

REPORT OF THE IOTC WORKSHOP ON
“IDENTIFICATION OF REGIONS IN THE IOTC CONVENTION AREA
TO INFORM THE IMPLEMENTATION OF THE ECOSYSTEM
APPROACH TO FISHERIES MANAGEMENT”

La Reunion Island, 30th,31st August and 1st of September 2019

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EXECUTIVE SUMMARY

WPEB14 recommended to convene a workshop in 2019 to provide advice on the identification of draft ecoregions to foster discussions on the operationalization of the ecosystem approach to fisheries management (EAFM) in the Indian Ocean Tuna Commission (IOTC) convention area. This workshop entitled “**Identification of regions in the IOTC convention area to inform the implementation of the ecosystem approach to fisheries management**” took place the 30th, 31st of August and 1st of September 2019 in La Reunion Island. The workshop gathered 17 participants with a wide range of expertise in IOTC species and fisheries and oceanography of the Indian Ocean. Prior to the workshop, a consultant was hired to prepare a baseline draft proposal of ecoregions to be presented and discussed at the workshop by all the participants.

The workshop was structured into seven sessions.

In the first session, the experience of developing and using ecoregions in NAFO, ICES, CCAMLR and the NPFMC in the USA were presented to the Group. The Group discussed the **potential benefits and uses of ecoregions** in the context of these organizations and in the context of IOTC species and fisheries.

In the second session, an overview of the current **existing biogeographic classifications** in the Indian Ocean, which are often used to inform the delineation of ecoregion boundaries, were presented to the Group, and their relevance in the context of IOTC species and its fisheries were discussed.

In the third session, a **check list of evaluation criteria** was presented to the Group in order to inform discussions of what factors and considerations could be used for the development of the draft ecoregions. The Group agreed that ecological factors including (i) major oceanographic patterns, (ii) main distribution of IOTC species (tunas, billfishes, neritics), in combination with (iii) the spatial distribution of IOTC fisheries (coastal and industrial fisheries) should be the primary factors to be considered in the development of initial draft ecoregions. Other considerations such as geopolitical factors were also discussed, but not considered primary factors.

In the fourth session, **existing data sets** were revised, presented and discussed in terms of availability, quality and completeness to guide the choice of key data inputs for deriving the draft ecoregions. The data sets included (i) existing biogeographic classifications, (ii) spatial distribution and catches of IOTC species (oceanic tunas, neritics, sharks, other bycatch species), (iii) spatial distributions of IOTC fisheries (baitboats, longlines, gillnets, purse seines, etc.) and (iv) “other” potentially relevant data layers. A selection of “good” quality data sets was used as inputs in the quantitative spatial analysis to develop the baseline draft ecoregions to be discussed by the group.

In the fifth session, several **quantitative spatial analyses** were presented and discussed by the Group. These included several spatial overlap analyses, calculations of fidelity and sensitivity indicators to examine species and fisheries composition across multiple biogeographic provinces, and clustering analyses to group biogeographic provinces according to their similarity in terms of species composition, fisheries composition and both species and fishery composition. The Group provided feedback on the technical aspects and methods used in the derivation of the baseline ecoregions.

In the sixth session, three **baseline ecoregions** were presented and discussed by the Group. The first ecoregion classification was based on similarities of the spatial patterns in species composition, the second on the spatial patterns of fisheries, and the third on the spatial patterns of both species and fisheries.

In the seventh session, the three baseline ecoregion classifications in combination with expert knowledge were used to derive **draft ecoregions within the IOTC convention area**, and the Group discussed conclusions and future steps.

The draft ecoregions are not intended to be used for management purposes. At this stage, the benefits and potential uses (e.g. development of ecosystem report cards, ecosystem status overviews, etc.) of the draft ecoregions should be tested as a tool to facilitate the operationalization of the EAFM in IOTC.

The Group requested that the WPEB reviews and comments on the delineation of the draft ecoregions and provides ongoing feedback. The Group also requested that the WPEB communicates with the rest of the WPs to solicit feedback on the draft ecoregions. The Group recommended that the WPEB endorses the draft ecoregions for further development as a tool to progress EAFM implementation (e.g. ecosystem report card, ecosystem overviews, fisheries overviews).

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INTRODUCTION

Why this workshop

The establishment of ecologically meaningful regions (or ecoregions) and their use to provide more integrated ecosystem-based fisheries advice may facilitate the operationalization of the ecosystem approach to fisheries management (EAFM) in the context of tuna and billfish fisheries. An EU funded project explored this idea and undertook some initial work towards a broad-scale delineation of the Indian Ocean into ecologically meaningful regions, large enough to be practical for providing ecosystem-based advice to inform fisheries management in the context of tuna and billfish fisheries. In 2018, this initial work was presented at the 14th session of the IOTC Working Party on Ecosystems and Bycatch (WPEB14) as a conceptual scientific exercise to discuss its potential utility and explore opportunities for future work (Juan-Jordá *et al.* 2019).

The WPEB14 discussed that the two candidate regions proposed by the EU project did not reflect adequately the characteristics of the IOTC region. This was in part because it did not entirely account for some of the main fisheries in the region, in particular the most coastal fisheries (IOTC–WPEB14 2018). The WPEB14 recommended that the criteria to inform boundaries of the ecoregions need to be revised, so they take into account a larger number of characteristics of the region. The WPEB14 advised that the revised criteria could account for (1) the biogeography of the Indian Ocean, (2) the spatial distributions of main IOTC species (tuna, billfishes, neritics, and other bycatch species), (3) the spatial distributions of the main IOTC fisheries (coastal artisanal, semi-industrial and industrial), (4) the spatial dynamics and overlaps of IOTC species and fisheries, (5) other relevant socio-economic and geopolitical factors, (6) compatibility with other regional initiatives (e.g. SWIOFC, IUCN, RFMOs, etc.), as well as (7) expert knowledge from IOTC Member States (IOTC–WPEB14 2018).

The WPEB14 recommended convening a workshop in 2019 to provide advice on the identification of draft ecoregions based on revised criteria to foster discussions on the operationalization of the ecosystem approach to fisheries management (EAFM) in the Indian Ocean Tuna Commission (IOTC) convention area (IOTC–WPEB14 2018).

A three-day Workshop entitled “**Identification of regions in the IOTC convention area to inform the implementation of the ecosystem approach to fisheries management**” was held at Reunion Island, 30 August-1 September 2019. The Workshop (hereafter referred to as the **Ecoregion Workshop**) was funded by IOTC, Common Oceans ABNJ Tuna Project and EU France. The Common Oceans ABNJ Tuna Project also funded a pre-workshop analysis and report to inform discussions at the Ecoregion Workshop (Nieblas *et al.* 2019). The WPEB14 also noted the importance of drawing on experiences from other Regional Fisheries Management Organizations (RFMOs), Regional Fisheries Bodies (RFB) and other relevant institutions that have already established and used large-scale spatial units or ecoregions to foster the operationalization of the EAFM in their waters of competence (IOTC–WPEB14 2018). To address the WPEB14 request, researchers from other organizations including NAFO, ICES and CCAMLR were invited to attend the Ecoregion Workshop and present their experiences delineating ecoregions and using them to support the implementation of the EAFM in their regions.

Objectives and format of the workshop

A **list of participants** is included in Appendix 1. The workshop gathered 17 researchers, including researchers from IOTC Member States and external researchers from other research institutions and international organizations, with a wide range of expertise in IOTC species and fisheries, ecology, fisheries management and oceanography of the Indian Ocean.

The **Welcome Session** included a presentation by Hilario Murua (former IOTC Scientific Committee Chair, 2015-2019) presenting the main objectives of the workshop and a presentation by Maria José Juan-Jordá

(FAO consultant, Common Ocean ABNJ tuna project) presenting the main motivation and background for the workshop.

The **overall goal** of the Ecoregion Workshop was to provide advice on the identification of candidate ecologically meaningful regions (or ecoregions) that can serve as a basis to support the operationalization of the ecosystem approach to fisheries management (EAFM) in the Indian Ocean Tuna Commission (IOTC). Ideally, candidate regions should have boundaries that make ecological sense, and at the same time be practical to structure and produce ecosystem-based advice to inform fisheries management in the context of tuna and billfish fisheries.

In preparation for the Ecoregion Workshop, a consultant (Anne-Elise Nieblas) prepared a **background report** with a draft revised evaluation criteria to inform the delineation of the ecoregions, and a baseline draft proposal of ecoregions to be discussed and refined by all the participants at the Ecoregion Workshop (full background report can be downloaded [here](#)).

