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A TEMPLATE FOR AN INDICATOR-BASED ECOSYSTEM REPORT CARD FOR ICCAT

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SUMMARY

To facilitate the implementation of Ecosystem-Based Fisheries Management in the ICCAT Convention Area, the Sub-Committee on Ecosystems recommended the development of an indicator-based ecosystem report card. The main purpose of the ecosystem report card is to improve the link between ecosystem science and management and increase the awareness, communication and reporting of the state of ICCAT's different ecosystem components to the Commission. Here, we first aim to initiate a discussion and make the case for the need and usefulness of an indicator-based ecosystem report card. Second, we provide a potential template of a ecosystem report card to contribute on the process towards its full development and use. Third, we calculate several ecosystem indicators to test its utility and identify potential challenges and opportunities for their development. We calculated an integrated multispecies B/B_{MSY} *and* F/F_{MSY} *ratio, which we use to monitor the status of ICCAT assessed stocks at several spatial and taxonomic scales. Continuing the development and refinement of the report card with the involvement of a diverse group of experts including scientist, managers and other key stakeholders will be pivotal to improve its utility and relevance to the management of tuna and tuna-like species and associated ecosystems in the Atlantic Ocean.*

RÉSUMÉ

Afin de faciliter la mise en œuvre de la gestion écosystémique des pêcheries dans la zone de la Convention ICCAT, le sous-comité des écosystèmes a recommandé l'élaboration d'une fiche informative sur les écosystèmes basée sur des indicateurs. La fiche informative sur les écosystèmes vise principalement à améliorer le lien entre la science des écosystèmes et la gestion et à accroître la sensibilisation, la communication et la transmission à la Commission de l'état des différentes composantes écosystémiques. Ici, nous voulons tout d'abord entamer une discussion et établir le bien-fondé de la nécessité et de l'utilité d'une fiche informative sur les écosystèmes basée sur des indicateurs. Deuxièmement, nous fournissons un modèle possible de fiche informative sur les écosystèmes afin de contribuer au processus menant à son plein développement et utilisation. Troisièmement, nous calculons plusieurs indicateurs écosystémiques afin d'en tester l'utilité et d'identifier les opportunités et défis potentiels pour leur développement. Nous avons calculé un ratio B/B_{PME} *et* F/F_{PME} *plurispécifique intégré qui nous permet de surveiller l'état des stocks évalués par l'ICCAT à plusieurs échelles spatiales et taxonomiques. Poursuivre le développement et l'affinement de la fiche informative avec la participation de divers groupes d'experts, y compris des scientifiques, des gestionnaires et d'autres parties prenantes clefs sera déterminant pour améliorer son utilité et sa pertinence pour la gestion des thonidés et des espèces apparentées ainsi que des écosystèmes associés dans l'océan Atlantique.*

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RESUMEN

Para facilitar la implementación de la ordenación basada en el ecosistema en la zona del Convenio de ICCAT, el Subcomité de ecosistemas recomendó el desarrollo de una ficha informativa de un indicador basado en el ecosistema. La finalidad principal de esta ficha informativa sobre ecosistemas es mejorar el vínculo entre la ciencia ecosistémica y la ordenación e incrementar la concienciación, comunicación e información sobre el estado de los diferentes componentes de l ecosistema de ICCAT a la Comisión. Aquí, nuestro primer objetivo es iniciar un debate y justificar la necesidad y utilidad de una tarjeta informativa de un indicador basado en el ecosistema. En segundo lugar, proporcionamos un posible modelo para una tarjeta informativa sobre el ecosistema para contribuir al proceso que conduzca a su desarrollo y utilización plenos. En tercer lugar, hemos calculado varios indicadores ecosistémicos para probar su utilidad e identificar retos y oportunidades potenciales para su desarrollo. Se calculó una ratio B/B_{RMS} *y* F/F_{RMS} *integrada para múltiples especies, que se utilizó para hacer un seguimiento del estado de los stocks de ICCAT evaluados en varias escalas espaciales y taxonómicas. Proseguir con el desarrollo y perfilamiento de la tarjeta informativa con la participación de un grupo de expertos diverso que incluya científicos, gestores y otras partes interesadas clave será fundamental para mejorar su utilidad y relevancia para la ordenación de los túnidos y especies afines, y de los ecosistemas asociados en el océano Atlántico.*

KEYWORDS

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

Introduction

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

Although ICCAT does not make reference to EBFM in its Convention Agreement, in 2015 the Commission adopted Resolution 15-11 concerning the application of an ecosystem approach to fisheries management. Resolution 15-11 requests the Commission to consider the interdependence of managed stocks and species or dependent species belonging to the same ecosystem, consider the impacts of fishing and environmental factors on target stocks, not-target species and the associated ecosystem, and minimize impacts of fishing on the ecosystem. ICCAT also adopted the 2015-2020 SCRS Science Strategic Plan, which contains as a research and management priority to advance ecosystem based fisheries management advice, and proposes several actions and measurable targets to facilitate its implementation. Some of these strategic actions include the development of ecosystem plans, ecosystem status reports or integrated ecosystem assessment, among other approaches, to enhance EBFM within ICCAT. Following the SCRS Strategic Science Plan, the Sub-Committee on Ecosystems (SUB-ECO) have also designed a long term research plan and has launched a list of short term and long term ecosystem activities that would be completed in the coming years to assess the feasibility and provide advice towards implementing EBFM within ICCAT. Among those research activities, the SUB-ECO agreed to develop an indicator-based ecosystem report card to be reviewed by the group in 2017 (ICCAT 2016).

An indicator-based ecosystem report card is one of many tools commonly used to better link ecosystem science with fisheries management and it can have multiple purposes and uses (Zador et al. 2016). Since EBFM started to be implemented around the world, multiple approaches and tools varying in complexity and with different degrees of data requirements have been developed and are being tested to better link ecosystem information into fisheries management, as well as providing ecosystem advice to the managers and policy-makers. An example of a simple approach would be to synthesize ecosystem information into an ecosystem synthesis report (or ecosystem overview report) to provide ecosystem context to inform single-species strategic management advice. These ecosystem reports aim to bring together many ecosystem related research efforts into one document to spur new understanding of the connections between ecosystem components (ICES 2013, Zador 2015). These ecosystem reports are usually accompanied by an indicator-based ecosystem report card which has the objective of summarizing the status of the top indicators, usually selected by a team of ecosystem experts and managers, to represent the ecosystem being monitored and managed. More advance approaches would consist of developing Ecosystem Assessments utilizing a blend of data analysis and modeling to communicate not only the current status of ecosystems but also possible future scenarios that account for the effects of climate change and fishing (Zador 2015, Zador et al. 2016). Using more complex tools such as end-to-end ecosystem and multispecies models can provide more tactical fisheries management advice (Plagányi et al. 2012, Collie et al. 2016, Skern-Mauritzen et al. 2016). These continuum of approaches require the development of a variety of tools ranging from ecosystem synthesis reports to ecosystem risk assessments, indicator-based ecosystem report cards, indicator-based assessments, ecosystem models, management strategy evaluation and the formalization on an ecosystem fishery plan (Garcia and Cochrane 2005, Smith et al. 2007, Fletcher et al. 2010, Link 2010, Fogarty 2014, Zador et al. 2016). These tools vary in complexity, data needs, expertise, and time and resources for their development.

To facilitate the implementation of EBFM, the SUB-ECO recommended in 2016 the development of an indicator-based ecosystem report card with the aim of testing a new approach for linking ecosystem science to fisheries management and increasing the awareness, communication and reporting of the state of the different components of the greater Atlantic Ocean ecosystem (including adjacent seas) to the Commission (ICCAT 2016). Here, we first aim to initiate a discussion and make the case to develop an indicator-based ecosystem report card in the ICCAT Convention Area. Second, we provide a potential template of an indicator-based ecosystem report card which will contribute to the discussion and contribute to the process towards its full development and use. In doing so, we propose a set of broad ecosystem components to be reported and monitored in the ecosystem report card, and provide examples of potential candidate ecosystem indicators to monitor. Third, we calculate several ecosystem indicators to test its utility and identify potential challenges and opportunities for its development. The ecosystem indicators calculated and explored include two common integrated multispecies indicators containing all ICCAT assessed stocks; one the average biomass of stocks relative to the agreed reference level for B_{MSY} (the B/B_{MSY} ratio) and the other, the average fishing mortality of stocks fished relative to the agreed reference levels for fishing mortality (the F/F_{MSY} ratio). Ultimately, we aim to build familiarity with this approach and seek to start a process to lead the way to an adaptive product that will suit the needs of fisheries managers and Commissioners to ensure ecosystem considerations is used in management decisions in the ICCAT Convention Area.

1. Initiating a discussion on the need and usefulness for an ecosystem report card for the ICCAT convention area

An indicator-based ecosystem report card can be viewed as a qualitative ecosystem assessment and it is used to synthesize multiple and complex ecosystem information into a succinct and visual product to communicate the state (trends and status) of several components of the ecosystem, and thus provide ecosystem context and advice to the fisheries managers and policy-makers (Harwell et al. 1999, Connolly et al. 2013).
The ecosystem report cards are usually used to summarize the status of top indicators that best describe the ecosystem and provide ecosystem context for fisheries managers to inform fisheries management decisions (Zador 2015). The ecosystem report card could potentially report on the impacts of ICCAT fisheries not only on the targeted stocks, but also on bycatch species, the broader ecosystem structure and function and habitat of species (See section 3). Similarly, it could report on the effects of natural environmental variation and climate change on the different ecosystem components. The ecosystem report card is considered an effective communication tool designed to distill information into simpler highly visual form that has the potential to educate and engage the fisheries managers, Commissioners and other stakeholders in the process of incorporating ecosystem considerations into fisheries management decisions.

Below we highlight nine main purposes and utilities to make the case for the need and usefulness to develop an indicator-based ecosystem report card in the ICCAT Convention Area:

(1) It synthesizes and summarizes multiple and complex ecosystem information from different sources into smaller and simpler number of grades to characterize the state (trends and status) of the different components of the ecosystem in question;
(2) It increases the visibility and utility of important ecosystem data and research;
(3) It is an opportunity to create a stronger link between the ever-expanding ecosystem research and fisheries management;
(4) It establishes an ecosystem context within which management decisions can take place;
(5) It is an effective communication tool since it synthesizes large and often complex amount of information into a succinct summary product to effectively communicate the state (trends and status) of several ecosystem components to the Commission and other interested stakeholders;
(6) It can be used to identify regions or issues of concern and direct and focus management actions on specific components or regions.
(7) It can be used as a framework for monitoring and communications activities and for providing accountability by measuring the success of a particular management measure.
(8) It has the potential to engage the Commission and other stakeholders in the process of incorporating ecosystem considerations into management decisions.
(9) It is a reminder (realization) of the management objectives contained in the EBFM framework developed by the SUB-ECO and encourages a more holistic and integrated approach on the management of the ICCAT fisheries.

2. A potential template for an indicator-based ecosystem report card

In order to inform the development of the ecosystem report card, we first use the Driver-Pressure-State-Ecosystem services-Response (DPSER) tool to build a conceptual ecological model for the ecosystem where ICCAT fisheries take place. We use this conceptual ecological model to identify major structuring themes and the ecosystem components, which we aim to report on and monitor. Second, we develop an Ecosystem Report Card to monitor and report on the state (trends and current status) of each major ecosystem component based on the conceptual ecological model for the ecosystem in the ICCAT area. Third, we provide examples of potential candidate indicators for each ecosystem components in the ecosystem report card. Fourth, we explore the potential different spatial scales of the report card and discuss the potential utility of defining well-defined ecoregions based on meaningful ecological boundaries to base the report card. To facilitate discussion, we propose some preliminary ecoregions based on some on-going research, which we will use in the following section (section 4) to calculate some of the ecosystem indicators.

