological sustainability, and for the Commission to consider implementation of EAFM through potential adoption of indicators and decision rules.

Detailed analyses undertaken in specific bycatch, ecosystem and climate assessments, and mitigation projects (e.g., EASI-Fish vulnerability assessments, climate-ready fisheries, and safe handling and release guidelines) will continue to be provided in separate SAC or WG documents to provide adequate detail required for scientific scrutiny. It is important that these detailed analyses and ongoing projects are recognized as complementary efforts to the ecosystem-related tools and products presented herein, since they are developed under the IATTC's SSP to explicitly contribute to fulfilling broader ecosystem research goals.

1.1. Objectives

The objectives of this document are twofold: (1) to review and summarize the available information on ecosystem research conducted by the other tuna-Regional Fisheries Management Organizations (t-RFMOs) and to detail progress made by the IATTC. This includes examining tools (e.g., ecosystem modeling, indicators and potential spatial units "*ecoregions*") that may be considered in the development of ecosystem-advice products (e.g., *EcoCards* and *Ecosystem Status Assessments*); and (2) to consider this information to propose an IATTC workplan aimed at supporting decision-making and potentially operationalizing EAFM in the EPO through the development of these ecosystem-advice products. The t-RFMOs considered here are the Western and Central Pacific Fisheries Commission (WCPFC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and the Indian Ocean Tuna Commission (IOTC).

It is important to note that although candidate indicators have been identified and *EcoCard* initiatives have commenced in other t-RFMOs, this work is still in its infancy and specific indicators, *EcoCards* and their spatial extent (i.e., ecoregions) have not yet been adopted by the respective Commissions. Therefore, it is timely to harmonize efforts among the t-RFMOs and to adapt and standardize tools and ecosystem-advice products and implementation to the fullest extent possible.

2. ONGOING EFFORTS TO DEVELOP TOOLS AND PRODUCTS TO SUPPORT EAFM IN T-RFMOS

t-RFMOs have long recognized the need for, and importance of, implementing EAFM. However, tangible progress has been limited, with haphazard implementation of some elements. Additionally, a clear long-term plan for operationalizing EAFM has been absent (FAO 2016, Juan-Jordá *et al.* 2018b, FAO 2019, Juan-Jordá *et al.* 2019a). Furthermore, the complexity of monitoring and predicting climate and ecosystem dynamics as well as the lack of agreement among scientists and management bodies regarding definitions—even of the concept of EAFM itself—and what elements should be included have hindered the operationalization of EAFM (Dolan *et al.* 2015, FAO 2016, FAO 2019). Yet, there has been an emergence of tools and products to facilitate the integration of bycatch, ecosystem, climate, economics, and social elements in fisheries-management advice to support EAFM implementation. There are ongoing processes and initiatives to advance the development of tools and products to support the implementation steps involved in operationalization of EAFM in the t-RFMOs (Figure 1, adapted from Bianchi *et al.* 2016). These tools, for example, include: (1) the development and use of ecoregions—ecologically meaningful and practical, spatial units—as a spatial framework to incentivize ecosystem planning, science and the development of advice products at the ecoregion level (Juan-Jordá *et al.* 2022a, Juan-Jordá *et al.* 2022c), (2) ecological risk assessments to identify and prioritize species at potential risk from the impacts of tuna fisheries (e.g., Griffiths *et al.* 2019) and to simulate the effect of hypothetical CMMs to assess changes in vulnerability status (e.g., Griffiths and Lezama-Ochoa 2021), and (3) development of ecosystem models and ecological indicators as platforms to understand and evaluate past, present and possible future effects of the environment and fishing on ecosystem structure and function (e.g., Olson and Watters 2003, Griffiths *et al.* 2013, Griffiths *et al.* 2018, Craig and Link 2023). Examples of ecosystem products include: (1) development of *Ecosystem Considerations* reports (like those produced by the IATTC e.g., SAC-14-11) or *Ecosystem-fishery overviews* (like those under development as pilot products by ICCAT e.g., Juan-Jordá *et al.* 2023b) that document the scope of the fishery, its dynamics with the ecosystems and relevant background information, and (2) development of indicator-based *EcoCards* and associated *Ecosystem Status Assessments* to provide a succinct evidence-based narrative of the state of the ecosystem using trends and status of selected indicators that best represent effects of fishing and the environment on multiple ecosystem components (similar to those recently produced by SPC-WCPFC e.g., SPC-OFP 2023). The *EcoCard* aims to supplement the *Ecosystem Status Assessments* by providing a concise and accessible summary of key indicators for operationalization of EAFM and more directly and efficiently communicating the main status and trends to end users (Juan-Jordá *et al.* 2018c).

All of these tools and products vary in complexity, have different degrees of data requirements, and have specific purposes. However, they all may be used to more effectively connect bycatch, ecosystem and climate considerations into advice for decision making in t-RFMOs. Moreover, the resulting ecosystem products aim to formulate and operationalize integrated ecosystem-based advice that can range from being strategic (i.e., related to decisions about *what* will be done to address a specific objective) to tactical (i.e., related to *how* resource managers will implement management actions) (Fletcher and Bianchi 2014, Craig and Link 2023).

The development of some of these tools and products are ongoing in various t-RFMOs and corresponding ocean regions (i.e., in the western and central Pacific Ocean (WCPO) by the SPC, the Atlantic Ocean by the ICCAT and the Indian Ocean by the IOTC). However, these ongoing efforts and development of products are not currently standardized across t-RFMOs. Therefore, and alongside improving our tools for monitoring and reporting ecosystem-related information more succinctly within the IATTC, an additional goal of the ideas presented herein is to align IATTC's efforts with those of other t-RFMOs, to the greatest extent possible.

2.1. Harmonization among t-RFMOs

The idea to develop an indicator-based *EcoCard* and complementary *Ecosystem Status Assessment* to inform fisheries management decisions in t-RFMOs was initiated by the IOTC and ICCAT around 2017 (Juan-Jordá *et al.* 2018b). These products were designed to evaluate and monitor the impact of fisheries and climate on the state of multiple ecological components—target species, bycatch species, ecosystem properties and trophic relationships, and habitats—with a suite of surveillance and operational indicators linked to management objectives, where possible. IATTC staff reviewed the progress of ecosystem reporting in the EPO based on these aforementioned ecological components (SAC-10 INF-B) as a first step to harmonizing indicators and reporting progress, but an *EcoCard* tool has not yet been formally developed for the IATTC. Currently, all t-RFMOs are making progress in considering fishing and climate impacts on ecosystems by using indicators for monitoring, reporting and communicating the status of fisheries and ecosystems (see e.g., SAC-14-04, SAC-14-11, SPC-OFP 2023, Juan-Jordá *et al.* 2018b), although standardization of indicators and the operational framework has not yet taken place.

Near the end of 2022, scientists from SPC, IEO (Instituto Español de Oceanografía – CSIC), AZTI and ISSF (International Seafood Sustainability Foundation) initiated meetings to discuss the advancement of fisheries, bycatch, ecosystem and climate indicators by ocean basin. Their overarching goal was to harmonize ecosystem tools and products, including indicator development, for consideration in operationalizing EAFM in t-RFMOs. IATTC staff joined these discussions in 2023. These ongoing meetings foster an open dialogue among scientists of the various institutions, enabling collaborations and the sharing of experiences in developing, testing, interpreting, and communicating indicators across different oceanic regions. This is a timely approach, particularly for the development of environmental and climate indices, as recent Resolutions on climate change have been adopted by the WCPFC (Resolution 2019-01), the IOTC (Resolution 22/01), the ICCAT (Resolution 22-13) and by the IATTC at its 101st Annual Meeting in 2023 (Resolution C-23-10).

ICCAT and the IOTC have created working groups to address ecosystem and bycatch impacts focused on fisheries and climate change (i.e., the Subcommittee on Ecosystems and Bycatch and Working Party on Ecosystems and Bycatch (WPEB), respectively). These working groups, along with the Ecosystem and Bycatch session of the WCPFC's Scientific Committee (SC) and IATTC's Ecosystem and Bycatch Working Group (EBWG), have a common objective to improve the knowledge and understanding on the ecosystem and bycatch species and to address fisheries and climate impacts on them. They also share common challenges such as difficulties involving the implementation of EAFM due to lack of clear EAFM plans, as well as conservation and management goals, including reference points. Additionally, all face limitations in data availability for many bycatch species and broader ecosystem dynamics, presenting challenges in providing management advice given these constraints (FAO 2019).

As the influence of climate change on tuna fisheries is now explicitly recognized by t-RFMOs through the adoption of Resolutions, ecosystem and climate indicators serve as a useful means to monitor changes over time and to address environmental concerns. At the 2022 SC meeting of the WCPFC, a recommendation was made for ecosystem and climate indicators to become a standing agenda item under the Ecosystem and Bycatch mitigation theme (WCPFC19-2022-SC18-01). Similarly, at IATTC's 14th meeting of the SAC and the EBWG in 2023, recommendations were endorsed to include climate change as a standing agenda item of the annual SAC, EBWG and IATTC meetings (IATTC-101-03), and Resolution C-23-10 was adopted. Furthermore, complementary to the work presented here, a proposed workplan for climate resilient fisheries will be presented at IATTC's 15th meeting of the SAC in 2024 (SAC-15-12).

In harmonizing efforts among t-RFMOs, it is important to initially assess the ongoing work within each t-RFMO on tools for developing ecosystem indicators and their incorporation into ecosystem-advice products such as the *EcoCard*. Therefore, the review presented here includes three primary tools or ecosystem products currently under development: (1) ecoregions, (2) ecosystem models and (3) indicators and report cards. In brief, delineation of "ecoregions" has been considered a first step towards EAFM implementation (Figure 1, Fletcher *et al.* 2010, Staples *et al.* 2014). Ecoregions are generally geographically defined areas exhibiting relatively homogeneous ecosystems, serving as units of analysis to support decision making for integrated management of natural resources (Omernik 2004). Studies conclude that these ecoregions must not only be ecologically meaningful but also large enough to facilitate effective and practical fisheries management advice (Todorović *et al.* 2019, Juan-Jordá *et al.* 2022c, Nieblas *et al.* 2022b). An indicator-based *EcoCard* may be produced for individual ecoregions to support regional management advice. Additionally, trophic mass-balance ecosystem models facilitate a description of the internal structure and flow of energy through the system and these have been used to derive annual values for ecological indicators, that in concert, identify changes to ecosystem structure and function and potential impacts from tuna fisheries (see e.g., [SAC-10-15]). These ecological indicators may be important considerations for inclusion in an *EcoCard* to provide holistic management advice on ecological effects from fishing. Indicators that ultimately form the basis of an *EcoCard*, are measurable quantities that enable monitoring and evaluation of trends over time and contribute to our understanding of ecosystem status. From a t-RFMO perspective, ideally, these indicators should be linked to management goals and actions and have associated performance thresholds that might elicit a management action if exceeded. Overall, the development and adoption of these tools and products in t-RFMOs aim to advance the provision of ecosystem-related management advice.

2.2. SPC-WCPFC

2.2.1. Ecoregions

As recognized in several papers from the beginning of the 2000s, there is a need to spatially define the area(s) to be managed with an ecosystem-based approach as, by definition, this approach is spatially explicit as opposed to species-specific (Sibert 2005, Dambacher *et al.* 2010, Allain *et al.* 2012b, Nicol *et al.* 2012). However, work by SPC on explicitly developing ecoregions has not yet come to fruition. One of the criteria decided upon at the 16th meeting of the SC (Allain *et al.* 2020a) was that indicators should be "*scalable across national, sub-regional and regional scales*" (Table 1), but this is the one criterion that was not met in recent papers where the indicators presented were only basin-scale (SPC-OFP 2023). Nevertheless, high-seas regions and boundaries within the WCPFC Convention Area were included in a new fishing effort indicator represented by the proportion of purse-seine sets made in these areas, by fishing mode (i.e., set type) (SPC-OFP 2023).

Other spatial analyses have been conducted and may be considered in formal development of ecoregions if appropriate. For example, an analysis of stable isotopes in tuna tissue across the WCPO led to the modification of the Longhurst biogeochemical province delineation (Longhurst 1998) in this region, as tuna presented a clear spatial pattern in isotopic values that was hypothesized to reflect differences in tuna habitat (Houssard *et al.* 2017). This work was not fully developed into an analysis of ecoregions, however, recent work on defining biomes at the global level using forcing variables in the SEAPODYM-LMTL model (low and medium trophic levels, i.e., zooplankton/micronekton), such as temperature stratification and primary production, has been used to validate ecoregions with acoustic transects and to examine how climate change might impact ecoregions.

