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OVERVIEW OF IATTC'S ECOSYSTEM REPORTING IN COMPARISON TO OTHER TUNA REGIONAL FISHERIES MANAGEMENT ORGANIZATIONS

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1. INTRODUCTION

Several projects identified in the staff research activities report (IATTC-93-06b) under the proposed IATTC Strategic Science Plan (SSP) for 2019-2023 (IATTC-93-06a) specifically pertain to ecosystem-related activities. Such research aims to further IATTC's progress towards ecosystem-based fisheries management (EBFM) to ensure the long-term sustainability of ecosystem components affected by the fishery, as mandated by the Antigua Convention, specifically Article VII 1(f) "*adopt, as necessary, conservation and management measures and recommendations for 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, with a view to maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened*."

The IATTC has already made substantial advances towards this goal through its "*Ecosystem Considerations*" report, first developed in 2007 (SAR-8-17 J) and updated annually (*e.g.* SAC-10-14). In that document the IATTC staff reports on, for example, the catches of non-target species, including marine mammals, sea turtles, sharks and rays, as well as other ecologically- and/or economically-important large pelagic fishes, such as wahoo and dorado. The report also covers trophic interactions, the physical environment, and ecosystem indicators. An ecosystem model of the tropical eastern Pacific Ocean (ETP) has also been developed (Olson and Watters 2003), which has recently been used to report additional ecological indicators. It has also been used to examine the potential ecological impacts that EPO fisheries may have had on the structure of the EPO ecosystem over the past 50 years and forecast the potential state of the ecosystem under various hypothetical fishery scenarios (SAC-10-15). The staff has produced preliminary Ecological Risk Assessments (ERA)—using the widely-used Productivity-Susceptibility Analysis (PSA)—to assess the relative risk of species to the impacts of the purse-seine (SAC-06-09) and longline (SAC-08-07d) fisheries. In 2018, the staff developed a new ERA approach called "Ecological Assessment of the Sustainable Impacts of Fisheries" (EASI-Fish) (SAC-09-12), which aims to overcome the many limitations of PSA, in particular quantitatively assessing the cumulative impacts of multiple fisheries on data-poor species.

Recently, Juan-Jordá *et al*. (2018) reported on progress by tuna Regional Fisheries Management Organizations (t-RFMOs) towards EBFM by defining a set of criteria to evaluate ecological components supporting EBFM (Table 1). In addition to evaluating the basic texts and structures of each t-RFMO in relation to EBFM, the authors evaluated four ecological components related to: 1) target species, 2) bycatch species, 3) ecosystem properties and trophic relationships, and 4) habitats. They developed a 'report card' and defined six categories of progress by each t-RFMO, differentiating between progress at

the Commission and the Scientific Committee levels, with green representing "full progress has been made by the Commission", yellow indicating "slight progress by the Commission", and red "slight or no progress only by the Scientific Committee" (Table 2).

In this document, we aim to: (1) identify synergies in ecological research shared between the IATTC and other t-RFMOs by comparing IATTC's ecosystem-reporting progress to that of other t-RFMOs, following the work by Juan-Jordá *et al*. (2018); (2) identify areas needing improvement to create cutting-edge reporting of ecosystem considerations at the IATTC; and (3) describe recent improvements in IATTC's ecosystem research. We first reviewed the strategic ecological goals identified in the SSP—to be executed by the Ecosystem Group, under the Biology and Ecosystem Program—and provide an update on the progress of each project in relation to ecosystem reporting. We then reviewed the ecosystem report card of Juan-Jordá *et al*. (2018) and summarized IATTC's progress towards EBFM, using their criteria. We conclude by highlighting potential areas of ecological research for the IATTC to consider for inclusion in future iterations of the *Ecosystem Considerations* report.

2. ECOSYSTEM-RELATED GOALS AND PROJECTS IN THE PROPOSED STRATEGIC SCIENCE PLAN

Goal A: Database maintenance, preservation, and access

Project A.3.b. Develop databases of biological and fisheries parameters to support Ecological Risk Assessment and ecosystem models.

Progress: A life-history database is in development for all species reported to have interacted with the purse-seine and large-scale industrial longline fisheries, an essential step in parameterizing ERAs and ecosystem models used to assess the vulnerability of bycatch species and ecological interactions among species, respectively.

