INTER-AMERICAN TROPICAL TUNA COMMISSION

WORKING GROUP ON ECOSYSTEM AND BYCATCH

4TH MEETING

La Jolla, California (USA)
01-02 June 2026

DOCUMENT EB-04-03

ADVANCING THE ECOCARD WORKPLAN: EXPLORING ECOREGIONS AND ESTABLISHING CRITERIA FOR CANDIDATE INDICATORS

Leanne Fuller, Jon Lopez, Dan Crear, Dan Ovando, Jean-François Pulvenis and Alexandre Aires-da-Silva

This document serves as an update and progress report on the IATTC's Workplan on *EcoCards* (EB-02-02). Specifically, it addresses the recommendation from the EBWG-02 meeting calling for, "*the SAC and the Commission to consider the further development of the proposed Climate Change and EcoCards Workplans, and encourage that this work be done in collaboration with expertise from other tuna RFMOs*" (Meeting WGEB-02 Report). It also responds to the EBWG-03 recommendation, "*The Working Group recommends continuing collaboration with other tRFMOs to establish criteria for delineating ecoregions and to develop indicators, including socioeconomics*" (Summary Report WGEB-03).

CONTENTS

SUMMARY 1
1. Introduction 2
2. Review of IATTC'S *EcoCard* workplan 3
3. Progress of the *Ecocard* workplan: Phase 2 (*Establishing criteria*) 3
3.1. Exploring ecoregions 3
3.2. Proposed methodological activities for delineating ecoregions 4
3.3. Establishing preliminary broad criteria for selecting and developing candidate indicators 10
4. Engaging with global experts working from the other t-RFMOs 12
5. Next steps: Phase 3 (*Development*) 14
6. Acknowledgements 14
7. References 14

SUMMARY

This document provides an update and progress report on the IATTC's *EcoCard* workplan presented in document EB-02-02 and supported by the Working Group on Ecosystem and Bycatch (EBWG) and the Scientific Advisory Committee (SAC; see IATTC-102-03 and IATTC-103-02). Building on the progress outlined in EB-03-04, this document focuses on achievements under the second Phase of the workplan—*Establishing criteria for indicators and ecoregions*. These achievements include the development of proposed methods for delineating potential ecoregions within the EPO Convention Area. Ecoregions are areas characterized by relatively homogeneous ecosystems that serve as ecologically meaningful and practical spatial units for ecosystem-based planning, scientific research, and the development of ecosystem-advice products (e.g., indicator-based *EcoCards*). In parallel, proposals for criteria were established to guide both the delineation of ecoregions and the selection of candidate indicators for use in ecoregion-level *EcoCards*. The criteria for defining ecoregions are based on three core factors:

oceanography, species and assemblage distributions, and distribution of fleet dynamics, based on the work by ICCAT and IOTC. The criteria for indicator selection comprise nine elements: scientific relevance, data availability and accessibility, transparency and reproducibility, sensitivity to ecosystem change, interpretability and communication value, practicality and efficiency, robustness and stability, comparability across regions or t-RFMOs (when relevant and practical), and ability to inform management. It is important to note that ecoregions are intended as a complementary descriptive and monitoring tool to provide regional ecosystem advice and are not meant to replace existing management systems. Noting that the *EcoCard* workplan—and the broader, long-term process to operationalize the Ecosystem Approach to Fisheries Management (EAFM)—is inherently iterative, with stakeholder feedback solicited and incorporated at each stage, the staff kindly request the EBWG to pay special attention to the following elements: (1) the proposed exploration of ecoregions and (2) the indicator criteria.

1. INTRODUCTION

International legal instruments have long underscored the shared obligation of nations and regional management bodies to mitigate the broader ecosystem impacts of fisheries. The 1982 United Nations Convention on the Law of the Sea (UNCLOS) established the international legal framework for the conservation and management of living marine resources. The FAO's 1995 Code of Conduct for Responsible Fisheries (CCRF) embodied the principle of an ecosystem approach to fisheries management (EAFM) by stipulating, "*States and users of living aquatic resources should conserve aquatic ecosystems" and "fisheries management should not only ensure the conservation of target species, but also of species belonging to the same ecosystem or associated with or dependent on target species*." This approach was expressly defined and adopted in the 2001 Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem. In line with the CCRF, the 2003 Antigua Convention incorporates in the legal framework of the IATTC the principle of the EAFM, in particular with the inclusion of references to "*non-target or associated or dependent species*" and "*species belonging to the same ecosystem and that are affected by fishing for, or dependent on or associated with, the fish stocks covered by this Convention*." In 2003, the same year the Antigua Convention was adopted, the IATTC initiated an Ecosystem Considerations (EC) report, subsequently updated annually, to broadly describe fisheries and environmental impacts on the eastern Pacific Ocean (EPO) ecosystems and therefore, to promote and strengthen awareness of these ecological impacts among IATTC CPCs and its stakeholders.

Due to the increasing length and complexity of the EC report over the past 20 years, IATTC's staff undertook an evaluation of the ways and means of better communicating the status of the ecosystems as well as advancing and supporting operationalization of the EAFM. To this end, in 2023–2024, the staff collaborated with experts working with other tuna-Regional Fisheries Management Organizations (t-RFMOs) to review and summarize ecosystem research conducted globally, and how this research is delivered to the respective Commissions. The ultimate goal was to propose a workplan for the IATTC to develop useful products for monitoring the status of EPO ecosystems and effectively inform the decision-making process (EB-02-02). Subsequently, two products were considered. The first consisted of a highly summarized, indicator-based ecosystem report card ("*EcoCard*") used to convey a suite of relevant bycatch, ecosystem, and climate indicators, among others, chosen to 'best' represent ecosystem status. The second consisted of a complementary "*Ecosystem Status Assessment*" that details the full suite of indicators considered to describe the annual status of marine ecosystems and is used primarily as a reference guide to support the *EcoCard*. The information obtained from the collaborative process with global experts was consequently used to inform an IATTC workplan to develop these products and support operationalization of the EAFM in the EPO (see EB-02-02). The tentative chronology of the proposed workplan extends over five years (2024–2028) and includes four primary Phases: (1) *Planning*, (2) *Establishing Criteria*, (3) *Development*, and (4) *Management Considerations and Communication*, with a series of corresponding activities under each Phase. Since its development in 2024, the workplan and its subsequent progress (EB-03-04) have received continued support from both the Working Group on Ecosystem and Bycatch (EBWG) and the Scientific Advisory Committee (SAC; see IATTC-102-03 and IATTC-103-02).

This document summarizes progress to date in advancing the *EcoCard* Workplan described in EB-02-02, with a focus on *Phase 2—Establishing criteria*. Key accomplishments include the exploration of ecoregions to provide regional ecosystem-focused advice and the creation of preliminary criteria to develop both ecoregions and candidate indicators for use in ecoregion-level *EcoCards*.

2. REVIEW OF IATTC'S *ECOCARD* WORKPLAN

The workplan provided in EB-02-02 is reproduced herein for reference; see Figures 1–2. Under the current international legal framework, t-RFMOs share a commitment to incorporate the EAFM in their operation and activities, and as such, collaborations between t-RFMOs facilitate information exchange on progress and challenges associated with, for example, technical activities and tools considered to address and advance operationalization of the EAFM. The *EcoCard* workplan was created to facilitate, prioritize and monitor activities to advance elements of the EAFM in the IATTC while considering and adapting experiences by other t-RFMOs and other organizations of interest (e.g., the Food and Agriculture Organization: FAO and International Council for the Exploration of the Sea: ICES). The fundamental goal of this work is to improve IATTC's communication of ecosystem status by restructuring the complex and lengthy EC report (e.g., EB-03-01) into the *EcoCards*- and *Ecosystem Status Assessments*-advice products. In the long term, these products would ideally inform the decision-making process in support of operationalizing the EAFM in the EPO. Activities completed under Phase 1 (*Planning*) of the workplan, as described in EB-03-04, included defining the purpose of an *EcoCard* (Figure 3), designing a conceptual framework to visualize and conduct the planned activities, and developing a visual dashboard to identify broad ecosystem components (Figure 4) that will guide the development of candidate indicators for assessing overall ecosystem status. The conceptual framework, designed as an iterative loop, is presented herein across multiple figures to demonstrate progress on its key steps completed to date (see Figures 3–5).

3. PROGRESS OF THE *ECOCARD* WORKPLAN: PHASE 2 (ESTABLISHING CRITERIA)

For 2025, the activities under Phase 2 outlined in the *EcoCard* Workplan (see Figures 1–2) focused on two main actions: (1) exploring the use of ecoregions as a potential tool (see Step 3 of the conceptual framework), and (2) establishing preliminary criteria for both delineating ecoregions and selecting or developing candidate indicators (Figure 5).

3.1. Exploring ecoregions

Ecoregions provide a spatial context for addressing ecological objectives related to tuna and tuna-like fisheries while supporting ecosystem-based planning, research, and the development of ecosystem products (e.g., *EcoCards*) in the EPO. Ecoregions are intended as a complementary monitoring and descriptive tool, not a replacement for existing management systems.

Biogeographic classifications of the pelagic ocean integrate biological and physical oceanographic variables to divide the ocean into ecologically meaningful areas where species experience similar environmental and anthropogenic pressures (UNESCO 2009, Rice *et al.* 2011). Several existing biogeographic classifications may be considered when exploring ecoregions for the EPO. These include LME: Large Marine Ecosystems (Sherman and Duda 1999), LBGCP: Longhurst Biogeochemical Provinces (Longhurst 1998), MEOW: Marine Ecoregions of the World (Spalding *et al.* 2007), PPOW: Pelagic Provinces of the World (Spalding *et al.* 2012), TBP: Biogeography of tuna and billfish communities and derived provinces (Reygondeau *et al.* 2012), and GOOB: Global Open-Ocean Biomes (Fay and McKinley 2014). Todorović *et al.* (2019), provide a comparative summary of these biogeographic classifications describing the type of input data used to derive each classification, the spatial coverage considered, the number of resulting classifications and the purpose for developing each classification. Such clearly defined ecological units enable more targeted management and are more likely to respond effectively to actions aimed at specific target species, non-target vulnerable species or assemblages. As a result, they are likely to be more effective and informative than approaches across broader regions with indistinct boundaries, and form the basis for developing ecoregions (Rice *et al.* 2011).