The Ecoregion Workshop was structured into the following seven sessions devoted to different topics:

- **Session 1:** Benefits and current uses of pelagic regionalizations in support of EAFM implementation – an examination of world case studies
- **Session 2:** Existing pelagic biogeographic classifications in the Indian Ocean
- **Session 3:** Criteria for evaluating ecoregions and the expected qualities of ecoregions
- **Session 4:** An overview of current knowledge and main data layers, and their quality to inform the delineation of draft ecoregions
- **Session 5:** Derivation of baseline proposal of ecoregions for IOTC
- **Session 6:** Wrap-up session including the refinement of the baseline proposals of ecoregions based on expert knowledge
- **Session 7:** Overarching conclusions and future steps

Maria José Juan-Jordá served as facilitator for the seven sessions and rapporteurs were assigned to each session (Appendix 2).

Each session consisted of detailed presentations made by the participants, and a general discussion in which all attendees shared their own observations and asked questions to the presenters. The presentations and the key discussion points by session are summarized below. All the Ecoregion Workshop presentations can also be downloaded from the following Dropbox [link](#).

WORKSHOP SESSIONS

Session 1: Benefits and current uses of pelagic regionalizations in support of EAFM implementation – an examination of world case studies

PRESENTATIONS

In this session, four presentations gave an overview of four regional examples with proven experience using spatially explicit units or ecoregions to assist in the implementation of the EAFM in their convention areas. The four world case studies presented were:

- PRESENTATION2 – The International Council for the Exploration of the Sea (ICES) ecoregions (Mark Dickey Collas, ICES)
- PRESENTATION3 – The Northwest Atlantic Fisheries Organization (NAFO) experience in delineation of ecoregions (Pierre Pepin, Fisheries and Oceans, Canada)
- PRESENTATION4 – The North Pacific Fisheries Management Council (NPFMC) experience in the delineation of ecoregions and their use to operationalize the EAFM (Maria José Juan-Jordá, FAO consultant)

- PRESENTATION5 – Pelagic ecoregionalisation in the subantarctic. Experiences from The Convention for the Conservation of Atlantic Marine Living Resources (Philippe Koubi, Sorbonne Université, France)

For each case study, these presentations gave (1) an overview how spatially explicit units or ecoregions have been identified to support EAFM implementation, (2) what were the main drivers to delineate them, (3) what are their main uses with examples, (4) strengths and weaknesses using ecoregions as a EAFM implementation tool, (5) and lessons learned. The presentation based on the CCAMLR experience was a bit different since it presented the ongoing work on developing a pelagic ecoregionalization on the subantarctic with the aim of informing the designation of Marine Protected Areas in CCAMLR.

The presentations reached the following conclusions:

- The desire to move from single-stock/species advice to the production of more integrated ecosystem-based advice to inform EAFM implementation (or Ecosystem Based Management EBF in the case of ICES) was the **principal driver** to identify ecoregions.
- **A strength** of the ecoregions as a tool for EAFM implementation is that they are a useful foundation to structure ecosystem advice for fisheries management bodies, and provide a useful foundation for developing a wide range of products to assist in the production advice. For example:
 - NAFO develops “State of the Ocean” reports which provide a summary of physical and biological oceanographic conditions within a region relevant to fisheries.
 - ICES develops “Fisheries Overview” reports which provide an overview of the impacts of fisheries on the ecosystem within a region.
 - The NPFMC develops “Ecosystem Report Cards and Ecosystem Considerations Assessments” to report on the status and trends of multiple ecosystem components within a region and provide ecosystem context for fisheries management decisions.
 - Ecoregions are also used as a foundation for planning research such as the development of multispecies and ecosystem models.
- **A weakness** of the ecoregions is that they may add a level of complexity to discussions which fisheries managers may not be willing to deal with.
- A series of **best practices and lessons learned** were also shared:
 - Identifying a set of criteria for defining ecoregion across a range of disciplines, considering both ecological and social processes, and the expected qualities of the ecoregions, while remaining flexible, was deemed important.
 - Engaging early with the Commission and fisheries managers in the discussions of ecoregion delineation and its potential uses, and being inclusive was deemed important, together with the design of an iterative process of communication.
 - The use of quantitative approaches that linked different data layers describing the ecosystems including fisheries, coupled with expert advice were favored for the ecoregion delineation
 - Flexibility for future refinements of ecoregions as data improve or as management approaches are updated was deemed important.

DISCUSSIONS

The following main points were made during the discussions:

- The Group acknowledged the best practices and lessons learned in the case studies presented.
- The Group noted the importance of providing a strong rationale of what might be the potential benefits and uses of ecoregions in the context of IOTC species and fisheries. The Group also agreed on the need to provide examples of how ecoregions might look and be used to the Commission early in the process, to build an inclusive and iterative process.
- The Group noted how the mandates in IOTC focus on monitoring the impacts of their fisheries, and how it has a limited mandate in evaluating the state of the marine ecosystem. It was also noted that ICES is an advisory body that covers a wide range of sectors (e.g. fisheries, pollution), and it is not a fisheries management body, such is the case of IOTC and NAFO.
- In these case studies, stocks continue to be managed based on the provision of advice derived from the traditional single species fisheries assessments, yet stocks are allocated/assigned to one or several ecoregions based on their core distributions, so other ecosystem-related products can be generated (e.g. Ecosystem Overview Reports in ICES) using information from those stocks and fisheries targeting them. Revisions are made periodically to address any major shifts in species/stocks distributions.
- The Group discussed how ecoregions are being used as a tool for planning resources and information and how the use of ecoregions to structure advice help managers to better understand the connection between their fisheries and the state of the ecosystem and help to translate indicators into more simple language by making it context and region specific.
- The Group noted how knowledge on ecosystem status and trends can then be used to provide context and advice for fisheries management decisions. For example, the Advisory Committee of ICES is assessing the productivity per region and how it translates into fisheries production, and therefore how this information can be used in the future to inform single species advice.
- From the case studies the Group noted how the products developed at the ecoregion level (e.g. ecosystem overview reports, ecosystem models) are used to provide strategic advice to fisheries management, and therefore they are not being used to form the basis for fisheries decisions and the provision of tactical fisheries management.
- The Group had some concerns about regionalizing the development of indicators in the context of IOTC data quality, since indicators would need to be interpreted carefully given data quality and informed by local knowledge and expertise.
- The Group discussed the challenges of how to integrate the dynamic features of marine ecosystem into the regionalization, and how to translate this into the provision of management advice.
- The Group encouraged maintaining communication and collaborations with these external organizations (NAFO, ICES, NPFMC and CCSBT).

Session 2: Existing pelagic biogeographic classifications in the Indian ocean

PRESENTATION6 - An overview of existing marine pelagic biogeographic classifications relevant to the Indian ocean and their relevance for tuna and tuna-like species (Anne-Elise Nieblas, workshop consultant)

This presentation gave an overview of the current existing biogeographic classifications in the Indian Ocean, which are often used to inform the delineation of ecoregion boundaries, and it showed their relevance in the context of IOTC species and its fisheries. The biogeographic classifications covered in the presentation were the Longhurst Biogeochemical Provinces, Large Marine Ecosystems (LMEs), Marine Ecosystems of the World (MEOW), Pelagic Provinces of the World (PPOW), Tuna Biogeographical Provinces, and the global Dynamic Biogeochemical Provinces.

The presentation also summarized best qualities and practices extracted from these existing classifications that could be transferred to derive ecoregions in IOTC. These include:

- Ecoregions should include coastal and oceanic pelagic waters to cover the distribution of neritic and oceanic species under IOTC mandate.
- Ecoregion boundaries are often derived using quantitative statistical methods coupled with expert opinion. The data used to inform the delineation of ecoregion boundaries also need to be carefully evaluated for their quality, completeness, and availability.
- The spatial scale at which ecoregions are defined can also have an important impact on their potential uses, therefore the ideal versus practical number of ecoregions, and whether they should have hierarchical subdivisions, should be examined.
- The ecoregion boundaries should be static and relatively few in number to make them practical for informing EAFM implementation.