2.1. The DPSRI framework as a tool to build a conceptual ecological model for the ecosystem in the ICCAT Convention Area

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

Based on the DPSER conceptual framework, we build a conceptual ecological model for the ecosystem where ICCAT fisheries take place. We identify two major *drivers* and associated *pressures* that may be influencing the *state* of the ecosystem in the ICCAT Convention Area (Figure 1b). The first driver, human population growth and a rising demand for fish protein, places fishing as the most important anthropogenic *pressure* impacting the *state* of fish species and associated ecosystems in the ICCAT Area (Collette et al. 2011). Second, the natural environmental variability in the Atlantic Ocean as well as the emerging climate change (and their associated environmental changes in the ecosystems) are also generating several pressures influencing the *state* of the ecosystem that also need to be accounted for (Bell et al. 2013). Potentially the *state* of the ecosystem could be characterized or described with multiple ecological elements and attributes that would need to be monitored. For practical reasons Regional Fisheries Management Organizations around the world intending to apply an ecosystem approach in managing their main fisheries have categorized the ecological state of their ecosystem into four different operational components that can be assessed and monitored over time. These include monitoring the state of: (1) target species (2) bycatch species, (3) ecosystem properties and trophic interactions and (4) habitats (Lodge et al. 2007). If monitored over time these components taken together would characterize and describe the overall state of tunas and tuna-like species and associated ecosystems in the ICCAT Convention Area. Another major element in the Conceptual Ecological Model of the ICCAT ecosystem is the *response*, which consists of a set of fisheries management responses to account for the impacts of fishing and the influence of environmental variation and climate change in the state of tuna and tuna-like species and associated ecosystem. Ultimately, it is also important to illustrate that a sustainable managed and healthy *state* of the ecosystem can deliver multiple *ecosystem services* including provisioning, regulating, cultural and habitat services.

In our conceptual ecological model, the proposed operational components to monitor the ecological state of ecosystems are in agreement with the ICCAT adopted EBFM framework which also aims to monitor the state of target species, bycatch species, ecosystem properties and trophic relationships and habitats (ICCAT 2014). The conceptual ecological model developed here allows us to go an step further, by linking what are the main drivers and pressures impacting the state of the different components of the ecosystems where ICCAT fisheries operate, and making the connection with potential management responses which should ensure that the state of the ecosystems continues to deliver multiple ecosystem services derived from sustainable ICCAT fisheries and stocks for human society to enjoy.

2.2. A potential template for an indicator-based ecosystem report card

The conceptual ecological model for the ecosystem where ICCAT fisheries take place provides a framework to develop an Ecosystem Report Card to monitor and track each major ecosystem component. Accordingly, we present an ecosystem report card with two major structuring themes (Figure 2a). The first theme devoted to monitor the trends and current status of the relevant *pressures* affecting the state of the ecosystem. A second theme devoted to monitor the trends and current status for the different ecological components describing the *state* of tuna and tuna-like species and associated ecosystems, which include target species, bycatch species, ecosystem-properties and trophic relationships, and habitats. At this state, the proposed template for an ecosystem card focuses mainly on reporting and monitoring the different components and attributes characterizing and describing the main pressures on, and the ecological state of the main ecosystem components where ICCAT fisheries interact. Yet this proposed template should be seen as a living document and treated as a first step to initiate discussions, as this will need to be further refined by a team of ecosystem experts with the involvement of fisheries managers, and therefore adapted to the needs of the managers and decision and policy makers. For example, in the future, if deem relevant, additional structural themes capturing the main management responses, ecosystem services delivered by sustainable stocks and fisheries as well as the socio-economic importance of fisheries in the ICCAT area could be easily added in the report card.

This ecosystem report card would need to be populated with a series of ecosystem indicators in order to monitor trends and characterize the current status of the different ecosystem themes and components in question. Ideally, relevant indicators for each component must be associated to pre-establish operational objectives and thresholds to activate specific management responses to ensure the objectives are met (Figure 2b). Additionally, we also need to decide what and how we want to communicate the trends and current status of each indicator. We might choose first to illustrate what it is the long-term trend of the indicators. Second, we could summarize what it is the most recent trend within a specific time window (e.g. using the last five years of data) and the current status (e.g using also the last five years of data). Third, we also need to visualize the current status of the indicator against a selected reference point(s). Last, it is also important to capture in the report card how confident we are on the indicators (trend and current status) and therefore the level of evidence (or uncertainty) in each indicator should also be illustrated (Figure 2b).

We highlight the importance of producing a succinct highly visual and communicative ecosystem report card. The card should be understandable by multiple audiences with ranging technical abilities and backgrounds. The visual presentation and communication of a complex subject such as the dynamics of marine ecosystems and how they respond to anthropogenic and environmental pressures is challenging. An important lesson learned in other regions of the world where the have been implementing the ecosystem approach for at least one or two decades tell us that this is an important issue to tackle from the very beginning (Zador et al. 2016).

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

2.3. Potential ecosystem indicators to populate the ecosystem-report card

We recommend working with a diverse group of experts on ecosystem indicators and fisheries management to refine the proposed template for the indicator-based ecosystem report card and also to select a short list of indicators to populate the card **(**see recommendation section below**)**. However, in the mean time, we provide examples of potential candidate indicators for each broad structuring theme and ecosystem components of the ecosystem report card (Table 1). In the examples, we highlight how each indicator should be associated to a pre-established operational objective, thresholds and management and conservation measures to ensure that those thresholds are not exceeded. We make a distinction between natural and anthropogenic drivers and pressures. Natural drivers such as environmental variability and the anthropogenic driver of climate change result into unmanageable pressures (at least within the ICCAT context), and the anthropogenic driver such as demand for fish protein result into manageable pressures such as fisheries extractions, which in this case it is under the purview of ICCAT. It is also important that the selected ecosystem indicators have a clear understanding of what they intend to represent in each of the ecosystem components (Link 2010). Sometimes the intent of the indicator may aim to describe the state of the ecosystem without a clear management link; other times it may be directly link to a relevant management response. Therefore, the purpose of each indicator should be early clarified. The ecosystem indicators chosen should also be responsive and reflective of the system-wide impacts of fishing and the environment. There exist criteria to guide the identification of useful ecosystem indicators (Rice and Rochet 2005, Shin et al. 2010, Queirós et al. 2016), which could be used by the ecosystem experts to guide their selection process. Furthermore, indicators can be developed based on empirical data collected by ICCAT or other external sources, or could be based on model-derived data from existing end-to-end ecosystem models. We also advised to identify desired indicators that cannot be currently developed given the current data availability and knowledge but that potentially could be developed in the future.

2.4. Potential area-based assessment units to inform the development of ecosystem report cards

The definition of EBFM specifies that it is place-based, therefore the delineation of spatial management units is a necessary element for the implementation of EBFM (Secretariat of the Convention on Biological Diversity 2005, Link 2010). ICCAT has its own spatial delineations within its Convention Area (Figure 3a) including some statistical areas for data reporting and single stock area delineations. The stock and statistical areas support the organization of information in the ICCAT datasets including Task I catch, Task II size and catch-effort databases as well as derivatives thereof like CATDIS and EFFDIS (catch distribution and effort distribution, respectively). The stock areas can be as large as the North Atlantic (e.g. in the case for the albacore tuna stock *Thunnus alalunga*) and are not shared by every species. Furthermore, the statistical areas for data reporting subdivide the stock areas. The ICCAT databases are available sometimes with some spatial information of where catches and efforts were exerted. For example, higher resolution spatial units are available in the Task II database and its derivatives (e.g. 5x5 or 10x10 grid cells). Despite ICCAT having its of spatial delineation and area-based reporting system, the existing area based data reporting frameworks were not developed with the intent of creating spatial assessment units with meaningful ecological boundaries to inform the development of spatial based ecosystem indicators.

Currently, in ICCAT there has not been an objective analysis of the biogeophysical characteristics of the pelagic ecosystem in the Atlantic Ocean and adjacent seas that could inform the delineation of areas with meaningful ecological boundaries (ecoregions) and that at the same time are practical from the management point of view. Developing an indicator-based ecosystem report card and ecosystem assessments based on delineated ecoregions could serve to highlight potential differences in environmental drivers, differences in the biological attributes and the productivity regions that could explain the differences in species compositions or even fishery production potential across regions (NAFO 2013). Indicator-based report cards based on different ecoregions would also allow monitoring of the ecological state of the different components of the ecosystem on an area basis since the environmental drivers and fisheries impacts on them would be presumably different. This would allow focusing management actions on specific regions and species and would provide a framework for monitoring and measuring success of a particular effort or measures that is spatially based. Based on some preliminary analyses, six ecoregions or ecosystem assessment units within the ICCAT Convention area are proposed (Figure 3b). The delineation of ecoregions was based on an analysis, which examined how the catch composition of tuna and billfishes varied spatially within the ICCAT Convention Area, and how the catch composition varies across a biogeographic classification of the world's surface pelagic waters (Spalding et al. 2012). The original pelagic provinces of the world are a classification, which draws both on known biogeography and on the oceanographic forces, which are major drivers of ecological patterns (Spalding et al. 2012). These ecoregions could be used to guide the development of ecosystem indicators used to monitor the impact of fisheries and the ecological state of different components of the ecosystem within each region. The ecoregions are an interim solution contingent upon further analysis.

Partitioning the pelagic ocean into areas with unique physical and biological attributes makes sense if the reporting is to be reflective of the interaction of the fisheries with these biophysical attributes; however, other considerations should also be taken into account. For example, if the reporting is to reflect the spatial dynamics of fisheries and fleets, jurisdictional boundaries and legal issues, operationalization and application of management measures, then the ecoregions may need to be reconfigured. These considerations open a discussion on what could be considered the ideal vs practical objectives of the reporting, which in the end should have the goal of providing the best ecosystem management advice to the Commission.

3. Testing of several ecosystem indicators to populate the ecosystem report card – an integrated multispecies B/B_{MSY} and F/F_{MSY} ratio

The indicator-based report ecosystem report card would need to be populated with a series of ecosystem indicators in order to monitor the trends and characterize the current status of the different ecosystem components in the ICCAT convention area so that it can provide useful advice on ecosystem status to the Commission.

Two common integrated multispecies indicators containing all the ICCAT assessed stocks are the average biomass of stocks relative to the agreed reference level for B_{MSY} (the B/B_{MSY} ratio) and the average fishing mortality of stocks fished relative to the agreed reference levels for fishing mortality (the F/F_{MSY} ratio). These indicators are used to provide an integrated synthesis of the status and trends in a group of fish stocks. Of the more than 50 stocks under the purview of ICCAT, we calculate the integrated multispecies B/B_{MSY} and F/F_{MSY} ratios using all ICCAT assessed stocks (21 stocks of 12 species of tunas, billfishes and sharks).

3.1. Data and methods

By December 2016, ICCAT has conducted and assessed with full fishery stock assessments a total of 21 stocks (12 species) of tunas, billfishes and sharks (Figure 4, Table 2). We compiled the stock assessment outputs for all these 21 stocks in order to calculate the integrated multispecies indicators. The B/B_{MSY} and F/F_{MSY} ratios were extracted for each ICCAT stock from the most recent single stock assessment (Table 2). The date of the most recent assessment varied between 2009 and 2012 across the 21 stocks (Table 2). In a typically stock assessment, each stock might be assessed using one or multiple assessment models (e.g SS3, ASPIC, BSP) where several runs or scenarios are conducted to test different biological and structural assumptions of the models. At the end, the Scientific Committee on Research and Statistics (SCRS) may adopt and use one single run, or if deemed necessary several runs (that can be produced by different models), to provide management advice for each stock to the Commission (Figure 4, Table 2). Therefore, the hierarchical nature of the data consisting of multi-runs and models for one stock needs to be accounted when estimating the integrated indicators.

