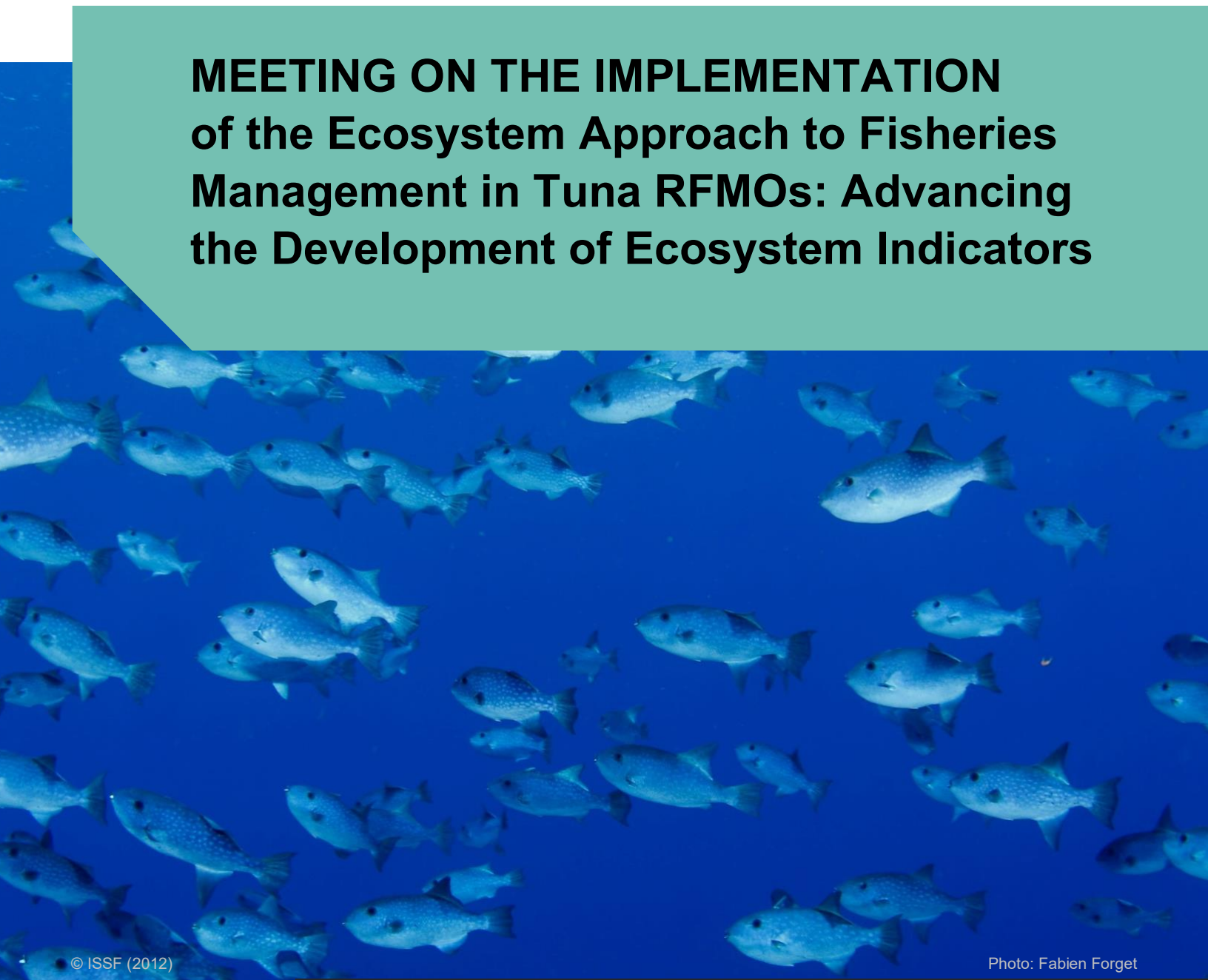


MEETING ON THE IMPLEMENTATION of the Ecosystem Approach to Fisheries Management in Tuna RFMOs: Advancing the Development of Ecosystem Indicators



© ISSF (2012)