Goal L: Evaluate the ecological impacts of tuna fisheries

Project L.1.a Develop habitat models for bycatch species caught in the EPO to support Ecological Risk Assessments (ERAs).

Progress: Several habitat models using the Relative Environmental Suitability (RES) approach have been produced for input in the EASI-Fish ERA model, including those for the target tunas, billfishes, epipelagic and mesopelagic fishes, elasmobranchs, turtles and dolphins. Habitat models are in development for additional species to eventually assess every species impacted by EPO tuna fisheries, using the EASI-Fish model.

Project L.1.b Develop a flexible spatially-explicit ERA approach for quantifying the cumulative impact of tuna fisheries on data-limited bycatch species in the EPO.

Progress: The initial phase of the EASI-Fish model was developed in 2018 to address this goal (SAC-09-12), and development is ongoing, to include additional species impacted by the various fisheries. This is a critical project for prioritizing species-specific research for those identified as 'most vulnerable' relative to a suite of conventional biological reference points.

Project L.2.a Develop and update Productivity-Susceptibility Analyses (PSAs) of tuna fisheries in the EPO

Progress: A preliminary PSA of the large-vessel purse-seine fishery (size class 6, > 363 t carrying capacity) (SAC-06-09) was refined, and a manuscript is in review at the peer-reviewed journal, *Fisheries Research*. A preliminary PSA of the large-scale industrial longline fishery was also presented in SAC-08-07d. EASI-Fish assessments are planned to eventually supersede PSAs to identify and prioritize the most vulnerable species for consideration by the Commission.

Goal N: Improve our understanding of the interactions among environmental drivers, climate, and fisheries

Project N.1.a Analyze EPO bycatch data to assess the influence of environmental drivers on catches and vulnerability.

Progress: Work is in progress to evaluate life history parameters of sharks—as reported in scientific peer-reviewed literature—and the delay in catch peaks relative to tuna species in the south EPO following extreme El Niño events. Additionally, environmental indices are now included in the *Ecosystem Considerations* report (SAC-10-14).

Goal O: Improve our understanding of the EPO ecosystem

Proposal O.1.a Develop a fishery-dependent ecological sampling program for EPO tuna fisheries

Progress: A proposal was submitted at the ninth meeting of the Scientific Advisory Committee (SAC-09) in 2018 but was not funded. The proposal will be resubmitted at SAC-10 in 2019 to begin sampling in 2020, if funded.

Project O.2.a Develop and implement analytical tools for understanding the trophic ecology of apex predators.

Progress: Although external collaborators have not provided data to fulfill tasks related to this project, improvements have been made to a statistical tool developed in collaboration with scientists at CSIRO (Australia) to analyze complex diet data, which is used to represent trophic interactions in ecosystem models.

3. REPORT CARD SYSTEM FOR ASSESSING EBFM

We present two tables from Juan-Jordá *et al*. (2018) below and compare IATTC's progress towards EBFM for each element in 3 of their 4 ecological components with those of the other t-RFMOs: the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), the Western and Central Pacific Fisheries Commission (WCPFC), and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Table 1 describes their criteria used to define and evaluate "the current state of EBFM implementation in t-RFMOs", and Table 2 shows the "state of EBFM implementation in t-RFMOs across 20 elements that would potentially make EBFM more operational" (Juan-Jordá *et al.* 2018). It is important to note that Juan-Jordá *et al*. (2018) ended their evaluation period in 2015, and the additional progress made by the IATTC and other t-RFMOs since then is not included.

Here, we focus only on their ecological components 2 through 4, because the Ecosystem Group is responsible for conducting research related to the effects of fisheries on the ecosystem. We assess elements under these ecological components to identify: 1) research synergies among t-RFMOs, 2) areas where the IATTC excels, and 3) areas where the IATTC needs to improve to progress EBFM. We excluded the elements listed under ecological component 1, because they refer to the target tunas, and work on these elements—including stock assessments, stock status indicators, and reference points—are extensively covered in the reports produced by the Stock Assessment Program that can be found elsewhere (*e.g.,* IATTC Stock Assessment Reports). In addition, elements under this component are expected to score highly since the IATTC and other t-RFMOs were created to manage tuna and tuna-like species, as pointed out by Juan-Jordá *et al*. (2018).