Each stock is assessed for different historical fishing periods and the most recent assessment year also varies by stock (Figure 5). Therefore, there is only a relatively short period of overlap for which it would be possible to provide an indicator that includes all the assessed stocks. If we restrict the number of stocks included in the indicator calculations, a longer (but less representative) indicator may be built. We explored different calculations to maximize the number of years to be included in the final integrated B/B_{MSY} and F/F_{MSY} ratios. Therefore, we consider three potential indicators: (1) an indicator with all the current assessed stocks including only those years for which all stocks were assessed; (2) an indicator based on a subset of stocks, including 60% of the stocks with the longest time series, to increase the number of years included while making it sufficiently representative; (3) an indicator based on extrapolation values to maximize the number of years included. The time series of each ratio were extrapolated backward to 1950 using the mean of the first three years of data, and extrapolated forward to 2015 using the mean of the last three years of data.

We used a mixed linear model or hierarchical linear model to estimate the integrated B/B_{MSY} and F/F_{MSY} ratio in order to account for the hierarchical structure of the data (multiple runs or scenarios for a given stock). In our models, the dependable variable was either B/B_{MSY} or F/F_{MSY} and our objective to estimate a yearly average of B/B_{MSY} or F/F_{MSY} across all stocks while accounting for the hierarchical nature of the data (consisting of multi-runs and models for one stock). Therefore, the fixed part of the models consisted of the variable year, since we are interested in estimating the average B/B_{MSY} or F/F_{MSY} for each year across all the stocks (and runs), while the random part of the model consisted of accounting that there might be several runs and models within each stock. At the end, despite the number of runs available for each stock, all the stocks are weighted equally towards estimating the overall annual B/B_{MSY} and F/F_{MSY} ratios. We fitted the models using the library "nlme" in the R statistical software (Pinheiro and Bates 2000, Pinheiro et al. 2007).

We calculated several versions of the integrated indicators by aggregating the data at different taxonomic and spatial scales. First, we estimated the overall annual B/B_{MSY} and F/F_{MSY} ratios across all the 21 stocks from 1950 to 2015. Second, we estimated the overall annual B/B_{MSY} and F/F_{MSY} ratios for each major taxonomic group (tunas, billfishes and sharks) separately. Third, we estimated the overall annual B/B_{MSY} and F/F_{MSY} ratios for each proposed ecoregion (Figure 3). Some stocks might be distributed across several of the ecoregions, yet they might be more dominant in one region over the others, therefore, we calculated the specificity of each stock within each ecoregion and weighted the B/B_{MSY} and F/F_{MSY} ratios of each ecoregion by the specificity of each species. Therefore, the area-based B/B_{MSY} and F/F_{MSY} ratios represent the most dominant or representative stocks for each ecoregion. The specificity of each stock (i) and region (j) ($S_{i,j}$) is calculated as the ratio of the mean abundance of stock i in each ecoregion ($N_{i,j}$) to the sum of the mean abundances of stock (i) across all the ecoregions (N_i); therefore $S_{i,j} = N_{i,j}/ N_i$. Since absolute abundance estimates was not available for all the 22 assessed stocks, we used instead catch data and specifically the average catch data of each stock between 2005 and 2015 available in the ICCAT CATDIS database. The CATDIS database is basically an estimate of the Task1 data nominal catches for the nine major tuna and billfish species and stocks, stratified in time (trimester) and space (5x5 degree squares). Therefore, this database does not include the shark assessed stocks, which were not included in the area-based B/B_{MSY} and F/F_{MSY} ratios

3.2. Results - diagnosing the state on the fished and assessed part of the ecosystem

Trends in the biomass ratio, reflecting the overall mean biomass of the assessed stocks relative to B_{MSY}, exhibits a continuous decreasing trend from the 1950s to the beginning of 2000s, followed by stabilization around B_{MSY} levels during around 6 years, and a final a overall increase in biomass to the year 2015 (Figure 6a). The fishing mortality ratio, reflecting mean fishing pressure on the assessed stocks relative to F_{MSY}, exhibits an increasing trend from the 1950s to the year 1998 with an intermediate pick in fishing mortality above F_{MSY} in the year 1964. Fishing mortality reaches the highest values and was above F_{MSY} between the years 1990 and 2006, then, it shows a clear decreasing trend over the last 9 years (Figure 6a). Results appear largely consistent for all the time series with different lengths and number of stocks included (Figure 6a and b). The three types of integrated ratios (shorter time series with all assessed stocks, longer time series with a smaller subset of assessed stocks, longer time series with all assessed stocks with extrapolated data) showed consistent results, with the exception of a differing trend at beginning and ending years of the series. This was expected since the indicator including a smaller subset of stocks will be dependent on the subset and number of stocks included.

When the biomass ratios were aggregated by taxonomic group, we observed a similar overall trends for tunas and billfishes, which first exhibited a steep decline in biomass, followed by a stabilization, and then a recovery in the case of tunas (Figure 7a). The overall biomass of billfishes has been below B_{MSY} levels since year 1989, and although there are some signs that the biomass might be recovering, currently it still is below B_{MSY} levels. The overall biomass of tunas was below B_{MSY} between the years 1999 and 2007, followed by a step increase in biomass for eight years. In the case of sharks, the average biomass shows a small steady decreasing trend followed by stabilization and it has always been above B_{MSY} levels. When the fishing mortality ratios were aggregated by taxonomic group, we observed the same overall trends for tunas, billfishes and sharks, an initial continuous increase, followed by a peak and stabilization at the end of the 1990s and beginning of 2000s, and a final decreasing trend (Figure 7a). However, the average fishing mortality differed among the groups. Billfishes have been subject to higher fishing mortalities, followed by sharks and then tunas.

The integrated ratios B/B_{MSY} and F/F_{MSY} within each ecoregion are influenced by the presence of the most dominant stocks with the highest specificity values (Figure 8, Table 3). For example, North Atlantic albacore tuna, Easter and Western bluefin tunas, and North Atlantic Swordfish tuna are the most dominant or influential stocks in the North temperate ecoregion and therefore they are weighted higher in the calculation of the integrated ratios (Figure 8). The ecoregion-based integrated biomass ratio shows a continuous decrease in biomass up to the end of the 1990s across all the ecoregions (Figure 9a). Then, we observe marked differences across trends by ecoregion. While the integrated biomass ratio continues decreasing in the Equatorial region, we observed the biomass increases in the rest of the regions with a steeper increase in the Northern temperate ecoregion. In the case of the integrated fishing mortality ratio, this ratio shows a continuous increase in biomass up to the end of the 1990s in the Northern temperate, Southern subtropical and Southern temperate ecoregions, followed by a decrease in fishing mortality up to 2015 (Figure 9b). The integrated fishing mortality ratio also shows a continuous increase in the Northern temperate region, but it is less steep, stabilizes between the 1960s and 1990s, and then decreases to the lowest observed fishing mortality values. The integrated fishing mortality ratio in the Equatorial region differs markedly from the rest. In the Equatorial region, the integrated fishing mortality shows a continuous increase in fishing mortality from the 1950s until 2015.

3.3. Discussion – challenges encountered and opportunities ahead

The calculation of the integrated ratios B/B_{MSY} and F/F_{MSY} across several spatial and taxonomic scales is an important step in our approach to implement EBFM in the ICCAT region. It provides a useful diagnosis of the state on the fished and assessed part of the ecosystem, using the best available estimates regarding the status of all assessed stocks (Gascuel et al. 2014). Additionally, it provides strong obligation for management intervention since these indicators are linked to established precautionary reference points (Shephard et al. 2014). These aggregated integrated indicators are commonly applied in other fisheries organizations such as ICES and other regions of the world (Gascuel et al. 2014, Shephard et al. 2014).

We encountered several challenges when estimating and interpreting the integrated biomass and fishing mortality indicators. These issues are listed below with some recommendations on solutions:

-The integrated B/B_{MSY} and F/F_{MSY} ratios are based on the compilation of the stock-based B/B_{MSY} and F/F_{MSY} ratios, which is a major output of the fishery stocks assessments conducted in ICCAT. It was challenging and time consuming to compile all these assessment outputs, as well as identifying and extracting the ratios from the output assessment files. In particular, it was time consuming identifying what runs and scenarios were used for management advice for each individual stock. The SUB-ECO recommended in 2016 to implement new mechanisms or to improve current ones within the SCRS to effectively coordinate, integrate and communicate ecosystem-relevant research across the SCRS Working Groups. This initiative might facilitate in the short-term the sharing of the stock assessment data outputs in a standardized format to generate EBFM indicators within the SCRS and help to establish a dedicated repository for this information.

- The estimation of the integrated B/B_{MSY} and F/F_{MSY} ratios across the 21 assessed ICCAT stock was challenging because each stock started to be assessed in different years and then are reassessed commonly within 2-5 year cycles (or even longer) depending on the need and the capacity of the SCRS to conduct the assessments. This process leads to stock-based B/B_{MSY} and F/F_{MSY} ratios which vary in length covering different time periods, resulting in a short period of overlap for which it would be possible to provide an indicator that includes all the assessed stocks. We suggest conducting a sensitivity analysis exploring several methods to maximize the number of stocks included in the integrated ratio in order to facilitate the utility of the indicators and thus yield an informed diagnosis of the state of the fished and assessed part of the ecosystem.

- A limitation of our integrated B/B_{MSY} and F/F_{MSY} ratios is that it only includes all ICCAT assessed stocks for which B/B_{MSY} and F/F_{MSY} estimates were reliably estimated in an assessment process. B/B_{MSY} and F/F_{MSY} ratios were not available for two commercially important stocks, the Mediterranean Albacore stock and Eastern Atlantic skipjack stocks, and therefore they were not included in the integrated ratios. This should be taken into account when interpreting the ratio.

-The ecoregion-based integrated B/B_{MSY} and F/F_{MSY} ratios rely on knowing the specificity of each ICCAT assessed stock in each ecoregion, and this information is not available for every stock. The calculation of the specificity for each stock in each region requires catch information disaggregated spatially within the stock's distribution, and this was not available for the assessed shark stocks. Therefore we could not estimate the specificity of these stocks by ecoregion, resulting in their exclusion from the ecoregion-based integrated ratios. We recommend the SCRS to make further efforts to request this kind of information from CPCs and have the SUB-ECO and the WG on Sharks work to make use of the current catch data while accounting for its limitations until more reliable spatially based catch data is available.

-We would like to highlight that our proposal of ecoregions is preliminary, as well as the specificity of stocks by ecoregions. This should be treated as an interim solution contingent upon further analysis, which has allowed us to develop and test area-based B/B_{MSY} and F/F_{MSY} ratios. Despite the preliminary nature of these analyses, there is an emergent pattern suggesting that different stocks preferentially use and dominate in some regions over the others, which suggest that some ecological indicators should be better for monitoring the pressures and current state on these species. We recommend continuing research to identify potential ecoregions within the ICCAT Convention Area which represent meaningful ecological boundaries that capture the core of a functional ecosystem, but that at the same time are practical from a management point of view.

We see the integrated ratios B/B_{MSY} and F/F_{MSY} as a potential ecosystem indicator to be used by the SCRS to diagnose the state on the fished and assessed part of the ecosystem in the ICCAT Convention area. It is clear than more research on potential complementary ecosystem indicators is still needed. These indicators need to be further developed, tested and routinely monitored as part of an ecosystem-based approach in order provide ecosystem context and inform fisheries management decisions.