Photo: Fabien Forget

H. Murua, S. Nicol, A. Wright, B. Fulton, M.J. Juan-Jordá, E. Andonegi, J. Lopez, D. Crear, L. Fuller, J. Hampton, A. Bundy, N. Hill, J. Potts, J. Meléndez-Arteaga, R. Amate, C. Bulman, V. Allain, V. Odongo, M. Gillespie, K. Sainsbury / **July 2026**

Suggested citation:

H. Murua, S. Nicol, A. Wright, B. Fulton, M.J. Juan-Jordá, E. Andonegi, J. Lopez, D. Crear, L. Fuller, J. Hampton, A. Bundy, N. Hill, J. Potts, J. Meléndez-Arteaga, R. Amate, C. Bulman, V. Allain, V. Odongo, M. Gillespie and K. Sainsbury. 2026. Meeting on the Implementation of the Ecosystem Approach to Fisheries Management in Tuna RFMOs: Advancing the Development of Ecosystem Indicators. ISSF Technical Report 2026-05. International Seafood Sustainability Foundation, Pittsburgh, PA, USA

Topic Categories: EAFM, fisheries management, RFMOs, marine ecosystem

Abstract

The workshop on “Implementation of the Ecosystem Approach to Fisheries Management in Tuna RFMOs: Advancing the Development of Ecosystem Indicators,” held at SPC in Noumea (New Caledonia) from 2–6 March 2026, brought together experts from tuna Regional Fisheries Management Organizations (tRFMOs) and partner institutions to advance the development and application of ecosystem and climate indicators in support of an Ecosystem Approach to Fisheries Management (EAFM) in tRFMOs.

Author Information

Hilario Murua | **ISSF** | hmurua@iss-foundation.org
Simon Nicol | **SPC** | simonn@spc.int
Andrew Wright | **SPC** | drewwright_1@yahoo.com
Beth Fulton | **CSIRO** | beth.fulton@csiro.au
Maria José Juan-Jordá | **IEO-CSIC** | mjuan.jorda@ieo.csic.es
Eider Andonegi | **AZTI** | eandonegi@azti.es
Jon Lopez | **IATTC** | jlopez@iattc.org
Dan Crear | **IATTC** | dcrear@iattc.org
Leanne Fuller | **IATTC** | lfuller@iattc.org
John Hampton | **Consultant** | JohnH@spc.int
Alida Bundy | **DFO Canada** | alida.bundy@dfo-mpo.gc.ca
Nick Hill | **SPC** | nickh@spc.int
Joanne Potts | **SPC** | joannep@spc.int
Josu Meléndez-Arteaga | **AZTI** | jmelendez@azti.es
Roger Amate | **AZTI** | ramate@azti.es
Cathy Bulman | **Consultant** | cathy.bulman@gmail.com
Valerie Allain | **SPC** | valeriea@spc.int
Victor Odongo | **SPC** | victoro@spc.int
Max Gillespie | **FFA** | max.gillespie@ffa.int
Keith Sainsbury | **Consultant** | ksainsbury@outlook.com

July 2026

The research reported in the present Technical Report was funded by the International Seafood Sustainability Foundation (ISSF) and conducted independently by the author(s). The report and its results, professional opinions, and conclusions are solely the work of the author(s). There are no contractual obligations between ISSF and the author(s) that might be used to influence the report's results, professional opinions, and conclusions.

The International Seafood Sustainability Foundation (ISSF) — a global coalition of seafood companies, fisheries experts, scientific and environmental organizations, and the vessel community — promotes science-based initiatives for long-term tuna conservation, FAD management, bycatch mitigation, marine ecosystem health, capacity management, and illegal fishing prevention. Helping global tuna fisheries meet and maintain sustainability criteria to achieve the Marine Stewardship Council certification standard is ISSF's ultimate objective. To learn more, visit iss-foundation.org, and follow ISSF on [Facebook](#), [X](#), [Instagram](#), [YouTube](#), and [LinkedIn](#).

Learn more at iss-foundation.org.