2.2.2. Ecosystem modeling

Since 2002, SPC has developed trophic mass-balance ecosystem models to describe the dynamics of the WCPO pelagic ecosystem using Ecopath with Ecosim. Impacts of climate change on target and non-target species and on mid-trophic level species (mesozooplankton and micronekton) were first explored in 2010 with this tool (Le Borgne *et al.* 2011, Allain *et al.* 2012a).

With improved catch time-series, an updated model was developed in 2019 to explore the impact of hypothetical longline and purse-seine fishing practices—including use of FADs—on the ecosystem (Allain *et al.* 2015, Griffiths *et al.* 2018). Outputs of this model included ecological indicators—the mean trophic level of the catch (MTLc), fishing-in-balance (FIB) index and Kempton's Q (a diversity index)—which together inform on changes to the ecosystem over time. These ecological indicators showed marked changes in the ecosystem structure from 1980–2010, including an expansion of the fishery and diversity of the catch as well as a decrease in the standing biomass of higher-level predators. However, these indicators have not yet been considered in the ecological indicators presented to the SC of the WCPFC, although this does not preclude them from being included in the future.

The 2019 Ecopath model was further updated after consultation with experts (Allain *et al.* 2020b) by updating both the diet matrix with recent trophic data and fisheries time series. The updated model was primarily used to explore the impact of climate change and fishing effort scenarios on biomass changes to bycatch species (Allain *et al.* 2021a). While no ecosystem indicators were explicitly produced from this project, they are available for extraction from the updated model, should constituents deem appropriate.

Qualitative trophic-based models were also tested in several regions of the Pacific (south-west, west and east) (Dambacher *et al.* 2010). Indicators such as number of species, predation links, link density, and percent connectance were used in this framework to describe and compare the ecosystems. Overall, the analysis demonstrated high species diversity but low connectance and very spatial-specific responses highlighting the importance of spatially defining the areas to be monitored and managed. However, this initiative was not explored further.

The Spatial Ecosystem and Populations Dynamics Model (SEAPODYM) has been continuously developed by SPC and CLS (https://www.cls.fr/en/) since 1995, with the aim of describing the spatial and temporal distribution and abundance of tuna, at high-resolution spatial scales with dynamic environmental scenarios and LMTL components. The original model aimed to incorporate the effect of environmental variability on the distribution of skipjack tuna in the WCPO area, (SEAPODYM, Lehodey *et al.* 1998). Over a fifteen-year period, SEAPODYM evolved into a full life cycle model for tuna and tuna-like species (Lehodey *et al.* 2008), including data assimilating mid-trophic tuna forage sub-models SEAPODYM-LMTL (Lehodey *et al.* 2010) and projections into the future using various climate scenarios (Lehodey *et al.* 2013). A review of SEAPODYM was conducted in 2020 (Dunn and Webber 2020) providing suggestions to further develop and improve the model (e.g., detailed documentation, validation with standard fisheries models, development of diagnostics and sensitivity analyses). A dashboard on data exploration for climate impacts on tuna based on SEAPODYM was recently developed to help visually investigate how climate may impact tuna in the Pacific Ocean at the regional and national level.

SEAPODYM has also been used in other contexts: seabird foraging (Miller *et al.* 2018), movement parameters for target tuna species by including mark-recapture tagging data (Senina *et al.* 2020a), contamination in the marine food web (e.g., ^{137}Cs Fukushima contamination, Senina *et al.* 2021), and the impact of large marine protected areas (Hampton *et al.* 2023). Recent developments have focused on improving the SEAPODYM-LMTL on zooplankton and micronekton. SEAPODYM also has the potential to be used to test indicators to understand how they are changing and how management should react to those changes (Smith *et al.* 2016).

2.2.3. Indicators and report cards

Ecosystem indicators have been included in discussions by the SC of the WCPFC since 2005 (Kirby *et al.* 2005, Smith *et al.* 2016). These have been discussed on a regular basis (Allain *et al.* 2012a, Allain *et al.* 2012b) and their need highlighted to inform EAFM implementation (Nicol *et al.* 2012). Some candidate indicators have been explored to assess their potential application for facilitating guidance on the impacts of fisheries on the ecosystem since 2015 (Griffiths *et al.* 2018, SPC-OFP 2023), and at the same time the need to test those indicators has been stressed repeatedly (Smith *et al.* 2016).

More recently, candidate ecosystem and climate indicators were introduced to the SC for potential adoption by the WCPFC (Allain *et al.* 2020a, Allain *et al.* 2020b, SPC-OFP 2022, SPC-OFP 2023). Staff in the Oceanic Fisheries Programme (OFP) of the SPC refined a list of proposed indicators under 3 topics: (1) *Environment* (8 indicators), (2) *Annual Tuna Catch and Fishing Effort* (8 indicators) and (3) *Biology and Bycatch* (12 indicators) (Allain *et al.* 2021a, Allain *et al.* 2021b, SPC-OFP 2022, SPC-OFP 2023) (Table 2a). Reference points and indicator thresholds to trigger management actions are not currently in place. Criteria used for developing indicators (SC19-EB-WP-01) are reproduced here in Table 1.

A potential ecological component in an ecosystem report card is the habitat component which aims to better characterize and monitor the habitat use by key species for informing fisheries management and developing appropriate conservation measures (Juan-Jordá *et al.* 2018b). The increasing development of species distribution models (SDMs), which combine interactions between environmental variables and species data, for species of interest is contributing to an advancement in our knowledge of species-environment relationships, and SPC has been developing SDMs for sharks and rays with the intention of predicting future species' distributions and fisheries interactions under climate change and other short-term environmental conditions.

2.3. ICCAT

2.3.1. Ecoregions

The establishment of pelagic ecoregions has been identified as an important element for guiding the development of regional *EcoCards* within ICCAT. Seven draft ecoregions were initially proposed, each with their own biogeographical and oceanographic characteristics, core tuna and billfish species' distributions and fishing fleets targeting them (Todorović *et al.* 2019).

Following the initial work by Todorović *et al.* (2019), ICCAT organized the 1st Ecoregion Workshop in 2022, during which a total of eight candidate ecoregions were identified within the ICCAT convention area based on pre-established criteria. These criteria, detailed in Table 3, were shaped by three thematic factors: (1) oceanography and biogeography of the Atlantic Ocean, (2) the distributions of the main target species managed by ICCAT and the spatial composition of the ecological communities they form, and (3) the spatial dynamics and core fishing grounds of main ICCAT fleets (Juan-Jordá *et al.* 2022c, Nieblas *et al.* 2022b). Another important outcome of the 1st Ecoregion workshop was the constructive and technical discussions that took place in framing the general process of ecoregion delineation, from discussing its potential uses, to defining the criteria guiding the delineation, evaluating data inputs and methods used, examining and refining candidate ecoregions based on expert knowledge within the ICCAT convention area, and developing a pilot project to test overall applicability of ecoregions (Figure 3). During this 1st ICCAT workshop, the participants provided feedback on each step in the ecoregion identification process to be considered in future revisions of the work. In 2022 the ICCAT Subcommittee on Ecosystems endorsed the eight candidate ecoregions to facilitate the development of pilot products aimed at testing their applicability. However, recognizing the complexities in delineating ecoregions for informing ecosystem planning, research and advice products, the ICCAT Subcommittee on Ecosystems considered that further consultation was needed within the SCRS and the broader ICCAT community. Therefore, it recommended a 2nd ICCAT Ecoregion Workshop. This workshop will be held in May 2024 to refine the ecoregion delineation process and provide an advanced version of candidate ecoregions. The benefits and lessons learned from ongoing work on ecoregion development in ICCAT are presented in Tables 4–5.

2.3.2. Ecosystem modeling

Research activities and practices to address the importance of trophic interactions, food web and diet analyses, and the development of ecosystem indicators and models have been scarce in ICCAT (Forrestal and Menard 2016). Nevertheless, the ICCAT Scientific Committee and the Subcommittee on Ecosystems and Bycatch encourage research on ecosystem approaches including diet studies to investigate the trophic interactions among predators and prey species interacting with ICCAT fisheries, and multi-species and ecosystem modelling to understand potential changes at the ecosystem level for alternative management strategies.

Currently the development of an ecosystem model (Ecopath with Ecosim) is underway in the tropical Atlantic ecoregions, which will facilitate improvements to the food webs and trophic relationships component in the ICCAT *EcoCards* (Andonegi *et al.* 2020, ICCAT 2022). Trophic ecology work, including stomach contents analysis, stable isotope analysis and eDNA of stomach contents, is also planned for tropical tunas to support the development of this ecosystem model in the region.

SEAPODYM models developed for each key tuna species in the Pacific are planned to be adapted to the Atlantic Ocean as well, which will provide, for example, predictions on the impact of climate change on tuna population distribution and biomass (Senina *et al*. 2020b, Bell *et al*. 2021, Nicol *et al*. 2022).

2.3.3. Indicators and report cards

Since 2017 the ICCAT Subcommittee on Ecosystems has also worked towards developing an *EcoCard* as a monitoring and communication tool, designed to include a small set of indicators to track the impacts of fishing, environmental variation and climate change on ICCAT species and their associated ecosystems. This initiative aligns with the objectives outlined in the Standing Committee on Research and Statistics (SCRS) strategic research plan and ICCAT Commission mandate, aiming to facilitate the implementation of EAFM in ICCAT (ICCAT 2017, Juan-Jordá *et al.* 2018c). The criteria for developing indicators are provided in Table 1, while the main stages in developing an *EcoCard* are provided in Figure 4. Although a comprehensive *EcoCard* has yet to be formally produced, candidate indicators proposed for the *EcoCard* are provided in Table 2b.

The SCRS has also created a Sub-Group on the Ecosystem Report Card, and has adopted Terms of Reference (TORs), to guide the intersessional work on the applicability and functionality of the *EcoCard* (Juan-Jordá *et al.* 2021). The 1st Sub-Group meeting in 2022 focused on identifying progress and best practices for the creation of the *EcoCard* process as well as identifying emerging challenges and actions that need further refinement, including gaps and opportunities and potential solutions to improve functionality (Juan-Jordá *et al.* 2022b).

In light of the recommendation from the 1st Ecoregion Workshop that proposed candidate ecoregions should be utilized for developing pilot projects, including regional *EcoCards*, the Sub-Group on the Ecosystem Report Card convened in 2023 to discuss how the ongoing regional case studies in the Mediterranean, tropical Atlantic Ocean and the Sargasso Sea, could contribute to the development of regional *EcoCards*. The Sub-Group also had the opportunity to identify and discuss potential synergies and collaborations with international projects and initiatives to support development of the ICCAT *EcoCard*.

Progress on those regional case studies was presented to the Subcommittee on Ecosystems in 2023 to show the utility of ecoregions as reporting units for developing regional ecosystem-advice products such as *EcoCards*. Currently, these regional pilot projects aim to incentivize ecosystem research for informing fisheries management advice along these topics (1) bycatch assessments with a focus on pelagic sharks and rays interacting with tropical tuna fisheries, (2) ecosystem modelling and assessments and (3) the development of ecosystem-fishery overview reports at the level of ecoregions, including development of ecosystem indicators (ICCAT 2023). TORs for the regional pilot studies for the Mediterranean (Alvarez Berastegui *et al.* 2023) and tropical Atlantic ecoregions (Juan-Jordá *et al.* 2023a) and the case study for the Sargasso Sea (Kell *et al.* 2023) have been developed and funds were secured by the SCRS to support some of this work in 2024.