Ecoregions should be designed to support IATTC's mandates under the Antigua Convention, particularly Article VII (f), (g), and (m), which emphasize science-based, precautionary, and ecosystem-focused management. These provisions call for enhanced monitoring of target and non-target species, ecosystem-based conservation measures that maintain populations above critical thresholds, and minimization of bycatch and broader ecosystem impacts.

The development of ecoregions, and their corresponding *EcoCards*, directly supports these objectives by providing a spatially-explicit framework and indicators to assess and monitor ecosystem status and trends. This approach improves understanding of ecological and environmental relationships, species interactions, and fishing impacts—informing adaptive and ecosystem-oriented management consistent with the Convention's mandates.

Because the EAFM is inherently collaborative, the delineation of ecoregions—like the conceptual framework guiding the *EcoCard* workplan—is designed as a continuous and iterative process. Ongoing communication with stakeholders, subsidiary bodies of the Commission, and the Commission itself is envisioned, with feedback incorporated at each stage (see Figure 5). Ecosystem-related objectives under the IATTC mandate, together with international commitments (e.g., UNCLOS, UNFSA, FAO CCRF, Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem, and the Biodiversity Beyond National Jurisdiction (BBNJ) Treaty), should guide indicator selection and define the role of ecoregions as a tool to strengthen and advance the operationalization of EAFM.

Below, the methodological activities for delineating ecoregions (section 3.2.)—from frameworks developed by ICCAT and IOTC (Juan-Jordá *et al.* 2022b, Nieblas *et al.* 2022a)—are adapted and summarized for IATTC's consideration (see Figure 5).

3.2. Proposed methodological activities for delineating ecoregions

3.2.1. Determine the benefits of transitioning to ecoregions

This activity mirrors the first step undertaken by ICCAT and IOTC to *determine the purpose and use of ecoregions*, and draws upon lessons shared by fisheries organizations such as NAFO, ICES, and NOAA. These organizations have applied spatially explicit management units or ecoregions to support the implementation of the EAFM, as discussed during ICCAT's first ecoregion workshop (Juan-Jordá *et al.*

2022b). Building on these experiences, the exploration of ecoregions within the IATTC Convention Area aims to provide a practical tool for structuring and guiding ecosystem-focused management advice through the development of regional, ecologically sound and more appropriate, indicator-based *EcoCards*. These *EcoCards* will help assess and monitor trends in key indicators representing ecosystem status across the categories outlined in the visual dashboard (see Figure 4).

Ecoregions facilitate assessment of environmental conditions, multi-species and multi-fishery interactions, and ecological trade-offs. They also enhance the capacity to monitor ecosystem and species responses to climate and environmental change and management measures, inform ecological modeling, guide research in data-limited areas, and integrate ecological and potentially socioeconomic information to advance the EAFM (Nieblas *et al.* 2022a, Nieblas *et al.* 2022b, Nieblas *et al.* 2024).

3.2.2. Establishing criteria to guide ecoregion delineation

This step of establishing ecoregions criteria (see Figure 5) also parallels the approaches developed by ICCAT and IOTC, where criteria for guiding ecoregion delineation are organized around three central topics, or "*thematic factors*" (Todorović *et al.* 2019, Nieblas *et al.* 2022a, Nieblas *et al.* 2022b, Nieblas *et al.* 2024). The overarching objective is to support the provision of ecosystem-focused management advice through the development of ecoregion-specific *EcoCards*. For IATTC's consideration, these thematic factors have been slightly adapted from those used by ICCAT and IOTC and include:

i. oceanography: biogeography and/or biophysical environment, including productivity patterns,
ii. species and assemblage distributions,
iii. fleet dynamics of tuna and tuna-like species fisheries.

An overview of these thematic factors is presented below, followed by a more detailed discussion of data availability, quality, and coverage in Section 3.2.3.

Thematic factor 1 – Oceanography

Oceanographic and biophysical factors are considered the primary drivers of ecoregion delineation, as they underpin the ecological and human-use patterns represented by the other two thematic factors. Oceanographic processes—such as currents, fronts, and productivity gradients—structure the physical and biological environment that determines where species occur and how fleets operate. In essence, species and fishing effort distribution patterns largely emerge as responses to the underlying biological, chemical and physical oceanography and environment, highlighting the foundational role of this first criterion for defining ecologically meaningful regions.

The development of ecoregions should also consider core qualities such as practicality, feasibility, adaptability, consistency, temporal resolution, as well as the spatial distribution of catches and their overlap with species, fleets, and biogeographic classifications of interest. ICCAT and IOTC considered several biogeographic classifications, including LMEs, LBGCPs, MEOWs, PPOWs, TBPs and GOOBs—summarized in Todorović et al. (2019)—to gain knowledge on the major oceanographic processes in their respective regions.

Thematic factor 2 – Species and assemblage distributions

The second thematic factor, identified in ICCAT documents as fish communities—defined as "*the spatial patterns in the distribution of ICCAT major target species, including oceanic tuna and billfish species, as well as neritic species, along with the ecological communities they form*" (Todorović *et al.* 2019, Nieblas *et al.* 2022b, Nieblas *et al.* 2024)—was slightly adapted for consideration by the IATTC and re-labeled as species distributions and assemblages. This adaptation broadens the scope beyond tuna and tuna-like species under the Commission's purview to also encompass the spatial distribution of species of conservation concern or special interest as defined in active IATTC resolutions (e.g., sharks).

Thematic factor 3 – Fleet dynamics of tuna and tuna-like fisheries

Following the approach used by ICCAT and IOTC for the fleet dynamics thematic factor—defined as "*the spatial patterns of the main fisheries and their core fishing grounds*" (Todorović *et al.* 2019, Nieblas *et al.* 2022a, Nieblas *et al.* 2022b, Nieblas *et al.* 2024)—and recognizing IATTC's primary focus on the conservation of tuna and tuna-like species in the Convention Area, this criterion should mainly encompass fisheries targeting these species as well as targeted shark species (e.g., blue shark).

Bycatch and trophic interactions

Consistent with ICCAT and IOTC, bycatch species are not explicitly included in the recommended delineation process for IATTC, apart from species of special concern (e.g., sharks) as mentioned under thematic factor 2. Instead, once ecoregions are defined, they provide the spatial foundation for monitoring the impacts of these main fisheries on key bycatch species (i.e., direct impacts) and the broader ecosystem. Similarly, trophic interactions among targeted species and their prey (i.e., indirect impacts) can be monitored within these regions to inform ecosystem models. These models are critical for improving understanding of ecosystem structure and function (Fulton *et al.* 2025, Fulton and Sainsbury 2025) and evaluating potential changes over time, contingent on adequate support and resources to refine IATTC's existing ecosystem model and advance the operationalization of the EAFM within its Convention Area. Ultimately, ecoregions should be delineated primarily on oceanographic and biophysical grounds, but balanced with ecological and anthropogenic relevance, practicality, and operational feasibility to ensure their effective application for monitoring ecosystems and guiding management advice (Nieblas *et al.* 2024).

3.2.3. Evaluating data availability, quality and coverage

The next methodological activity (see Figure 5) recommended for IATTC's consideration closely mirrors the approach considered in the ICCAT and IOTC frameworks. It involves evaluating the availability, quality, and spatial coverage of data across the three primary thematic factors briefly described in section 3.2.2 to identify the key data layers for each thematic factor to best inform the delineation of ecoregions. Throughout this process, it is essential to document all details and caveats to ensure transparency and to identify data limitations that may influence the delineation of ecoregions.

Thematic factor 1 – Oceanography

As an initial step in this assessment, existing classifications of the pelagic ocean should be reviewed to gain knowledge of the major oceanographic patterns in the EPO and to identify the most suitable classifications for supporting IATTC's objectives, particularly the development of ecoregion-level communication products on ecosystem status. For example, both ICCAT and IOTC first evaluated a range of established bioregionalizations to address the oceanographic thematic factor, including LMEs, LBGCPs, MEOWs, PPOWs, TBPs, and GOOBs.

Following this evaluation, ICCAT identified the PPOW classification as the most suitable. This approach integrates water-column oceanographic processes with patterns in species distributions and communities, providing an ecologically and biophysically reasonable basis for delineation. In addition, the

PPOW framework includes fewer provinces than the Longhurst system, making it more practical to implement (Todorović et al. 2019, Nieblas et al. 2022a, Nieblas et al. 2024).

In contrast, the IOTC considered a combined approach, using MEOW coastal provinces alongside PPOW oceanic provinces. This allowed for representation of both coastal and island-associated fisheries, as well as the open-ocean pelagic zones of the Indian Ocean, thereby ensuring inclusion of neritic habitats. However, this approach resulted in a relatively large number of regions (24 provinces) within the IOTC Convention Area (Nieblas *et al.* 2022b).

Building on these examples, IATTC could begin by evaluating these classifications to better characterize the dominant oceanographic processes in the EPO. The PPOW may serve as a practical starting point for ecoregion delineation, with potential adjustments to ensure adequate representation of coastal and island-associated fisheries that are characteristic of the EPO.

Thematic factor 2 – Species distributions and assemblages

Regarding the second thematic factor, the availability, quality, and coverage of data should be evaluated not only for target tunas and tuna-like species, but also for species of special interest or conservation concern and the dynamics of these species as defined under the Antigua Convention and in IATTC Resolutions (e.g., sea turtles, sharks, mobulid rays). As in the ICCAT and IOTC ecoregion frameworks, catch data can provide valuable insights into the spatial distribution of species to identify the core distributions and co-occurrence of species assemblages (Todorović *et al.* 2019, Nieblas *et al.* 2022a, Nieblas *et al.* 2022b, Nieblas *et al.* 2024). However, additional sources—both fishery-dependent (e.g., catch data or conventional tagging data) and fishery-independent (e.g., species distribution models, SDMs, electronic tagging data)—should also be assessed to improve understanding of species distributions and assemblages, and to evaluate their overlap with oceanographic features that can inform and refine ecoregion delineation.