Table of Contents

Executive Summary	6
1 Introduction.....	8
1.1 Opening Session and Workshop Objectives	8
2 Status of EAFM Implementation in Various Regions	10
2.1 EAFM Implementation in t-RFMOs	10
2.1.1 Western and Central Pacific Fisheries Commission (WCPFC).....	10
2.1.2 Inter-American Tropical Tuna Commission (IATTC).....	11
2.1.3 International Commission for the Conservation of Atlantic Tunas (ICCAT)	12
2.1.4 Indian Ocean Tuna Commission (IOTC)	12
2.1.5 Cross-t-RFMO Observations	13
2.2 Experiences from Other Organizations.....	15
2.2.1 EAFM implementation in Canada	15
2.2.2 EAFM implementation in Australia	16
2.2.3 EAFM Implementation in the ICES Area	16
2.2.4 Key Lessons for t-RFMOs from Other Regions	17
3 Ecosystem and Climate Indicators for Tuna RFMOs	19
3.1 Types of Indicators	19
3.2 Indicator Selection Criteria	21
3.3 Harmonization Across Tuna RFMOs	23
3.4 Communication Across tRFMOs.....	24
3.5 Future Steps and Collaboration.....	25
3.6 Ecosystem/Climate Indicator Session Recommendations	26

4. Ecosystem Traits Index (ETI) Indicator	28
4.1 Conceptual Basis of the ETI	28
4.2 Modeling Approaches and Data Requirements	29
4.3 Regional Applications of ETI	32
4.3.1 Western and Central Pacific Ocean (WCPO)	33
4.3.2 Eastern Pacific Ocean (EPO)	34
4.3.3 Atlantic Ocean (ICCAT Region).....	34
4.3.4 Indian Ocean (IOTC Region).....	34
4.3.5 Cross-Regional Insights.....	34
4.4 Strengths of ETI	37
4.5 Limitations and Challenges	37
4.6 Interpretation of ETI as a Management Tool	38
4.7 Key Messages from ETI Session	39
4.8 Future Directions and Collaboration.....	39
5 Synthesis, Recommendations, Action Plan and Cross-Cutting Conclusions	41
5.1 Synthesis of Key Findings	41
5.1.1 Status of EAFM Across RFMOs	41
5.1.2 Role and Limitations of Current Indicators	41
5.1.3 Communication as a Central Constraint.....	42
5.1.4 Integration into Management Frameworks.....	42
5.1.5 Role of ETI and Model-Based Indicators.....	42
5.2 Cross-Cutting Themes.....	43
5.3 Recommendations	43
5.4 Action Plan.....	46

5.5 Conclusions	50
References	52
Annex 1	53
Annex 2	69
Annex 3	137
Annex 4	168
Annex 5	197
Annex 6	224
Annex 7	255
Annex 8	286
Annex 9	307
Annex 10	330

Executive Summary

The workshop on “Implementation of the Ecosystem Approach to Fisheries Management in Tuna RFMOs: Advancing the Development of Ecosystem Indicators,” held at SPC in Noumea (New Caledonia) from 2–6 March 2026, brought together experts from tuna Regional Fisheries Management Organizations (tRFMOs) and partner institutions to advance the development and application of ecosystem and climate indicators in support of an Ecosystem Approach to Fisheries Management (EAFM) in tRFMOs.

This report synthesizes discussions from the Workshop. Across all tRFMOs, EAFM is partially implemented through measures such as bycatch mitigation, FAD management, and ecosystem monitoring; however, ecosystem indicators remain largely descriptive and are not yet systematically integrated into decision-making frameworks. A central theme of the workshop was the transition from monitoring indicators to operational indicators capable of informing management advice — for example, through Management Strategy Evaluation (MSE) and management procedures (MP) processes. The workshop also highlighted the importance of improving communication tools and strengthening collaboration across tRFMOs to support the uptake of ecosystem information into the management advice for EAFM implementation in support of the sustainable management of tuna fisheries.