4. Connecting ecosystem science to management advice

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

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

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

We propose the following activities and research tasks to be conducted by the SUB ECO to facilitate the development of an indicator-based ecosystem report card:

(1) Preparation of an **Ecosystem Synthesis Report** to provide the context and directions for the development of the ecosystem report card. The aim of an Ecosystem Synthesis Report, sometimes also referred to as Ecosystem Overview Reports or Ecosystem Considerations Reports, is to synthesize and integrate existing research and information about the main physical and ecological components of the ecosystem and their interactions and relevance to ICCAT fisheries. This report could also review what it is known about the direct and indirect impact of the fisheries on the different components of the ecosystems, as well as review known links between the environment and fisheries productivity in the region. The Ecosystem Synthesis Report should provide the context and directions for the development of the ecosystem report card. The SUB-ECO launched in 2016 as an activity to develop this type of report within the SCRS in the medium-term and include it as part of the ICCAT manual in a section on Ecosystems Based Fisheries Management. We further recommend to the SUBECO to develop a detailed plan to identify roles, responsibilities and timelines to further advance this initiative.

(2) Preparation of an **Ecosystem Assessment or Integrative Ecosystem Assessment** to supplement the Ecosystem Report Card as it develops. In order to support the interpretation of the ecosystem report card and to demonstrate the credibility and scientific rigor of its indicators, it should be supplemented by a companion document known as an Ecosystem Assessment or Integrative Ecosystem Assessment. The ecosystem assessment should include all the details about the ecosystem indicators portrayed in the ecosystem report card, and include other additional ecosystem indicators that are deemed necessary to monitor the main pressures and the state of the ecosystem. The in-depth Ecosystem Assessment could include a detailed description of each indicator, including how it was calculated, data sources and data requirements, a description and interpretation of its trends and current state capturing the uncertainty of the indicators, factors causing the observed trends and a final section with its implications and link to fisheries management. This ecosystem assessment will increase the credibility of the report card as well as provide managers with the scientific rigor needed to make management decisions.

(3) Identification and engagement of a **Group of Ecosystem Experts** in the Sub-ECO and SCRS to contribute to the development, refinement and revision of the proposed template of the ecosystem report card (and potential developments on an Ecosystem Synthesis Report and Ecosystem Assessment). The objective here is to contribute to their development in order to define an ecosystem-based reporting framework for ICCAT. We also encourage that the team of ecosystem experts be composed of a group

of diverse stakeholders including both scientists and managers with a diverse scientific, management fishing, and ecosystem background. The potential list of ecosystem indicators to be monitored within ICCAT should be determined following vetted criteria and selected by consensus. We expect all aspects of the process to be influenced by the extent of scientific knowledge, the data, as well the particular expertise of the ecosystem team.

(4) Continuation of a **Formal Dialogue with the Commission** on the implementation of EBFM in ICCAT. A template of the ecosystem report card could be presented to the Commission once developed, so that the Commission can provide inputs and suggestions on the content and design of the report card that could be incorporated in future versions. A frequent dialogue between all interested stakeholders will lead to adaptive products to better suit the needs of fisheries managers to ensure the ecosystem report card and associated integrative ecosystem assessment is used in management decisions. The SUB-ECO already engages with the Commissions through the Working Group on the Dialogue Meeting between Scientists and Managers to establish a discussion on EBFM and increase awareness of the need to account for ecosystem consideration in fisheries management. We recommend that the SUB ECO continue this formal dialogue with the Commission by requesting an agenda item on EBFM in the next Dialogue Meeting between Scientists and Managers.

(5) Investigation of what would be the **Ideal Scale(s) of the Ecosystem Report Card**. A management area could be related to known ecological boundaries but also political and traditional fishing ground boundaries. We recommend the SUB ECO investigate what would be the Ideal Scale(s) to develop a suitable framework that could allow ICCAT to implement EBFM tailored to the needs and characteristics of the organization. The identification and delineation of ecoregions, as well as ecosystem-level management units, with meaningful ecological boundaries, is a key element of any ecosystem approach. An area-based framework would also allow monitoring the pressures and the ecological state of the different components of the ecosystem and focus management action on an area basis since the environmental drivers and species composition and fisheries impacts on them would be presumably different.

(6) Encouragement of the development of the **Human Component (Social, Economic and Cultural)** to fully implement EBFM in ICCAT. The proposed template for the ecosystem report card captures the major ecological components of the ecosystems and their interactions with the environment and fisheries but it does not capture the main socio-economic components of fisheries and ecosystems. We recommend that the SUB ECO explore opportunities to link the Human Component (Social, Economic and Cultural) to the ecosystem report card and other ecosystem-related initiatives.

(7) **Coordination of the content and objectives** of the Ecosystem Overview, Ecosystem Report Card and Ecosystem Assessment documents to ensure that they are all internally consistent with the management objectives for the components and elements contained within the EBFM framework.

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

DRIVERS/PRESSURES				
	Operational objectives	**State indicators**	**Thresholds**	**Management response**
Environment & climate change	Monitor average sea surface temperature	Average sea surface temperature over time	-not applicable	Pressure unmanageable by the ICCAT
Fishing	Landings do not exceed global fishery yields of the ICCAT area Fishing capacity does not exceed total productivity of the stocks	-Landing over time -Total number of vessels	-Global fishery yields estimated for the ICCAT area -Capacity levels of 2006/2007	-Adjustment of total allowable catches -Adjustment of capacity.
ECOLOGICAL STATE				
Target species	Maximize sustainable harvest of target species applying the precautionary approach.	-Biomass trends relative to B_{MSY} -Fishing mortality rate trends relative to F_{MSY} -Proportion of stocks above sustainable levels	-Target and limit reference points are defined for population biomass and fishing mortality (B_{MSY} and F_{MSY} or proxies)	-Harvest control rule -Recovery plans -Capacity-reduction plans - Catch quotas
Bycatch species	Maintain and restore populations of bycatch species above levels at which their reproduction may become seriously threatened	-Population size trends -Size/age structure trends -Catch trends -Vulnerability of a species to overfishing	-Bycatch limits allocated to vulnerable species -In absence of information apply the precautionary approach	-Bycatch limits or caps for species or groups -Gear modifications and practices to reduce bycatch -Adoption of good practices by crews and release of capture life animals following protocol

Ecosystem properties and trophic relationships	Maintain viable trophic interactions and interdependencies involving species that are affected by fishing	-Species composition of the catch -Size based indicators -Trophic level based indicators -Diversity indices -Relative catch of a species or groups -Trophic links and biomass flows	-Limit reference point for the impacts of fishing on key stone predators and preys in the ecosystem -In absence of knowledge, precautionary reference point values based on general expectations	- Multispecies management plans (e.g. one bycatch specie limiting the catch of other target species) - Mitigation measures - Safe release practices
Habitats	Describe, identify and protect habitats of special concern and habitat utilization of species	-Identification and mapping of habitats of special concern (e.g. reproduction, migration, feeding, hotspots) -Habitat shifts and range contractions -Habitat suitability index -Habitat size (e.g. O2 minimum zones)	-Minimum habitat needs for population viability	-Restriction or limit fishing on habitats of special concern such as spawning and nursery habitats.

Table 2. Summary of the main models and scenarios adopted by the SCRS for each ICCAT assessed stock which are used to provide management advice (e.g. construct the Kobe plots and Kobe II matrices)

Group	Species	Stock	Last Assessed	Model	Scenarios
Tunas	ALB	albn	2016	Production model	Basecase
Tunas	ALB	albs	2016	ASPIC	Run2
Tunas	ALB	albs	2016	ASPIC	Run6
Tunas	ALB	albs	2016	ASPIC	Run7
Tunas	ALB	albs	2016	ASPIC	Run8
Tunas	ALB	albs	2016	BSP	Run CW_FOX
Tunas	ALB	albs	2016	BSP	Run CW_SH
Tunas	ALB	albs	2016	BSP	Run EQW_FOX
Tunas	ALB	albs	2016	BSP	Run EQW_SH
Tunas	ALB	albmed	2011	Several models were run. Too uncertain and unreliable.	
Tunas	YFT	yft	2016	ASPIC	Cluster1 -1_Fox_eq
Tunas	YFT	yft	2016	ASPM	Cluster 1 - Run01
Tunas	YFT	yft	2016	ASPM	Cluster 2 - Run05
Tunas	YFT	yft	2016	VPA	VPA-Cluster1
Tunas	YFT	yft	2016	VPA	VPA-Cluster2
Tunas	YFT	yft	2016	SS	Cluster1 - run5
Tunas	YFT	yft	2016	SS	Cluster2 -Run7
Tunas	BET	bet	2015	ASPIC	Run 1
Tunas	BET	bet	2015	ASPIC	Run 2
Tunas	BET	bet	2015	ASPIC	Run 3
Tunas	BET	bet	2015	SS	Run1
Tunas	BET	bet	2015	SS	Run2
Tunas	BET	bet	2015	SS	Run3
Tunas	BET	bet	2015	SS	Run4
Tunas	BET	bet	2015	SS	Run5
Tunas	BET	bet	2015	SS	Run6
Tunas	BET	bet	2015	SS	Run7
Tunas	BET	bet	2015	SS	Run8
Tunas	BET	bet	2015	SS	Run9
Tunas	BET	bet	2015	SS	Run10
Tunas	BET	bet	2015	SS	Run11
Tunas	BET	bet	2015	SS	Run12
Tunas	SKI	skje	2014	Several models were run. Too uncertain and unreliable.	
Tunas	SKJ	skjw	2014	ASPIC	Run1
Tunas	BFT	bfte	2014	VPA	ReportedCatch-LowRec
Tunas	BFT	bfte	2014	VPA	ReportedCatch-MediumRec
Tunas	BFT	bfte	2014	VPA	ReportedCatch-HighRec

Tunas	BFT	bfte	2014	VPA	InflatedCatch-LowRec
Tunas	BFT	bfte	2014	VPA	InflatedCatch-MediumRec
Tunas	BFT	bfte	2014	VPA	InflatedCatch-HighRec
Tunas	BFT	bftw	2014	VPA	LowPotential
Tunas	BFT	bftw	2014	VPA	HighPotential
Billfishes	SWO	swon	2013	ASPIC	Run2
Billfishes	SWO	swos	2013	ASPIC	Run2
Billfishes	SWO	swomed	2016	XSA	ContinuityRun
Billfishes	SAI	saie	2016	ASPIC	E1
Billfishes	SAI	saiw	2016	SS	Model1.1-IncreasingCPUEs
Billfishes	SAI	saiw	2016	SS	Model2.2-DecreasingCPUEs
Billfishes	BUM	bum	2011	SS	run1
Billfishes	WHM	whm	2012	SS	run1
Billfishes	WHM	whm	2012	ASPIC	run1
Sharks	BSH	bshn	2015	BSP	N1
Sharks	BSH	bshn	2015	BSP	N2
Sharks	BSH	bshn	2015	BSP	N3
Sharks	BSH	bshn	2015	BSP	N4
Sharks	BSH	bshn	2015	BSP	N5
Sharks	BSH	bshn	2015	BSP	N6
Sharks	BSH	bshn	2015	BSP	N7
Sharks	BSH	bshn	2015	SS	Run4
Sharks	BSH	bshn	2015	SS	Run6
Sharks	BSH	bshs	2015	BSP	S1
Sharks	BSH	bshs	2015	BSP	S2
Sharks	BSH	bshs	2015	BSP	S3
Sharks	BSH	bshs	2015	BSP	S4
Sharks	BSH	bshs	2015	BSP	S5
Sharks	BSH	bshs	2015	BSP	S6
Sharks	BSH	bshs	2015	BSP	S7
Sharks	BSH	bshs	2015	BSP	S8
Sharks	BSH	bshs	2015	BSP	S9
Sharks	BSH	bshs	2015	BSP	S10
Sharks	SMA	smana	2012	BSP	Run1
Sharks	SMA	smana	2012	BSP	Run2
Sharks	SMA	smana	2012	BSP	Run3
Sharks	SMA	smana	2012	BSP	Run4
Sharks	SMA	smana	2012	BSP	Run5
Sharks	SMA	smana	2012	BSP	Run6
Sharks	SMA	smana	2012	BSP	Run7
Sharks	SMA	smana	2012	BSP	Run8
Sharks	SMA	smana	2012	BSP	Run9