Catch data:

For purse-seine fisheries, extensive datasets are available for target tunas, including set-by-set vessel logbooks, cannery unloading records, port sampling, and observer data (e.g., SAC-12-09, FSR No 22, WSDAT-02-01, EB-03-01). The most comprehensive source of information on non-target species is the observer program for large purse-seine vessels ("*size-class 6*," carrying capacity >363 mt). These data, include detailed catch and effort records collected since the La Jolla Agreement mandated 100% observer coverage for such vessels in 1993 (IATTC Special Report 25, EB-03-01).

For smaller purse-seine vessels (size classes 1–5; ≤363 mt carrying capacity), observer data coverage has improved, currently reaching 30–40% through the voluntary TUNACONS program. This level of coverage is likely to be sufficiently representative for estimating total catches of common bycatch species (e.g., dorado, wahoo, silky shark) but may not be sufficient for total catch estimation for less frequently encountered species (e.g., oceanic whitetip shark, leatherback turtle) (WSDAT-02-02).

In contrast, data for longline fisheries are considerably less detailed. Observer coverage remains limited to 5% for vessels >20 m (Resolution C-19-08). Some CPCs have exceeded this level in recent years (SAC-16 INF-B), though coverage remains variable over time. Set-by-set logbook data are not submitted to IATTC (WSDAT-01-01), instead operational-level data are shared with IATTC scientific staff under Memorandums of Understanding to support tuna and swordfish stock assessments. Most longline information is submitted by CPCs under Resolution C-03-05 as either total removals ("TASK I") or aggregated spatial and temporal data ("TASK II," levels 2–3; 1°×1° or 5°×5°, monthly) (see technical specifications of data provision). These data remain incomplete and limited for non-target species (BYC-10 INF-D, WSDAT-01-01).

Recent efforts to improve data collection and submission for fisheries other than large-vessel purse seiners have been documented (SAC-12-09, WSDAT-01-01, WSDAT-02-01, SAC-16 INF-O). The 2025 SAC Report and Recommendations (IATTC-103-02) also emphasized strengthening longline data reporting, recommending that:

"*The Commission consider amending Resolution C-03-05 to enable IATTC scientific staff to access operational set-by-set longline logbook data, or at a minimum, data aggregated at 1°×1° resolution by vessel, month, and hooks per basket (or hooks between floats) to construct abundance indices and other information useful for stock assessments of tropical and temperate tunas. This may currently be achieved through memorandums of understanding between CPCs and the IATTC during the development of stock assessments*".

Despite these advances, the longline observer data remain insufficient even for estimating catches of relatively well-monitored species such as yellowfin and bigeye tunas, implying that estimates for bycatch species are considerably less reliable due to data scarcity (BYC-10 INF-D, EB-03-01).

Complementary datasets: Species distribution models (SDMs)

Fishery-dependent catch data are not the only datasets relevant to this thematic factor. Additional sources can enhance understanding of species overlap with oceanographic regions, thereby supporting the delineation of ecoregions. One such source includes species distribution models (SDMs), which have been a major focus of development at the IATTC as key inputs to the ecological risk assessment approach known as EASI-Fish (Ecological Assessment of the Sustainable Impacts by Fisheries) (Griffiths *et al.* 2019b) or the basis for climate projections. SDMs have been developed for a range of taxa, including small, medium, and large bigeye tuna (SAC-10 INF-D); the spinetail devil ray (Lezama-Ochoa *et al.* 2020, Griffiths and Lezama-Ochoa 2021); silky and oceanic whitetip sharks; and the leatherback sea turtle (Lopez *et al.* 2024). SDMs for several shark species including silky and hammerhead sharks were also developed to inform EASI-Fish assessments in the EPO (SAC-13-11; SAC-14-12, respectively).

SDMs are statistical models that use presence or presence and absence data in conjunction with environmental variables to describe and predict species distributions. As such, they provide a powerful means of integrating biological and oceanographic information. These models can therefore serve as a key analytical tool for evaluating spatial relationships between species and environmental processes, offering another scientific foundation for defining ecologically meaningful ecoregions.

Complementary datasets: Tagging data and movement patterns

Additionally, tagging data should be evaluated as part of the ecoregion delineation process, given the extensive datasets available for tunas in the EPO which describe their movement patterns and habitat use (Schaefer and Fuller 2002, Schaefer and Fuller 2005, Schaefer and Fuller 2007, Schaefer et al. 2009, Schaefer and Fuller 2010, Schaefer et al. 2011, Schaefer and Fuller 2013, Schaefer et al. 2014, Fuller et al. 2015, Schaefer et al. 2015). These data provide valuable insights into spatial connectivity, movement patterns, and regional residency that can inform the spatial structure of ecoregions.

Comparable electronic tagging datasets are also available—though to a lesser extent—for IATTC priority shark species (Resolution C-25-08 Annex 4) offering important complementary information on movement and habitat use. Examples include studies on blue sharks (Musyl *et al.* 2011, Maxwell *et al.* 2019), silky sharks (Hutchinson *et al.* 2019, Lara-Lizardi *et al.* 2020, Salinas-de-León *et al.* 2024, Talwar *et al.* 2025), shortfin makos (Nasby-Lucas *et al.* 2019), bigeye thresher sharks (Nakano *et al.* 2003), common thresher sharks (Cartamil *et al.* 2016, Kinney *et al.* 2020), scalloped hammerhead sharks (Bessudo et al. 2011, Hutchinson et al. 2023) and whale sharks (Guzman et al. 2022). These represent only a subset of available shark movement research but collectively highlight the potential value of integrating tagging data across taxa to better define ecologically and behaviorally coherent ecoregions.

Complementary datasets: Predator-prey relationships

An important component of the EAFM is enhancing understanding of trophic interactions and how localized fishing impacts and broader climate-related changes may alter ecosystem structure and function. Stomach content analyses provide valuable insights into food web dynamics and predator–prey distributions and thus represent a potential data source to support ecoregion delineation by linking biological interactions with spatial and oceanographic patterns. As tunas are often regarded as opportunistic predators (Olson *et al.* 2016), they serve as 'biological samplers' of the communities they inhabit across varying oceanographic conditions. For instance, diet diversity has been observed to be lower in highly productive upwelling regions (e.g., the California and Humboldt Currents) and higher in offshore oligotrophic waters for both yellowfin tuna (Olson *et al.* 2014) and skipjack tuna (Fuller *et al.* 2021) in the EPO. Furthermore, grouping prey into functional groups—based on shared ecological roles (e.g., habitat use, diet) or biological traits (e.g., body size, production and consumption rates) (Griffiths *et al.* 2019a)—forms the foundation of ecosystem models. In the EPO, an Eastern Tropical Pacific (ETP) ecosystem model has produced seven ecological indicators since 2019 that collectively describe variations in ecosystem structure and function, contributing to the EAFM (SAC-10-15; SAC-12-13). Collectively, these data on predator–prey relationships can help identify ecologically coherent regions and thus inform and refine ecoregion delineation efforts.

Thematic factor 3 – fleet dynamics of tuna and tuna-like fisheries

The third thematic factor concerns the fleet dynamics of the main tuna and tuna-like fisheries in the EPO. The catch and effort data described under the second thematic factor should also be analyzed here to map core fishing grounds across space and time. Following the approach used by ICCAT and IOTC, both coastal small-scale fisheries and large-scale, high-seas ('industrial') fisheries should be evaluated to capture the full spectrum of fishing activity (Nieblas *et al.* 2022b, Nieblas *et al.* 2024). Assessing these spatial and temporal patterns of fishing effort will help identify areas of concentrated fishing pressure and interaction with ecological features, thereby providing a crucial data layer for informing and refining ecoregion delineation.

Global Fishing Watch:

Global Fishing Watch (GFW) is a research organization that has developed methods for tracking fishing activity using geolocation and remote sensing of vessels based on products such as Automatic Identification System (AIS), Vessel Monitoring System (VMS) and radar data (Kroodsma *et al.* 2023). These data can be used to provide estimates of relatively high resolution of fishing-effort dynamics in space and time, and subsequently help identify potential overlap of fishing effort with distributions of species of interest, including cases where observer or logbook data are not available (McCauley *et al.* 2016, Welch *et al.* 2024). In addition, these GFW data could fill gaps in fine-scale fishing-effort data that could help us better understand the spatio-temporal dynamics of fishing fleets targeting tuna and tuna-like species in the EPO.

3.2.4. Proposing preliminary ecoregions

The next activity in the iterative process (see Figure 5), is to delineate potential ecoregions in the EPO as baseline spatial units to support ecosystem monitoring, indicator development, and ultimately, effective, operationalization of EAFM. To characterize these regions, analyses similar to ICCAT and IOTC's "*specificity and fidelity (SF) indicator*" approach (Todorović et al. 2019, Nieblas et al. 2022a, Nieblas et al. 2022b, Nieblas et al. 2024) could be applied to assess the dominance and spatial prevalence of species and fisheries within a chosen biogeographic classification (e.g., PPOW). These t-RFMOs used SF indicators to identify which species and fisheries were most representative of each province—specificity describing dominance and fidelity describing spatial prevalence. Thresholds for fidelity were also introduced to improve robustness by excluding rare or unrepresentative grid cells, based on (i) a persistence threshold (years present in a grid cell) and (ii) a catch threshold (the amount of catch in a grid cell). Applying higher thresholds helped reveal the core distributions of the most spatially consistent and abundant species and fisheries, while reducing noise from sparse data. This approach provided a quantitative basis for depicting community composition within provinces—an analysis that IATTC staff is planning to similarly consider or refine to guide ecoregion delineation and improve the ecological relevance of regional boundaries.

Once delineated, the baseline ecoregion proposal will be presented to the EBWG and the SAC for expert review and refinement. As needed, informal virtual discussion forums—similar to the ecoregion workshops convened by ICCAT and IOTC—may also be organized to better integrate expert knowledge. All expert feedback should be clearly documented, justified, and verified to ensure transparency and traceability. Following this approach, case studies should be developed to demonstrate the practical value of delineating ecoregions and producing ecoregion-specific *EcoCards* for regional ecosystem advice. In doing so, it may be important to revisit the management objectives established in the Antigua Convention and relevant IATTC Resolutions to assess how effectively ecoregions can support these goals. This interactive, participatory process is expected to strengthen the preliminary ecoregion proposals into finalized versions.