Indicators comprising an *EcoCard* are useful for monitoring the state of ecosystem components over time, but their utility is limited without mechanisms in place to test their effectiveness against management scenarios. Huynh *et al.* (2022) developed a proof-of-concept methodology for the Atlantic Ocean, synonymous with single-species Management Strategy Evaluation (MSE), which focused on multi-species fisheries dynamics to evaluate indicators and test their reliability in the decision-making process to guide management through an "*EcoTest*" framework. They used the Atlantic longline fishery to describe how management procedures that are applied to target species impact the conservation of bycatch species. They simulated the indicators longline catch-per-unit-effort (CPUE) and mean length of the catches for six species (target: bigeye tuna, swordfish; bycatch: blue shark, shortfin mako, blue marlin, white marlin). Stock assessments were available for all the species considered in the *EcoTest* pilot study, and therefore data on key model parameters (i.e., growth, fecundity, natural mortality, historical trends in abundance, recruitment, and fishing mortality) were available. In contrast, data quality for these parameters is poor, or absent, for many bycatch species, therefore potentially limiting the direct applicability of the methodology for these species. The study revealed varying outcomes across different scenarios of interactions between target and bycatch species. For example, the authors noted that a change in the fishing mortality rate (*F*) for blue shark was highly dependent on the *F* for swordfish but not dependent on the *F* for bigeye tuna (Huynh *et al.* 2022). Additional research is needed to assess the utility of this *EcoTest* framework for testing indicators and their reliability on data-limited species for which conventional stock assessment approaches are not possible. Such efforts may contribute to the testing and validation of selected indicators that may be chosen to represent ecosystem status in an *EcoCard*.

2.4. IOTC

2.4.1. Ecoregions

Initial work on broad-scale delineation of ecoregions in the IOTC was first presented in 2018 at the 14th session of the IOTC Working Party on Ecosystems and Bycatch (WPEB) (WPEB14-42). Recommendations from this session included the need to revise criteria to inform ecoregion boundaries to adequately characterize candidate ecoregions. Consequently, the 1st IOTC ecoregion workshop was held in 2019 to design a process for delineating ecoregions and discuss their role and potential uses as a tool to progress and inform operationalization of EAFM in the IOTC (Juan-Jordá *et al.* 2019b). The primary driver for identifying ecoregions was to advance the implementation of EAFM by more effectively linking regional bycatch, ecosystem and climate considerations into fisheries management advice, as opposed to linking ecosystem considerations for the larger IOTC region, as each region might have its own challenges, characteristics, priorities and needs. During the 1st workshop, seven draft ecoregions were initially proposed, each with their own biogeographical and oceanographic characteristics, core tuna and billfish species' distributions and fishing fleets targeting them (see Table 3). These draft ecoregions were considered valuable for communicating the benefits and the role of ecoregions in the context of IOTC fisheries with the Commission early in the process. Furthermore, the participants noted the benefits of starting the process without an explicit request from the Commission (i.e., a "bottom-up" approach), to help identify major needs and gaps in the approach (Juan-Jordá *et al.* 2019b). Benefits and lessons learned from current work on ecoregion development in IOTC are presented in Tables 4–5.

Following the 1st IOTC workshop, the WPEB recommended a second ecoregion workshop to advance the identification of ecoregions and their role in guiding EAFM implementation in IOTC. During the 2nd workshop, held in 2022, the number of candidate ecoregions within the IOTC convention area was refined to nine, following the recommendation of the 1st workshop (Juan-Jordá *et al.* 2022a, Nieblas *et al.* 2022a). Subsequently, the WPEB and the Scientific Committee endorsed the refined candidate ecoregions to develop pilot projects to test the effectiveness and utility of ecoregions as tools to incentivize ecosystem research and provide integrated advice products including *EcoCards* and ecosystem assessments at the ecoregion level. As a priority in its work plan, the WPEB also suggested selecting two ecoregions, one coastal and one oceanic, to start developing the pilot products (e.g., regional *EcoCards*, regional ecosystem overviews, regional integrated bycatch assessments), starting with the integration and synthesis of existing knowledge within an ecoregion.

2.4.2. Ecosystem modeling

Similar to the Atlantic Ocean, a pelagic ecosystem model has not been developed for the Indian Ocean, but a trophic mass-balance ecosystem model to describe the dynamics of the tropical pelagic ecosystem using Ecopath with Ecosim is currently underway (IOTC 2022). Trophic ecology work including stomach contents analysis, stable isotope analysis and eDNA of stomach contents is also planned for tropical tunas to support the development of this ecosystem model and improvement of the trophic relationship component of the *EcoCard* for the region.

SEAPODYM models developed for each key tuna species in the Pacific are also planned to be adapted to the to the Indian Ocean, which will provide, for example, predictions on the impact of climate change on tuna population distribution and biomass (Senina *et al.* 2020b, Bell *et al.* 2021, Nicol *et al*. 2022).

2.4.3. Indicators and report cards

The concept of *EcoCards* aimed to facilitate operationalization of EAFM in the IOTC was initially proposed to the WPEB in 2016 to improve the connection between ecosystem science and fisheries management advice, enabling more efficient communication of the state of relevant ecosystem components to the Commission—i.e., impacts of fisheries on target species, bycatch, ecosystem structure, function and essential habitats as well as environmental and climate effects (Juan-Jordá et al. 2016, Juan-Jordá et al. 2018a). The *EcoCard* concept was introduced to the WPEB as an effective communication tool that facilitates visualization of complex ecosystem components with the potential to inform the decision-making process in fisheries management. A framework to guide the *EcoCard* development was presented that included drivers and pressures (e.g., oceanographic conditions and fishing activities), ecological states, and indicator-based operational objectives, thresholds and management response (Figure 2). Juan-Jordá et al. (2018a) proposed "states" to monitor within the *EcoCard* (i.e., state of non-retained species, state of foodweb and biodiversity, state of habitats of ecological concern and state of productivity) (Figure 5) but noted these elements may need to be refined, revised and/or added as feedback is received.

Candidate indicators (reproduced here in Table 2c) have also been proposed for monitoring the state of each of the ecosystem components (Juan-Jordá et al. 2016, Juan-Jordá et al. 2018a) and a criteria for developing indicators in the IOTC have also been endorsed (Table 1). This task of "practical implementation of EAFM with the development and testing of EcoCards" is included as a priority in the WPEB workplan but has not yet been funded. The progression of this initiative within the WPEB has been hindered by the COVID-19 pandemic, but plans are underway to resume the process and secure support for funding.

2.5. IATTC

Ecosystem work in the EPO has progressed in many ways since staff reviewed IATTC's ecosystem reporting in document SAC-10 INF-B. These efforts include, among others, developing SDMs for many vulnerable species and taxa (turtles, sharks, rays) that are key inputs for the EASI-Fish ecological risk assessment approach (SAC-09-12, BYC-09-01, BYC-10 INF-B, BYC-11-02, SAC-13-11, SAC-14-12) and the hypothetical habitat criteria of the *EcoCard* (see Juan-Jordá *et al.* 2018b), refining reporting of bycatch and environmental data and updating ecological indicators from the ETP Ecopath model in the *Ecosystem Considerations* document (e.g., SAC-14-11, SAC-12-13), efforts to improve data collection (WSDAT-01-01, WSDAT-01-Rpt, SAC-14 INF-Q, SAC-14 INF-J), exploration of bycatch mitigation options through dynamic ocean management (SAC-10 INF-D, BYC-11-04), and adoption of several resolutions (e.g., FADs, sharks, climate change). IATTC is using SDMs in EASI-Fish to identify species that may be highly vulnerable to fisheries interactions for which additional research should be focused and/or to simulate the potential efficacy of existing and hypothetical CMMs that may be implemented individually or in various combinations. The collaborations involving other t-RFMOs on advancing ecosystem and climate indicators began considering how EASI-Fish assessments may be used to produce quantitative and reproducible vulnerability indicators based on proxies for conventional fisheries biological reference points. SDMs and EASI-Fish assessments may be considered complementary to individual time series of catches and environmental plots to help with potential explanations, or to support more sophisticated analyses, between species and the environment. However, formal plans have yet to be developed to better synergize with ongoing efforts by the other t-RFMOs, including a plan and framework for exploring, proposing, nominating, assessing, adapting, validating, interpreting and implementing candidate indicators—including those from EASI-Fish or ecosystem models—to form the basis of an *EcoCard* for the EPO.

2.5.1. Ecoregions

Although no formal identification of ecoregions has been undertaken by the IATTC, its staff have conducted several spatial analyses over the years that may be useful in considering delineation of ecoregions in the EPO to provide regional-based management advice. For example, past work has divided the EPO into 13 areas—based on catch and fisheries distributions of yellowfin, bigeye and skipjack tunas—for sampling sizes and species composition and estimating total catches for these species (Suter 2010). Reviewing spatial distributions and catches of target species and spatial distributions of the fisheries targeting them is important for the data collection and quality evaluation, as also identified in ICCAT's general framework for delineating ecoregions (Figure 3) and in their TORs (see Annex 1, TOR 5). IATTC staff have also collected diet data in these 13 sampling areas in historic studies on trophic ecology of yellowfin and skipjack tunas (Alverson 1963). However, considering that developing an *EcoCard* for each sampling region is impractical and unrealistic given the extensive size of IATTC's convention area, alternative approaches need to be explored. More recently, Longhurst biogeochemical provinces have been used in trophodynamic studies of tunas sampled in the EPO (nine Longhurst provinces) and in global studies (Duffy *et al.* 2017, Pethybridge *et al.* 2018, Logan *et al.* 2020, Fuller *et al.* 2021). These spatial units may be a more realistic and practical consideration for informing potential ecoregion delineation in the EPO, recalling ecoregions are defined as areas exhibiting relatively homogeneous ecosystems, designed to support ecosystem planning and research at a regional level. Additionally, the utility of spatially-explicit stock assessments are currently being explored, utilizing boundaries determined from numerous fisheries, genetic and tagging studies (e.g., see IATTC Project E.5.a and a conceptual model for yellowfin tuna SAC-14-06), which may also serve as useful datasets to contemplate when defining ecoregions. A dedicated EPO study on ecoregion delineations will need to be conducted adapting the criteria used in ICCAT and IOTC (see Table 3) and the methodology in Nieblas *et al.* (2022a, b) to inform the potential number of ecoregions within the IATTC convention area.

2.5.2. Ecosystem modeling

The IATTC eastern tropical Pacific Ocean (ETP) Ecopath model (Olson and Watters 2003) has been updated near-annually since 2019 to produce ecological indicators (SAC-10-14). These are the same indicators that were produced for the SPC's Warm Pool ecosystem model and include: mean trophic level of the catch (TL_c), the Marine Trophic Index (MTI), the Fishing in Balance (FIB) index, Shannon's index, and the mean trophic level of the modelled community for trophic levels 2.0–3.25 ($TL_{2.0}$), ≥3.25–4.0 ($TL_{3.5}$), and >4.0 ($TL_{4.0}$) (see e.g., SAC-14-11, SAC-12-13, SAC-10-15). Together, these indicators provide information on the ecosystem structure in the ETP over time. For example, a decrease in the mean TL of high TL predators can result in an increase in lower TL communities, due to reduced predation. Combined with an increase in FIB indicating a spatial expansion of sets made on FADs, suggests that monitoring efforts include predator-prey interactions. An ecological sampling program has been proposed to the Commission for the past several years to update the Ecopath model's foundational diet matrix, among collection of other biological information (IATTC-101-04, SAC-14 INF-J, IATTC-100-04, IATTC-98-02b, IATTC-97-02, IATTC-95-08b, IATTC-94-04, IATTC-93-06c), but funding has not been available to date.

There is increasing interest in the use of ecological indicators derived from ecosystem models by the other t-RFMOs to support EAFM implementation. Therefore, it is critical to support and fund a long-term, ecological sampling program to the success of, among others, developing a spatially-explicit EPO-wide Ecopath model to produce reliable ecosystem indicators and to communicate important changes in the ecosystem due to fisheries and climate impacts. This has ultimately hindered the progress towards implementing EAFM based on predator-prey interactions and/or potential shifts in distribution of species and habitats.

2.5.3. Indicators and report cards

The Antigua Convention and IATTC's SSP identify the impacts of EPO tuna fisheries in an ecosystem context as a key overarching goal, which may be best assessed and reported using a set of indicators and communicated through an *EcoCard* to support decision-making. At present, the *Ecosystem Considerations* document (e.g., SAC-14-11) includes bycatch and oceanographic indices as well as the aforementioned seven ecological indicators derived from annual updates of the Ecopath model of the ETP (Table 2d). An important factor in developing a workplan for communicating these indicators will be forming collaborations between scientists, regional and global experts, CPCs and policy makers to select and monitor appropriate indicators, the spatial units to monitor them (i.e., ecoregions) and to set relevant thresholds and reference points for indicators where needed, or a combination of indicators, to elicit a management response. For example, if Biological Reference Points (BRP) in EASI-Fish were agreed upon, when they are exceeded, the species moves to a "management intervention" state requiring the implementation of appropriate conservation and management measures, such as enhanced data collection efforts, the use of safe handling practices and/or other bycatch mitigation techniques. These indicators could be used in concert as a complementary tool to guide fisheries management advice in the EPO, and in turn support the operationalization of EAFM in the context of the Antigua Convention and other international instruments.