DISCUSSION

The following main points were made during the discussions:

- Marine ecosystems and oceanographic processes are dynamic and populations and fisheries respond to those changes. The Group noted the boundaries of ecoregions should account for these dynamics and capture and describe the main tuna species biogeography and fisheries. However, the Group agreed to delineate static ecoregions boundaries for practical reasons and review their boundaries at regular time intervals (e.g. 10-20 years as needed) to account for changes.
- The catch and CPUE based habitat distribution of species used as a data layer in some of the biogeographic classification presented should be taken with caution as the distribution of the fish could not be limited to where they are caught.
- The Group discussed the importance of distinguishing between the broad scale oceanographic features and the more local features (e.g. mesoscale eddies), and their effect on species dynamics. Fish behavior is linked to local environmental features that can affect their distribution. The broad scale oceanographic features should be considered further when defining ecoregion boundaries.

PRESENTATION7 –A marine bioregionalization for the Indian Ocean (the GOBI/CSIRO project) (Donna Hayes from CSIRO, Australia)

This presentation gave an overview of the GOBI/CSIRO bioregionalization project of the Indian Ocean. It showed how through two expert workshops and novel statistical analyses of physical and biological data, the project has derived a single combined bioregionalization of the Indian Ocean. This bioregionalization incorporates datasets from shallow, deep and pelagic ecosystems, the species that inhabit them, their

physical characteristics and their likely boundaries based on current information. The bioregionalization includes deep sea benthic regions and epipelagic regions. The presentation also showed examples of qualitative ecosystem models identifying important ecosystem components (eg. phytoplankton, squid, turtles), pressures (e.g temperature, fishing) and processes (e.g. predation, competition) in the system.

DISCUSSION

The following main points were made during the discussions:

- The Group noted that the first draft of the Epipelagic Bioregionalization was defined based on oceanographic and biological data using quantitative analysis/modelling and then the boundaries were refined using expert knowledge available in the expert workshop. The Group also noted some missing fisheries/biological data that could be included as long as it becomes available to fine-tune the regions.
- The Epipelagic Bioregionalization by this project was done in a two step process. First, in a 1st Workshop the regions were delineated mostly based on oceanographic characteristics, and during a 2nd Workshop the regions were reviewed using information from tuna fishery experts. However, the resultant regionalization is mostly based on tuna catches and fishery expert advice. The Group noted some inconsistencies in some areas (e.g the northern Indian Ocean was divided into three regions: a western, central and eastern region) which do not depict well the current knowledge of tuna distributions, their fisheries nor the regional oceanography.
- The concept of dynamic boundaries was discussed again, and the Group valued the benefits of having established fixed boundaries, which could be reviewed intermittently to adjust for major oceanographic/biological changes. The Group noted that coastal areas were not identified in this GOBI/CSIRO regionalization which could be a limitation for using it in IOTC as neritic tunas are mostly restricted to coastal waters.

Session 3: Criteria for evaluating ecoregions and the expected qualities of ecoregions that would be appropriate for EAFM implementation in IOTC

PRESENTATION8- Criteria for evaluating ecoregions and the expected qualities of ecoregions that would be appropriate for EAFM implementation in IOTC (Anne-Elise Nieblas, workshop consultant)

This presentation provided an overview of the revised evaluation criteria, which establishes the core principles to define the ecoregions and the expected qualities of ecoregions that would be appropriate to inform EAFM implementation. The presentation showed revised criteria which covered both ecological and socio-political factors following the recommendations of the WPEB14.

The presentation reached the following conclusions:

- The ecological evaluation criteria included the following core principles: oceanography, the spatial distribution of main IOTC species and the spatial distribution of main IOTC fisheries.
- The socio-political evaluation criteria included the following factors: compatibility with other regional initiatives, socio-economic factors, geopolitical factors and management factors. These were presented as additional criteria for potential consideration when defining the ecoregions.
- For each subcriteria, the expected qualities of ecoregions that would be appropriate for the implementation of the EAFM in the IOTC were outlined.
- It was explained how the core evaluation criteria were used to guide the data selection and the quantitative spatial analyses for deriving a baseline proposal of draft ecoregions for IOTC.

DISCUSSIONS

The following main points were made during the discussions:

- In response to the WPEB 2018 recommendation of examining a wider range of factors to be included in the evaluation criteria, the Group agreed that the core ecological criteria should prevail to define ecoregions, as the objective is to have ecoregions that make ecological sense.
- The Group agreed that the socio-political evaluation criteria should not be used to define ecoregions. The Group considered that the socio-political evaluation criteria (i) could be used as “extra considerations” to inform the ecoregions rather than as a necessary criteria to be met by the ecoregions, (ii) that the inclusion of these criteria (i.e., the socio-economic and geopolitical factors) should be considered based on IOTC Commission guidance but not to be a “must” for ecoregion delineation and they can be incorporated in a later process if relevant. As such, socioeconomic/geopolitical factors could be included in the Criteria as optional/informative but not as the core criteria to define ecoregions.
- While the Group agreed not to use the criterion 5.1 socioeconomic factors and criterion 5.2 geopolitical factors to define ecoregions, it noted that socioeconomic factors are to some extent already included in the core criteria as the spatial distribution of fisheries are considered when delineating ecoregions.
- The Group recommended that the criterion 4.1 addressing the compatibility of the ecoregions with other regional bodies should be changed the wording to “optimize linkages” between ecoregions and other existing regional initiatives. The Group noted that SWIOFC might be a relevant organization to look for linkages.
- The Group agreed that any criteria to be included in the delineation of ecoregions or to change boundaries should be **objective, robust and defensible**. Ecoregion delineation should be science-based and pragmatic.

Session 4: An overview of current knowledge and main data layers and their quality to inform the delineation of draft ecoregions

PRESENTATION9 -The physical environment and main oceanographic processes in the Indian Ocean (Francis Marsac, IRD, France)

The presentation gave an overview of the main physical environment and oceanographic process in the Indian Ocean. The presentation showed how the oceanography of the Indian Ocean exhibits specific patterns, which make it different from the two other oceans. The presence of the Asian landmass in the Northern hemisphere creates the monsoon system and a unique wind forcing pattern driving the surface circulation. There is no equatorial upwelling, but a thermocline ridge at 10°S, an upwelling develops in a western boundary current; off Somalia, and among the thickest oxygen depleted zones are located in the enclosed Arabian Sea and Bay of Bengal. The presentation showed different peculiarities by region with their consequences on the biological productivity at the base of the food web.

Three striking features were also detailed in relation to tuna fisheries:

- 1) the Somali upwelling, where FAD tuna catches by purse seiners are gathered in the gyres created off the upwelling core area;
- 2) the Southeast Madagascar bloom which fluctuates under the influence of the ENSO cycle, with a high diversity of pelagic species exploited by longline fisheries; and
- 3) the Mozambique Channel where mesoscale eddies aggregate seabirds and tunas.

The presentation also showed how variable signals in tuna surface fisheries production are also demonstrated at the inter-annual time scale (ENSO and Indian Ocean Dipole) and in the perspective of climate change.

DISCUSSIONS

The following main points were made during the discussions:

- The Group noted how the presentation illustrated both the broad large-scale oceanographic features together with the more regional striking features of the Indian Ocean, and their relationships with tuna catches.
- The Group favored the use of the large-scale oceanographic features to inform the boundaries of ecoregions, yet the local peculiarities should not be put aside of the process, as they could be special features found within the larger ecoregions.
- The Group discussed how climate change aspects can come at a later stage in the process, as ecoregions can be revised later on to account for that when relevant.
- The Group noted how the Longhurst biogeographic classification and Spalding PPOW classification, both being very similar for the Indian Ocean, matched very well with the catches of tunas (both purse seine and long line catches), forming a consistent spatial framework for tuna ecosystems.
- The Group noted how the inter-annual climate variability (e.g. dipole anomalies) might alter the average delineation of provinces (or ecoregions) and how the anomalous years would also need to be taken into account when using ecoregions.

PRESENTATION10 -The main biological and fishery data layers with potential to inform the delineation of draft ecoregions (Anne Elise Nieblas, workshop consultant)

This presentation gave an overview of the main biological and fishery data layers available at IOTC with potential to inform the delineation of draft ecoregions. The data layers examined were:

- 1) a pre-selection of the existing biogeographic classification relevant to IOTC species
- 2) the spatial distributions and co-occurrence of main IOTC species (oceanic tunas and billfishes, neritic species, sharks, other taxonomic groups) based on georeferenced catch data
- 3) the spatial distribution of main life history stages of selected species (e.g. juvenile versus adult distribution) using size frequency data
- 4) the spatial distribution of main IOTC fisheries based on georeferenced catch data to identify their fishing grounds

The presentation showed how each of the data layers were assessed based on their quality, completeness, and availability as to whether they could be included in subsequent spatial analyses to inform the delineation of ecoregions. Missing or inadequate data layers were expected to be further informed by the workshop participants.