3.1. Synergies with IATTC and other t-RFMOs in progressing EBFM

Ecological component 2—bycatch species: IATTC, like all the other t-RFMOs, scored moderately. On the positive side, all t-RFMOs, with the exception of CCSBT, showed moderate progress in the development of indicators for billfishes, meaning that the stock status of billfishes has been assessed and stocks are being monitored. Conversely, no t-RFMO had made meaningful progress, if any, in providing indicators of stock status for sea turtles, nor reference points for sea turtles or seabirds.

Ecological component 3—ecosystem properties and trophic relationships: According to Juan-Jordá *et al*. (2018), by the end of 2015 IATTC had not progressed in defining or developing ecosystem and/or multispecies management plans relevant to reference points, or in initiating management responses from results of ecosystem models (but see section 4 for recent improvements).

Ecological component 4—habitats: This is another area in which t-RFMOs appeared to fall short, based on the Juan-Jordá *et al*. (2018) evaluation criteria. For example, at the time of Juan-Jordá *et al*.'s (2018) evaluation period, no t-RFMO had identified and adopted minimum habitat needs for relevant species with habitats of special concern, nor evaluated habitats of special concern in the decision-making process. This is understandable however, since the fisheries managed by t-RMFOs generally operate in offshore waters where the fishing gears have minimal, if any, contact with physical habitats, such as the seafloor. However, it is important to consider the fate of lost gear that may impact demersal habitats and continue to impact marine life via 'ghost fishing'. One such example of concern is the impact of fish-aggregating devices (FADs) on habitats, discussed in section 4 below.

3.2. Elements in which the IATTC is surpassing other t-RFMOs

Ecological component 2—bycatch species: IATTC scored highest primarily because 1) conceptual and operational objectives for bycatch species are formally stated in the Antigua Convention, 2) stock status indicators for billfishes have been developed, 3) reference points for dolphins have been defined under the Agreement on the International Dolphin Conservation Program (AIDCP), and 4) the AIDCP established management measures for dolphins, whereby a management response is initiated if dolphin mortality limits are reached.

Ecological component 3—ecosystem properties and trophic relationships: IATTC and WCPFC were reported to have made moderate progress in this component. The highest scores were found under the objectives element because the both Conventions explicitly acknowledge the importance of broader ecosystem impacts resulting from fishing activities. Both t-RFMOs have developed ecosystem and food web models.

IATTC has included ecosystem metrics (*e.g.* trophic level of the catch) in the *Ecosystem Considerations* report (*e.g.* SAC-09-11) to describe changes in the community over time, and has focused on diet studies (*e.g.* Olson and Galván-Magaña 2002, Olson *et al.* 2014, Duffy *et al.* 2015, Duffy *et al.* 2017) and food-web models (Olson and Watters 2003) as a means of describing trophic interactions.

3.3. Elements needing improvement

Ecological component 2—bycatch species: Many of the elements under this component showed deficiencies in reporting for nearly all the t-RFMOs at the time of evaluation, using the criteria of Juan-Jordá *et al*. (2018). IATTC fell short on assessing and providing indicators and reference points for bycatch species, including seabirds, sea turtles and other finfishes, due to inadequacies in data reporting (see SAC-08-07b), while ICCAT and WCPFC had provided indicators for sharks, and IOTC for other finfishes. IATTC still does not provide indicators for the majority of bycatch species, with the exception of silky sharks, which have been monitored using purse-seine indicators and presented to the SAC since 2014 (SAC-05-11a). However, the new EASI-Fish model (SAC-09-12, **Project L.1.b**) may address this deficiency by using traditional biological reference points for bycatch species, except seabirds.

Ecological component 3—ecosystem properties and trophic relationships: As stated above, and was true for the other t-RFMOs, IATTC was reported to be deficient in producing reference points or measures related to ecosystem and/or multispecies management plans and using ecosystem models to guide management advice.

Ecological component 4—habitats: This component was identified as the most deficient for IATTC and consequently, IATTC scored low—along with IOTC and CCSBT—indicating that little progress had been made. ICCAT and WCPFC had moderate scores because management measures have been adopted that acknowledge the importance of habitat (*e.g.* shark pupping grounds, tuna spawning grounds, and specific provisions related to habitats of special concern). However, Juan-Jordá *et al*. (2018) note that no t-RFMO

had specifically identified habitats of special concern or, with the exception of ICCAT, adopted measures to conduct habitat research, nor had such habitat research yet been considered in management decisions at the Commission level.