Key outcomes include the need to:

- Develop a set of prioritized and harmonized ecosystem indicators across tRFMOs
- Further advance integrated ecosystems indexes, such as the Ecosystem Traits Index (ETI), to support ecosystem level assessment
- Integrate those indicators into management frameworks through practical tools such as Ecocards and risk tables
- Strengthen communication of ecosystem indicators and enhance dialogue between scientist and managers to better inform ecosystem-based decision-making
- Reinforce collaboration, knowledge exchange, and capacity development related to EAFM across tRFMOs

A major outcome was the evaluation of the Ecosystem Traits Index (ETI), which provides an integrative measure of ecosystem structure and function. While it provides valuable system-level insights, its interpretation requires caution. ETI should be used as an ecosystem-level diagnostic indicator that complements, but does not replace, species-specific advice (i.e., stock assessments or Management Procedures). While recognizing the potential of ETI to strengthen EAFM in tRFMO decision-making, further work is needed to improve ETI model inputs, validation, and interpretation frameworks. A stepwise approach was recommended, combining pragmatic empirical indicators with progressively more integrated model-based tools.

The workshop concluded that progress toward EAFM is not limited to scientific knowledge. It also requires clear, practical pathways to integrate ecosystem information into management advice.

1 Introduction

The Common Oceans Tuna Project “Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction” aims to support responsible, efficient, and sustainable tuna production while conserving marine biodiversity in a changing environment.

A key objective of the Common Oceans Tuna Project is to enhance tuna-fishery management by incorporating ecosystem and climate considerations into fisheries management advice. To achieve this, the Common Oceans Tuna Project provides support for the implementation of the Ecosystem Approach to Fisheries Management (EAFM) in tRFMOs.

A key challenge in implementing EAFM is its practical application within the context of tuna fisheries management, as ecosystem indicators become operational when linked to decision-making frameworks that connect ecosystem status to management responses. While progress within tRFMOs may appear limited, there are numerous examples where elements of EAFM have already been integrated into fisheries science and advisory practices, such as bycatch mitigation measures, FAD management, and ecosystem monitoring. In addition, each tRFMO is currently developing ecosystem, environmental, and climate indicators and related tools (Fuller et al., 2024), but collaboration and exchange across tRFMOs remain limited. To further advance these efforts, there is a priority need to strengthen coordination and sharing approaches among tRFMOs.

The objective of this workshop was to bring together tuna and ecosystem expert scientists to review, discuss, and advance the development and application of ecosystem and climate indicators to support the practical implementation of the EAFM across tRFMOs.

The specific objectives of the workshop were to:

- Review progress on Ecosystem and Environmental Indicators across tRFMOs
- Advance the development of Ecosystem/Environmental Indicators to evaluate fishing/climate impacts
- Identify challenges and propose practical solutions to progress
- Develop recommendations to support their use in tRFMO management processes

Overall, the workshop aimed to move beyond indicators as simple reporting tools and focus on how they can support the practical implementation of EAFM across tRFMOs. A key emphasis was placed on strengthening the link between science and management to ensure that indicators and analyses are directly relevant to decision-making. The workshop discussions therefore focused on identifying practical recommendations that could strengthen the application and effectiveness of EAFM within tRFMO processes.

1.1 Opening Session and Workshop Objectives

Simon Nicol (SPC) welcomed participants to the Workshop and outlined logistical arrangements, emphasizing the importance of aligning scientific developments with the operational realities of

RFMO processes, including time constraints associated with the existing workload of Scientific Committees and Commissions.

Hilario Murua (ISSF) formally opened the workshop and positioned it within the broader context of the Common Oceans Tuna Project. He recalled that the fourth workshop built on a series aimed at advancing the practical implementation of EAFM across tRFMOs. While earlier workshops focused on conceptual development and identification of the main challenges of EAFM implementation, the present meeting was designed to move towards operationalization, including harmonization of indicators and their integration into tRFMO advisory processes.

He emphasized that a central challenge remains the transition from descriptive ecosystem information to decision-relevant indicators. He noted that although a wide range of ecosystem indicators have been developed across tRFMOs, their application in management advice remains limited. He stressed that for ecosystem indicators to be effective, they must be embedded within existing advisory frameworks, rather than presented as standalone scientific products.