In addition to the ecological indicators output from the ecosystem model mentioned above, IATTC's comprehensive bycatch database (IATTC Special Report 25) allows staff to provide total estimates for the purse seine fishery from the start of bycatch data collection in 1993 due to the voluntary La Jolla Agreement, and the binding documents (Resolution C-09-04, Agreement on the International Dolphin Conservation Program (AIDCP)), which stated that all large purse-seine vessels (i.e., size class 6 with a fish carrying capacity of >364 mt) must carry an onboard observer on all trips. Therefore, species-specific catches are provided where available for each broad taxonomic group (i.e., incidental catches of marine mammals, sea turtles, sharks, rays and other fishes; see, for example, SAC-14-11). The IATTC staff also include minimum estimates of longline catches, but there is uncertainty in these data due to low observer coverage, uncertainty in the methods to collect and process the data, and partial reporting with Resolution C-03-05 for non-tuna and non-billfish taxa. The same issues on data availability apply for fisheries other than the large purse-seine fishery operating in the EPO (see section 2. Data Sources in SAC-14-11)—although it is important to note the outdated nature of Resolution C-03-05 and current text should be updated to better align with the Antigua Convention and IATTC's SSP (SAC-12-09), which require extensive research on the ecosystem, including research on non-target species. Efforts are underway to improve data collection by gear type as a result of a SAC-endorsed recommendation to hold a series of workshops with the primary goal of discussing ideas and producing recommendations for updating Resolution C-03-05 and improving data availability for the IATTC scientific staff (see WSDAT-01-01, WSDAT-01-RPT, SAC-14 INF-Q). These datasets and their associated data availability will be an important consideration in developing an *EcoCard* for the EPO that may include candidate indicators on trends in incidental catches by the various fisheries.

The *Ecosystem Considerations* document also includes a time series for environmental variables including mean sea-surface temperature (SST) and chlorophyll-a concentration (Chl-a) for the equatorial zone (5°N-5°S) as well as mean quarterly values for the EPO for the previous year (e.g., see SAC-14-11). Additionally, IATTC staff provide a time series for the Oceanic Niño Index (ONI) and the Pacific Decadal Oscillation (PDO). With the expansion of the Ecosystem and Bycatch Program, the creation of the Ecosystem and Bycatch Working Group (C-22-06) and the adoption of the Resolution on climate change (C-23-10), a complementary workplan is in progress towards assessing and mitigating the impacts of climate change on tuna fisheries, their target species, and non-target species in the EPO (SAC-15-12). Part of this proposed workplan includes the development of a framework and a series of tools to assess and mitigate climate impacts, identify and implement adaptation plans, and track effectiveness of plans. Some examples of tools include further development of ecosystem indicators of change along with species distribution models and projections of species' distributions under different climate change scenarios. These climate indicators may also be considered as candidate indicators to monitor in an EPO *EcoCard*.

3. CONSIDERATIONS FOR IATTC TO DEVELOP AN INDICATOR-BASED ECOSYSTEM REPORT CARD

In initiating the development of an *EcoCard*, the IATTC should seek to use the existing EBWG to foster discussion between scientists, policy makers, CPCs, dedicated experts and other relevant stakeholders. The discussions should aim to define clear goals, objectives and functions of an *EcoCard*, create frameworks to determine criteria for delineating ecoregions to inform the spatial extent of the *EcoCard*, identify drivers and ecosystem elements to monitor, and to develop tools and indicators to be monitored for ensuring goals and objectives are met. Given cross-Pacific collaborations have been fostered through IATTC-SPC and IATTC-WCPFC Memorandums of Understanding (MoUs), it is an opportune time for the IATTC to consider harmonizing its expansion of ecological indicators with the work already initiated by SPC and the WCPFC as well as to consider efforts and accomplishments made by the other t-RFMOs, to the extent possible. Within the proposed workplan, it will be important for the IATTC to establish a framework and document criteria (e.g., see SC19-EB-WP-01) for indicator selection and validation as defined by ICCAT's SC-ECO group's rules of procedure and best practices (Juan-Jordá *et al.* 2022b). Learning from the SC-ECO group's challenges, establishing strong collaborations and, if needed, creating space for dedicated discussion forums in addition to the EBWG will be essential for progressing *EcoCard* development inter-sessionally. These discussions, for example, will encourage and foster dialogue and engagement to define an appropriate spatial scale of indicators by considering IATTC staff's proposals based on the best available science and examples, such as the ICCAT's and IOTC's framework for delineating ecoregions (e.g., Figure 3). For example, the five main stages of ecosystem indicator development as used by ICCAT (Juan-Jordá *et al.* 2022b) will help to facilitate this process (Figure 4). A priority for IATTC staff is to create a conceptual plan for delineating ecoregions and developing *EcoCards* (e.g., following IOTC's ecosystem components: Figure 5 and framework for ecosystem assessments and report cards: Figure 2). These conceptual plans will be presented to the EBWG and the SAC to initiate review and feedback on IATTC staff's proposals. This feedback will be particularly helpful since some of the indicators were identified as not yet being clearly defined (e.g., indicators to monitor the state of essential habitat in ICCAT). Additionally, the SPC-WCPFC noted challenges associated with adoption of indicators such as the need for appropriate interpretation, clear reference points and thresholds, baselines and reliability of the potential indicators (SPC-OFP 2023), and therefore these criteria are essential to address in discussions about selecting indicators.

4. PROPOSED WORKPLAN TO DEVELOP AN EPO ECOCARD

The ongoing t-RFMO work summarized herein was considered to inform a proposed workplan for developing the necessary tools to support potential operationalization of EAFM for the tuna fisheries in the EPO through two ecosystem-advice products: (1) an indicator-based *EcoCard*, possibly at the ecoregion level, and (2) a complementary *Ecosystem Status Assessment*. A suite of definitions, complementary to those for the proposed workplan on climate resilient fisheries (SAC-15-12), is provided below for consistency and supporting common language:

(1) "W*orkplan:*" the hierarchical structure of phases, components, and associated activities to accomplish the main goal.

(2) "*Component:*" a major requirement needed to reach the main goal.

(3) "*Framework:*" a set of operational steps, often iterative, that guide and support decisions and actions.

(4) *"Tool:"* strategic or tactical instrument used to support management decisions and actions.

(5) *"Strategic tools:"* a scientific instrument used to support management and address *what* scientists will do to assess, monitor, and track the performance and/or status of a specific concern (e.g., ecosystem indicators, ecosystem models, ecological risk assessments).

(6) *"Tactical tools:"* an operational instrument used to support management and address *how* resource managers will implement management actions for a specific concern (e.g., spatial management, catch limits, fishery closures, gear requirements, bycatch mitigation techniques, prioritization of research or data collection to fill data gaps).

(7) *"Phases:"* a period of time where specific actions are taken.

(8) "*Activity:"* the actions required to accomplish the goals of a specific component.

The flow diagram (Figure 6) and tentative phased chronogram (Table 6) provide a proposed workplan, reflective of the main goal, to develop an indicator-based *EcoCard* at the ecoregion level and a complementary *Ecosystem Status Assessment* to support potential implementation of EAFM in the EPO (i.e., the gray box in Figure 6), through monitoring of bycatch, climate and ecosystem indicators. It is important to note that the process is meant to be flexible, iterative and consultative to determine the scope, to develop indicators and corresponding thresholds or decision rules, and to maintain, review and refine *EcoCards* to inform management advice.

The workplan is described from top to bottom to provide a general overview and subsequently detailed from left to right. Beneath the main goal is a red box labeled "Adoption of indicators and decision rules" (Figure 6), which involves the Commission for example considering indicator performance thresholds and decision rules for a management action to occur that are recommended by the staff after consultation with global experts and stakeholder input. To achieve the main goal over the next 5 years, four major components of the workplan were identified as "frameworks", "tools and indicators", "management considerations", and "communication tools" (blue boxes in Figure 6), and these components flow into adoption (red box in Figure 6). Flowing upwards into each component is the purpose, or intention, associated with the major components (yellow boxes in Figure 6), and below these are the phases and corresponding activities to achieve those (green boxes in Figure 6). Four phases (Table 6, green boxes in Figure 6)—similar to FAO's generic roadmap (Figure 1) of operational steps (Bianchi *et al.* 2016)— were identified as “planning”, “identifying and prioritizing issues for establishing criteria”, “development”, and “management considerations and communication”.

An important objective of this workplan is to define objectives and functions of ecoregions and *EcoCards* (1st yellow box, far left, Figure 6). This objective is closely linked with the management considerations component. Ultimately management will need to consider these functions provided that ecoregions and *EcoCards* are valuable for supporting decision making processes. The corresponding phase (phase 1 occurring in quarters 1–2, 2024, Table 6) and activity involves reviewing and summarizing the current work of t-RFMOs to inform the development of a workplan for IATTC’s efforts in this field, harmonized, to the extent possible, with those of the other t-RFMOs (i.e., this document, EB-02-02).

Engaging with global experts and other relevant stakeholders via the EBWG or other discussion forums, as needed, to determine the scope of the work and to create frameworks for guiding delineation of ecoregions and developing *EcoCards* are also planned for phase 1 (quarters 3–4, 2024). These frameworks will facilitate visualization and guidance for determining criteria for drafting ecoregions and identifying ecosystem elements to monitor. The purpose of the framework component is twofold: (1) to determine criteria, data quality, and analytical models for guiding ecoregion delineation and (2) to determine drivers (e.g., fishing, climate) and ecosystem elements to monitor (e.g., state of non-retained species, food webs, habitats). These frameworks flow to the right into the next component, tools and indicators, as determining the spatial units and the elements to monitor are essential for considering available tools or new tools that might be needed to develop indicators. The frameworks also may need to be adopted by the Commission depending on the operational objectives, performance thresholds, status and confidence levels in the selected indicator(s) (e.g., Figure 2), and as a result also flow upwards into the red adoption box.

The tools and indicators component comprises the bulk of the workplan. The purposes associated with this component are (1) to develop indicators while considering available tools (e.g., EASI-Fish, Ecopath); to determine spatial units of an *EcoCard* (i.e., ecoregions), and (2) to select indicators and determine associated performance thresholds (e.g., increase/decrease/no change in overall trends, above/below/at threshold status, and identifying confidence in candidate indicators i.e., high, moderate, low). The former is part of phase 2 and is slated for 2025 (Table 6), where discussion forums could be used to establish criteria for delineating ecoregions and to discuss available tools for selecting, calculating, assessing, validating and interpreting candidate indicators for monitoring the state of ecosystem components. These discussions could take place within the EBWG or new discussion forums could be created, as needed. Both strategic and tactical tools will need to be considered for developing indicators and defining performance thresholds. The latter is proposed to occur in phase 3, 2026–2027 (Table 6), where the criteria established in phase 2 will be used to draft ecoregions and develop indicators.

Strategic and tactical tools are inter-related as both are applications used to support management advice but differ in their approach (Craig and Link 2023). For example, strategic tools that may be considered for the development of bycatch, ecosystem, and climate indicators consist of ecosystem models and ecological risk assessments, because these types of tools are used to assess, monitor and track the structure and function of the ecosystem and the relative vulnerability of species to fishing and environmental impacts, respectively. On the other hand, tactical tools help resource managers implement a decision or action based on results or output from the strategic tool. For example, stakeholders participating in the proposed discussion forums may conclude that biological reference points from EASI-Fish applied to data-poor species may be appropriate indicators for an EPO *EcoCard*. EASI-Fish could be considered a strategic tool because it is used to identify potentially vulnerable species. In the most recent EASI-Fish assessment for sharks in the EPO, 20 of the 32 species assessed were identified as being "most vulnerable" to tuna fisheries (SAC-13-11). Consequently, a tactical tool is needed to improve the vulnerability status of these shark species. Such tactical tools might consist of (1) prioritizing research to fill data gaps and reassessing the vulnerability status, or (2) to implement a bycatch mitigation measure, or (3) some other conservation measure(s) (e.g., fishery closures in nursery habitats). Any strategic tools that might be used as indicators will help to inform recommendations to provide management advice, as the Commission's adoption of indicators and decision rules for determining performance thresholds will be critical. Consequently, the tools and indicator component flows into the management considerations component, as well as the adoption of indicators and decision rules, and the communication tools component.