The presentation reached the following conclusions:

- The Longhurst, PPOW, and MEOW biogeographic classifications were selected for subsequent spatial analyses as they include both coastal and pelagic provinces (pelagic PPOWs and coastal MEOWs complement one another), capture well the main oceanographic features of the Indian Ocean, have fixed spatial boundaries and a hierarchical classification structure.

- Among all the species data-layers examined, the estimated raised catch data for the five main oceanic IOTC species provided by the IOTC Secretariat were the only data considered to be of good quality and to have a high degree of completeness, and therefore, they were used for subsequent spatial analyses.
- The catch data available at the IOTC Secretariat for neritic tunas and shark species were found to be of low quality and to have a low degree of completeness, and therefore were not included in subsequent spatial analyses.
- The IOTC regional observer data set administered by the IOTC Secretariat was also considered to be of low quality and to have a low degree of completeness in terms of capturing the spatial distribution and the extent of interactions of bycatch species with IOTC fisheries and was not included in subsequent spatial analysis.
- The spatial maps showing the different life history stages of selected species were also not used in subsequent spatial analyses since data were often biased by different selectivity of the gears, not reflecting adequately the spatial distributions of the different size classes.
- The spatial distribution of main IOTC fisheries based on georeferenced catch data used to determine the main fishing grounds were also considered to be of good quality and had a high degree of completeness, and therefore, they were included in subsequent spatial analyses.

DISCUSSIONS

The following main points were made during the discussions:

- Among all **biogeographic classifications**, only the Longhurst, MEOW and PPOW were retained for the spatial analysis. The Group agreed that other available classifications were not suitable for the objective of the ecoregion delineation, as they were either too coastal (LMEs classification) or because of seasonally varying boundaries between ecoregions, making them impractical for management purposes.
- **The Group noted the oceanic species** were well documented, but some issues related to possible species misidentification were noted for swordfish in the North Arabian Sea, which would presumably be marlins instead. However, the oceanic species data layer was considered suitable for the spatial analysis.
- **The Group noted** the distribution of **neritic tunas** (with reported catches for Kawakawa, longtail tuna and Spanish mackerel only) formed a data layer affected by major issues with reporting and statistics. Catch statistics along the East African coast were absent, while it is known that local communities catch and consume neritic tunas on a daily basis. In the North Indian Ocean, catches reported by IOTC Member States (gillnets and other gears) are often not disaggregated by area, so this spatial disaggregation is done by the IOTC Secretariat on the basis of several hypotheses. It was noted that sources of information other than IOTC (e.g. national reports) could be consulted as they likely hold better information on neritics (e.g. the WIOFish data base), however the Group was reminded that the project was designed to be based on IOTC datasets only, at least for the first stage of the project. The Group concluded that the neritic tuna data layer could not be retained for further spatial analyses.
- **The Group noted sharks** were also an underreported species group. It is only during the past 10 years that reporting shark catches became mandatory at the IOTC. The Group recommended that the data from the last five years should be considered for the analyses, rather than the period 2003-2017 initially selected by the consultant. Sharks

species considered as potential data layers were blue shark, silky shark, oceanic white tip and porbeagle shark. For porbeagle, the Group identified misreporting in the tropical region, as this species is only distributed south of 35°S. The Group recommended that the bycatch data set of the IOTC could be used for sharks in order to complement the information of the IOTC catch/effort datasets. For instance, the EU PS fleet has maintained a high observer rate since 2016, with good estimates of shark bycatch, especially for silky shark, which could be used to inform distributions maps. Better shark distribution maps could be obtained from a combination of the data available at IOTC (nominal catches and observer data) coupled with expert knowledge. Provided the uncertainties on the shark IOTC catch and effort dataset, the Group recommended not retaining this data layer for the spatial analysis.

- Different **life history stages** for main IOTC species were examined based on the size frequency data held at the IOTC and found in the peer-reviewed literature. The Group noted it was not possible to distinguish areas that are specific to adults or juveniles. Only albacore displayed a clear spatial pattern for adults and juveniles. Therefore, the partitioning by life cycle stage cannot be retained further.
- The **spatial distribution of major IOTC fisheries** were examined by gear and species, from maps of raised catch data established by the IOTC Secretariat. The Group noted purse seine and longline fisheries (freezers and fresh longline) are well documented as catch and effort statistics are provided by fishing nations according to the standard grid (1°x1° for purse seine and 5°x5° for longline). Purse seiners operate mainly in the Western Indian Ocean whereas longliners have a broader, basin-scale, distribution. Other gears mostly operated by coastal developing countries are seldom reported in the standard grid, and the Secretariat must rebuild spatialized catches using proxies and assumptions. The spatial resolution for gillnet, handline and troll fisheries is then of lower quality compared to purse seine or longline, however they can provide some information for the spatial analysis. However, the spatial distribution of major IOTC fisheries layer was considered suitable for the spatial analysis.
- **Synthesis:** The Group agreed that the ecological data layers to be retained for ecoregion spatial analysis were the species distribution for tropical tunas (YFT, BET, SKJ), albacore and swordfish. The fisheries distribution for all gears was also retained. However, because of biases and incompleteness, the data layers corresponding to neritic tunas, sharks, bycatch species, as well as life history distributions cannot be considered further for the analyses.

PRESENTATION11 -A closer view to the distribution and dynamics of IOTC coastal fisheries and species (Umair Shahid and Marcel Kroese, WWF)

This presentation introduced the characteristics of Pakistan gillnet catch collected by five crew observers from four vessels which had the longest period of data collection (five years). By the end of the 5-year period, the total number of crew observers who have participated were 75, having more than 10% coverage of the fleets. The paper provided data on four participating vessels from the observer program of the approximately 700 tuna targeting gillnet vessels in Pakistan. The Pakistan gillnets are operating within its EEZ and majority of catch is sent to Iran for canning. The presentation showed 70% of catch was composed of tunas, and the remaining 30 % of sharks and other fish species, but occurrence of manta, rays, sea turtle and marine mammals were rare (less than 0.1% of total catch). There are two gear settings operating in the Pakistan fishery, one sets at the surface and the other is submerged at 2m depth below the surface. Subsurface sets catch more yellowfin, skipjack, kawakawa, frigate and bullet tunas and mobulids than surface sets, while longtail tuna, queen fish, sharks, cetaceans, and sea turtles are caught

more in surface sets. There was significant lower by-catch of sharks observed in the sub surface gillnets during the five years of observation, in addition to cetaceans.

DISCUSSIONS

The following main points were made during the discussions:

- The Group noted that the gillnet fisheries are widely operated in coastal areas throughout the Indian Ocean from South Africa, Tanzania, Zanzibar, Kenya, Iran, Pakistan, India, and Thailand, though Iran and Pakistan are considered the two major producers.
- The Group also noted trawl fishery operations along the coast of Kenya, Thailand, and Indonesia, as well as small purse seine and handline fisheries are taking large quantity of oceanic tunas, including yellowfin, bigeye, and albacore, including many juveniles.
- Considering the amount of yellowfin catch observed in Pakistan gillnets, the coastal fisheries seems to take a substantial component of oceanic tuna catch, even though they are not well represented in the official statistics.
- The spatial resolution of fisheries statistics for gillnet remain of low quality compared to other fisheries such as purse seine or longline.

PRESENTATION12 -Distribution and ecology of seabirds & their spatial interactions with IOTC fisheries (Anton Wolfaardt, ACAP)

This presentation provided an overview of the distribution and ecology of seabirds and their interactions with IOTC fisheries. There are two types of interactions between fisheries and seabirds within the IOTC. The first is a direct interaction, involving bycatch by longline fisheries operating in the southern area. The other is an indirect one, involving indirect competition for prey. Many tropical seabirds associate with subsurface predators, such as tuna and billfish, which drive forage fish to the surface where they become available to the seabirds. Reductions in the biomass of these subsurface predators may lead to a reduced availability of forage fish to seabirds foraging at the surface. The latter would be more relevant in the tropical areas.

The presentation reached the following conclusions:

- Seabird bycatch by longline fisheries operating occur mainly in the southern area of the Indian Ocean.
- The indirect competition for prey in the tropical areas has not been well documented in the Indian Ocean, although a recent study has highlighted the potential scale of the interaction in the Western Indian Ocean.
- Seabird bycatch associated with gillnets is considered a major threat to diving seabirds in other oceans, yet it has not been studied/reported in the Indian Ocean.