3.2.5. Developing a case study for ecoregions

The final activity in the iterative process of delineating ecoregions (see Figure 5) is the development of a case study to evaluate their performance. Testing ecoregions through practical application is an essential prerequisite before they are presented to the Commission for consideration or used to inform resource planning and ecosystem-based management advice. This case study will assess whether the proposed ecoregions meet their intended objectives and demonstrate their utility as practical tools for ecosystem planning, prioritization, research, and the provision of integrated advice. The staff will initially focus on a single tropical case study; however, a second, contrasting subtropical ecoregion may be included, subject to resource availability. An individual *EcoCard* will be developed for the selected ecoregion to illustrate its potential application in delivering regional ecosystem insights.

3.3. Establishing preliminary broad criteria for selecting and developing candidate indicators

In parallel with the delineation of ecoregions, and as outlined in the *EcoCard* workplan (see Figures 1–2), it is essential to establish overarching screening criteria for the selection of candidate indicators (see Figure 5). These criteria provide a structured foundation for developing the draft case study described in section 3.2.5. The preliminary criteria proposed below were adapted for IATTC based on existing frameworks developed by SPC-WCPFC (SPC-OFP et al. 2025), ICCAT and IOTC (Juan-Jordá et al. 2019) and

NOAA's Ecowatch (NOAA 2025) (see Table 1). It also benefited from discussions with global experts.

3.3.1. Indicator selection criteria

Nine criteria are proposed to guide the selection of candidate indicators (Table 2).

The first criterion, **scientific relevance**, ensures that the indicator captures key ecological pressures, states or responses relevant to tuna fisheries and associated ecosystems. This includes, for example, impacts on non-target and vulnerable species, biodiversity, trophic structure, habitats, and environmental variability, including those driven by anthropogenic activities such as fishing, pollution, or habitat modification.

The second criterion, **data availability and accessibility**, requires that indicators rely on datasets that are readily available, regularly updated, and accessible to scientists and member countries.

The third, **transparency and reproducibility**, emphasizes that methods used to calculate indicators are clearly documented and reproducible, ideally supported by open code and standardized workflows. However, these practices must fully respect established data-confidentiality policies of t-RFMOs; while analytical methods and code can be openly documented, confidential data underlying indicator calculations will not be shared and must be handled in accordance with each RFMO's data protection rules.

The fourth, **sensitivity to ecosystem change**, ensures that the indicator responds to meaningful changes in ecosystem conditions or pressures over time, including shifts in variability or the frequency of extreme events.

The fifth, **interpretability and communication value**, is particularly important criteria, as indicators must be understandable and easily interpreted by scientists, managers, and decision-makers. For example, presenting a small set of clearly interpretable indicators, even in an integrated way, is likely to be more effective than providing a large number of complex metrics.

The sixth, **practicality and efficiency**, reflects the need for indicators to be calculated, updated and communicated with reasonable effort. This is particularly important given the limited time allocated to ecosystems within Scientific Committee agendas.

The seventh, **robustness and stability**, requires that indicators provide consistent signals and are not overly sensitive to noise or short-term fluctuations unrelated to ecosystem processes.

The eighth, **comparability across regions or t-RFMOs (when relevant and practical)**, ensures that indicators can be harmonized and applied consistently across different ocean regions or jurisdictions.

The ninth and most challenging criterion, **ability to inform management**, focuses on whether the indicator provides information directly relevant to fisheries or ecosystem management objectives. Ideally, such indicators can support scenario-based analyses and simulations (e.g., within Management Strategy Evaluation, MSE, frameworks) and help translate trends into potential management responses.

Most indicators developed under these criteria may function as either **surveillance (monitoring)** or **operational** indicators, with the exception of the final criterion, which applies specifically to operational indicators. Surveillance indicators are primarily useful for tracking and monitoring long-term trends and identifying the need for more detailed analyses, particularly for understanding complex relationships within ecosystems (e.g., environmental influences on target and associated species).

For **operational indicators**, additional emphasis is placed on their direct relevance to inform management decision-making. This may be achieved, for example, by incorporating ecosystem indicators into MSE or similar simulation frameworks, or by linking indicators to Commission-defined reference points that could elicit management action. In this context, indicators may serve several complementary roles:

1. Performance indicators within MSE
Ecosystem considerations may be incorporated into candidate management procedures (MPs) under MSE simulation, as a practical pathway, to evaluate their performance relative to broader ecosystem objectives, such as environmentally driven changes in recruitment, growth and movement, without immediately requiring ecosystem-based harvest control rules.

2. Monitoring ecosystem responses to management actions
Indicators may help assess whether management measures designed for target species produce unintended ecosystem consequences.

3. Informing the development of ecosystem-related objectives
Indicator trends may help identify ecosystem changes that warrant new research, improved data collection or the development of additional management objectives or mitigation measures.

4. Supporting adaptive management
Indicators may provide early signals of ecosystem change, prompting further scientific evaluation or adjustments to management strategies.

3.3.2. Data criteria

Data criteria supporting both operational and surveillance indicators (see Table 2) include adequate temporal and spatial coverage, ideally spanning more than 10 years and encompassing broad areas across the EPO. Data should be specific, directly measurable or observable, and of sufficient precision to detect meaningful changes over time. Where model-based data are used, underlying assumptions must be clearly described.

Data should also be reliable, with low levels of uncertainly and regularly accessible to the IATTC staff at no cost. Clear documentation of caveats and limitations is essential to support proper interpretation. Finally, data should uphold standards of transparency and reproducibility to ensure consistency and credibility in indicator development and application.

4. ENGAGING WITH GLOBAL EXPERTS WORKING FROM THE OTHER T-RFMOS

Building on approaches undertaken by other t-RFMOs, and as recommended by the EBWG, IATTC staff have actively engaged with global experts to harmonize, where feasible, processes that support the long-term goal to operationalize EAFM. This collaboration includes a joint manuscript submitted to the *Fisheries Research* special issue on Bycatch in the World's Tuna Fisheries, which reviews ongoing EAFM initiatives across t-RFMOs and extends the work summarized in EB-02-02. These efforts were advanced during the *3rd Joint Meeting of tuna RFMOs on the Implementation of EAFM*, held at FAO headquarters in Rome in 2025 under the Common Oceans Tuna Project.

Further collaboration included informal exchanges with ICCAT and IOTC scientists and has provided valuable insights on the exploration of ecoregions, emphasizing that ecoregions should serve as flexible, non-restrictive tools applied when management needs are spatially defined, for example, to distinguish between tropical and subtropical regions. Discussions highlighted the importance of selecting environmental indicators that meaningfully inform tuna management by linking environmental change to species life history, productivity, and stock dynamics. Their experiences also underscored the need for effective communication between ecosystem scientists and stock assessment experts to ensure indicators translate into actionable fisheries advice. Challenges remain in developing socio-economic indicators, given the limited data available to t-RFMOs and the differing objectives among stakeholders and Members.

Insights from these interactions have proven valuable for IATTC's exploration of ecoregions, as they enable the sharing of practical lessons, methodological frameworks, and governance experiences from parallel efforts at ICCAT and IOTC, where ecoregions are still under development. For instance, ICCAT's recent SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis (Nieblas et al. 2024) highlighted that ecoregions can provide an effective spatial framework for understanding regional ecosystem status and trends, distinguishing fishing strategies and ecological conditions, and organizing ecosystem-based advice through regionally tailored products such as *EcoCards* and *Ecosystem Considerations* reports. They also have potential to inform adaptive management by linking fisheries advice to region-specific changes in productivity driven by environmental and climatic factors. At the same time, the ICCAT experience underscores several challenges, including added complexity in management decisions, limited data—particularly for bycatch species—high resource demands, and institutional barriers that complicate coordination across working groups and organizations.

SPC-WCPFC's *EcoCards* incorporate region-specific indicators (e.g., those related to the western Pacific warm pool and the Pacific gyres), which may provide useful models for IATTC's regional applications (SPC-OFP 2023, SPC-OFP et al. 2025), especially in indicator development.

The next major collaborative discussions were held at SPC in Noumea in March 2026 at the *4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators*, convened under the FAO Common Oceans Tuna Project in collaboration with ISSF and SPC. This technical workshop focused on the development and application of ecosystem indicators, with emphasis on integrated indicators, to support fisheries management across t-RFMOs. Discussions highlighted that most t-RFMOs are at a similar stage of development: developing or updating ecosystem models, exploring candidate indicators, defining selection criteria, and determining how indicators can inform management. Participants emphasized that ecosystem indicators should initially serve a monitoring and communication role, helping scientists and managers track ecosystem conditions, identify emerging changes, and provide context and a framework for ecosystem-based fisheries management decisions. Many participants noted that immediate integration of ecosystem indicators into formal management actions (e.g., through MSE, reference points or explicit harvest control rules) is challenging; therefore, indicators may first function as performance metrics or contextual indicators within existing management frameworks. In addition, indicator validation, via testing, should be warranted to ensure these are representing the processes of interest accurately and robustly through time. A key outcome of the discussions was the recognition that a structured, and where possible harmonized, indicator selection process is essential to ensure that indicators presented to Scientific Committees are scientifically robust, transparent, and manageable in number.

Continued collaboration among t-RFMOs will help ensure that ecosystem indicators are scientifically robust, operationally practical, and aligned with the evolving implementation of EAFM.

5. NEXT STEPS: PHASE 3 (*DEVELOPMENT*)

The tasks outlined in IATTC's *EcoCard* workplan for 2026 (Figures 1–2) include applying the selection criteria presented herein (see Figure 5)—incorporating feedback from the EBWG and SAC as appropriate—to draft preliminary ecoregions in the EPO and propose candidate indicators for the tropical case study.

6. ACKNOWLEDGEMENTS

We gratefully acknowledge the valuable contributions by Shane Griffiths to the early development of this document.

7. REFERENCES

Bessudo, S., G. Soler, P. Klimley, J. Ketchum, R. Arauz, A. Hearn, A. Guzmán, and B. Calmettes. 2011. Vertical and horizontal movements of the scalloped hammerhead shark (*Sphyrna lewini*) around Malpelo and Cocos Islands (Tropical Eastern Pacific) using satellite telemetry. Boletín de Investigaciones Marinas y Costeras - INVEMAR 40: 91-106.