The main purpose of the management considerations component is to support operationalization of EAFM. Phase 4 is tentatively scheduled for the latter half of 2027 (Table 6), and the corresponding activity associated with this component includes producing recommendations from strategic and tactical tools for management considerations.

The last component, communication tools, feeds into the management considerations component. There are two main purposes of this component: (1) to develop communication tools for visualizing progress and constraints and (2) to develop guideline documents for establishing ecoregions and *EcoCards*. This component is also planned for phase 4 in 2028 (Table 6). The corresponding activities include developing pilot ecosystem-advice products. These consist of an *EcoCard* of 'key' indicators chosen to 'best' represent ecosystem status at the ecoregion level, as appropriate, and a complementary *Ecosystem Status Assessment* of data sources, methodology, interpretation, links to management objectives, associated challenges and uncertainty of all indicators considered. These ecosystem-advice products will aim to improve visualization and communication of ecosystem status. Lastly, establishing guideline documents for delineating ecoregions and developing these ecosystem-advice products, based on the pilot projects, will help to inform management decisions and update these products regularly (e.g., annually).

Success of this workplan is dependent on collaborative efforts between IATTC staff in the scientific, data, and policy programs, as well as with global experts with experience in *EcoCard* development (e.g., scientists supporting the other t-RFMOs) and other relevant stakeholders (e.g., IATTC's EBWG, SAC, the Commission). The borders around the phases and activities (green boxes in Figure 6) and the adoption of indicators and decision rules (red box in Figure 6) highlight the collaborative nature of this project and identify likely constituents (e.g., whether the phase and activity involve the IATTC staff (dark, solid line), the IATTC staff plus the Commission and stakeholders (large, dashed lines) or only the Commission (small, dashed lines)). For example, discussion forums will be essential to obtain guidance and clarity on available tools (e.g., ecosystem models, ecological risk assessments, NOAA's Ecowatch) that could be used to develop candidate indicators including incorporating a level of uncertainty or confidence for each indicator. By engaging with global experts and holding discussion forums, IATTC will progress work towards developing an EPO *EcoCard* and its corresponding indicator components, which subsequently will be presented to the EBWG and the SAC, as appropriate, for consideration and harmonization, where possible, across t-RFMOs. Expert participation on specific components (e.g., climate, ecosystem and socio-economic experts) will be beneficial for improving indicators, particularly indicators for ecosystem structure and function as these indicators have been identified as a main challenge in implementing EAFM (Juan-Jordá *et al.* 2018b). For example, a Lenfest Foundation project was established in 2017 to address this challenge and develop indices for ecosystem structure (e.g., ecosystem components: species, habitats, predator-prey relationships) and function (e.g., biological, geochemical and physical processes: fish production or decomposition of organic material) using four case study areas. This project was recently published and describes guidelines for practical ecosystem-based fishery management. Lessons learned from their work, may be useful for IATTC's efforts towards indicator development. ICCAT and IOTC have already developed TORs from an EcoRegion Workshop (ICCAT 2021) (Annex 1) and TORs for EcoCards (Annex 2) while SPC-WCPFC has developed TORs for ecosystem and climate indicators (SPC-OFP 2022) (Annex 3). IATTC could also consider these TORs in the planning and development phases, processes and procedures, while developing its own set of guidelines, based on the proposed workplan and development of a pilot *EcoCard* and complementary *Ecosystem Status Assessment*.

5. REFERENCES

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TABLE 1. Criteria, by tuna-Regional Fisheries Management Organization (t-RFMO), for developing indicators used as the foundation of an ecosystem indicator-based report card.

TABLA 1. Criterios, por organización regional de ordenación pesquera del atún (OROP atunera), para el desarrollo de indicadores utilizados como base de una ficha informativa sobre ecosistemas basada en indicadores.

Region (t-RFMO)	Criteria	Reference
Western and central Pacific Ocean (WCPFC)	1. science and data based; 2. characterize the states and trends of WCPFC marine ecosystems with respect to fishing activity and/or climate (including reference levels and baselines); 3. reflect well-defined processes underlying fishing activity and fishery responses to climate; 4. responsive to changes attributable to fishing pressure and climate (i.e., minimal time-lags and capability to provide early warning); 5. estimable on a routine basis with a historical data time-series available; 6. cost-effectiveness; 7. scalable across national, sub-regional and regional scales; 8. linked to existing WCPFC models and decision-making processes (for inclusion in MSE scenarios, validation of predictions and testing of model assumptions); 9. can be routinely estimated by members without reliance of the SSP	SC19-EB-WP-01
Atlantic and Indian Ocean (ICCAT and IOTC)	1. Scientific basis 2. Ecosystem relevance 3. Responsiveness to pressure 4. Possibility to set targets 5. Precautionary capacity/early warning 6. Quality of sampling methods 7. Cost effective 8. Existing/ongoing data	(Juan-Jordá *et al.* 2019a): see TASK 2: A proposal of ecosystem indicators and their data requirements

TABLE 2a. Ecosystem indicators currently monitored by SPC and the WCPFC in the western and central Pacific Ocean WCPFC Convention Area (CA).

TABLA 2a. Indicadores ecosistémicos actualmente monitoreados por la SPC y la WCPFC en el Área de la Convención (AC) de la WCPFC en el Océano Pacífico occidental y central.

Region (t-RFMO)	Type of indicator	Indicator	Reference
Western and central Pacific Ocean (WCPFC)	Sea surface temperature anomalies	Mean annual SST anomaly (°C) across WCPO area	[WCPFC-SC19-2023/EB-WP-01]()
		Mean annual SST anomaly (°C) across WCPO equatorial zone	
		Mean annual SST anomaly (°C) within warm-pool extent	
	Warm pool	Approximate size of warm-pool in millions of km^2	
		Longitude of strongest sea surface salinity boundary	
		Mean depth (m) of the mixed layer within the warm pool	
	Climate	ONI indicates SST anomalies in the Niño 3.4 region during Nov-Jan each year	
		IPO represents long-term oscillation between El Niño favourable and La Niña favourable phases	
	Annual tuna catch	Total SKJ catch for entire WCPFC-CA, in millions of tonnes	
		Total YFT catch for entire WCPFC-CA, in 100,000 of tonnes	
		Total BET and ALB catch for the entire WCPFC-CA, in 100,000 of tonnes	
	Fishing effort	Mean longitudinal centre of gravity of purse-seine effort	
		Total area occupied by the **purse-seine** fleet annually, in millions of km^2	
		Total area occupied by **Longline** fleet annually, in millions of km^2	
		Annual proportion of **purse-seine** sets made in High Seas areas within the WCPFC-CA	
		The mean, annual longitude of UNA catch for SKJ, YFT, and BET	
	Biology & bycatch indicators	Mean (FL, cm) of **Skipjack** tuna caught by WCPO purse seine and longline fisheries	
		Mean (FL, cm) of **Yellowfin** and **Bigeye** tuna caught by WCPO Longline fisheries	
		Mean observed individual tuna weight divided by predicted length at weight (Mean condition factor from longline catch)	
		Mean fat content (%) of **Skipjack, Yellowfin** and **Bigeye** tuna measured by fatmeter during annual PTTP research cruises informing on tuna condition: fatter fish being considered in better condition	
		Annual finfish: Estimated **Unassociated Purse-seine** catch in 1000s of metric tonnes	
		Annual finfish: Estimated **Associated Purse-seine** catch in 1000s of metric tonnes	
		Annual finfish: Estimated **Longline** catch of finfish bycatch in millions of individuals	
		Annual billfish: Estimated **Purse-seine** catch in 1000s of individuals from unassociated and associated sets	
		Annual billfish: Estimated **Longline** catch of billfish bycatch in millions of individuals	
		Annual shark: Estimated **Unassociated Purse-seine** catch of sharks in 1000s of individuals	
		Annual shark: Estimated **Associated Purse-seine** catch of sharks in 1000s of individuals	
		Annual shark: Estimated **Longline** catch of sharks in millions of individuals	

TABLE 2b. Candidate indicators proposed to ICCAT for consideration in an indicator-based ecosystem report card for the Atlantic Ocean.
TABLA 2b. Indicadores candidatos propuestos a la CICAA para su consideración en una ficha informativa sobre ecosistemas basada en indicadores para el océano Atlántico.

Region (t-RFMO)	Type of indicator	Indicator	Reference
Atlantic Ocean (ICCAT)	Drivers/Pressure: Environment and climate change	Average sea surface temperature over time	(Juan-Jordá *et al.* 2018c)
	Drivers/Pressures: Fishing	Landings over time Total number of vessels	
	Ecological state: Target species	Biomass trends relative to B_{MSY} Fishing mortality rate trends relative to F_{MSY} Proportion of stocks above sustainable levels	
	Ecological state: Bycatch species	Population size trends Size/age structure trends Catch trends Vulnerability of a species to overfishing	
	Ecological state: Ecosystem properties and trophic relationships	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	
	Ecological state: Habitats	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)	

TABLE 2c. Candidate ecosystem indicators presented to the IOTC for the Indian Ocean for consideration in the development of an indicator-based ecosystem report card.

TABLA 2c. Indicadores ecosistémicos candidatos presentados a la CAOI para el Océano Índico para su consideración en la elaboración de una ficha informativa sobre ecosistemas basada en indicadores.

Region (t-RFMO)	Type of indicator	Indicator	Reference
Indian Ocean (IOTC)	Climate and environment	Sea surface temperature Water column descriptions (e.g., mixed layer depth) Chlorophyll concentrations/primary production Chlorophyll concentrations and sea surface temperature gradients (fronts) Sea level anomaly Eddie kinetic energy Dissolved oxygen concentration	(Juan-Jordá *et al.* 2018a)
	Fishing pressure and effort	Number of active ICCAT vessels operating in the area annually Total number of longline 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 Mean trophic level indicators (catch data)	
	State of retained and assessed fish species*	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	
	State of retained and non-assessed fish species*	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)	

Region (t-RFMO)	Type of indicator	Indicator	Reference
		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*	
	State of non-retained vulnerable taxa**	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*	
	State of the community structure, foodweb and biodiversity	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 data) 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)	
	State of productivity	Primary production Zooplankton biomass and/or abundance Zooplankton biomass and size structure	

Region (t-RFMO)	Type of indicator	Indicator	Reference
	State of habitats of ecological concern	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	

TABLE 2d. Ecosystem indicators currently monitored by IATTC in the eastern Pacific Ocean.
TABLA 2d. Indicadores ecosistémicos actualmente monitoreados por la CIAT en el Océano Pacífico oriental.