DISCUSSIONS

The following main points were made during the discussions:

- For the purpose of the delineation of eco-regions, the Group suggested that seabirds could be considered at a relatively coarse scale, even though interactions can be characterized at finer scales, e.g. hot spots areas have been identified and investigated.
- The area of application of IOTC's seabird conservation measure (Resolution 12/06) provides a good basis to broadly consider seabird issues within IOTC in relation to the delineation of ecoregions (i.e. south and north of 25°S).
- The distribution of seabirds, and particularly albatrosses and petrels, has been well investigated in particular through satellite tracking, and although data gaps and biases

exist, these data are very useful for informing processes considering risks and management associated with seabird bycatch. The Group was informed about the ongoing efforts to fill data gaps and facilitate regular access of integrated tracking data to assist with the assessment of seabird mortality caused by interaction with fisheries.

- The Group noted how many of the marine Important Bird and Biodiversity Areas (IBAs) that have been identified show linkages with existing bioregion boundaries as well as key oceanographic features.

PRESENTATION13 -Distribution and ecology of sea turtles & their spatial interactions with IOTC fisheries (Mayeul Dalleau, CEDTM, La Réunion)

This presentation provided an overview of the spatial ecology of marine turtles crossing the French EEZ of the Indian Ocean, with a focus from a long-term collaboration with Reunion Island longline fisheries. Five of the seven species of sea turtles are found in the western Indian Ocean. The presentation showed how regional management units have been established for each sea turtle based on their nesting sites, abundance and trends, genetics, satellite telemetry and core distributions. It also showed global bycatch patterns of sea turtle interactions with major fishing gears (longline, nets and trawls). Last, it presented how a combination of genetics, satellite tracking, modelling and isotope analysis suggest a juvenile developmental cycle for loggerhead sea turtle at whole Indian Ocean basin scale.

DISCUSSIONS

The following main points were made during the discussions:

- The Group noted that the spatial dynamics and distribution of sea turtles in the Indian Ocean is complex and how this information should not be used for the purpose of delineating the ecoregions. Instead it was noted that once established, ecoregions could be used to characterize sea turtle dynamics and fisheries interactions on a regional basis at the ecoregion level.
- The Group noted how the bycatch groups such as sea turtles, cetaceans and seabirds could be the “end users” of the ecoregions, and not used as major data inputs to inform the delineation of ecoregion boundaries.

PRESENTATION14 - “Other” relevant data layers with potential to inform the delineation of draft ecoregions (Anne Elise Nieblas, workshop consultant)

This presentation gave an overview of data layers covering relevant socio-political processes and its objective was to inform discussions at the workshop to evaluate how the socio-political criteria presented in Session 3 could also contribute in the delineation of draft ecoregions. The presentation showed how the IOTC convention area overlaps with other RFMOs/RFBs (SWIOFC, SIOFA, CCSBT) and other regional processes (e.g. CBD designation of EBSAS). The presentation showed the difficulties of mapping and creating layers with socio-economic information from IOTC fisheries and countries. It also showed some layers with geopolitical information and presented examples of territorial disputes in the western Indian Ocean.

The presentation reached the following conclusions:

- While these socio-economic and political data layers prepared in this study were not included in subsequent spatial analyses, the workshop participants were asked to examine what type of socio-economic and geopolitical information should or should not be considered in these types of analyses in the future, and how this information, if relevant, could be used to inform and refine the delineation of draft ecoregions.

DISCUSSIONS

The following main points were made during the discussions:

- The Group had already discussed the relevance on the socio-political Criteria to inform the delineation of ecoregion in Session 3. It was noteworthy that the inclusion of socio-economics and political criteria was only noted (and not recommended) by the WPEB14. It was discussed how the socio-economic dimension in IOTC fisheries as part of the EAFM is not yet implemented in IOTC, yet a scoping study of socio-economic aspects is under development (Res 18/09). However, this study was not available when conducting this analysis, so its potential usefulness for this work could not be evaluated.
- The Group noted that the inclusion of diverse fishing gears and fleets that represent a mix of industrial, semi-industrial, and artisanal fisheries as part of the core ecological criteria already addressed the human component and incorporates to some extent some of the diversity of the socio-economics of the IOTC fleets into the definition of the ecoregions. The Group also noted that by including the MEOW classification, which cover the EEZs of coastal states, into the spatial analysis, was also indirectly bringing a social layer into the analysis.
- The Group again noted that fishing countries operating in the same region may not share the same range of socio-economic and political attributes, and for such reason, concluded that those attributes cannot be included in the definition of ecoregions. Nevertheless, there is still a possibility that economic and political factors be handled when impact and ecosystem assessments are performed by region/ecoregion if requested.

Session 5: Derivation of baseline proposal of ecoregions for IOTC

Several spatial analyses were conducted as part of the pre-workshop analysis to derive a baseline draft proposal of ecoregions to support EAFM implementation in IOTC. These analyses were presented in three steps at the workshop:

- 1) A basic spatial overlapping analysis with the purpose of selecting a final biogeographic classification to base all subsequent spatial analysis,
- 2) A specificity and fidelity indicator analysis that measures the association of individual species and fisheries with the selected biogeographic classification
- 3) A hierarchical clustering analysis to group biogeographic provinces according to their degree of similarity based on the species and fishery-specific indicators.

These spatial analyses were based on the ecological data layers identified to be of “good” quality under Session 4.

PRESENTATION15 -spatial analysis step 1 – A selection of biogeographic classification (Ane-Elise Nieblas, workshop consultant)

The presentation provided an overview of the spatial overlapping analysis, which examined the degree of overlap between pre-selected biogeographic classifications (i.e., Longhurst, PPOWs, and MEOWs) and the spatial distribution of the five IOTC oceanic tuna and billfish species and the fisheries targeting them. The distribution of neritic species was implicitly represented by the inclusion the coastal MEOW biogeographic classification.

The presentation reached the following conclusions:

- After a qualitative examination of the species data layers and their overlap with the pre-selected biogeographic classifications, a combination of PPOWs and MEOWs classification was selected as they best represent and cover the distribution of coastal and oceanic IOTC species and the fisheries targeting them.
- The combined classification was also selected because MEOWs specifically include the EEZ of islands in the Indian Ocean, unique in terms of both species and fisheries compositions, and they are not considered in other biogeographic classifications.
- The combined MEOW and PPOW classification scheme resolve to 24 provinces in the IOTC convention area.

DISCUSSIONS

The following main points were made during the discussions:

- The Group noted the Spalding PPOW classification represents well the major oceanographic features of the Indian Ocean and matches well with the main distribution of oceanic tunas and fisheries targeting them
- The coastal MEOW classification (with their spatial representations as polygons covering the EEZs of coastal countries and islands) covers well the IOTC coastal species and fisheries and therefore it can be used as a proxy of their spatial distributions.
- The Group also suggested that instead of using the biogeographic classifications as proxies of major oceanographic patterns, the raw oceanographic data (e.g. climatologies of sea surface temperature, sea surface height, chlorophyll-a, etc...) could have also been used to inform the delineation of ecoregions. It was explained, that while it was originally discussed as an option, it was decided to build on existing biogeographic classification which at the end have also been derived using the raw oceanographic datasets.

PRESENTATION16 -Spatial analysis step 2 – Specificity-fidelity indicators to characterize the species and fisheries composition of biogeographic provinces (Ane-Elise Nieblas, workshop consultant)

The presentation described the specificity-fidelity indicator (SF indicator), which is an indicator that characterizes the association of each species and type of fishery to each biogeographic province (Dufrene & Legendre 1997; Reygondeau *et al.* 2012). This SF indicator is the product of two indices: specificity and fidelity. Specificity is a measure of how much a species associates with a province, or a representation of its “preference” of one province over others. Fidelity is a measure of how broadly a species is found (caught) within a province. The product of specificity and fidelity gives the SF Indicator and provides a species community and fisheries makeup of that province. SF indicators were calculated for (i) species and (ii) fisheries.

The presentation reached the following conclusions:

- Each of the MEOW-PPOW provinces show different patterns in their SF Indicators, but some clear groupings can be made.
- A quantification of the extent of these similarities can be used to group provinces and therefore reduce the final number of provinces in the IOTC convention area to a practical number of ecoregions.