Sharks	SMA	smana	2012	BSP	Run10
Sharks	SMA	smana	2012	BSP	Run11
Sharks	SMA	smana	2012	BSP	Run12
Sharks	SMA	smana	2012	BSP	Run13
Sharks	SMA	smana	2012	BSP	Run14
Sharks	SMA	smana	2012	BSP	Run15
Sharks	SMA	smana	2012	BSP	Run16
Sharks	SMA	smasa	2012	BSP	Run1
Sharks	SMA	smasa	2012	BSP	Run2
Sharks	SMA	smasa	2012	BSP	Run3
Sharks	SMA	smasa	2012	BSP	Run4
Sharks	SMA	smasa	2012	BSP	Run5
Sharks	SMA	smasa	2012	BSP	Run6
Sharks	SMA	smasa	2012	BSP	Run7
Sharks	SMA	smasa	2012	BSP	Run8
Sharks	SMA	smasa	2012	BSP	Run9
Sharks	SMA	smasa	2012	BSP	Run10
Sharks	SMA	smasa	2012	BSP	Run11
Sharks	SMA	smasa	2012	BSP	Run12
Sharks	SMA	smasa	2012	BSP	Run13
Sharks	POR	pornw	2009	BSP	NW1
Sharks	POR	porsw	2009	BSP	SW1
Sharks	POR	porsw	2009	BSP	SW2
Sharks	POR	porsw	2009	BSP	SW3
Sharks	POR	porsw	2009	BSP	SW4
Sharks	POR	porsw	2009	BSP	SW5
Sharks	POR	porne	2009	BSP	NE1
Sharks	POR	porne	2009	BSP	NE2
Sharks	POR	porne	2009	BSP	NE3
Sharks	POR	porne	2009	BSP	NE4
Sharks	POR	porne	2009	BSP	NE5
Sharks	POR	porne	2009	BSP	NE6
Sharks	POR	porne	2009	BSP	NE7
Sharks	POR	porne	2009	ASPM	InitialRun
Sharks	POR	porne	2009	ASPM	50percentofF
Sharks	POR	porne	2009	ASPM	0percentofF

Table 3. Specificity of stocks by major ecoregions. The proposed ecoregions should be seen as preliminary and an interim solution contingent upon further analysis.

Ecoregions	ICCAT assessed stocks	Specificity of stock for each ecoregion
Northern temperate ecoregion	BFT West Atlantic	0.77
Northern temperate ecoregion	BFT East Atlantic	0.70
Northern temperate ecoregion	ALB North Atlantic	0.68
Northern temperate ecoregion	SWO North Atlantic	0.42
Northern temperate ecoregion	WHM North Atlantic	0.08
Northern temperate ecoregion	YFT Atlantic	0.03
Northern temperate ecoregion	SAI West Atlantic	0.03
Northern temperate ecoregion	BUM North Atlantic	0.03
Northern temperate ecoregion	SAI East Atlantic	0.02
Northern temperate ecoregion	BET Atlantic	0.01
Northern temperate ecoregion	SKJ West Atlantic	0.01
Northern temperate ecoregion	SKJ East Atlantic	0.00
Northern subtropical ecoregion	BUM North Atlantic	0.64
Northern subtropical ecoregion	WHM North Atlantic	0.62
Northern subtropical ecoregion	SAI West Atlantic	0.44
Northern subtropical ecoregion	SKJ West Atlantic	0.37
Northern subtropical ecoregion	SWO North Atlantic	0.33
Northern subtropical ecoregion	ALB North Atlantic	0.21
Northern subtropical ecoregion	BFT East Atlantic	0.15
Northern subtropical ecoregion	BFT West Atlantic	0.13
Northern subtropical ecoregion	YFT Atlantic	0.12
Northern subtropical ecoregion	BET Atlantic	0.09
Northern subtropical ecoregion	SKJ East Atlantic	0.04
Northern subtropical ecoregion	SAI East Atlantic	0.02
Tropical ecoregion	SKJ East Atlantic	0.95
Tropical ecoregion	SAI East Atlantic	0.86
Tropical ecoregion	BUM South Atlantic	0.84
Tropical ecoregion	BET Atlantic	0.84
Tropical ecoregion	YFT Atlantic	0.81
Tropical ecoregion	WHM South Atlantic	0.62
Tropical ecoregion	SWO South Atlantic	0.49
Tropical ecoregion	BUM North Atlantic	0.33
Tropical ecoregion	SAI West Atlantic	0.32
Tropical ecoregion	WHM North Atlantic	0.30
Tropical ecoregion	SWO North Atlantic	0.25
Tropical ecoregion	BFT East Atlantic	0.12
Tropical ecoregion	ALB North Atlantic	0.12
Tropical ecoregion	ALB South Atlantic	0.07
Tropical ecoregion	SKJ West Atlantic	0.06
Tropical ecoregion	BFT West Atlantic	0.00
Southern subtropical ecoregion	ALB South Atlantic	0.76

Southern subtropical ecoregion	SWO South Atlantic	0.47
Southern subtropical ecoregion	SKJ West Atlantic	0.38
Southern subtropical ecoregion	WHM South Atlantic	0.33
Southern subtropical ecoregion	SAI West Atlantic	0.19
Southern subtropical ecoregion	BUM South Atlantic	0.14
Southern subtropical ecoregion	BFT West Atlantic	0.09
Southern subtropical ecoregion	SAI East Atlantic	0.08
Southern subtropical ecoregion	BET Atlantic	0.06
Southern subtropical ecoregion	YFT Atlantic	0.03
Southern subtropical ecoregion	BFT East Atlantic	0.03
Southern subtropical ecoregion	SKJ East Atlantic	0.01
Southern temperate ecoregion	SKJ West Atlantic	0.18
Southern temperate ecoregion	ALB South Atlantic	0.17
Southern temperate ecoregion	WHM South Atlantic	0.05
Southern temperate ecoregion	SWO South Atlantic	0.04
Southern temperate ecoregion	SAI East Atlantic	0.02
Southern temperate ecoregion	SAI West Atlantic	0.01
Southern temperate ecoregion	BUM South Atlantic	0.01
Southern temperate ecoregion	BFT West Atlantic	0.01
Southern temperate ecoregion	YFT Atlantic	0.00
Southern temperate ecoregion	BFT East Atlantic	0.00
Southern temperate ecoregion	BET Atlantic	0.00
Southern temperate ecoregion	SKJ East Atlantic	0.00

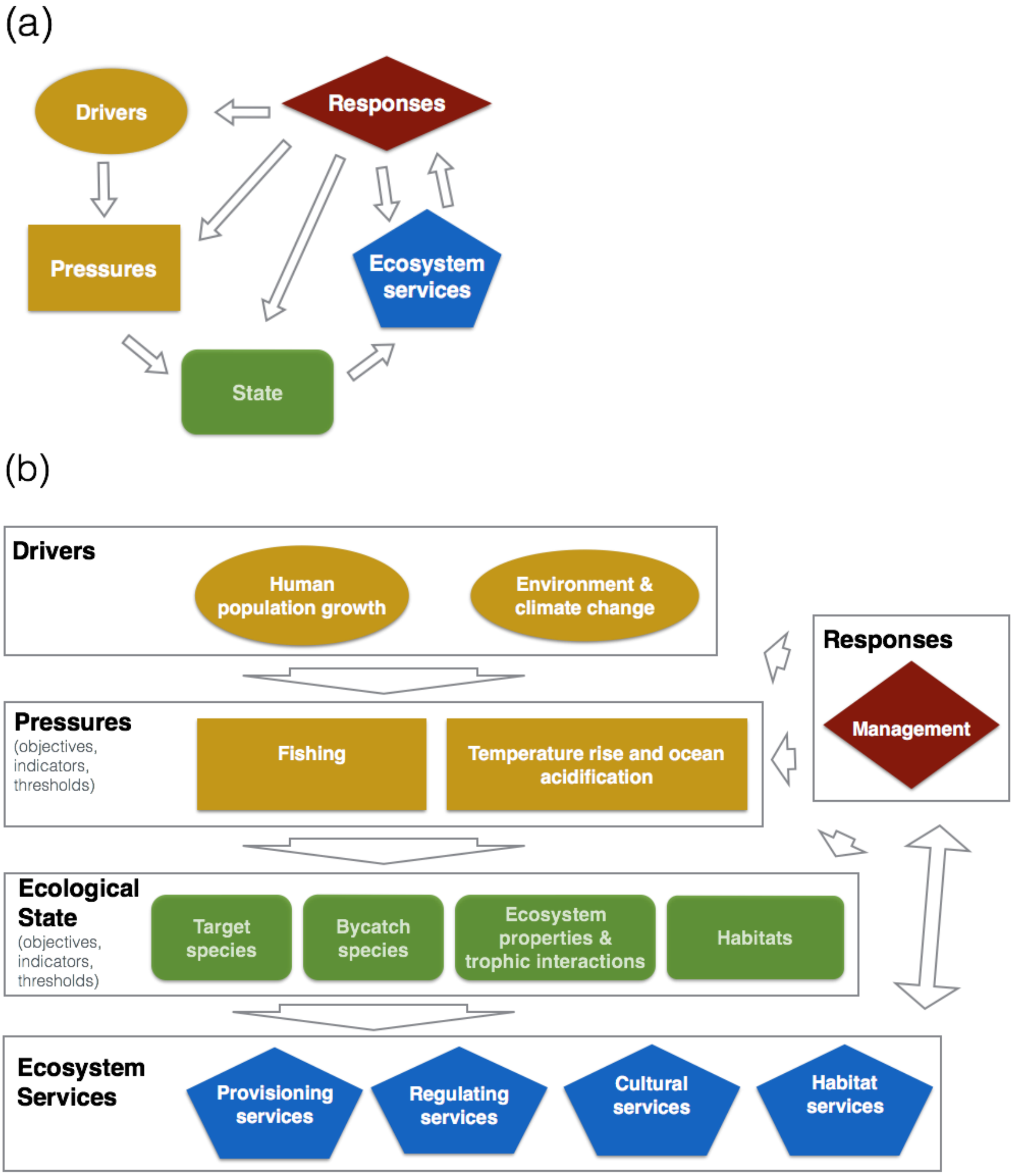


Figure 1. Framework and conceptual ecological model to inform the indicator-based ecosystem report card. (a) The Driver-Pressure-State-Ecosystem services-Response (DPSER) framework and (b) a conceptual ecological model of the ecosystem where ICCAT fisheries operate.