He also presented the agenda (Annex 1), outlining the objectives of each day:

- Day 1 - Build a shared understanding of EAFM across tRFMOs, outlining current work in each tRFMO.
- Day 2 - Discuss ecosystem and climate indicators and how tRFMOs can apply them.
- Days 3 and 4 - Introduction and explanation of the ecosystem trait index (ETI), and its supporting indices, to evaluate the pelagic ecosystem under the purview of tRFMOs, explaining required inputs, outputs, and example case studies of its application.
- Day 5 - Summarize outputs from discussions, consider future work, and produce conclusions/recommendations.

2 Status of EAFM Implementation in Various Regions

The objective of this session was to establish a shared understanding of EAFM implementation across regions, including policy mandates, scientific activities, and the current use of ecosystem and climate indicators in decision-making.

2.1 EAFM Implementation in t-RFMOs

Presentations from representatives of four tRFMOs (WCPFC, IATTC, ICCAT, and IOTC) provided an overview of the current status of EAFM implementation, highlighting both commonalities and important differences.

2.1.1 WESTERN AND CENTRAL PACIFIC FISHERIES COMMISSION (WCPFC)

Simon Nicol (SPC) presented the progress of EAFM implementation, both at the Commission and Scientific Committee level, in the WCPFC. The presentation is attached as Annex 1.

He highlighted that although EAFM is not explicitly defined in the WCPFC Convention, the principles of EAFM are implicitly embedded within the existing mandate as well as through Conservation and Management Measures (CMMs) addressing bycatch species, FAD management, climate change, and marine pollution. Thus, no formal revision of the Convention is considered necessary to advance EAFM. Instead, progress can be achieved through the explicit articulation of EAFM objectives and processes within dedicated CMMs.

Current efforts in the WCPFC reflect a pragmatic orientation, with a strong focus on empirical indicators that can be readily calculated and reported by Commission Members, Cooperating Non-Members, and Participating Territories. There is a general preference for empirical indicators, rather than model-based indicators, that can be reproduced using publicly available data, including examples of fishing pressure, bycatch rates, and environmental variability indicators.

There is also a preference for tracking ecosystem trends over time, rather than relying on absolute values, which aligns with the data-limited nature of many ecosystem indicators. These ecosystem and climate indicators are generally descriptive, providing context on ecosystem status rather than directly informing management decisions.

Several challenges remain in operationalizing EAFM within the WCPFC framework. Key gaps include the absence of agreed baselines and reference points, which limits the ability to translate observed trends into concrete management responses. Interpreting changes in ecosystem indicators remains complex, making it difficult to determine when and how management action should be taken. The lack of baselines or reference points to inform management was identified as a key limitation.

To address that challenge, the workshop suggested that ecosystem and climate indicators may be more effectively used as performance metrics within management strategy evaluation (MSE) processes when selecting candidate management procedures (MPs). Additionally, a practical

benefit might be realized if an evaluation of ecosystem impacts was integrated into proposals for new CMMs, including consideration of whether certain measures may impose disproportionate burdens on specific ecosystem components. Addressing these challenges will be critical to moving from descriptive monitoring toward more decision-oriented, ecosystem-based management within the Commission.

Notably, the WCPFC has adopted selection criteria for ecosystem indicators and recognizes the need to account for different spatial scales, including the use of eco-regions, to better capture ecosystem variability.

2.1.2 INTER-AMERICAN TROPICAL TUNA COMMISSION (IATTC)

Jon Lopez (IATTC) described the progress of EAFM implementation at the IATTC. Particularly, he mentioned that important building blocks for an EAFM are already in place, most notably through the Ecosystem Considerations report updated annually by the scientific staff. This report provides a comprehensive overview of ecosystem dynamics, including a wide range of indicators related to bycatch, environmental variability, and ecosystem structure. The presentation is attached as Annex 2.

He also highlighted that although EAFM is not formally adopted by the IATTC, many ecosystem elements are incorporated into scientific work, but the absence of a clear strategic vision remains a limitation. In 2025, a formal proposal for an EAFM Resolution was tabled but not yet adopted by the Commission, which would represent a significant first step toward more structured integration of ecosystem considerations.