Cartamil, D., J. Wraith, N.C. Wegner, D. Kacev, C.H. Lam, O. Santana-Morales, O. Sosa-Nishizaki, M. Escobedo-Olvera, S. Kohin, J.B. Graham, and P. Hastings. 2016. Movements and distribution of juvenile common thresher sharks Alopias vulpinus in Pacific coast waters of the USA and Mexico. Marine Ecology Progress Series 548: 153-163.

Fay, A.R., and G.A. McKinley. 2014. Global open-ocean biomes: mean and temporal variability. Earth Syst. Sci. Data 6(2): 273-284.

Fuller, D.W., K.M. Schaefer, J. Hampton, S. Caillot, and B.M. Leroy. 2015. Vertical movements, behavior, and habitat of bigeye tuna (*Thunnus obesus*) in the equatorial central Pacific Ocean. Fisheries Research 172: 57-70.

Fuller, L., S. Griffiths, R. Olson, F. Galván-Magaña, N. Bocanegra-Castillo, and V. Alatorre-Ramírez. 2021. Spatial and ontogenetic variation in the trophic ecology of skipjack tuna, Katsuwonus pelamis, in the eastern Pacific Ocean. Marine Biology 168(5): 73.

Fulton, E., K. Sainsbury, C. Bulman, C. Novaglio, J. Porobic, D. Hayes, E. Putten, L. Dutra, L. Thomas, W. Norris, C. Pert, A. Willock, S. Montenegro, L. Garay-Narvaez, S. Hernandez, A. Saso, K. Mohamed, T. Sathianandan, S. Kuriakose, and D. Evans. 2025. The Green Band: Using Production and Catch to Judge Distortive Pressure on an Ecosystem

Fulton, E.A., and K. Sainsbury. 2025. The ecosystem traits index is proposed as a composite index of ecosystem robustness for use in marine resource management. Scientific Reports 15(1): 32281.

Griffiths, S., B. Wallace, V. Cáceres, L.H. Rodríguez, J. Lopez, M. Abrego, J. Alfaro Shigueto, S. Andraka, M.J. Brito, L.C. Bustos, I. Cari, J.M. Carvajal, L. Clavijo, L. Cocas, N. de Paz Campos, M. Herrera, A.M. Lauritsen, J. Mangel, M. Pérez-Huaripata, and P. Zarate. 2024. Vulnerability of the Critically Endangered leatherback turtle to fisheries bycatch in the eastern Pacific Ocean. II. Assessment of mitigation measures. Endangered Species Research 53: 295-326.

Griffiths, S.P., V. Allain, S.D. Hoyle, T.A. Lawson, and S.J. Nicol. 2019a. Just a FAD? Ecosystem impacts of tuna purse-seine fishing associated with fish aggregating devices in the western Pacific Warm Pool Province. Fish Oceanogr. 28: 94-112.

Griffiths, S.P., K. Kesner-Reyes, C.V. Garilao, L.M. Duffy, and M.H. Román. 2019b. Ecological Assessment of the Sustainable Impacts by Fisheries (EASI-Fish): A flexible vulnerability assessment approach to quantify the cumulative impacts of fishing in data-limited settings. Marine Ecology Progress Series 625: 89-113.

Griffiths, S.P., and N. Lezama-Ochoa. 2021. A 40-year chronology of the vulnerability of spinetail devil ray (*Mobula mobular*) to eastern Pacific tuna fisheries and options for future conservation and management. Aquatic Conservation: Marine and Freshwater Ecosystems 31(10): 2910-2925.

Guzman, H.M., C.M. Collatos, and C.G. Gomez. 2022. Movement, Behavior, and Habitat Use of Whale Sharks (Rhincodon typus) in the Tropical Eastern Pacific Ocean. Volume 9 - 2022

Hutchinson, M., D.M. Coffey, K. Holland, D. Itano, B. Leroy, S. Kohin, R. Vetter, A.J. Williams, and J. Wren. 2019. Movements and habitat use of juvenile silky sharks in the Pacific Ocean inform conservation strategies. Fisheries Research 210: 131-142.

Hutchinson, M., M. Scott, R. Bauer, J. Anderson, D.M. Coffey, K. Holland, C. Meyer, J. O'Sullivan, and M. Royer. 2023. Habitat use and movement patterns of adult male and juvenile scalloped hammerhead sharks Sphyrna lewini throughout the Hawaiian archipelago. Endangered Species Research 52: 41-64.

Juan-Jordá, M., A. Nieblas, S. Tsuji, F. Marsac, E. Chasso, D. Hayes, U. Shahid, M. Khan, E. Andonegi, P. de Bruyn, F. Fiorellato, P. Thoya, M. Green, R. Kitakado, L. Nelson, L. Ramos-Alonso, S. Martin, J. Moss, L. Lopetegui-Eguren, Z. Hoque, L. Pierre, A. Sheikh, and H. Murua. 2022a. Report of the second IOTC ecoregion workshop on "the identification of regions in the IOTC convention area to inform the implementation of the ecosystem approach to fisheries management". IOTC-2022-WPEB18-22. Pages 1-34.

Juan-Jordá, M.J., H. Murua, P. Apostolaki, C.P. Lynam, A. Rodriguez, J. Barrionuevo, F. Abascal, R. Coelho, S. Todorović, N. Billet, M. Uyarra, E. Andonegi, and J. Lopez. 2019. Selecting ecosystem indicators for fisheries targeting highly migratory species: An EU project to advance the operationalization of the EAFM in ICCAT and IOTC. WCPFC-SC15-2019/EB-WP-12.

Juan-Jordá, M.J., A.E. Nieblas, A. Hanke, S. Tsuji, E. Andonegi, A.D. Natale, L. Kell, G. Diaz, D. Alvarez Berastegui, C.A. Brown, D. Die, H. Arrizabalaga, O. Yates, D. Gianuca, F. Niemeyer Fiedler, B. Luckhurst, R. Coelho, S. Zador, M. Dickey-Collas, P. Pepin, and H. Murua. 2022b. Report of the ICCAT Workshop on the identification of regions in the ICCAT Convention Area for supporting the implementation of the ecosystem approach to fisheries management. Collect. Vol. Sci. Pap. ICCAT 79(5): 178-211.

Kinney, M.J., D. Kacev, T. Sippel, H. Dewar, and T. Eguchi. 2020. Common thresher shark Alopias vulpinus movement: Bayesian inference on a data-limited species. Marine Ecology Progress Series 639: 155-167.

Kroodsma, D., J. Turner, C. Luck, T. Hochberg, N. Miller, P. Augustyn, and S. Prince. 2023. Global prevalence of setting longlines at dawn highlights bycatch risk for threatened albatross. Biological Conservation 283: 110026.

Lara-Lizardi, F., M. Hoyos-Padilla, A. Hearn, A.P. Klimley, F. Galván-Magaña, R. Arauz, S. Bessudo, E. Castro, E. Clua, E. Espinoza, C. Fischer, C. Peñaherrera-Palma, T. Steiner, and J.T. Ketchum. 2020. Shark movements in the Revillagigedo Archipelago and connectivity with the Eastern Tropical Pacific. 2020.03.02.972844.

Lezama-Ochoa, N., M.G. Pennino, M.A. Hall, J. Lopez, and H. Murua. 2020. Using a Bayesian modelling approach (INLA-SPDE) to predict the occurrence of the Spinetail Devil Ray (Mobular mobular). Scientific Reports 10(1): 18822.

Longhurst, A.R. 1998. Ecological Geography of the Sea. Academic Press, San Diego, CA. 398 pp.

Lopez, J., S. Griffiths, B.P. Wallace, V. Cáceres, L. Helena Rodríguez, M. Abrego, J. Alfaro-Shigueto, S. Andraka, M. José Brito, L. Camila Bustos, I. Cari, J.M. Carvajal, L. Clavijo, L. Cocas, N. de Paz, M. Herrera, J.C. Mangel, M. Pérez-Huaripata, R. Piedra, J.A. Quiñones Dávila, L. Rendón, J.M. Rguez-Baron, H. Santana, J. Suárez, C. Veelenturf, R. Vega, and P. Zárate. 2024. Vulnerability of the Critically Endangered leatherback turtle to fisheries bycatch in the eastern Pacific Ocean. I. A machine-learning species distribution model. Endangered Species Research 53: 271-293.

Maxwell, S.M., K.L. Scales, S.J. Bograd, D.K. Briscoe, H. Dewar, E.L. Hazen, R.L. Lewison, H. Welch, and L.B. Crowder. 2019. Seasonal spatial segregation in blue sharks (Prionace glauca) by sex and size class in the Northeast Pacific Ocean. 25(8): 1304-1317.

McCauley, D.J., P. Woods, B. Sullivan, B. Bergman, C. Jablonicky, A. Roan, M. Hirshfield, K. Boerder, and B. Worm. 2016. Ending hide and seek at sea. 351(6278): 1148-1150.

Musyl, M.K., R.W. Brill, D.S. Curran, N.M. Fragoso, L.M. McNaughton, A. Nielsen, B.S. Kikkawa, and C.D. Moyes. 2011. Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the central Pacific Ocean. Fishery Bulletin 109(4): 341-368.

Nakano, H., H. Matsunaga, H. Okamoto, and M. Okazaki. 2003. Acoustic tracking of bigeye thresher shark *Alopias superciliosus* in the eastern Pacific Ocean. Marine Ecology Progress Series 265: 255-261.

Nasby-Lucas, N., H. Dewar, O. Sosa-Nishizaki, C. Wilson, J.R. Hyde, R.D. Vetter, J. Wraith, B.A. Block, M.J. Kinney, T. Sippel, D.B. Holts, and S. Kohin. 2019. Movements of electronically tagged shortfin mako sharks (Isurus oxyrinchus) in the eastern North Pacific Ocean. Animal Biotelemetry 7(1): 12.

Nieblas, A., E. Andonegi, H. Murua, and M. Juan-Jordá. 2024. Pre-workshop analysis in preparation for the second ICCAT ecoregion workshop "Identification of Regions in the ICCAT Convention Area to Inform the Implementation of the Ecosystem Approach to Fisheries Management". Collect. Vol. Sci. Pap. ICCAT 81(4): 1-94.