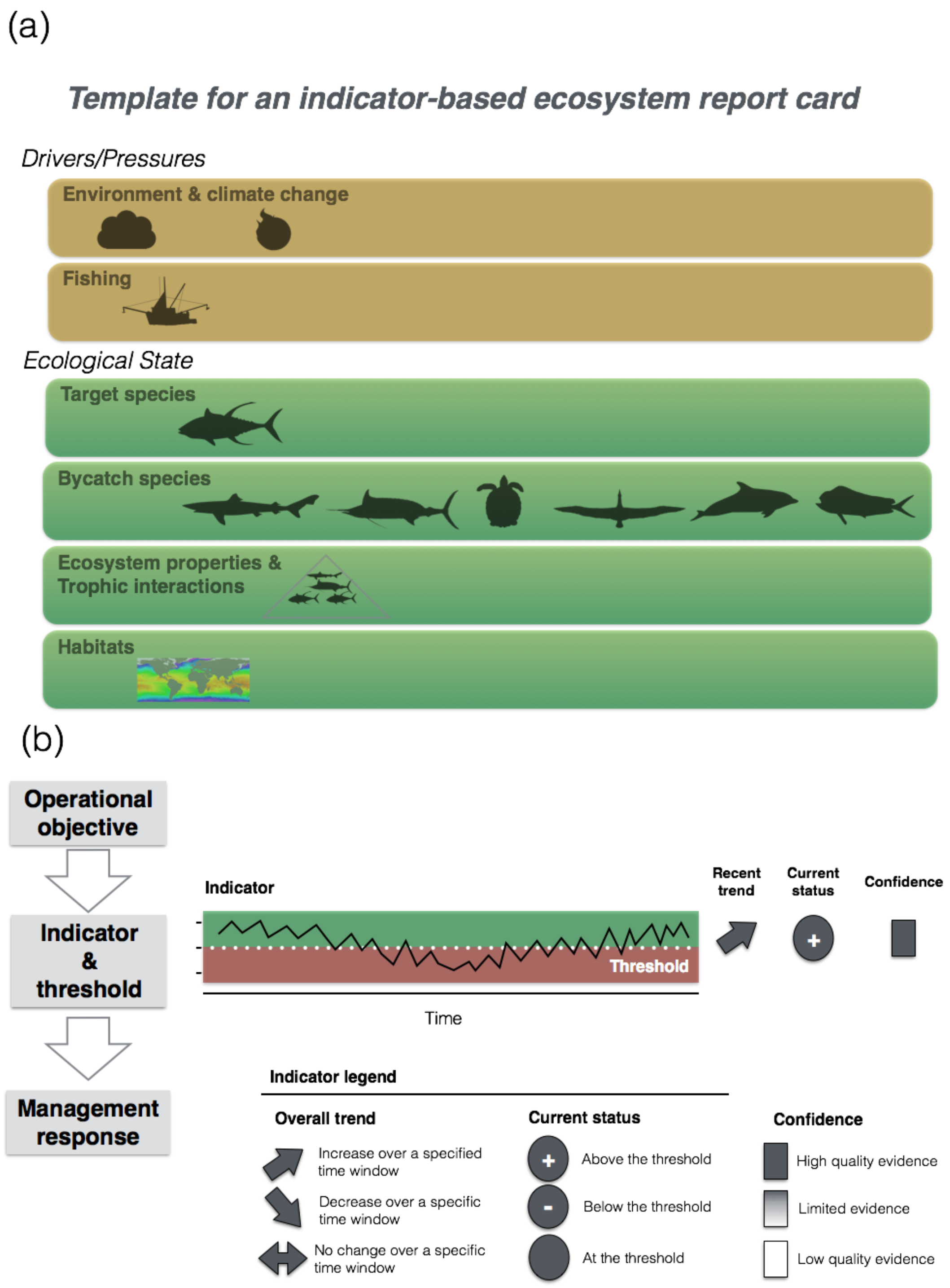


Figure 2. A template for an indicator-based ecosystem report card for the ICCAT Convention Area. (a) Template illustrating the main ecosystem components to monitor and report on, and (b) a template illustrating what aspects of an indicator should be reported on the ecosystem card.

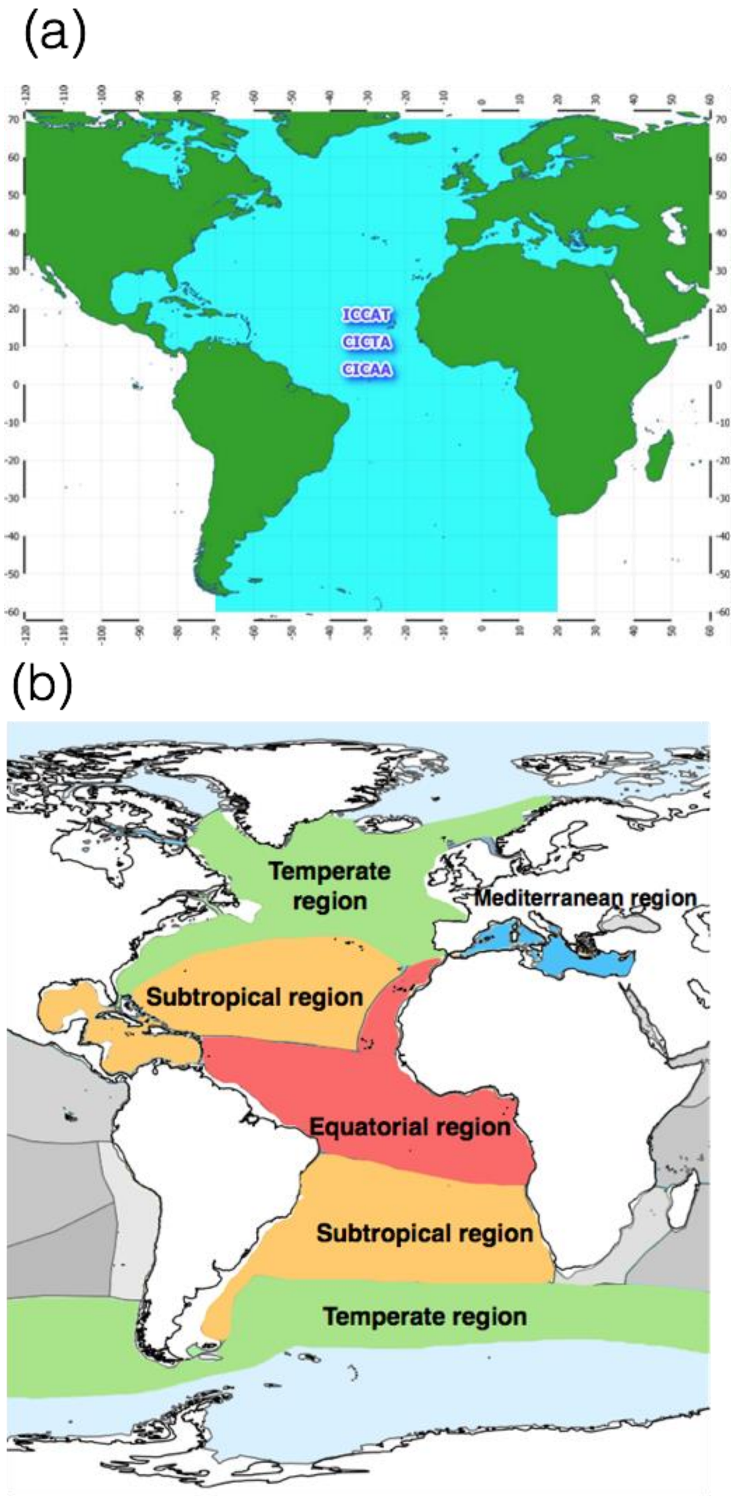
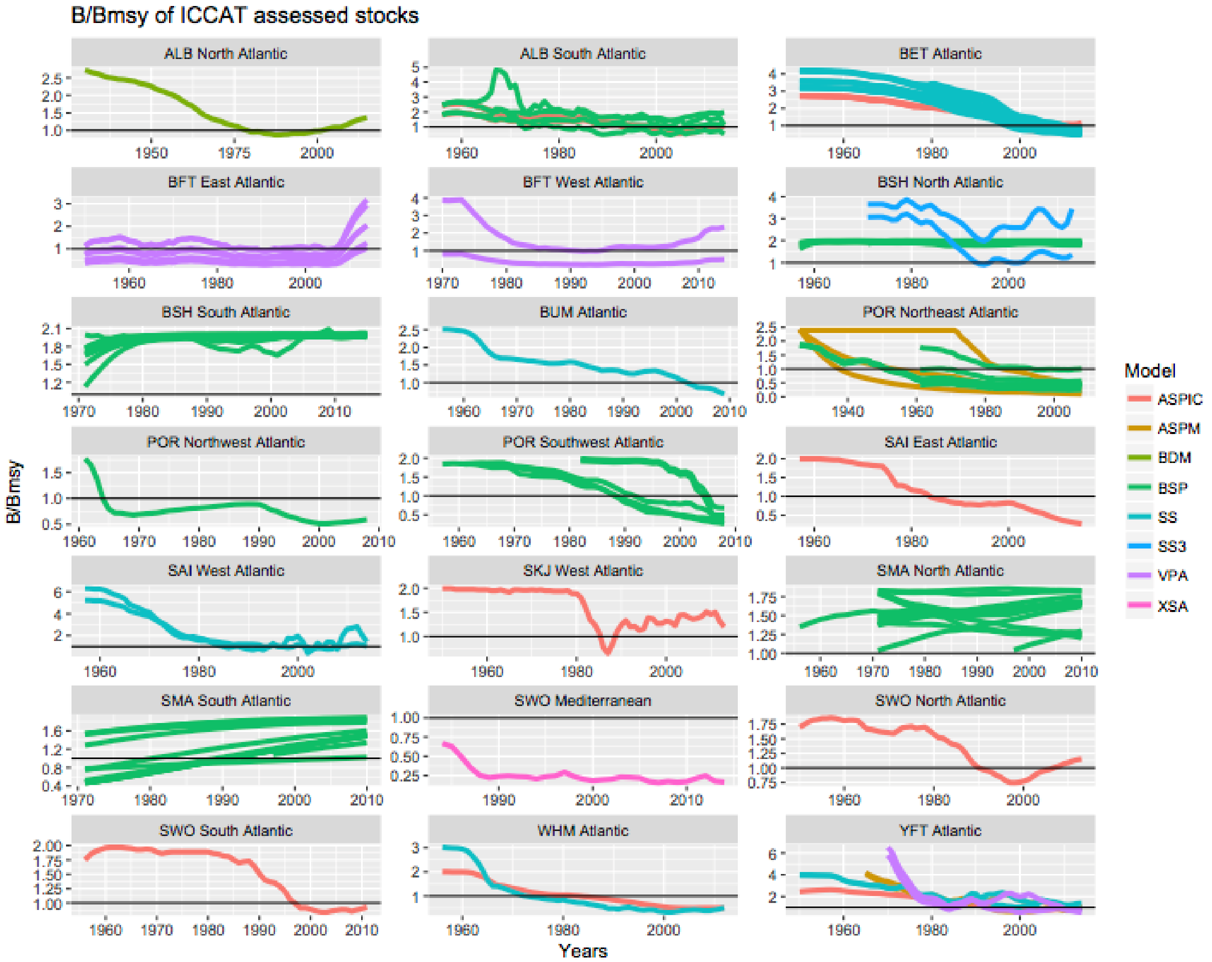


Figure 3. Potential area-based assessment units to develop ecosystem indicators. (a) ICCAT Convention AREA. (B) Preliminary ecoregions with meaningful ecological boundaries (based on preliminary on-going analyses).