IATTC has made progress in compiling indicators related to (i) bycatch and ecosystem impacts, (ii) environmental variability, and (iii) fishing practices, including the use of fish aggregating devices (FADs) referenced in IATTC's FAD Fishery Indicators report (Lopez et al., 2026). In parallel, ongoing efforts to develop indicator selection criteria further demonstrate a commitment to strengthening the scientific foundation of EAFM in the IATTC.

Despite these advances, there is currently no clearly defined pathway for translating these indicators into management-relevant advice. This disconnect constrains the practical application of EAFM within decision-making processes. To address this, the group suggested the development of a summary framework that integrates stock assessment results (or MP advice), industry perspectives, and ecosystem considerations into a single, coherent format. Such an approach could support more holistic advice by ensuring that, while management decisions remain primarily grounded in stock assessments or management procedures, ecosystem factors are at least qualitatively incorporated into the evaluation of management options.

As such, the IATTC presentation also highlighted the transition to Ecocards, which synthesize a range of indicators into accessible formats. The Ecocard approach was recognized as a promising step towards improving communication of ecosystem status with managers and stakeholders. In addition, the IATTC presented the Ecocard workplan (Fuller et al., 2025) to support the operationalization of EAFM, as endorsed by the Ecosystem and Bycatch Working Group and the Scientific Advisory Committee. Strengthening this linkage between scientific outputs and management advice will be essential for advancing EAFM within the Commission.

2.1.3 INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS (ICCAT)

Eider Andonegi presented a summary of ICCAT progress on the implementation of EAFM. She noted that the ICCAT Convention has been amended and that it currently explicitly references EAFM principles, providing a stronger legal basis for ecosystem-based management compared to other RFMOs. She also noted Resolution 15/05 for the application of EAFM when providing management advice. However, as is the case for other RFMOs, implementation remains limited. She also highlighted that many ecosystem elements are incorporated into scientific work, despite not being in an integrated manner. The presentation is attached as Annex 3.

Most of the ecosystem related work is carried out at the Scientific Committee level through the Sub-Committee on Ecosystem and Bycatch. Ecosystem indicators, and their selection criteria, are being developed through Ecocards (Juan-Jorda et al., 2018; Juan-Jorda et al., 2022a) to inform EAFM implementation and ecosystem modeling. Despite this progress, as in other RFMOs, implementation challenges remain. Indicators are still largely descriptive, and their integration into stock assessment advice and management decisions is limited.

She also noted that ICCAT faces challenges in implementing EAFM due to lack of coordination across multiple working groups (e.g., stock assessment vs. bycatch working groups), difficulties ensuring consistency in indicator development, and difficulties communicating ecosystem information effectively to the Commission.

Within ICCAT, advancing EAFM will require strengthening dialogue between scientific bodies and decision-makers. Enhancing communication pathways between scientists and managers, particularly in translating complex ecosystem information into actionable advice, will be critical to ensuring that ecosystem perspectives are more effectively reflected in conservation and management measures.

She noted that emerging international processes may provide new opportunities to support this transition and EAFM implementation. The adoption of the Biodiversity Beyond National Jurisdiction Agreement (BBNJ), and ICCAT's related Resolution 25/05, could serve as a catalyst for strengthening ecosystem-based approaches within the Commission. The BBNJ framework emphasizes the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction, aligning closely with EAFM principles. Leveraging this momentum may encourage ICCAT to further operationalize ecosystem considerations, foster cross-sectoral collaboration, and reinforce the role of science in informing more holistic, ecosystem-oriented management decisions.

2.1.4 INDIAN OCEAN TUNA COMMISSION (IOTC)

María José Juan-Jorda reported that EAFM is not explicitly included in the IOTC Convention, but EAFM elements are incorporated through scientific workplans and CMMs, such as management measures addressing bycatch and FADs. Limited resources and competing priorities constrain progress in IOTC. The presentation is attached as Annex 4.