Region (t-RFMO)	Type of indicator	Indicator	Reference
eastern Pacific Ocean (IATTC)	Fishery interactions with species groups	Estimated number of incidental dolphin mortalities by observers onboard purse-seine vessels	SAC-14-11
		Estimated number of sea turtle a) mortalities and b) interactions by observers onboard large purse-seine vessels by set type	
		Estimated catches (weights, mt) of sharks recorded by observers onboard large purse-seine vessels by set type	
		Minimum estimated gross annual removals (weights, mt) of sharks (Task 1 data) reported by CPCs for longline gear	
		Relative catch (weight) of sharks reported by observers onboard large purse-seine vessels by set type	
		Spatial distribution of purse-seine catches (weights, mt) of sharks by set type	
		Estimated catches (numbers of individuals) of rays recorded by observers onboard large purse-seine vessels by set type	
		Relative catch (numbers) of rays reported by observers onboard large purse-seine vessels by set type	
		Spatial distribution of purse-seine catches (numbers of individuals) of rays by set type	
		Estimated catches (weights, mt) of large fishes recorded by observers onboard large purse-seine vessels by set type	
		Minimum estimated gross annual removals (weights, mt) of large fishes (Task 1 data) reported by CPCs for longline gear	
		Estimated catches (weights, mt) of small fishes recorded by observers onboard large purse-seine vessels by set type	
	Environmental indicators	Oceanic Niño index (ONI) used to monitor El Niño Southern Oscillation (ENSO) events in the Pacific Ocean	
		Pacific Decadal Oscillation (PDO) index	
		Time-longitude Hovmöller diagram of mean monthly sea surface temperature averaged across the tropical eastern Pacific Ocean from 5°N to 5°S	
		Time-longitude Hovmöller diagram of mean monthly sea surface temperature averaged across the tropical eastern Pacific Ocean from 5°N to 5°S	
		Spatial distribution of mean quarterly sea surface temperature for the previous year	
		Spatial distribution of mean quarterly chlorophyll-a for the previous year	
	Ecological indicators output from the ecosystem mass-balance model	Mean trophic level of the catch (TL_c)	SAC-14-11; SAC-10-15
		Marine trophic index (MTI)	
		Fishing in Balance (FIB) index	
		Shannon's index	
		Mean trophic level of the modelled community for trophic levels 2.0–3.25 ($TL_{2.0}$)	
		Mean trophic level of the modelled community for trophic levels ≥3.25 ($TL_{3.25}$)	
		Mean trophic level of the modelled community for trophic levels >4.0 ($TL_{4.0}$)	

TABLE 3. Criteria used to guide the process of delineating ecoregions in the Atlantic and Indian Oceans to support EAFM implementation in ICCAT and IOTC and their expected qualities, as defined by Nieblas *et al.* (2022b) and Nieblas *et al.* (2022a).
TABLA 3. Criterios utilizados para guiar el proceso de delineación de ecorregiones en los océanos Atlántico e Índico para apoyar la implementación del EEOP en la CICAA y la CAOI y sus cualidades esperadas, según lo definido por Nieblas *et al.* (2022b) y Nieblas *et al.* (2022a).

Thematic factors	Expected qualities
Oceanography and biogeography of the Atlantic & Indian Oceans	The boundaries of proposed ecoregions appropriately demarcate areas with a clear oceanographic/biogeographic justification
	The proposed ecoregions are characterized by distinct environmental/oceanographic conditions
	It should be possible to link ecosystem research, assessment and monitoring of environmental/climate effects to effectively provide integrated advice and support integrated management
The distribution of the main ICCAT & IOTC species and the spatial composition of the ecological communities they form (biogeography of tuna and billfish communities)	The proposed ecoregions demarcate the core distribution of ICCAT & IOTC tuna and billfish species (including both neritic and oceanic species)
	The proposed ecoregions are characterized by distinct communities of tuna and billfish species
The spatial patterns of the fishing grounds of the main ICCAT & IOTC fisheries	The proposed ecoregions demarcate the core distribution of major ICCAT & IOTC fisheries (artisanal and industrial) operating in the convention area
	The proposed ecoregions are characterized by distinct ICCAT & IOTC fisheries
	It should be possible to link ecosystem research, assessment and monitoring of fishing impacts to effectively provide integrated advice and support integrated management (e.g., mixed fisheries scenarios, cumulative impacts of fisheries)

TABLE 4. Potential benefits of delineating ecoregions in the Atlantic and Indian Oceans, as defined by Juan-Jordá *et al.* 2022c and 2019b.
TABLA 4. Beneficios potenciales de la delimitación de ecorregiones en los océanos Atlántico e Índico, según lo definido por Juan-Jordá *et al.* 2022c y 2019b.

Region (t-RFMO)	Benefit	Reference
Atlantic Ocean (ICCAT)	Ecoregions facilitate understanding of ecosystem status and trends. They are used for structuring ecosystem advice for fisheries management bodies and provide a useful foundation for developing a wide range of products to assist in the production of advice.	(Juan-Jordá *et al.* 2022c)
	The ecosystem-scale products create a platform to allow dialogue and facilitate information sharing;	
	Ecoregions can enhance coordination with other ecosystem-based products and projects such as the development of multispecies, ecosystem and climate models, management strategy evaluations, fishery ecosystem plans, etc.	
Indian Ocean (IOTC)	Delineation of ecoregions may help promote communication between scientists and managers (e.g., through regional ecosystem reports and EcoCards)	(Juan-Jordá *et al.* 2019b)
	Ecoregions may be a potential tool to structure ecosystem and fisheries considerations and to provide management advice towards implementation of EAFM	

TABLE 5. Best practices and lessons learned throughout the process of drafting candidate ecoregions in the Atlantic and Indian Oceans to support EAFM implementation in ICCAT and IOTC as defined by Juan-Jordá *et al.* 2022.

TABLA 5. Buenas prácticas y lecciones aprendidas a lo largo del proceso de elaboración de ecorregiones candidatas en los océanos Atlántico e Índico para apoyar la implementación del EEOP en la CICAA y la CAOI, según lo definido por Juan-Jordá *et al.* 2022.

Region (t-RFMO)	Lessons learned	Reference
Atlantic Ocean (ICCAT) and Indian Ocean (IOTC)	*Clear management objectives are pivotal for guiding the development of the science needs and approaches tailored to the ecoregions;*	(Juan-Jordá *et al.* 2022a, Juan-Jordá *et al.* 2022c)
	Establishing a criteria for defining ecoregions across a range of disciplines, considering both ecological and social processes, and the expected qualities of the ecoregions, while remaining flexible, was deemed important;	
	Engaging early with the Commission and fisheries managers in the discussions of ecoregion delineation and its potential uses, and being inclusive and transparent was deemed important to build trust, together with the design of an iterative process;	
	The use of quantitative approaches coupled with expert advice that linked the criteria with different data layers describing the ecosystems including fisheries were favored for informing ecoregion delineation;	
	Flexibility for future refinements of ecoregions as data improve or as management approaches are updated was deemed important. Ensure long-term management of the regionalization system and process;	
	Once adopting ecoregions, do it with commitment and visibility, to show that the ecosystem approach is at the heart of your science and advice.	

TABLE 6. Tentative timeline of phases and proposed activities for restructuring IATTC's *Ecosystem Considerations* document into an indicator-based *EcoCard* at the ecoregion level and corresponding *Ecosystem Status Assessment* for EPO fisheries in support of implementation of the Ecosystem Approach to Fisheries Management (EAFM). Q=Quarter; EBWG=Ecosystem & Bycatch Working Group.

TABLA 6. Cronograma tentativo de fases y actividades propuestas para reestructurar el documento *Consideraciones Ecosistémicas* de la CIAT en una *EcoCard* basada en indicadores a nivel de ecorregión y la *Evaluación del estado de los ecosistemas* correspondiente para las pesquerías del OPO en apoyo de la implementación del enfoque ecosistémico de la ordenación pesquera (EEOP). T=Trimestre; GTECI=Grupo de Trabajo sobre Ecosistema y Captura Incidental.

Phase	Activities	2024				2025				2026				2027				2028			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1) Planning	***Review & summarize*** current t-RFMO work to harmonize IATTC's efforts on developing an EcoCard (EB-02-02)																				
	Draft a proposed workplan to develop EcoCard(s) for the EPO																				
	Present proposed workplan to the EBWG																				
	Engage with global experts to determine functions of an EcoCard, scope of work & frameworks																				
	Create frameworks for (1) delineating ecoregions (2) developing EcoCards at the Ecoregion level																				
2) Identifying & Prioritizing Issues for Establishing Criteria	Discussion forums on tools to ***establish criteria*** for (1) delineating ecoregions, (2) developing indicators																				
	Present progress on EcoCard functions, frameworks and criteria to the EBWG																				
3) Development	Use established criteria from Phase 2 to ***draft ecoregions***																				
	Use established criteria from Phase 2 to ***draft indicators***																				
	Present progress on draft ecoregions and indicators to the EBWG																				
4) Management Considerations & Communication	***Produce recommendations*** from strategic & tactical & corresponding indicators for management considerations																				
	Develop pilot ecosystem-advice products: (1) EcoCard of 'key' indicators (2) detailed Ecosystem Status Assessment of all indicators																				
	Present progress on the pilot products to the EBWG																				
	Present recommendations for decision rules to the Commission																				
	Establish guideliines for delineating ecoregions & developing EPO EcoCards at the Ecoregion level, based on the pilot products																				
Timeline is flexible and subject to change Process is iterative Maintain, review, refine Ecoregions and EcoCards on an annual basis to support EAFM																					

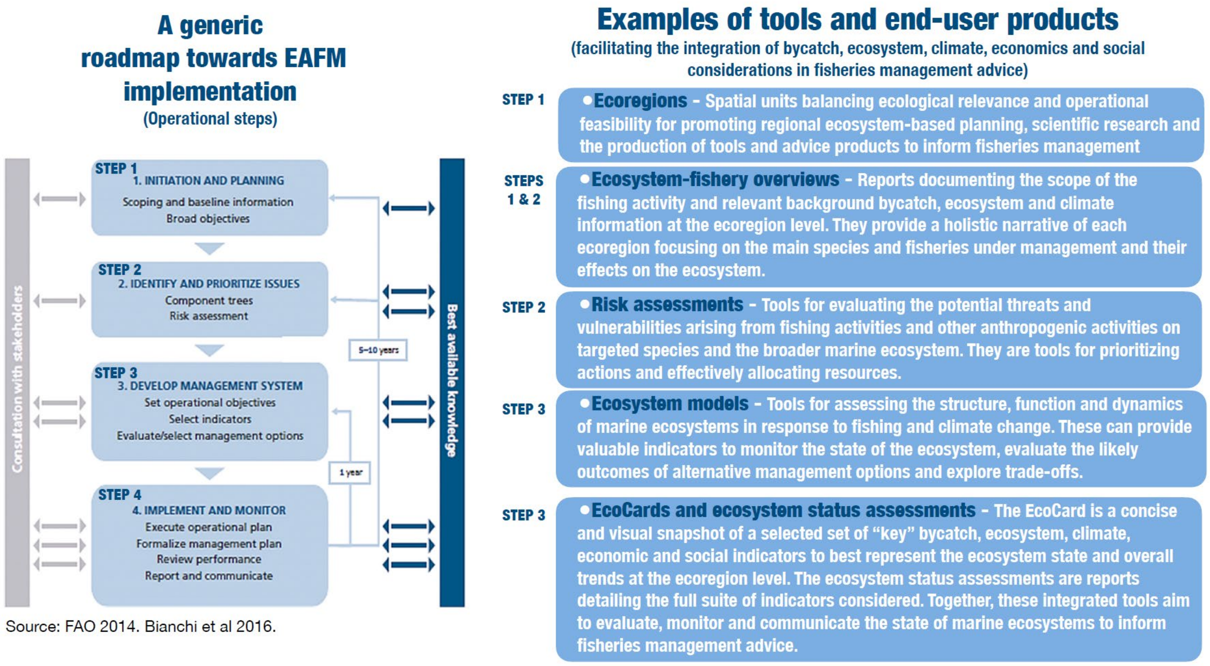

FIGURE 1. A generic roadmap of Ecosystem Approach to Fisheries Management (EAFM) implementation and examples of tools and end-user products to support its planning and implementation (adapted from Bianchi *et al.* 2016).

FIGURA 1. Hoja de ruta genérica para la implementación del enfoque ecosistémico de la ordenación pesquera (EEOP) y ejemplos de herramientas y productos de usuario final para apoyar su planificación e implementación (adaptada de Bianchi *et al*. 2016).