(a)



B/Bmsy of ICCAT assessed stocks
ALB North Atlantic
ALB South Atlantic
BET Atlantic
BFT East Atlantic
BFT West Atlantic
BSH North Atlantic
BSH South Atlantic
BUM Atlantic
POR Northeast Atlantic
POR Northwest Atlantic
POR Southwest Atlantic
SAI East Atlantic
SAI West Atlantic
SKJ West Atlantic
SMA North Atlantic
SMA South Atlantic
SWO Mediterranean
SWO North Atlantic
SWO South Atlantic
WHM Atlantic
YFT Atlantic
B/Bmsy
Years
Model
ASPIC
ASPM
BDM
BSP
SS
SS3
VPA
XSA

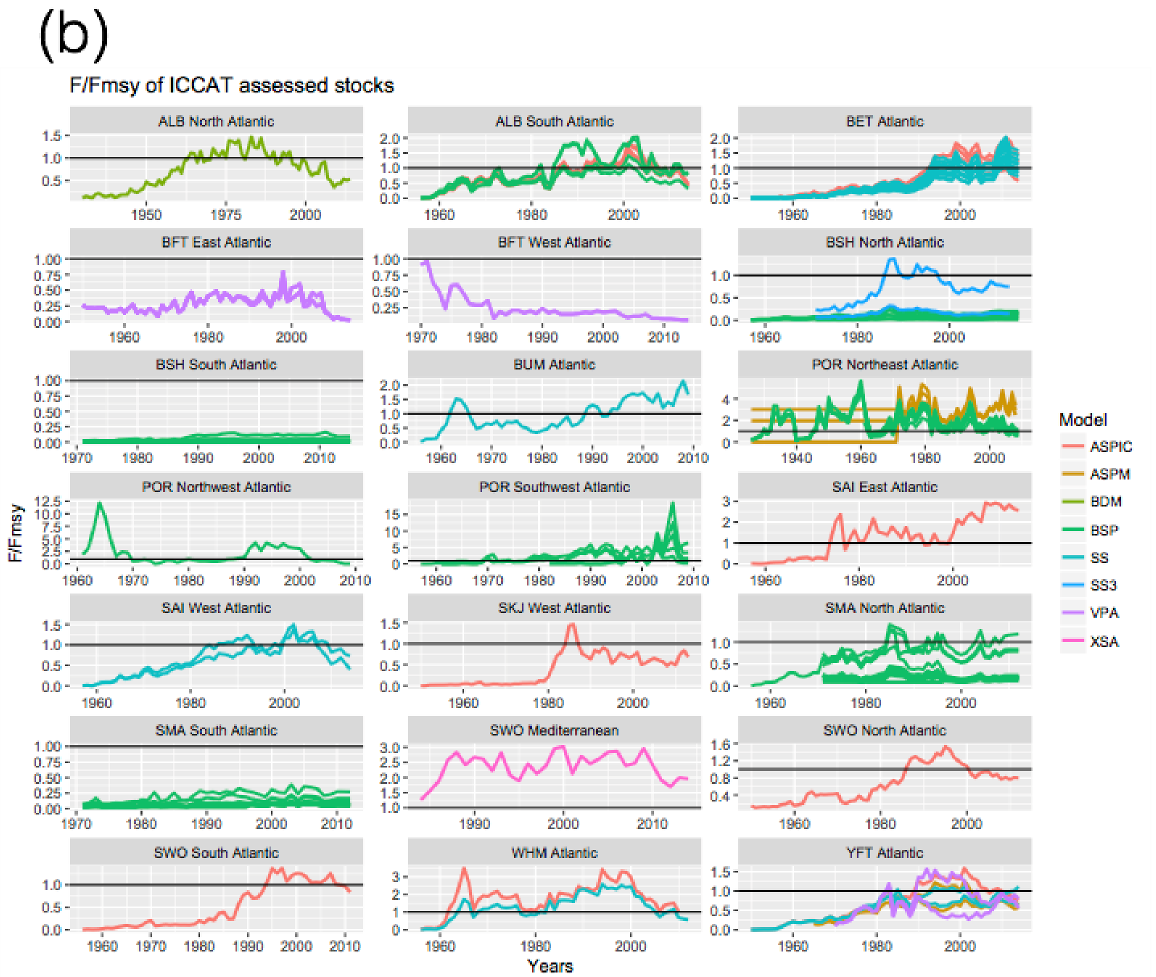


Figure 4. ICCAT assessed stocks by 2016. (a) B/B_{MSY} ratios and (b) F/F_{MSY} ratios extracted from the fisheries stock assessment models including all model runs adopted by the SCRS and used to provide management advice.

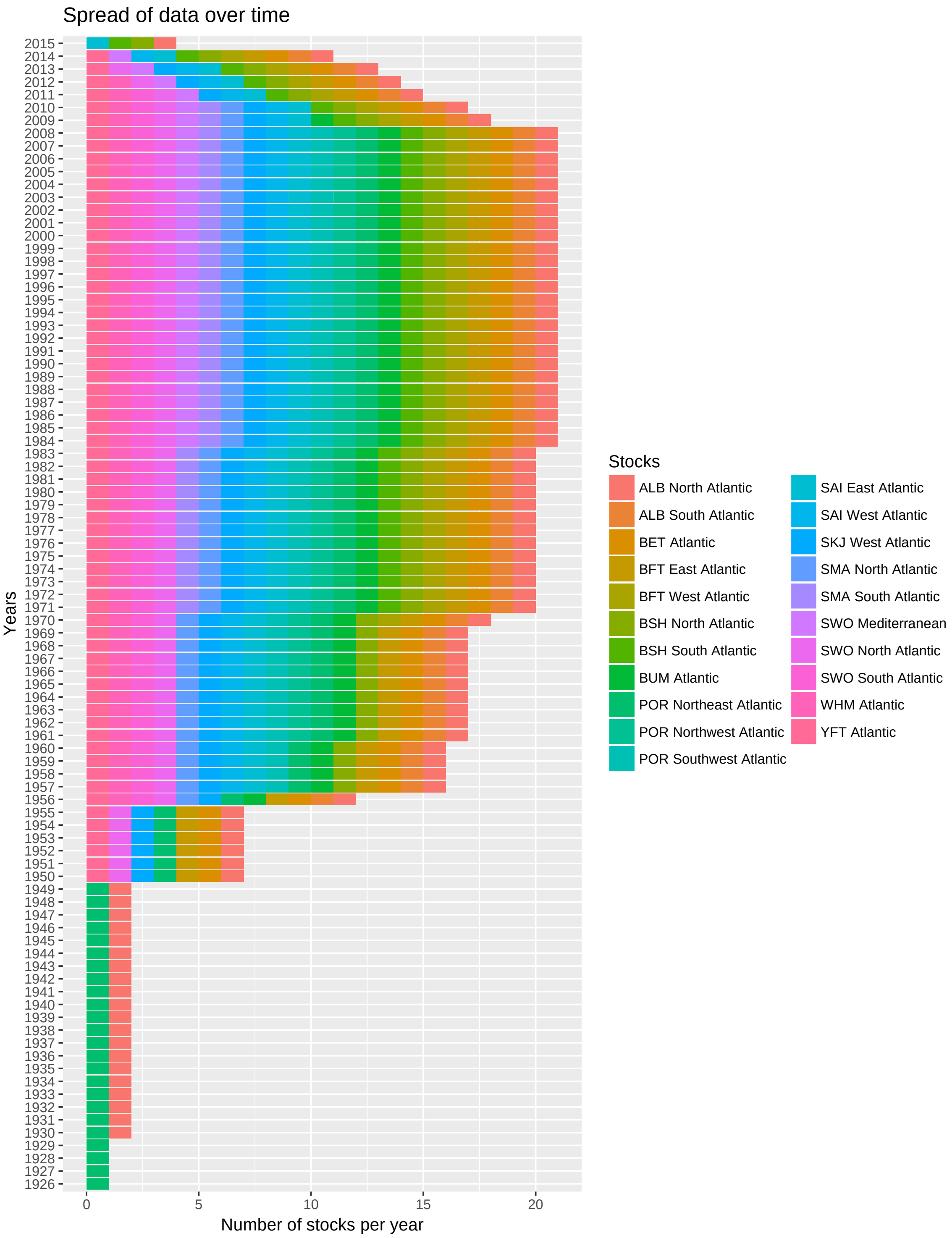


Figure 5. Number of stocks per year with estimates of B/B_{MSY} and F/F_{MSY} ratios for all ICCAT assessed stocks.

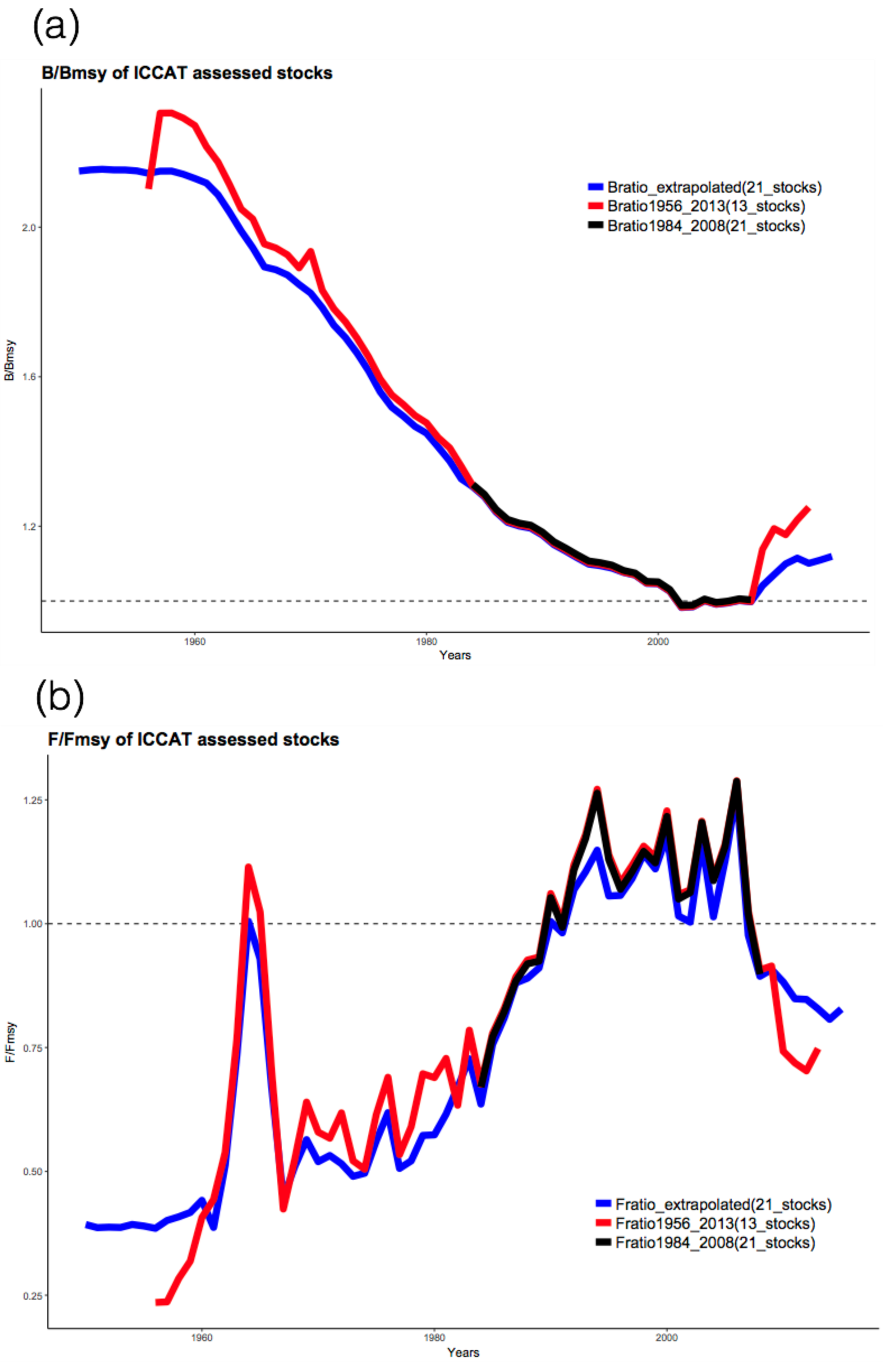


Figure 6. Integrated B/B_{MSY} (a) and F/F_{MSY} (b) ratios including all ICCAT assessed stocks. The solid black line shows the indicator with all the current assessed stocks including only those years for which all stocks were assessed; The solid red line shows the indicator based on a subset of stocks, including 60% of the stocks with the longest time series in order to increase the number of years included while making it sufficiently representative; The solid blue line shows the indicator based on ratios where values have been extrapolated backward to 1950 using the mean of the first three years of data, and extrapolated forward to 2015 using the mean of the last three years of data.