Substantial progress by the IATTC has been made under these components, and is discussed in the next section.

4. IATTC'S RECENT EFFORTS TO IMPROVE ECOSYSTEM-RELATED RESEARCH

Ecological component 2—bycatch species: The AIDCP On-Board Observer Program covers all trips[1] by large[2] purse-seine vessels. A comprehensive observer database has been developed, which encompasses detailed catch information for a wide range of taxa. These data have enabled the Stock Assessment Group to provide purse-seine indicators for silky sharks (SAC-10-17) to the SAC on an annual basis since 2014 (SAC-05-11a), although the methods developed to compute trends for silky sharks date back to 2007 (Minami *et al.* 2007).

Reliable estimates of catches of non-target species caught in the large-scale industrial longline fishery have not been available due to a low level of observer coverage and insufficient taxonomic resolution of reported catch data. However, in 2017—pursuant to paragraph 7 of Resolution C-11-08—the SAC adopted a requirement for Members and Cooperating Non-Members (CPCs) to supply operational-level observer data (SAC-08-RPT, item 14 page 34), which may, in future, allow improved estimation of catches and standardization of CPUE for these species.

Additionally, progress is being made on better understanding the artisanal fishing sector in Central America (**Project C.4.a**) with research efforts underway to quantify the effects of these fleets, particularly on the catches of sharks (Aires-da-Silva *et al.* 2016, Siu and Aires-da-Silva 2016). In future, the IATTC staff will be able to more reliably assess the status of such stocks.

Regarding ERAs to assess the vulnerability of bycatch species, PSAs have been developed for t-RFMOs (Cortés *et al.* 2010, Arrizabalaba *et al.* 2011, Nel *et al.* 2013, Griffiths *et al.* 2017, Lucena Frédou *et al.* 2017a, Lucena Frédou *et al.* 2017b, Murua *et al.* 2018), but they do not provide quantitative estimates of population status, do not use biologically meaningful reference points, and do not account for cumulative impacts on species by multiple fisheries. However, IATTC's EASI-Fish model (SAC-09-12) was developed to evaluate the cumulative impacts of fisheries on data-limited bycatch species (**Project L.1.b**). Traditional biological reference points (*e.g.* F_{MSY}, $F_{0.1}$, $SSB_{40\%}$) and associated uncertainties are estimated within the model. The vulnerability status of each species is presented on a phase plot, like the Kobe plot used to convey the status of target species from stock assessments. For example, species located in the green and red quadrants of the plot are considered 'least vulnerable' and 'most vulnerable', respectively, to becoming unsustainable under current fishing effort regimes. This information can be transparently translated into scientific advice to the Commission for use in decision-making. For example, the Commission could mitigate a key risk by implementing a specific conservation and management measure, or prioritize species-specific research for the most vulnerable species, with the aim of obtaining more reliable data for a traditional stock assessment to more reliably assess stock status in future.

Ecological component 3—ecosystem properties and trophic relationships: Ecological indicators such as mean trophic level of the catch (TL_c) have been previously reported in the IATTC *Ecosystem Considerations* report. Since 2018, the ecological modeling software *Ecopath with Ecosim* (EwE) was used to estimate TL_c, the Marine Trophic Index (MTI), the Fishing in Balance index (FIB), Kempton's Q diversity index, and three

[1] 50% of trips are covered by the IATTC observer program, the other 50% by national observer programs; together they constitute the AIDCP On-Board Observer Program

[2] Carrying capacity > 363 t; IATTC capacity class 6

indicators that describe the mean trophic level of three components or 'communities' (TL 2.0-3.5, 3.5-4.0, and >4.0), after fisheries have extracted biomass as catches (SAC-09-11). At SAC-10, an updated ecosystem model of the ETP will be presented, with an analysis of ecological indicators and the potential impacts of FAD fishing on ecosystem dynamics (SAC-10-15).