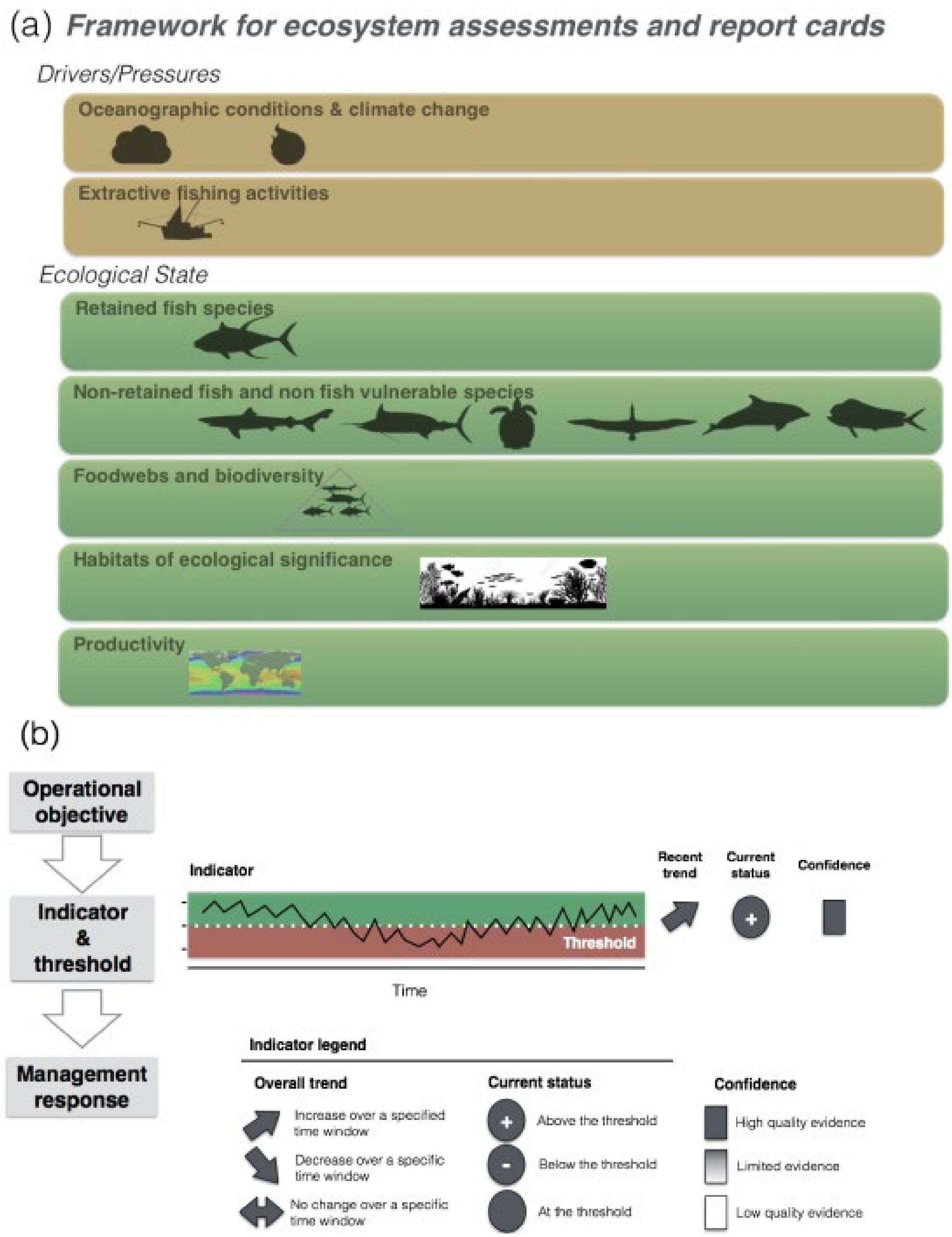

FIGURE 2. Example of the framework used by IOTC for ecosystem assessments and report cards from Juan-Jordá *et al.* (2018a).

FIGURA 2. Ejemplo del marco utilizado por la CAOI para las evaluaciones de ecosistemas y las fichas informativas, tomada de Juan-Jordá *et al*. (2018a).

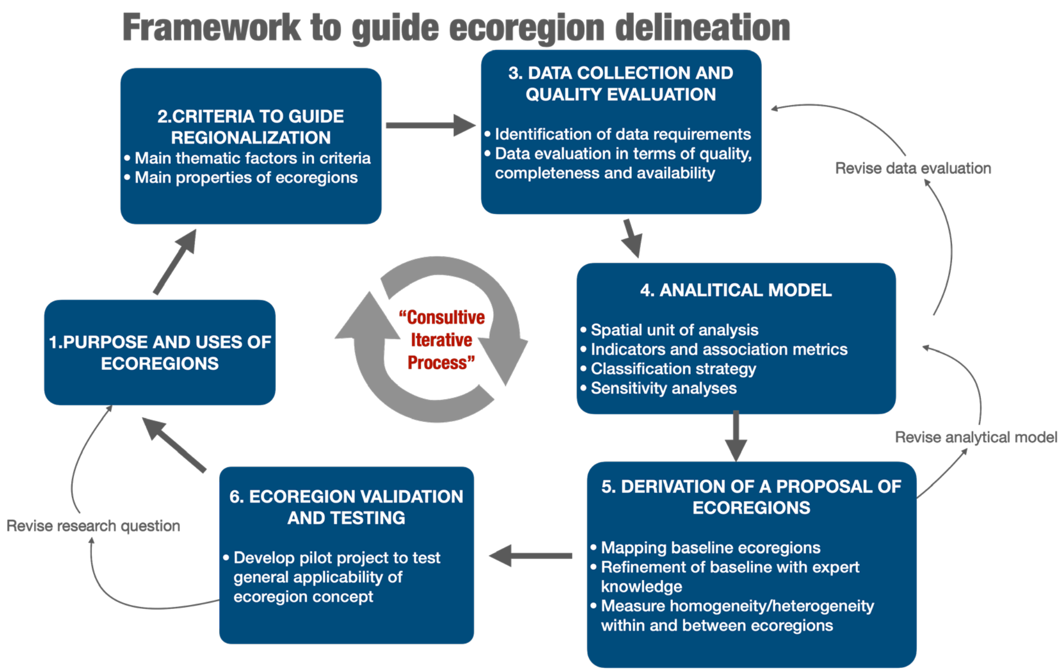

FIGURE 3. The general framework undertaken by ICCAT in delineation of ecoregions reproduced here from Juan-Jordá *et al.* (2022c) for the purposes of IATTC's consideration in developing ecoregions for the eastern Pacific Ocean.

FIGURA 3. Marco general adoptado por la CICAA para la delimitación de las ecorregiones, reproducido aquí a partir de Juan-Jordá *et al.* (2022c), para la consideración de la CIAT en el desarrollo de ecorregiones para el Océano Pacífico oriental.

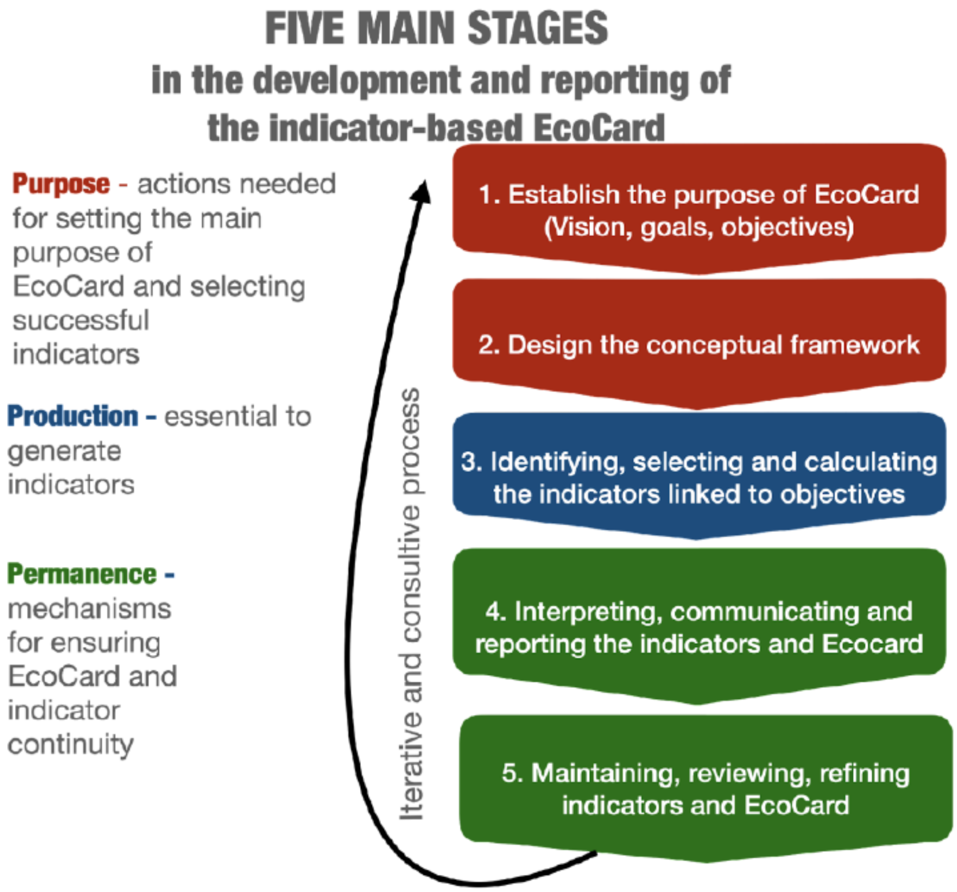

FIGURE 4. Five main stages for developing an indicator-based *EcoCard* from Juan-Jordá *et al.* (2022) for consideration by IATTC.

FIGURA 4. Cinco etapas principales de la elaboración de una *EcoCard* basada en indicadores, tomada de Juan-Jordá *et al.* (2022), para su consideración por la CIAT.

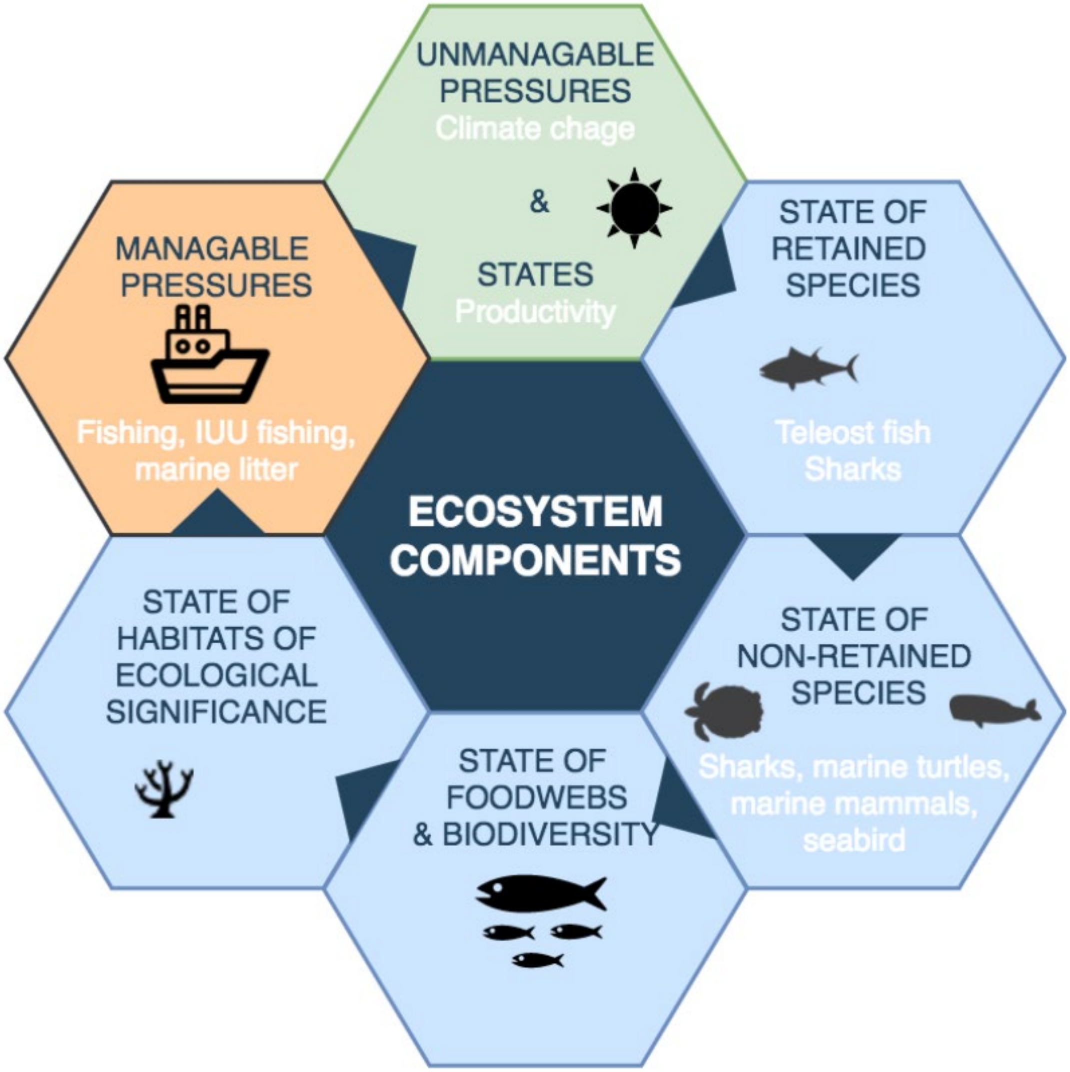

FIGURE 5. Ecosystem components that are monitored in the IOTC Convention area from Juan-Jordá *et al.* (2018a) for IATTC to consider in developing an *EcoCard*.