DISCUSSIONS

The following main points were made during the discussions:

- The Group suggested a number of ways the SF indicator figures could be improved to increase interpretability. For example: (1) rescaling and fixing the y axis from 0 to the max value of the indicators, and (2) grouping tropical vs temperate species or grouping similar types of fisheries with the same color coding to increase interpretability.
- How the specificity-fidelity indicators are estimated were not well understood and the Group spent considerable time understanding the methods. There was some disagreement about the methods used for estimating this indicator. The Group suggested the following refinements and considerations for improving the indicator analysis:
 - The Group suggested assessing the **temporal and spatial heterogeneity/homogeneity of provinces** and exploring its effect on the interpretation of the indicators and subsequent clustering analyses. For example, changes in the spatial distribution of species might be due to reporting or fleet operations and not species presence/absence.
 - In reference to the **fisheries-based specificity indicator**, the Group suggested to group the fisheries by gear type (e.g. coastal fisheries, high seas longline fisheries, high seas purse seiner fisheries) to help differentiate coastal vs high sea fisheries by region in the analysis and improve visualization of the results. The Group also suggested attempting to differentiate between longline fisheries setting deep and setting shallow since they might operate in different fishing grounds and target different species, which might help in the delineation of ecoregions.
 - In reference to the **fidelity indicator**, there were some opinions that the fidelity indicator as it is calculated now (based on presence/absence approach) is not very informative. The potential high correlation between the fidelity value of a province and the province size (number of pixels of the province) could be a problem since small provinces might have a higher chance of getting a high fidelity value. The Group suggested checking the relationship between the size of the province and their fidelity values to assess the validity of the methods to calculate this indicator.
 - In reference to the **fidelity indicator**, the Group also suggested examining the potential of using thresholds to evaluate the inclusion or exclusion of pixels into the calculation of the fidelity indicator. It was suggested exploring a threshold (1) based on the relative catches in each pixel to discards those pixels with very small catches or (2) based on the total number of years a species is found to occur in each pixel or the number of years a particular pixel is fished to discard those pixels where species or fisheries are rarely found.

PRESENTATIONS -Spatial analysis step 3 – Hierarchical clustering and proposal of baseline draft ecoregions (Ane-Elise Nieblas, workshop consultant)

The presentation provided an overview of the hierarchical clustering analysis performed on the SF Indicators for each province based on 1) their species composition (SF based on species), 2) fisheries composition (SF based on fisheries) and 3) species and fisheries composition combined. The resulting clusters were used to delineate the baseline draft ecoregions for IOTC, which were presented to the workshop participants for discussion and further refinement.

The presentation reached the following conclusions:

- Overall, the first-order clustering of the provinces based on their species composition, fisheries composition, and a combination of both species and fisheries composition all gave roughly similar results indicating three major groupings: a large northern oceanic

cluster of provinces, a large southern oceanic cluster with the inclusion of some bordering coastal provinces, and a smaller central coastal cluster including coastal areas bordering the northern Indian Ocean.

- The second-order clusters were more variable across the analyses performed in how the coastal areas were subdivided.
- In general, the large northern oceanic cluster is primarily dominated by purse seine fisheries catching tropical tunas (SKJ, YFT and BET) and secondarily dominated by longline fisheries catching also tropical tunas (BET and YFT) and some SWO; the southern oceanic cluster is dominated by longline activity catching temperate ALB and SWO; and the coastal clusters represent a diverse mix of both fisheries activities and species communities.

DISCUSSIONS

The following main points were made during the discussions:

- The **cluster analyses using the specificity and fidelity indicators** calculated based on the species composition by province, the fisheries composition by province, and both, were presented and discussed by the Group. The Group discussed whether both indicators (the specificity and fidelity indicators) should be used (or not) to describe the species composition and fisheries composition of each province, and later used to inform the clustering analyses.
- Some Group members suggested to use only the specificity indicator to describe the species composition, and only the fidelity indicator (with the modifications suggested by the Group) to describe the fishery composition of each province, and combine them for subsequent clustering analysis. Other Group members suggested exploring both the sensitivity and fidelity indicators (with the modifications suggested by the Group) to characterize the composition of species and fisheries by province, and looking at their different combinations and their effects on the clustering of provinces (similar to a sensitive analysis).
- The Group also suggested assessing the **temporal and spatial heterogeneity/homogeneity** of the resultant defined clusters (potential ecoregions). The more homogeneous a cluster group is the more confident it forms a unique group.

The Group suggested to **explore both first order and second order clustering cuts** to interpret the clustering results.

- The Group valued the clustering of provinces based on their species/fisheries similarities since it provides examples of type of outputs/potential ecoregions to be considered by the Group. The clustering outputs can be used as a starting point for discussions and adjustments based on expert knowledge (see Session 7).

Session 6 and 7: Wrap up session including the refinement of the baseline proposals of ecoregions based on expert knowledge

The Group decided to use the third day of the workshop to address the following three topics: (1) the potential benefits and uses of the ecoregions in the context of IOTC, (2) refinement of the core process from criteria to main data inputs and methods to inform the ecoregion delineation, (3) evaluation of the baseline proposal of ecoregions derived from the quantitative spatial analysis against the core criteria using expert judgement, and (4) future steps.

Topic 1 -Potential uses and benefits of using ecoregions in the context of IOTC

The following main points were made during the discussions:

- While the IOTC mandate does not have a clear ecosystem vision, the Group noted ecosystem considerations are becoming increasingly important and are part of FAO mandate of which IOTC is a part. Ecoregions could be used as a tool to better structure ecosystem considerations and advice. The Group noted the use of ecoregions to structure advice is not a revolutionary idea since it does not impose a new management system on managers, and it does not impose additional burdens in terms of resources or new data collection or monitoring. The Group suggested the importance of reassuring that the use of ecoregions to structure ecosystem-based advice is not going to change the status quo, and instead the focus should be on showing the potential benefits of using them.
- The Group noted that there are some benefits in starting the process of developing ecoregions as a bottom up approach (without the explicit request from the Commission). It was noted ecoregions could be used to better promote communication at the Scientific Community level and between the Scientific community and Managers (e.g. in the Technical Committee on Management Procedures). Ecoregions could be used to improve communication of regional issues to managers since it can inform scientists and guide management advice without completely changing current practices.
- The Group noted the process of developing ecoregions is a work in progress which needs to be further developed and tested as a tool. It acknowledged the importance of sharing the process of developing the ecoregions with the WPEB and the rest of the Scientific Committee to seek engagement and feedback on the process. It recommended carefully building the message and rationale of potential uses and benefits of ecoregions before these results are conveyed to the rest of the Scientific Community and managers.
- The Group suggested that the benefits of this process need to be carefully packaged and presented to managers. It should be kept very simple and informative at this stage, without trying to push through anything definitive.
- The Group suggested following examples of other regions, such as those discussed during this workshop on how ecoregions are used to better structure ecosystem-based advice, for example, developing regional reports on ecosystem considerations, ecosystem report cards, etc... using as an example the resultant ecoregions agreed in the WS.

Topic 2- Suggestions for refining the core process from criteria, main data inputs to methods to inform the ecoregion delineation

The following main points were made during the discussions:

- The Group agreed on the approach presented by the consultant to select the input datasets for ecoregion delineation based on their data quality, completeness, and availability. The input data for the current ecoregion analysis (biogeographic classifications, IOTC georeferenced catches by species and fisheries) was generally accepted. Yet the Group acknowledged the value of continuing using expert knowledge to refine the main inputs and address misclassification and errors in catch data.
- There are significant coastal catches that are not officially reported to the IOTC, and while national datasets could be used to fill these gaps and local experts could provide feedback on this information, the Group noted that it would be difficult to compile these coastal datasets and expert knowledge for the purpose of defining the ecoregions. Instead, a layer of the EEZ (as used in the MEOW classification) could be used as a proxy to account for coastal species/fisheries into the analysis.
- The Group suggested to keep exploring how the bycatch groups of seabirds, sea turtles and marine mammals can inform the delineation of ecoregions. Some Group members

did not view these taxa groups as important in informing ecoregion boundaries, and instead considered these taxa groups as the “end users” of the ecoregions, since bycatch assessments could be done at the ecoregion level.

- The Group also agreed largely on the methods presented by the consultant to derive the first baseline ecoregion which were based on two major steps, calculation of SF indicators to characterize the species and fishery composition of each province, and the clustering of provinces based on the SF indicators. However, the Group suggested a number of refinements on the methods (which have been summarized in Section 5) which should be explored and tested.
- The Group favored the use of quantitative methods to derive a first approximation of how ecoregions would look based on the input data, which should be coupled with expert knowledge to refine the boundaries.
- The Group recommended that expert decisions/refinements on the data inputs, methods and results need to be carefully documented at every step, similar to the process of conducting single stock assessments for IOTC species.