Nieblas, A., H. Murua, P. De Bruyn, E. Chassot, F. Fiorellato, and M. Juan-Jordá. 2022a. Pre-workshop analysis in preparation for the 2022 IOTC Ecoregions Workshop: "Identification of regions in the IOTC Convention Area to inform the implementation of the ecosystem approach to fisheries management" online, 19-21 January 2022. IOTC-2022-WPEB18-INF14. 56 pp.

Nieblas, A.E., H. Murua, and M.J. Juan-Jordá. 2022b. Pre-workshop analysis in preparation for the 2022 ICCAT ecoregion workshop "Identification of regions in the ICCAT Convention Area for supporting the implementation of ecosystem based fisheries management. . Collect. Vol. Sci. Pap. ICCAT 79: 80-151.

NOAA. 2025. National Marine Ecosystem Status Website. ecowatch.noaa.gov/about "Indicator Selection".

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

Olson, R.J., J.W. Young, F. Ménard, M. Potier, V. Allain, N. Goñi, J.M. Logan, and F. Galván-Magaña. 2016. Bioenergetics, trophic ecology, and niche separation of tunas. *In* B. E. Curry (ed.), Advances in Marine Biology, 74 p. 199-344. Academic Press, UK.

Reygondeau, G., O. Maury, G. Beaugrand, J.M. Fromentin, A. Fonteneau, and P. Cury. 2012. Biogeography of tuna and billfish communities. 39(1): 114-129.

Rice, J., K.M. Gjerde, J. Ardron, S. Arico, I. Cresswell, E. Escobar, S. Grant, and M. Vierros. 2011. Policy relevance of biogeographic classification for conservation and management of marine biodiversity beyond national jurisdiction, and the GOODS biogeographic classification. Ocean & Coastal Management 54(2): 110-122.

Salinas-de-León, P., J. Vaudo, R. Logan, J. Suarez-Moncada, and M. Shivji. 2024. Longest recorded migration of a silky shark (Carcharhinus falciformis) reveals extensive use of international waters of the Tropical Eastern Pacific. 105(1): 378-381.

Schaefer, K.M., and D.W. Fuller. 2002. Movements, behavior, and habitat selection of bigeye tuna (*Thunnus obesus*) in the eastern equatorial Pacific, ascertained through archival tags. U.S. National Marine Fisheries Service, Fishery Bulletin 100: 765-788.

Schaefer, K.M., and D.W. Fuller. 2005. Behavior of bigeye (*Thunnus obesus*) and skipjack (*Katsuwonus pelamis*) tunas within aggregations associated with floating objects in the equatorial eastern Pacific. Marine Biology 146: 781-792.

Schaefer, K.M., and D.W. Fuller. 2007. Vertical movement patterns of skipjack tuna (*Katsuwonus pelamis*) in the eastern equatorial Pacific Ocean, as revealed with archival tags. Fishery Bulletin 105(3): 379-389.

Schaefer, K.M., and D.W. Fuller. 2010. Vertical movements, behavior, and habitat of bigeye tuna (*Thunnus obesus*) in the equatorial eastern Pacific Ocean, ascertained from archival tag data. Marine Biology 157: 2625-2642.

Schaefer, K.M., and D.W. Fuller. 2013. Simultaneous behavior of skipjack (*Katsuwonus pelamis*), bigeye (*Thunnus obesus*), and yellowfin (*T. albacares*) tunas, within large multi-species aggregations associated with drifting fish aggregating devices (FADs) in the equatorial eastern Pacific Ocean. Marine Biology 160: 3005-3014.

Schaefer, K.M., D.W. Fuller, and G. Aldana. 2014. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in waters surrounding the Revillagigedo Islands Archipelago Biosphere Reserver, Mexico. Fisheries Oceanography 23(1): 65-82.

Schaefer, K.M., D.W. Fuller, and B.A. Block. 2009. Vertical movements and habitat utilization of skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), and bigeye (*Thunnus obesus*) tunas in the equatorial eastern Pacific Ocean, ascertained through archival tag data. *In* J. L. Nielsen, H. Arrizabalaga, N. Fragoso, A. Hobday, M. Lutcavage, and J. Sibert (eds.), Tagging and Tracking of Marine Animals with Electronic Devices, p. 121-144. Springer.

Schaefer, K.M., D.W. Fuller, and B.A. Block. 2011. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the Pacific Ocean off Baja, California, Mexico, determined from archival tag data analyses, including unscented Kalman filtering. Fisheries Research 112: 22-37.

Schaefer, K.M., D.W. Fuller, J. Hampton, S. Caillot, B. Leroy, and D. Itano. 2015. Movements, dispersion, and mixing of bigeye tuna (*Thunnus obesus*) tagged and released in the equatorial Central Pacific Ocean, with conventional and archival tags. Fisheries Research 161: 336-355.

Sherman, K., and A.M. Duda. 1999. Large Marine Ecosystems: An Emerging Paradigm for Fishery Sustainability. 24(12): 15-26.

Spalding, M.D., V.N. Agostini, J. Rice, and S.M. Grant. 2012. Pelagic provinces of the world: A biogeographic classification of the world's surface pelagic waters. Ocean & Coastal Management 60: 19-30.

Spalding, M.D., H.E. Fox, G.R. Allen, N. Davidson, Z.A. Ferdana, M. Finlayson, B.S. Halpern, M.A. Jorge, A. Lombana, S.A. Lourie, K.D. Martin, E. McManus, J. Molnar, C.A. Recchia, and J. Robertson. 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. Bioscience 57(7): 573-583, 11.

SPC-OFP. 2023. Ecosystem and Climate Indicators. WCPFC-SC19-2023/EB-WP-01. Pages 24. *Western and Central Pacific Fisheries Commission Scientific Committee Nineteenth Regular Session* Koror, Palau.

SPC-OFP, CSIRO, MOi, and IRD. 2025. Ecosystem and climate indicators of the western and central Pacific Ocean. WCPFC-SC21-2025/EB-IP-01. Pages 43. *Western and Central Pacific Fisheries Commission Scientific Committee Twenty-First Regular Session*, Nuku'alofa, Tonga.

Talwar, B.S., B.X. Semmens, A. Aires-da-Silva, S. Griffiths, J. Humberstone, M. Hutchinson, J. Lopez, C. Minte-Vera, D. Ovando, M. Román-Verdesoto, S. Siu, and L.F. Bellquist. 2025. Informing the spatial management of Silky Shark (Carcharhinus falciformis) in the Eastern Pacific Ocean. Reviews in Fish Biology and Fisheries 35(2): 1031-1062.

Todorović, S., M.J. Juan-Jordá, H. Arrizabalaga, and H. Murua. 2019. Pelagic ecoregions: Operationalizing an ecosystem approach to fisheries management in the Atlantic Ocean. Marine Policy 109: 103700.

UNESCO. 2009. Global Open Oceans and Deep Seabed (GOODS) - Biogeographic Classification. Paris, UNESCO-IOC (IOC Technical Series, 84.).

Welch, H., T. Clavelle, T.D. White, M.A. Cimino, D. Kroodsma, and E.L. Hazen. 2024. Unseen overlap between fishing vessels and top predators in the northeast Pacific. 10(10): eadl5528.

Weng, K.C., A.M. Boustany, P. Pyle, S.D. Anderson, A. Brown, and B.A. Block. 2007. Migration and habitat of white sharks (Carcharodon carcharias) in the eastern Pacific Ocean. Marine Biology 152(4): 877-894.

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.

t-RFMO/organization	Indicator Criteria	Data Criteria	Source
WCPFC	1. science and data based;	Data should be publicly available and be quantitative, specific, and preferably directly measurable or observable.	(SPC-OFP *et al.* 2025)
	2. characterize the states and trends of WCPFC marine ecosystems with respect to fishing activity and/or climate (including reference levels and baselines);	Data should be updated on a regular basis, preferable at least annually.	
	3. reflect well-defined processes underlying fishing activity and fishery responses to climate;	Time-series used should be long-term (>10-years preferred).	
	4. responsive to changes attributable to fishing pressure and climate (i.e., minimal time-lags and capability to provide early warning);	Data should have appropriate and adequate spatial coverage.	
	5. estimable on a routine basis with a historical data time-series available;	Data should have sufficient signal-to-noise ratio to estimate measurement, process uncertainty, and detect significant change.	
	6. cost-effectiveness;	Explanation of the limits of data must be documented.	
	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		
ICCAT & IOTC	1. Scientific basis	Not provided	(Juan-Jordá *et al.* 2019)
	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		
NOAA (Ecowatch)	1. Indicators should be theoretically sound, reliably represent key ecosystem attributes and hold up to peer review.	Data should be publicly available and be quantitative whenever possible. Qualitative information and expert opinion can provide context for quantitative indicators.	(NOAA 2025)
	2. Indicators should have demonstrable importance to the ecosystem (e.g., keystone or structural architect species) and society (e.g., charismatic or subsistence species))	Data should be specific, preferably directly measurable or observable.	
	3. Indicators should be relevant and understandable to management, to the public, and to policy makers	Data should be updated on a regular basis, preferably at least annually.	
	4. Indicators should be responsive, showing sensitivity to and reacting predictably to environmental variability and/or management or policy actions.	Time-series should be long-term (>10-years preferred) and likely to extend for the foreseeable future.	
	4a. The direction of response should be theoretically- or empirically-expected.	Data should have appropriate and adequate spatial coverage.	
	4b. When possible, indicators should provide early warning of ecosystem change.	Normal ranges of spatial (e.g. patchiness) and temporal (e.g. diel, seasonal, annual, and decadal) variation for data should be considered to ascertain status and trends.	
	5. Indicators should complement the indicators already served on the portal in ways such that they are not redundant	Data should have sufficient signal-to-noise ratio to estimate measurement, process uncertainty, and detect significant change.	

TABLE 2. Proposed indicator criteria and definitions—adapted from criteria developed by SPC-WCPFC[1], ICCAT[2], IOTC[2] and NOAA's Ecowatch[3]—for selecting and developing candidate indicators under the broad categories highlighted in the visual dashboard (see Figs. 4–5) in the eastern Pacific Ocean (EPO) to advance the *EcoCard* workplan in EB-02-02. These criteria were refined based on discussions at the *4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators* (March 2026).