Most of the ecosystem related work is carried out at the Scientific Committee level through the Working Party on Bycatch activities, such as the development of Ecocards and ecoregions work (Juan-Jorda et al., 2018b). Progress has been made in developing ecosystem indicators,

addressing bycatch impacts through management measures, and incorporating ecosystem considerations into MSE and MPs. Despite this progress, implementation challenges remain.

The recent developments and adoption of the ecoregion concept represent an important step forward in facilitating EAFM implementation (Juan-Jorda et al., 2020). This approach acknowledges the spatial heterogeneity of the Indian Ocean and provides a more ecologically meaningful framework for assessing ecosystem status and fishing impacts. The Scientific Committee adopted preliminary Indian Ocean ecoregions and has begun operationalizing this concept through pilot initiatives, including the development of ecosystem Ecocards and the evaluation of associated indicators across defined ecoregions (Juan-Jorda et al., 2022b). These efforts facilitate the testing and feasibility of organizing and communicating ecosystem information into a more integrated and accessible format (Juan-Jorda et al., 2024). While still at an early stage, such work has the potential to support more coherent indicator frameworks and, over time, strengthen the link between ecosystem monitoring and management advice. Continued refinement and uptake of these tools will be key to advancing EAFM implementation in IOTC.

However, significant constraints in IOTC were highlighted, including limited scientific and technical capacity, competing priorities within the Scientific Committee, and challenges related to sustaining long-term ecosystem monitoring and data gaps. These constraints may limit the ability of IOTC to advance ecosystem indicator development at the same pace as other tRFMOs.

2.1.5 CROSS-T-RFMO OBSERVATIONS

Across tRFMOs, ecosystem considerations are increasingly incorporated into scientific work and management measures, including bycatch mitigation and FAD management, although the formal operationalization of EAFM frameworks in decision-making remains limited.

Across all four tRFMOs, several common themes emerged:

- EAFM is partially implemented, but often implicitly rather than through explicit mandates or formal programs of work.
- Although a wide range of ecosystem indicators is available, they are largely descriptive and used primarily for monitoring rather than informing management advice.
- There is a lack of clearly defined objectives and reference points for ecosystem indicators, making it difficult to interpret observed trends.
- Communication of ecosystem information to managers needs to be strengthened and improved.
- There is limited capacity, both at Scientific Committee and Commission levels, due to existing workloads.

In particular, SPC emphasized that WCPFC is planning to initially use empirical indicators to monitor and report trends, while IATTC highlighted ecosystem reports and Ecocards as communication tools. ICCAT and IOTC noted ongoing development of ecosystem indicators and Ecocards.

In summary, across the four tRFMOs, the implementation of EAFM continues to face a common set of structural and operational challenges. While most tRFMOs have mandates broad enough to accommodate ecosystem considerations, governance arrangements and institutional priorities often limit the extent to which EAFM is operationalized. Existing ecosystem indicators are, in most cases, primarily descriptive and are rarely integrated into formal management advice. As a result, they tend to inform general understanding rather than directly inform decision-making. A key challenge lies in interpreting trends in these indicators and determining how such changes should translate into potential management responses, particularly in the absence of baselines or reference points. This is further compounded by the “few versus many” indicators dilemma — that is, balancing comprehensiveness with usability. The workshop noted that prioritizing a small set of informative indicators is preferable to relying on a large number that complicates interpretation.

Additional constraints stem from the need to strengthen communication between scientific bodies and managers to support the effective uptake of ecosystem information in decision-making processes. At the same time, many tRFMOs face resource limitations, even as Commissions place increasing demands on Scientific Committees to address a wide range of high-priority issues, often leaving limited space for advancing EAFM-related work. Despite these challenges, emerging global frameworks such as those established under the BBNJ Treaty present a valuable opportunity to catalyze progress. By aligning tRFMO processes with broader international commitments on biodiversity conservation there is potential to strengthen ecosystem-based approaches, enhance cross-institutional coherence, and elevate the role of ecosystem considerations within fisheries management.