Studies of trophic relationships have been a primary focus of the Ecosystem Group, and the staff plans to continue such studies, as defined by Project O.1 in the SSP: *Conduct trophodynamic studies for defining key assumptions in EPO ecosystem models*. The IATTC has an extensive 'diet' database of over 60 predator species covering the periods 1992–1994 and 2003–2005. A new project on analyzing skipjack tuna diets (SAC-10-01, Project O.1b) is underway to identify linkages between oceanography, ontogeny, and skipjack feeding ecology, which will contribute to improving diet matrices in ecosystem models of the EPO.

A review of methods for estimating prey consumption rates, gastric evacuation, and daily ration has recently been completed as a precursor to developing a proposal to experimentally estimate these parameters, specifically the consumption/biomass ratio (Q/B), for a range of predators that represent different trophic levels in the EPO, which will improve the reliability of parameter inputs for future models planned to be developed for the EPO (SAC-10 INF-E).

The Stock Assessment Group has also made progress on the ecosystem properties component of the development of multispecies management plans relevant to reference points. For example, the IATTC harvest control rule (HCR) for tropical tunas—outlined in Resolution C-16-02, adopted in 2016—is a multispecies HCR. The duration of the fishery closure has previously been determined by the tuna species (*i.e.*, yellowfin or bigeye) with the lowest *F* multiplier (*e.g.* IATTC-93-04). Fishing then ceases for a predetermined length of time, which is also a reprieve for all species impacted by the tropical tuna fishery, including non-tuna species caught as bycatch.

These are all positive steps by IATTC towards EBFM, given that these ecosystem-based reference points have not been well defined.

Ecological component 4—habitats: In general, regarding specific provisions related to habitats of special concern, the IATTC has since 2009 implemented a 30-day closure of an area known as the "*corralito*" (*e.g.* Resolution C-09-01) aimed at reducing the catches of small bigeye tuna, but is now recognized to have a concomitant effect on small yellowfin and skipjack tunas.

The IATTC Ecosystem Group has made progress on habitat research by means of habitat suitability maps **(Project L.1.a**). These maps are a critical component of the EASI-Fish model (**Project L.1.b**), as the 'volumetric overlap' of fisheries and the areal distribution of a species are used to estimate the instantaneous fishing mortality rate (*F*) (SAC-09-12). In EASI-Fish, relative environmental suitability (RES) models (Kaschner *et al.* 2006) are created based on presence-only data and environmental data (*e.g.* depth, sea surface temperature, salinity, primary productivity, and distance to land) to estimate the total number of grid cells occupied by a species, a component in the calculation of a species' susceptibility to fisheries impacts (SAC-09-12).

Additionally, the IATTC's SSP recognizes other goals with projects for the Biology and Bycatch Groups related to habitat (IATTC-93-06b). For example, **Project E.3.a** will investigate geographic variation in the movements, behavior, and habitat utilization of yellowfin tuna in the EPO; **Project F.2.a** aims to investigate the movements, behavior, and habitat utilization of silky sharks in the EPO; **Project M.1a** evaluates the effect of the depth of non-entangling FADs on catches of tunas and bycatches of other species in the purse-seine fishery; and **Project M2.b** evaluates best handling practices for maximizing post-release survival of silky sharks in longline fisheries, and identification of silky shark pupping areas for bycatch mitigation. In collaboration with the industry, experiments will be conducted to develop best practices for mitigating the impacts of fishing on habitats in the EPO under **Project M.5.a**, to develop and test non-

entangling biodegradeable FADs, while **Project M.5.b** aims to reduce losses, and foster recovery, of FADs in the purse-seine fishery in the EPO.

Regarding sharks (**Project C.4.a**), research efforts on artisanal fisheries in Central America (Aires-da-Silva *et al.* 2016, Siu and Aires-da-Silva 2016) will continue to provide insight into habitats, potentially contributing to improving conservation measures on habitats of special concern, for example, nursery areas.

The *Ecosystem Considerations* report (SAC-10-14) includes a section titled "Physical Environment" which now includes broad-scale changes in sea surface temperature anomalies and chlorophyll-a concentration to provide general descriptions of habitat.

In concert, these efforts will greatly improve our understanding of habitat-related concerns from the effects of fishing in the EPO, which may contribute to advice for the development of conservation and management measures.