FIGURA 5. Componentes ecosistémicos que se monitorean en el Área de la Convención de la CAOI, tomada de Juan-Jordá *et al.* (2018a), para consideración de la CIAT al desarrollar una *EcoCard*.

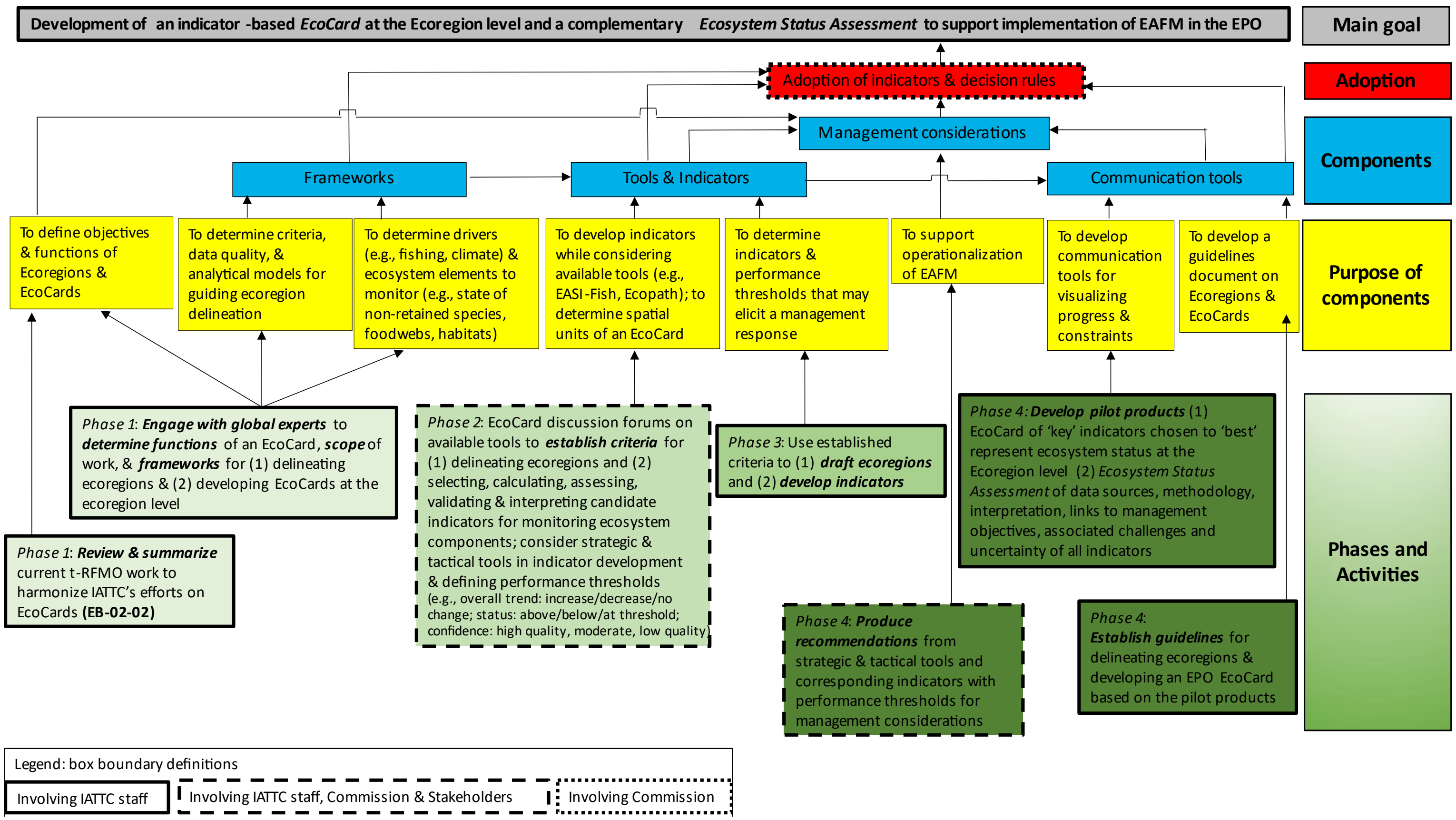

FIGURE 6. A proposed workplan for restructuring IATTC's *Ecosystem Considerations* document into two ecosystem-advice products (1) an *EcoCard* of 'key' indicators chosen to 'best' represent ecosystem status at the ecoregion level and (2) a complementary *Ecosystem Status Assessment* for the EPO to support implementation of the Ecosystem Approach to Fisheries Management (EAFM). Phase definitions: Phase (1) Planning, Phase (2) Identifying & Prioritizing Issues for Establishing Criteria, Phase (3) Development, Phase (4) Management Considerations & Communication.

FIGURA 6. Un plan de trabajo propuesto para reestructurar el documento de *Consideraciones Ecosistémicas* de la CIAT en dos productos de asesoramiento sobre ecosistemas (1) una *EcoCard* de indicadores "clave" elegidos para representar "mejor" el estado de los ecosistemas a nivel de ecorregión y (2) una *Evaluación del estado de los ecosistemas* complementaria para el OPO para apoyar la implementación del enfoque ecosistémico a la ordenación pesquera (EEOP). Definiciones de las fases: Fase (1) Planificación, Fase (2) Identificación y priorización de cuestiones para establecer criterios, Fase (3) Desarrollo, Fase (4) Consideraciones de ordenación y comunicación.

ANNEX 1. Terms of Reference (TOR) for an ICCAT Ecoregion Workshop (reproduced here from Appendix 6 in ICCAT (2021))

In 2020, the process used to delineate candidate ecoregions in the IOTC Convention area was presented to the SC-ECO. From this experience, the SC-ECO recommended convening a workshop in 2021 to advance in the identification of draft ecoregions and foster discussions on their potential use to facilitate the implementation and operationalization of EBFM within ICCAT.

The overall aim of the workshop is to advance in the identification of ecologically meaningful regions that can serve as a basis to produce integrated ecosystem-based advice, and thereby support the implementation and operationalization of EBFM in ICCAT.

During the workshop the following terms of reference will be addressed:

***TOR 1.** Review several world case studies (e.g. NAFO, ICES, CCAMLR, USA, Australia) in order to understand how pelagic regionalization have supported the implementation of EBFM in other organizations and countries.*

***TOR 2**. Review the current reporting structure of ICCAT data and stock boundaries and discuss potential constraints on using ecoregions to structure ecosystem-based advice.*

***TOR 3.** Discuss and develop a check list of evaluation criteria which identifies the factors to be considered when defining ecoregions in the ICCAT Convention area.*

***TOR 4.** Review existing biogeographic classifications in the Atlantic Ocean, which are often used to inform the delineation of ecoregion boundaries and discuss their relevance in the context of ICCAT species and its fisheries.*

***TOR 5.** Review existing data sets in terms of availability, quality and completeness to guide the choice of key data inputs for deriving the draft ecoregions. The data sets revised will include (i) existing biogeographic classifications, (ii) spatial distribution and catches of ICCAT species (e.g., oceanic tunas, billfishes, sharks, neritic species, other bycatch species), (iii) spatial distributions of ICCAT fisheries (e.g., baitboats, longlines, gillnets, purse seines) and (iv) other potentially relevant data layers.*

***TOR 6.** Develop a baseline ecoregion proposal analyzing selected datasets using spatial analysis that will be adjusted with expert knowledge. The spatial analysis will include examining the spatial patterns of species compositions and fishing fleets dynamics across multiple biogeographic provinces, and clustering analyses to group biogeographic provinces according to their similarity in terms of species composition and fisheries composition. The use of quantitative approaches that link different data layers describing the ecosystems including fisheries, coupled with expert advice are often used to ecoregion delineation.*

***TOR 7.** Test and validate the usefulness of the candidate ecoregions with respect to monitoring large scale changes in the ecosystem.*

1. Expected outputs

- An evaluation checklist criterion with major factors to be considered to guide the development of draft ecoregions.
- An understanding of the data layers and methods used for deriving the ecoregions with its strengths and weaknesses.
- A proposal for candidate draft ecoregions.
- A workshop report with an executive summary with the main outcomes to be presented at the SC-ECO meeting in 2022

ANNEX 2. Recommended terms of reference (TOR) for Ecosystem Report Cards (EcoCards) as a tool for monitoring impacts of ICCAT fisheries reproduced from Juan-Jordá *et al.* (2021)

TOR 1. *Create a guideline document which reviews the components of ICCAT's EcoCard and summarizes the development and current state of ICCAT's EcoCard. This baseline document may include*
(i) The main scope and objectives for each of the EcoCard component.
(ii) The data requirements to evaluate them considering ICCAT data requirements.
(iii) The attributes the EcoCard components are meant to monitor as well as a list of candidate indicators.
(iv) A proposal for possible thresholds of the candidate indicators that would trigger management actions (e.g. SCRS recommendation to management actions), applicable throughout the different EcoCard components.
(v) The connections and synergies among the EcoCard components will be reviewed and described.

TOR 2. *Identify successes and lessons learned since its creation as well as identify emerging concerns and inefficiencies, including the gaps, weaknesses, and strength in the monitoring framework for the estimation of the indicators of different components as well as develop a proposal to improve monitoring systems required.*

TOR 3. *Seek feedback and synergies with other relevant work and processes across all species groups and subcommittees of the SCRS to make the EcoCard more functional and adaptable to end-use needs. This will include (1) identifying the ongoing relevant research in the SCRS and connect it to the EcoCard development, (2) considering the role of the ongoing work on case studies (Sargasso Sea case study and Tropical Region case study), (3) considering the ongoing work on risk assessment approaches to prioritize work, and (4) identify opportunities and collaborations with other organizations that can bring new expertise and resources.*

TOR 4. *Provide recommendations for improvements to make the EcoCard more functional and adaptable to enduser needs and propose mechanisms for regular revision by the SCRS and feedback from the Commission to advance towards EBFM implementation in ICCAT.*

ANNEX 3. Draft Terms of Reference (TOR) on ecosystem and climate indicators for SPC-WCPFC reproduced from SPC-OFP (2022)

Objectives

• Develop and test candidate ecosystem and climate indicators to track the impact of climate and ecosystem changes on WCPFC fisheries and ecosystems.

• Provide technical advice to the Scientific Committee on the suitability of criteria used for testing and evaluating the performance of candidate indicators.

• Support the Scientific Committee in developing tools to communicate ecosystem and climate change impacts to WCPFC and external stakeholders and interest group.

Rationale

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 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 Harvest Strategy framework and detecting when climate and ecosystem changes fall outside the ranges of uncertainty against which a management procedure was tested, and whether broader ecosystem objectives are being met.

WCPFC has already recognised the importance of preparing the region to adapt to the emerging impacts of climate change (see Resolution 2019-01 "Resolution on Climate Change as it relates to the Western and Central Pacific Fisheries Commission"). Well-designed climate indicators should provide information on the pace at which physical properties of the WCPO are approaching climate change induced tipping points. This will not only be important for adapting the region's tuna fisheries to the impacts of climate change but also provide necessary information for WCPFC members to voice the impact of climate change on tuna fisheries at global forums such as UNFCCC.

In addition to the role that ecosystem and climate indicators play in assisting with the formulation of management advice and decisions, they can also be effective in communicating information within WCPFC's membership and to external stakeholders and interest groups.

Assumptions

• WCPFC and the Scientific Committee continue to require the development of ecosystem and climate indicators.
• External funds remain available to support the development, testing and analyses of ecosystem and climate indicators.

Scope of Work

• Technical analyses to develop and test candidate indicators.
• WCPFC member and expert workshops to refine indicators.
• Scientific Committee Reporting.
• Routine preparation of adopted indicators
• Development of tools for communication to WCPFC and wider stakeholders.

Timeframe

A timeframe of five-years is proposed for this project, after which preparation of adopted indicators should be regularised into the work of the Scientific Committee or an alternative approach will need to be considered to progress the work (if minimal progress has been achieved).

Budget

This is a no-cost project for 2023. Any budgetary support required by the SSP or members beyond 2023 is subject to approval once specific workplans and proposal are reviewed and prioritised by the Scientific Committee.