Selection Criterion	Description
Scientific relevance (operational* or surveillance)	The indicator captures ecological pressures, states or responses relevant to tuna fisheries and associated ecosystems (e.g., biodiversity, trophic structure, environmental variability), including those driven by human activities such as fishing, pollution, or habitat modification.
Data availability and accessibility (operational* or surveillance)	The indicator relies on datasets that are readily available, regularly updated, and accessible to scientists and member countries.
Transparency and reproducibility (operational* or surveillance)	Methods used to calculate indicators are clearly documented and reproducible, ideally supported by open code and standardized workflows.
Sensitivity to ecosystem change (operational* or surveillance)	The indicator responds to meaningful changes in ecosystem conditions or pressures over time.
Interpretability and communication value (operational* or surveillance)	The indicator is understandable and easily interpretable by scientists, managers, and decision-makers.
Practicality and efficiency (operational* or surveillance)	The indicator can be calculated and updated with reasonable effort.
Robustness and stability (operational* or surveillance)	The indicator provides consistent signals and is not overly sensitive to noise or short-term fluctuations unrelated to ecosystem processes.
Comparability across regions or t-RFMOs (when relevant and practical) (operational* or surveillance)	The indicator can be applied consistently across different ocean regions or t-RFMO jurisdictions.
Informs management* (operational*)	The indicator provides information directly relevant to defined fisheries or ecosystem management objectives, and can support scenario-based analyses (e.g., within MSE frameworks) that could translate indicator trends into potential management responses.

[1] SC21-EB-IP-01 (2025)
[2] Juan-Jorda et al. 2019 WCPFC-SC15-2019/EB-WP-12
[3] https://ecowatch.noaa.gov/about (see "Indicator Selection" tab)

*Indicates criteria are suitable only for 'operational' indicators (i.e., those directly linked to management objectives outlined in the Antigua Convention and/or in active IATTC Resolutions). The remaining criteria may be suitable for either operational or 'surveillance' indicators.

Surveillance indicators are those that are not directly linked to specific management objectives but are used to track and monitor long-term trends and help identify when detailed analyses may be needed to understand more complex relationships with target stocks, associated and/or dependent species belonging to the same ecosystem (e.g., environmental indicators like sea-surface temperature, SST).

Data criteria for both 'operational' and 'surveillance' indicators should:

a) have adequate temporal coverage, ideally spanning more than 10 years, and broad spatial coverage (e.g., across the eastern Pacific Ocean (EPO) or region-specific within the EPO);
b) be specific and preferably directly measurable or observable, rather than relying on indirect proxies; or where model-based data are used, underlying assumptions must be clearly described
c) have sufficient signal-to-noise ratio, allowing reliable estimation of measurement and process uncertainty and detection of meaningful changes;
d) include documented caveats and limitations to ensure transparency and support interpretation;
e) be reliable, with low levels of uncertainly, and regularly accessible to the IATTC staff at no cost

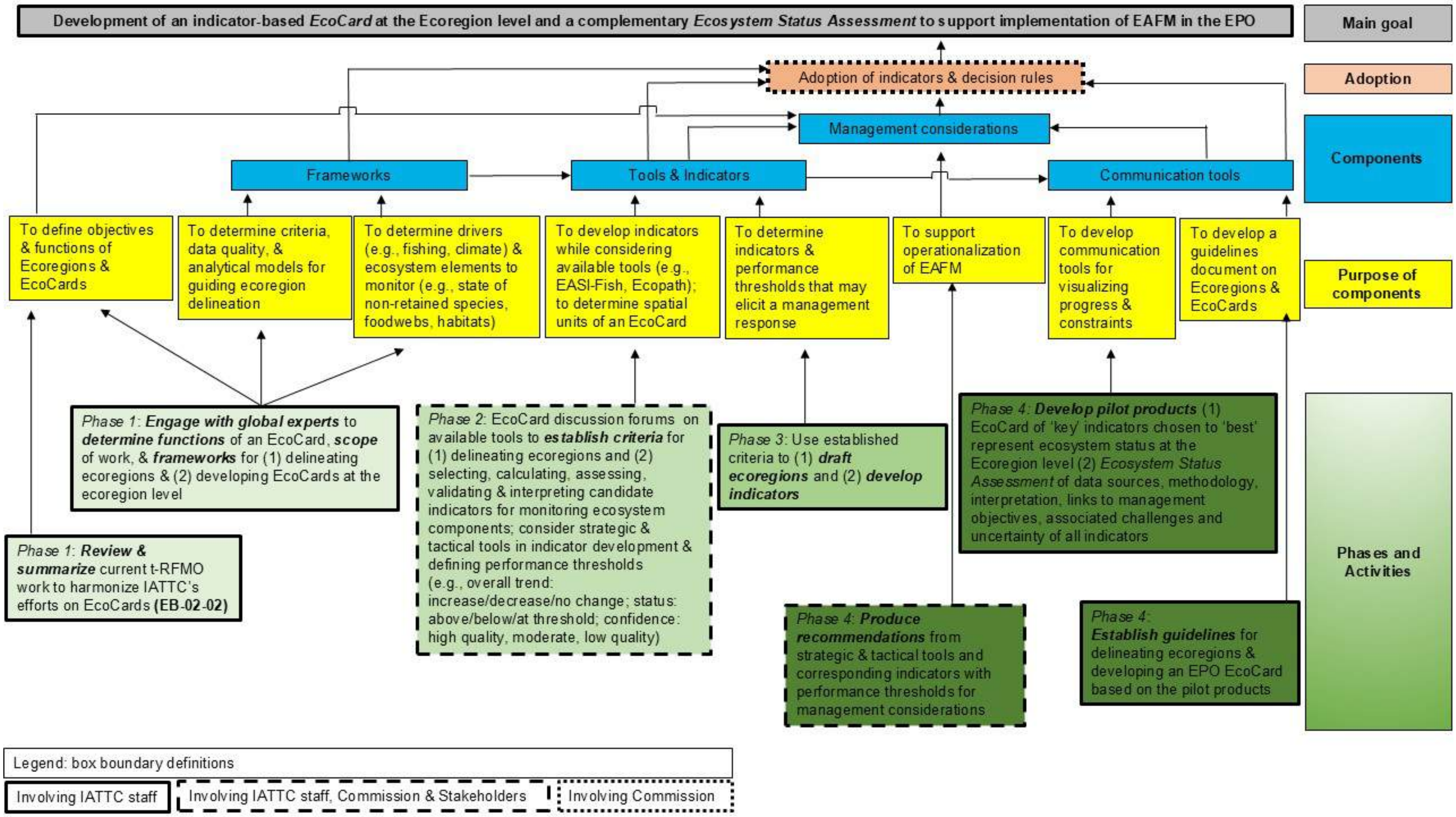


FIGURE 1. Workplan for restructuring IATTC's *Ecosystem Considerations* document into two ecosystem-advice products, produced in EB-02-02, (1) an *EcoCard* of 'key' indicators chosen to 'best' represent ecosystem status at the ecoregion level and (2) a complementary *Ecosystem Status Assessment* for 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*.

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 2. 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 operationalization of the Ecosystem Approach to Fisheries Management (EAFM), as produced in the *EcoCard* workplan EB-02-02. Q=Quarter; EBWG=Ecosystem & Bycatch Working Group. This document focuses on Phase 2 of the workplan.

Goal: *To facilitate operationalization of the EAFM by improving ecosystem-science advice for management through the development and application of meaningful and effective tools and communication products.*

Objective: *To transition to an indicator-based EcoCard to guide the decision-making process by increasing awareness, communication and reporting of the status of different ecosystem components to the IATTC for prioritization of research and potential management intervention.*

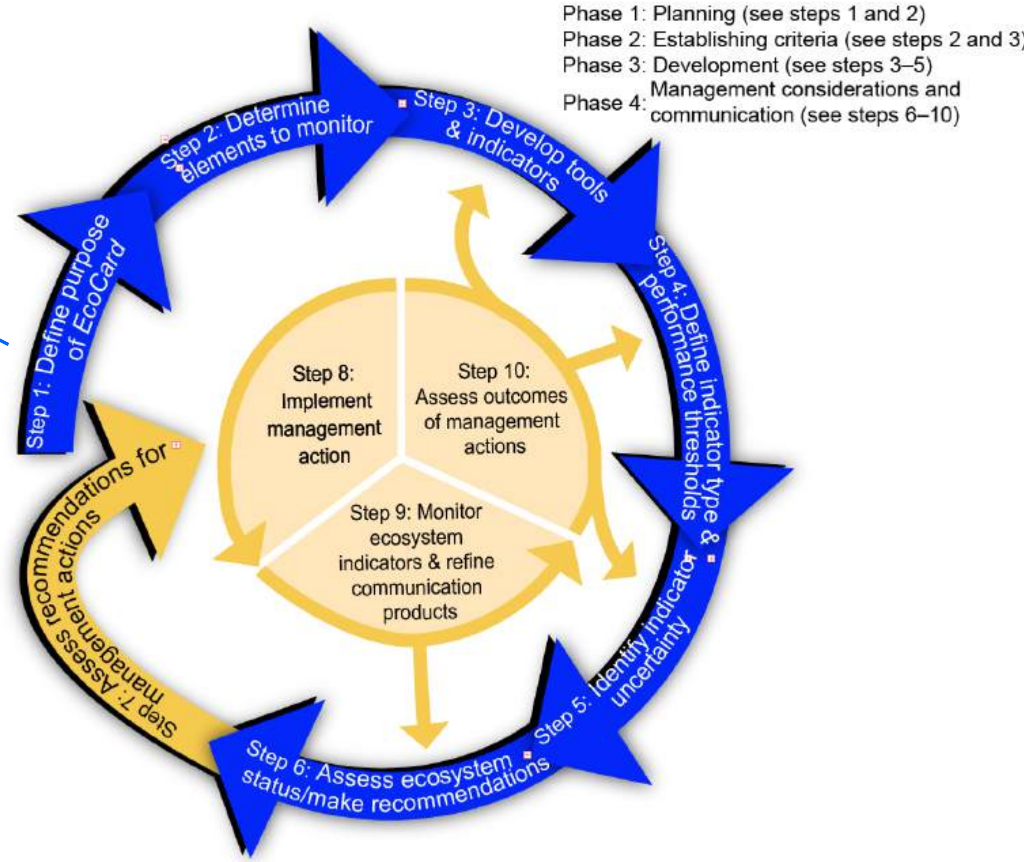


FIGURE 3. IATTC staff's proposed conceptual framework of the *EcoCard* workplan, produced in EB-03-04, to facilitate implementation of EAFM through the development of communication products (i.e., indicator-based *EcoCards* and complementary *Ecosystem Status Assessments*) used to prioritize research and potential management intervention. Blue arrows primarily represent scientific steps (1–6) required to provide ecosystem advice to the Commission. Yellow arrows primarily represent steps (7–10) needed by the Commission to determine any potential management action(s), implementation of actions and assessment of management actions based on scientific recommendations. The process is iterative and requires consistent communication between scientists, managers and other relevant stakeholders to refine ecosystem-advice communication products. The framework follows the four phases identified in IATTC's *EcoCard* workplan (EB-02-02 and Figures 1 and 2). The goal and objective added here were defined in EB-03-04, contributed to step 1 in the framework, under Phase 1: *Planning*, and show the progress made to advance IATTC's *EcoCard* workplan.