5. FUTURE WORK AND SUGGESTED IMPROVEMENTS TO THE *ECOSYSTEM CONSIDERATIONS* REPORT

It's important to note that the only area with the highest score "Full progress by the Commission (best case t-RFMO)" for ecological components 2 through 4 (IATTC and WCPFC) was the "objectives" element under ecological component 2—bycatch species (Table 2). Specifically, "conceptual and operational objectives have been formally stated relevant to bycatch species" (Table 1), while most of the remaining elements received yellow or red categories ("slight progress by the Commission" and "slight or no progress only by the Scientific Committee", respectively).

A major shortcoming in implementing EBFM is that much of the ecosystem-related research does not generate benchmark values that can be compared with reference points, which are also currently lacking for ecosystems. Therefore, it is difficult to translate ecosystem work into meaningful management responses. However, the EASI-Fish model (**Project L.1.b**) represents a significant improvement, as it addresses this issue by quantitatively estimating traditionally-used reference points for data-limited species, thus more reliably estimating vulnerability and assisting managers in prioritizing species-specific research. Organizations including the US National Marine Fisheries Service (NMFS), IOTC, and ICCAT have already expressed interest in EASI-Fish, suggesting it has the potential to be a particularly useful model for assessing data-limited species.

For the staff to create cutting-edge reporting of ecosystem research that can be communicated to the Commission for consideration in the decision-making process, we recommend the following improvements for the Ecosystem Group:

- Further develop the EASI-Fish model to include all species impacted by EPO tuna fisheries and identify the most vulnerable species
- Periodically update bycatch assessments using EASI-Fish to assess species' vulnerability to account for potential spatial changes in fishing effort patterns by gear type
- Develop an ecological sampling program to collect new data for updating diet matrices in potential spatially-explicit ecosystem models of the EPO
- As new data become available, reconstruct an ecosystem model of the EPO to enable a wider range of conservation and management scenarios to be simulated, which will satisfy the interests of the Commission, its CPCs, and other stakeholders (*e.g.* NGOs)
- Report on ecological indicators to monitor changes in the EPO ecosystem on an annual basis
- Include maps of the relative suitability models of a species' estimated distribution relative to presence data and environmental data from the EASI-Fish model to provide insight into its distribution and its overlap with the fishery, which may also potentially identify hotspots for

particular species.

- Routine reporting of catches of non-tuna and non-billfish species, as in the current *Ecosystem Considerations*

The IATTC staff will continue to strive to provide the best available information of the effects of the fishery on the ecosystem, to communicate its research to the Scientific Advisory Committee, and to provide advice for consideration by the Commission.

6. ACKNOWLEDGEMENTS

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TABLE 1 (after Figure 4 in Juan-Jordá *et al*. (2018)). "Summary of the criteria used for assessing the current state of EBFM implementation in t-RFMOs. Online supporting information provides the full criteria used (Table S1)."