Topic 3-Evaluation of baseline proposal of ecoregions against the criteria using expert judgement

Anne Elise Nieblas, the workshop consultant, presented to the Group a revised version of the specificity and fidelity indicators and clustering analysis of the provinces. Three cluster analyses were presented, one based on the species composition of the provinces, another based on their fisheries composition and the last based on both the species and fisheries composition of the provinces (Figure 1). Following the suggestions from the Group, the revised version included a small correction on how the species-based specificity indicator was estimated for each province and some figure modifications.

The Group evaluated the revised specificity and fidelity indicators and resulting clustering analyses, and derived a draft ecoregion based on expert knowledge (Figure 2).

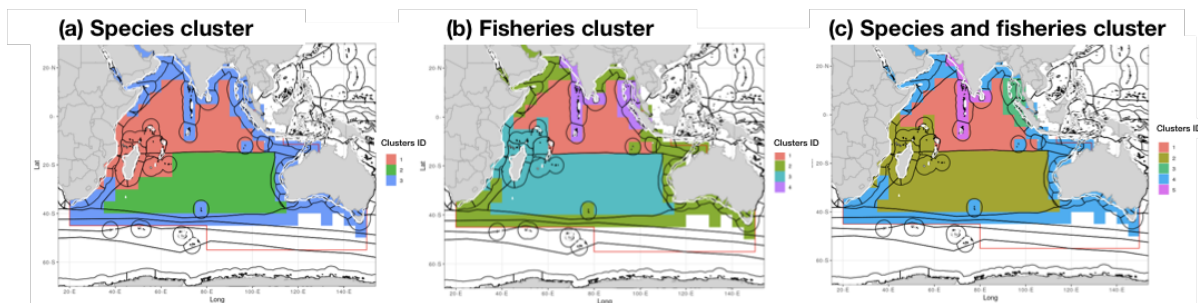


Figure 1. Highest order clusters (colored polygons) resulting from the hierarchical cluster analysis of the MEOW and PPOW provinces using specificity-fidelity indicators (a) based on the species composition of the provinces, (b) based on fisheries composition of the provinces and (c) based on both species and fisheries composition of the provinces. Details on the provinces and associated clusters can be found in Nieblas *et al.* 2019.

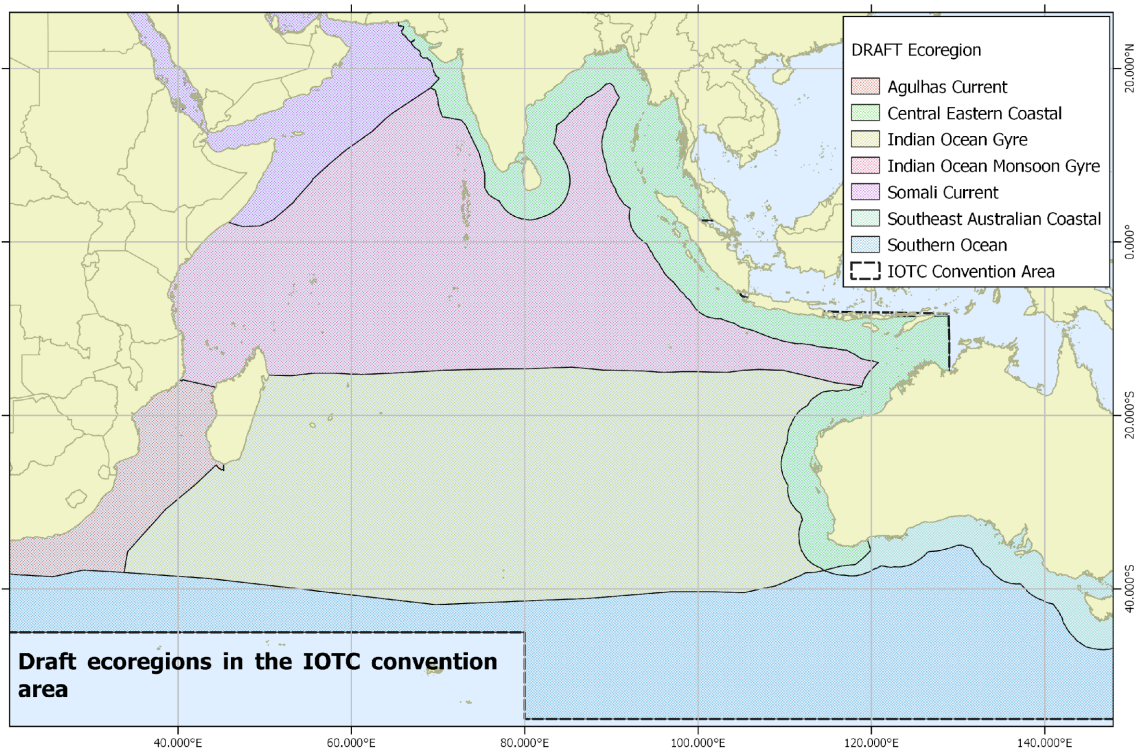


Figure 2. Draft ecoregions delineated within the IOTC convention area. These regions were informed by quantitative analysis of the MEOW and PPOW provinces and their species and fisheries compositions coupled with expert knowledge.

The following points summarize the main discussions and the rationale in refining the cluster groupings into draft ecoregions (figure 2) based on expert knowledge:

- The Group used the clusters (figure 1) as a starting point for discussions and adjustments based on expert knowledge. While there was not sufficient time to discuss thoroughly many of proposed refinements and the strengths and weaknesses of each clusters/ecoregions against the evaluation criteria, the Group decided to derive a quick draft of the ecoregions within the IOTC convention area. The Group acknowledged the positive value of having a preliminary product which could be used to better communicate the process of deriving and using ecoregions to the rest of the IOTC community.
- The Group suggested and discussed the following refinements for the cluster groups to derive **seven draft ecoregions** with the IOTC convention area (Figure 2):
 - The Group noted that the three clustering analyses (Figure1) tended to differentiate multiple coastal provinces from the northern oceanic province (Northern Indian Ocean Monsoon Gyre) and the southern oceanic province (Southern Indian Ocean Gyre). Each cluster analysis grouped the coastal provinces into slightly different groups.

- The Group favored the division of the oceanic waters into three distinct ecoregions, the northern **Indian Ocean Monsoon Gyre Ecoregion**, the southern **Indian Ocean Gyre Ecoregion**, and the **Southern Ocean Ecoregion**. This decision was made based on the distinct species and fisheries composition in these three provinces.
- The Group also noted that the clustering of the pre-existing classification (PPOW – MEOW) forces some provinces to be in one region or another, when expert advice would suggest splitting them or assigning them to another region. The Group divided the Western Indian Ocean provinces (MEOW province around Madagascar Island) and merged different areas with the neighboring ecoregions (with the northern Indian Ocean Monsoon Gyre, the southern Indian Ocean Gyre, and the Agulhas Current ecoregions). This decision was made based on the observations that the Western Indian Ocean provinces clustered with the Northern Indian Ocean Monsoon Gyre in the species-driven clustering analysis (Figure 1a), and clustered with the Southern Indian Ocean Gyre in the fisheries and species-fisheries-driven clusters. This incongruity arises because there are clear differences in terms of species composition and type of fisheries operation within Western Indian Ocean provinces which do not make it an independent, homogeneous province.
- The Group merged the Central Indian Ocean Islands (MEOW province around the Maldives and Chagos Island) with the neighboring oceanic ecoregion (Northern Indian Ocean Monsoon Gyre). This decision was made since the species and fisheries around these islands are considered oceanic, similar to the species and fisheries characterizing the Northern Indian Ocean Monsoon Gyre.
- The Group also favored the Agulhas Current PPOW and the Somali Current PPOW as two distinct ecoregions (The **Agulhas Current Ecoregion** and the **Somali Current Ecoregion**), since they are characterized by unique oceanographic features and associated species and more coastal fisheries.
- The Group decided to group the remaining coastal provinces expanding from the coast of Pakistan all the way to western Australia in the **Central Eastern Coastal Ecoregion**, and the **Southern Australian Coastal Ecoregion**. This decision was made based on the cluster groups and expert knowledge indicating unique coastal fisheries in these regions.