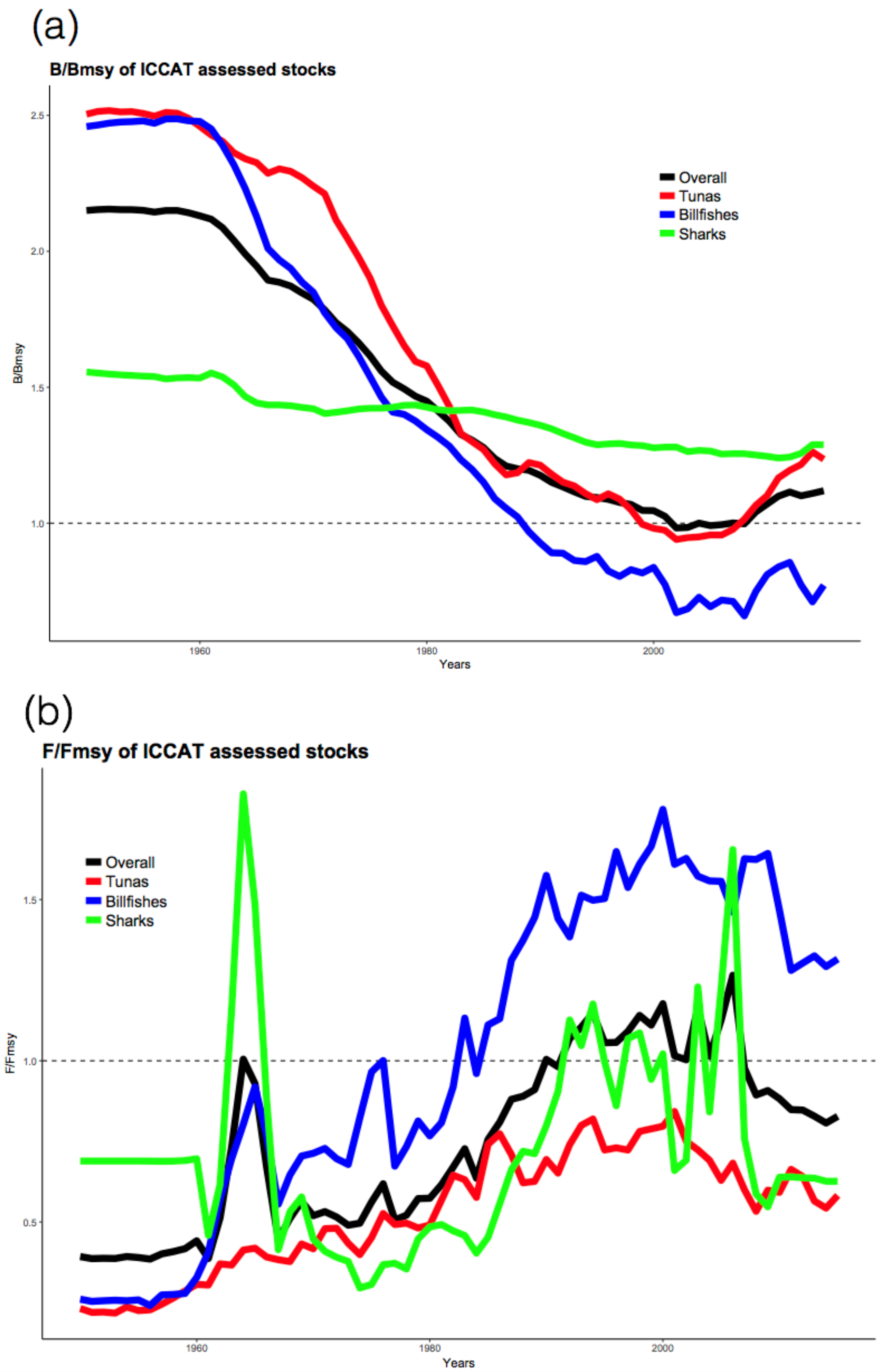


Figure 7. Integrated B/B_{MSY} (a) and F/F_{MSY} (a) ratios by major taxonomic groups (tunas, billfishes and sharks).

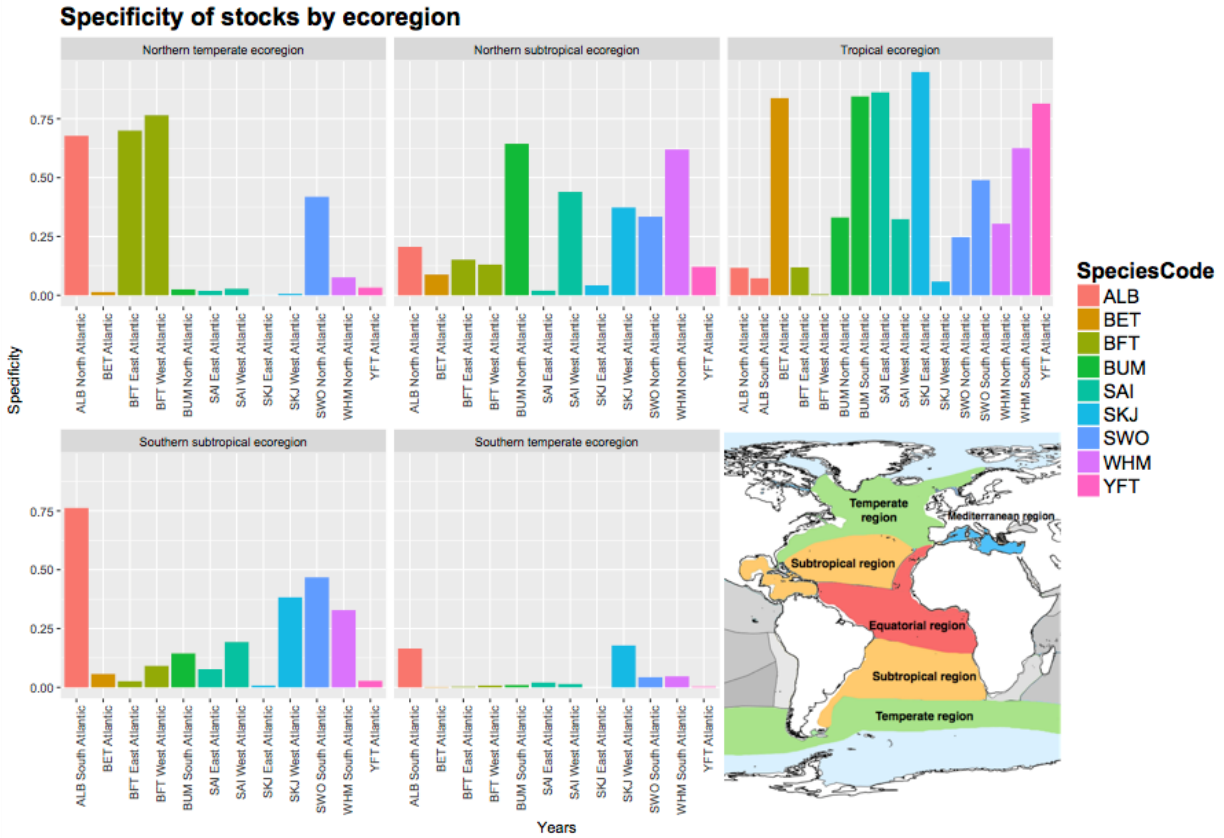


Figure 8. Specificity of stocks by major ecoregions. The proposed ecoregions should be seen as preliminary and an interim solution contingent upon further analysis.

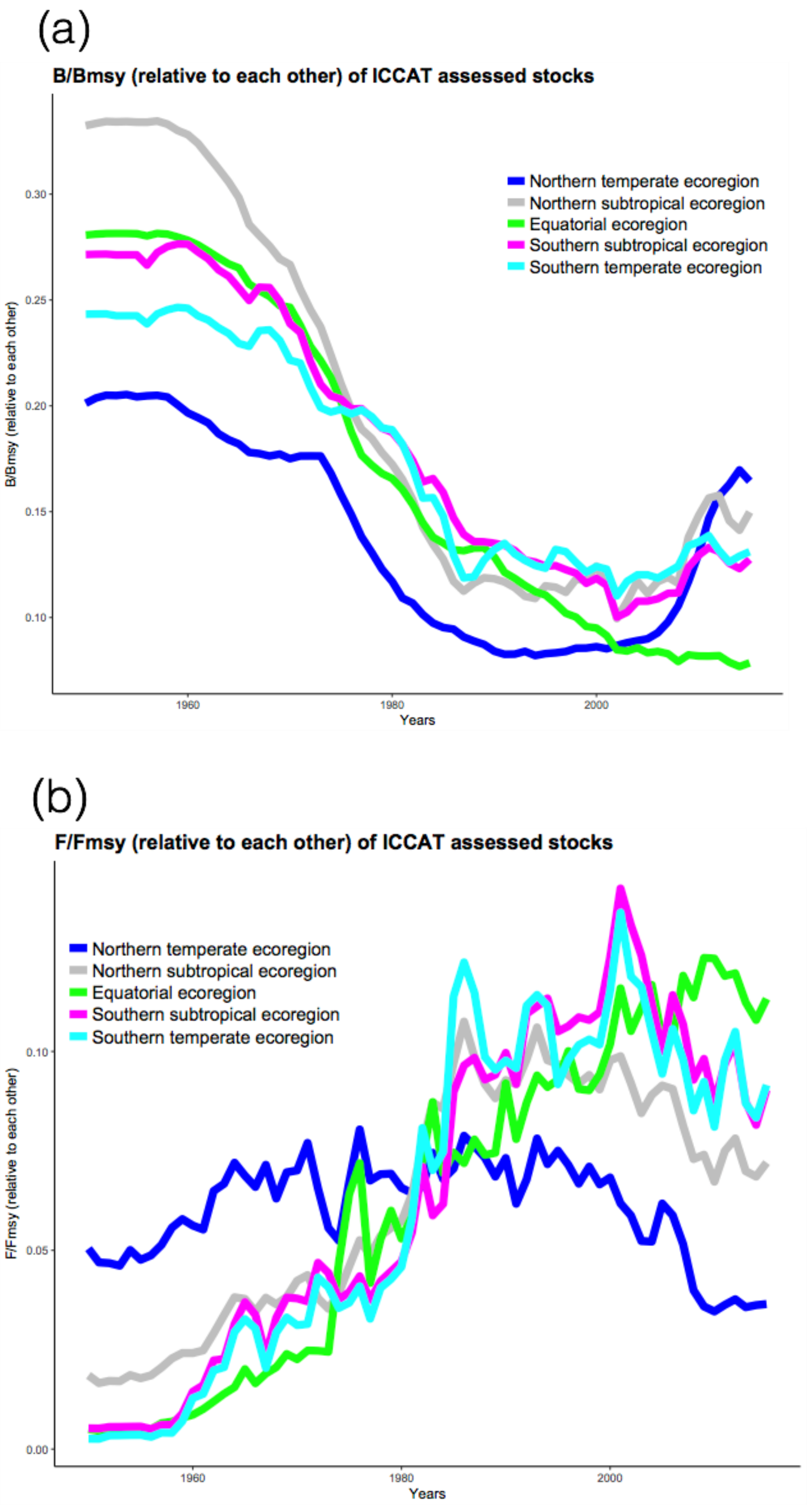


Figure 9. Integrated B/B_{MSY} (a) and F/F_{MSY} (b) ratios by ecoregions. The proposed ecoregions should be seen as preliminary and an interim solution contingent upon further analysis.