EVALUATION FIELD 1: **REVIEW OF BASIC TEXTS AND MAIN STRUCTURES OF tRFMOs IN SUPPORT OF EBFM**
Element 1: Does the tRFMO refer to the principles of the precautionary approach and EBFM in accordance with relevant rules of international fisheries governance? **Element 2:** Has the tRFMO designated a lead entity to advance the progress and implementation of EBFM, advance progress on ecosystem science and provide advice on impacts of fishing on marine ecosystems? **Element 3:** Has the tRFMO developed and adopted an operational EBFM plan?
Element 4: Does it exist a long-term data collection and monitoring program to support the implementation of EBFM? Does a database of high quality exist and is accessible to allow for EBFM analyses?
EVALUATION FIELD 2: **REVIEW OF MAIN ECOLOGICAL COMPONENTS IN SUPPORT OF EBFM**
Ecological component 1 – Target species *Relevant to objectives:* **Element 5:** Have conceptual and operational objectives been formally stated relevant to target species? *Relevant to indicators*: **Element 6:** Have target species been assessed with full stock assessments, and have indicators of stock status been developed (associated to pre-established objectives) and are being monitored? *Relevant to reference points* **Element 7:** Have reference points, including target and limit reference points, been defined, developed and linked to pre-established objectives and indicators? *Relevant to management responses and measures:* **Element 8:** Have management responses including harvest control rules or conservation and management measures been put in place and linked to pre-established management objectives, indicators and reference points?
Ecological component 2 – Bycatch species *Relevant to objectives:* **Element 9:** Have conceptual and operational objectives been formally stated relevant to bycatch species? *Relevant to indicators*: **Element 10:** Have bycatch species been assessed, and have indicators of stock status been developed (associated to pre-established objectives) and are being monitored? *Relevant to reference points* **Element 11:** Have reference points, including target and limit reference points, been defined, developed and linked to pre-established objectives and indicators relevant to bycatch species? *Relevant to management responses and measures:* **Element 12:** Have management responses and management measures been put in place and linked to pre-established management objectives, indicators and reference points relevant to bycatch species?
Ecological component 3 – Ecosystem properties and trophic relationships *Relevant to objectives:* **Element 13:** Have conceptual and operational objectives been formally stated relevant to ecosystem properties and trophic relationships? *Relevant to indicators*: **Element 14:** Have food web models with interactions of relevant species and components of the ecosystem been developed, and multispecies and ecosystem level indicators been developed (associated to pre-established objectives) and are being monitored? *Relevant to reference points* **Element 15:** Have ecosystem and/or multispecies management plans (including harvest strategies) been developed with pre-defined reference points and are being used for management advice? *Relevant to management responses and measures:* **Element 16:** Have ecosystem and/or food web models and multispecies management plans been developed and their use evaluated in decision-making and incorporated in management measures to ensure pre-established objectives are met?
Ecological component 4 – Habitats *Relevant to objectives:* **Element 17:** Have conceptual and operational objectives been formally stated relevant to habitats of special concern? *Relevant to indicators*: **Element 18:** Have habitat of special concern and/or habitat utilization and preferences been investigated, and habitat indicators been developed (associated to pre-established objectives) and are being monitored? *Relevant to reference points* **Element 19:** Have minimum habitat needs and requirements (linked to pre-established indicators and objectives) been identified and adopted for relevant species with habitats of special concern? **Element 20:** Have habitats of special concern and/or habitat utilization and preferences of relevant species been delineated and their use evaluated in decision-making to ensure pre-established objectives are met?

TABLE 2. "State of EBFM implementation in tRFMOs across 20 elements that would potentially make EBFM more operational. Several matters differentiate CCSBT from the rest of the t-RFMOs which made challenging to review its bycatch component against our criteria (further discussed in the main text)." (Figure 5 in Juan-Jordá *et al*. (2018))

PROGRESS CATEGORIES	
Full progress by the Commission (best case tRFMO)	FP - by C
Moderate progress by the Commission	MP - by C
Slight progress by the Commission	SP - by C
Full progress only by the Scientific Committee	FP - only by SC
Moderate progress only by the Scientific Committee	MP - only by SC
Slight or no progress only by the Scientific Committee	SP or NP - only by SC

REVIEW OF MAIN TEXTS AND BASIC STRUCTURES OF tRFMOs IN SUPPORT of EBFM					
Elements	**ICCAT**	**IOTC**	**WCPFC**	**IATTC**	**CCSBT**
1. Reference to EBFM					
2. Lead entity exists to advance progress of EBFM and ecosystem science					
3. EBFM plan exists					
4. Data collection programme exists to support the implementation of EBFM					
REVIEW OF MAIN ECOLOGICAL COMPONENTS IN SUPPORT of EBFM					
Ecological component 1 - Target species					
5. Objectives					
6. Indicators					
7. Reference points					
8. Measures					
Ecological component 2 - Bycatch species					
9. Objectives					
10. Indicators - billfishes					
10. Indicators - sharks					
10. Indicators - seabirds					
10. Indicators - sea turtles					
10. Indicators - marine mammals					
10. Indicators - other finfishes					
11. Reference points - billfishes					
11. Reference points - sharks					
11. Reference points - seabirds					
11. Reference points - sea turtles					
11. Reference points - marine mammals					
11. Reference points - other finfishes					
12. Measure - billfishes					
12. Measures - sharks					
12. Measures - seabirds					
12. Measures - sea turtles					
12. Measures - marine mammals					
12. Measures - other finfishes					
Ecological component 3 - Ecosystem properties and trophic relationships					
13. Objectives					
14. Indicators					
15. Reference points					
16. Measures					
Ecological component 4 - Habitats					
17. Objectives					
18. Indicators					
19. Reference points					
20. Measures					

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