OVERARCHING CONCLUSIONS AND FUTURE STEPS

- The Group acknowledged the most important output of this workshop was the constructive and technical discussions that took place in framing the general **process of ecoregion delineation**, from defining a check list evaluation criteria, to evaluate data inputs and methods, and examining and refining candidate ecoregions based on expert knowledge within the Indian Ocean (Figure1).
- This process resulted in a **proposal of seven draft ecoregions within the IOTC convention area** (Figure 2).
- The draft ecoregions are **not intended to be used for management purposes**. The draft ecoregions aim to be a tool to better structure ecosystem considerations and advice to inform fisheries management. This will also allow further work on these draft ecoregions with a bottom-up approach to learn what is needed to develop the implementation of EAFM in the IOTC region

- At this stage, **the benefits and potential uses** (e.g. development of ecosystem report cards, ecosystem status overviews, etc.) of the draft ecoregions **should be tested** as a tool to facilitate the work of the WPEB and assist the operationalization of the EAFM in IOTC.

The following main **recommendations were also made to the WPEB**:

- The Group requests that the WPEB review and comment on the delineation of the draft ecoregions and provide ongoing feedback.
- The Group requests to the WPEB to communicate with the rest of the WPs to solicit feedback on the draft ecoregions.
- The Group recommends that the WPEB endorse the draft ecoregions for further development as a tool to progress EAFM implementation (e.g. ecosystem report card, ecosystem overviews, fisheries overviews).

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APPENDIX 1. LIST OF PARTICIPANTS

| Participant name | Affiliation | Email |
|---|--|--|
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APPENDIX 2. WORKSHOP AGENDA AND RAPORTEURS

Workshop Details

“IDENTIFICATION OF REGIONS IN THE IOTC CONVENTION AREA TO INFORM THE IMPLEMENTATION OF THE ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT”

La Reunion Island, 30th,31st August and 1st of September 2019

1. VENUE

The meeting will take place at the Tamarun Seminar Venue, located 8 Rue Des Argonautes at La Saline-Les Bains (97434), a seaside village on the west coast of La Reunion Island.

2. TENTATIVE AGENDA

| SESSION | TIME | RAPORTEURS |
|---|--------------------|----------------------|
| FRIDAY, 30TH AUGUST | | |
| WELCOME SESSION | 9:00-9:30 | |
| <ul style="list-style-type: none">● Welcome (Hilario Murua)● Main objectives and expected outputs● Logistics● Agenda● Background information -why are we here? (Maria José Juan Jordá) | | <i>PAUL DE BRUYN</i> |
| SESSION 1: BENEFITS AND CURRENT USES OF PELAGIC REGIONALIZATIONS IN SUPPORT OF EAFM IMPLEMENTATION – WORLD CASE STUDIES | 9:30-10:30 | <i>PAUL DE BRUYN</i> |
| <ul style="list-style-type: none">● ICES insights, development and use of ecoregions to support EAFM implementation (Marc Dickey Collas)● NPFMC insights, development and use of ecoregions to support EAFM implementation (Maria José Juan Jordá)● CCAMLR insights, development and use of ecoregions to support EAFM implementation (Philippe Koubbi) | | |
| COFFEE BREAK | 10:30-11:00 | |

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|---|--------------------|--|
| SESSION 1: CONTINUATION | 11:00-11:30 | |
| <ul style="list-style-type: none"> ● NAFO insights, development and use of ecoregions to support EAFM implementation (Pierre Pepin) ● Panel discussion ---Potential uses of ecoregions, best practices, good properties and principles for guiding regionalizations | | |
| SESSION 2: EXISTING PELAGIC BIOGEOGRAPHIC CLASSIFICATIONS IN THE INDIAN OCEAN | 11:30-12:30 | HILARIO MURUA |
| <ul style="list-style-type: none"> ● An overview of existing marine pelagic biogeographic classifications relevant to the Indian Ocean and their relevance for tuna and tuna-like species (Anne Elise) ● A marine bioregionalization for the Indian ocean (Donna Hayes) | | |
| LUNCH | 12:30-14:00 | |
| SESSION 3: CRITERIA FOR EVALUATING ECOREGIONS AND THE EXPECTED QUALITIES OF ECOREGIONS THAT WOULD BE APPROPRIATE FOR EAFM IMPLEMENTATION IN IOTC | 14:00-15:00 | HILARIO MURUA |
| <ul style="list-style-type: none"> ● Criteria for evaluating ecoregions and the expected qualities of ecoregions that would be appropriate for EAFM implementation in IOTC (Anne Elise) | | |
| SESSION 4: AN OVERVIEW OF CURRENT KNOWLEDGE AND MAIN DATA LAYERS AND THEIR QUALITY TO INFORM THE DELINEATION OF DRAFT ECOREGIONS | 15:00-15:30 | FRANCIS MARSAC, DONNA HAYES, SACHIKO TSUJI, MARCEL KROESE |
| <ul style="list-style-type: none"> ● The physical environment and main oceanographic processes in the Indian ocean (Francis Marsac) ● The main biological and fishery data layers with potential to inform the delineation of draft ecoregions (Anne Elise) | | |
| COFFEE BREAK | 15:30-16:00 | |
| SESSION 4: CONTINUATION | 16:00-17:30 | |
| <ul style="list-style-type: none"> ● A closer view to the distribution and dynamics of IOTC coastal Fisheries and species (Umair Shahid and Marcel Kroese) | | |

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|--|--------------------|-----------------------|
| <ul style="list-style-type: none"> ● Distribution and ecology of seabirds & their spatial interactions with IOTC fisheries (Anton Wolfaardt) ● Distribution and ecology of sea turtles & their spatial interactions with IOTC fisheries (Mayeul Dalleau) | | |
| SATURDAY, 31ST AUGUST | | |
| SESSION 4: CONTINUATION | 9:00-10:30 | |
| <ul style="list-style-type: none"> ● “Other” relevant data layers with potential to inform the delineation of draft ecoregions (Anne Elise) | | |
| SESSION 5: DERIVATION OF BASELINE PROPOSAL OF ECOREGIONS FOR IOTC | | MARIA JOSE JUAN JORDA |
| <ul style="list-style-type: none"> ● Spatial analyses to develop a baseline proposal of ecoregions to support EAFM implementation in IOTC (Anne Elise) | | |
| <i>COFFEE BREAK</i> | <i>10:30-11:00</i> | |
| SESSION 5: CONTINUATION | 11:00-12:30 | |
| <ul style="list-style-type: none"> ● Session 5 discussion | | |
| <i>LUNCH</i> | <i>12:30-14:00</i> | |
| SESSION 6: EVALUATION OF BASELINE PROPOSAL OF ECOREGIONS AGAINST THE CRITERIA | 14:00-15:30 | PAUL DE BRUYN |
| <ul style="list-style-type: none"> ● Breakout group exercise to evaluate the baseline proposal of ecoregions against the criteria and propose refinements | | |
| <i>COFFEE BREAK</i> | <i>15:30-16:00</i> | |
| SESSION 6: CONTINUATION | 16:00-17:00 | |
| <ul style="list-style-type: none"> ● Continuation break-up group exercise | <i>1 HOURS</i> | |
| SUNDAY, 1ST SEPTEMBER | | |
| SESSION 6: CONTINUATION | 9:00-10:30 | |

| | | |
|---|--------------------|---|
| <ul style="list-style-type: none"> ● Presentations from the break-up groups & discussion | 1 HOURS | |
| <i>COFFEE BREAK</i> | 10:30-11:00 | |
| SESSION 6: CONTINUATION | 11:00-12:30 | |
| <ul style="list-style-type: none"> ● Presentations from the break-up groups & discussion | 1.5 HOURS | |
| <i>LUNCH</i> | 12:30-14:00 | |
| SESSION 7: SYNTHESIS AND FUTURE STEPS | 14:00-15:30 | PAUL DE BRUYN, MARIA JOSE JUAN JORDA |
| <ul style="list-style-type: none"> ● Synthesis break-up group discussions ● Lessons learned ● Future steps | | |
| <i>COFFEE BREAK</i> | 15:30-16:00 | |
| SESSION 7: CONTINUATION | 16:00-17:00 | |

3. BACKGROUND MATERIALS

Some background reading has been placed in the following dropbox folder link that might be useful to participants:

<https://www.dropbox.com/sh/8sh2inkkwnjmrp6/AACowx-JOBZYAHWQqU9JrXGda?dl=0>