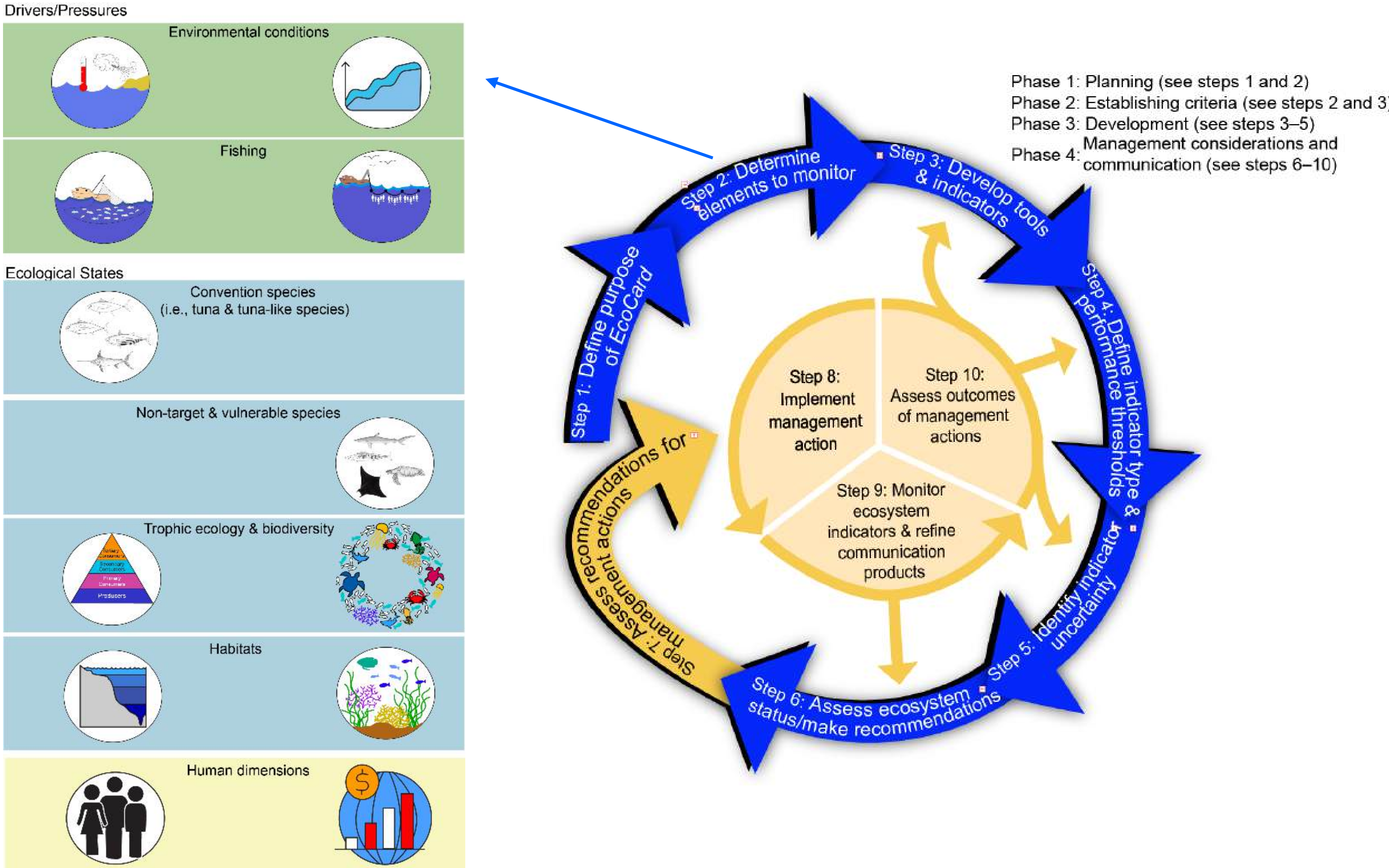
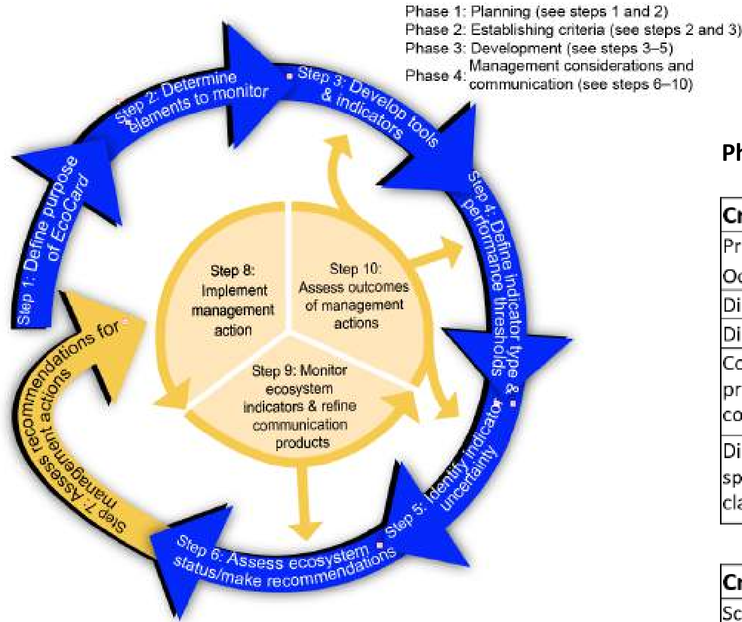


FIGURE 4. Building upon the staff's proposed conceptual framework of the *EcoCard* workplan, presented in EB-03-04, and displayed herein (Figure 3), a proposed visual dashboard (left panel) designed in EB-03-04 shows the broad categories of elements to monitor within an *EcoCard* and corresponds to step 2 in the framework under Phase 1: *Planning*.

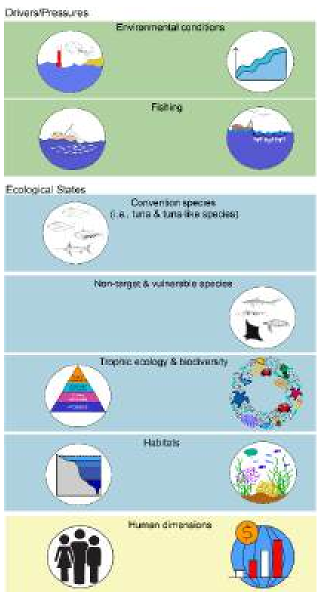


Phase 2, Establishing Criteria: Step 3

Criteria to guide Ecoregions
Primary factors to consider:
Oceanography
Distributions of species and assemblages
Distribution of fleet dynamics
Core qualities of ecoregions (e.g., practicality, feasibility, adaptability, consistency, temporal resolution)
Distribution of catches and overlap with species, fleets and biogeographic classifications of interest

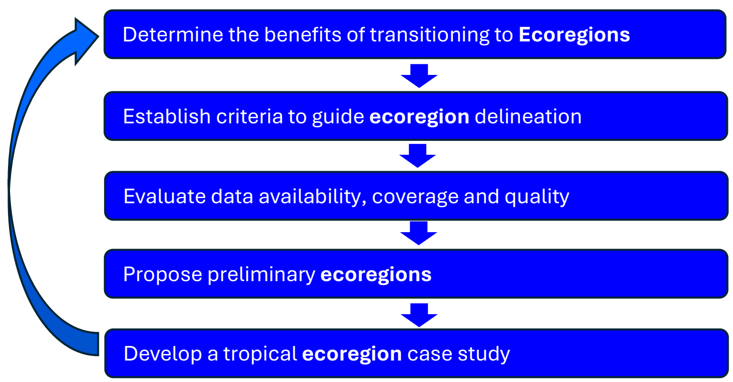
Phase 1, Planning: Step 2

Visual Dashboard: Elements to Monitor



Phase 2, Establishing Criteria: Step 3

Key activities to develop Ecoregions



Criteria to guide indicator selection
Scientific relevance (operational* or surveillance)
Data availability and accessibility (operational* or surveillance)
Transparency and reproducibility (operational* or surveillance)
Sensitivity to ecosystem change (operational* or surveillance)
Interpretability and communication value (operational* or surveillance)
Practicality and efficiency (operational* or surveillance)
Robustness and stability (operational* or surveillance)
Comparability across regions or t-RFMOs (when relevant) (operational* or surveillance)
Informs management (operational* or surveillance)

FIGURE 5. Proposed conceptual framework for advancing the ecosystem approach to fisheries management (EAFM) in the eastern Pacific Ocean (EPO) (**top panel**, iterative loop), designed in EB-03-04; also presented in Figures 3–4 depicts the sequence of phases and steps identified in the workplan (see Figs. 1–2), emphasizing the iterative structure and feedbacks that allow outcomes from later phases to inform earlier phases. The **bottom panels** summarize key steps developed to date: (**left**) the visual dashboard developed in EB-03-04 under *Phase 1 (Planning), Step 2 (Elements to monitor)*, which identifies broad categories for candidate indicator development (see also Fig. 4); (**middle**) the main activities for exploring and defining potential ecoregions, adapted from Juan-Jordá *et al.* (2022b), representing a potential tool under *Phase 2 (Establishing criteria)*, *Step 3* (*Develop tools and indicators*); and (**right**) the proposed criteria to guide both ecoregion delineation and candidate indicator selection also within *Phase 2*.