Table 1. Status of EAFM Implementation in Tuna RFMOs

tRFMO	EAFM Recognition	Indicator Status	Integration into Advice	Key Constraints
WCPFC	Implicit in the Convention	Empirical, trend-focused	Qualitative; no triggers yet	Reference points uncertainty
IATTC	Implicit in the Convention	Multiple (incl. bycatch, environmental, ecosystem and FAD indicators); Ecocard workplan in progress	Limited Commission uptake; indicators are mostly descriptive	Lack of operational indicators with defined thresholds
ICCAT	Elements embedded in recommendations	Developing; linked to SC processes	Dialogue with managers limited	Institutional integration gap
IOTC	Bottom-up scientific initiative	Ecoregions adopted	Not formally embedded in advice	Capacity & budget limitations

2.2 Experiences from Other Organizations

Case studies from different regions (e.g., Canada, Australia, USA, and the ICES region) were presented to illustrate different approaches to implementing ecosystem-based fisheries management. These examples highlighted the use of ecological indicators, risk-based frameworks, ecosystem overview reports, and communication tools to support the integration of ecosystem information into fisheries decision-making to operationalize EAFM. These case studies also highlighted the importance of communication tools and iterative engagement between scientists and managers in bridging science and management.

2.2.1 EAFM IMPLEMENTATION IN CANADA

Alida Bundy presented Canada's structured and science-driven approach to implementing EAFM, led by Fisheries and Oceans Canada (DFO). EAFM is embedded within national legislation and operationalized through a coordinated national EAFM working group that brings together science, management, and policy. The working group has developed key tools — including an implementation plan, methodological toolboxes, and a Fisheries Management-Science feedback mechanism— to facilitate the integration of ecosystem considerations into the full fisheries management cycle, from stock assessments to management advice. The presentation is attached as annex 5.

DFO describes EAFM as: “EAFM is a single-stock approach that enables the incorporation of ecosystem information into stock assessments, science advice, management recommendations, and integrated fishery management plans or other harvest strategies (i.e., the entire science-management cycle) to better inform stock and individual fishery-focused decisions.”

The workshop noted that defining EAFM as an extension of single-species management creates a conceptual inconsistency with the FAO definition of EAFM, which already encompasses broader ecosystem considerations. However, this narrower interpretation, similar to that used in the United States, can be applied as an incremental approach to achieve full EAFM operationalization, starting with the basic step of incorporating ecosystem considerations (environment, bycatch, etc.) into single species management advice.

A central focus of Canada's approach is the development and application of ecological indicators. In the Maritimes Region, a rigorous selection process reduced a large pool of indicators to a manageable and operational suite across multiple spatial scales. These indicators have been used to detect long-term ecosystem changes, with analyses showing significant shifts since 1970 and little evidence of recovery. Ongoing research is improving understanding of how indicators respond to environmental and fishing pressures, including the identification of potential thresholds.

This work feeds into the production of Ecosystem Summary Reports, which provide ecosystem context for stock assessments and support more informed decision-making. These reports synthesize indicator trends relative to historical baselines (acting as reference points), providing information for fisheries management. Supporting tools, such as standardized data packages and workflows, aim to enhance transparency, reproducibility, and efficiency. Overall, Canada's experience demonstrates a developing, relatively advanced operational model of EAFM, with strong emphasis on indicator development, integration into advisory processes, and continuous methodological refinement.

Key features of the Ecosystem Summary reports include the use of standardized plots to visualize trends across indicators, aggregation of indicators into thematic groups, and clear narrative summaries accompanying stock assessments. The workshop noted this approach is effective in synthesizing, facilitating the communication of complex information, and providing a structured overview of ecosystem status to support high-level decision-making.

2.2.2 EAFM IMPLEMENTATION IN AUSTRALIA

The Australian approach to implementing EAFM, as presented by Beth Fulton, demonstrates a strong emphasis on decision relevance and structured integration of ecosystem information into management processes. Central to this approach is the use of risk assessment frameworks that explicitly link pressures, such as fishing, environmental change, and habitat impacts, to ecosystem components, including target species, non-target species, and broader ecosystem functions. These relationships are systematically captured in risk tables, which provide a transparent and consistent mechanism for incorporating diverse sources of information into single fisheries assessments and management advice. Australia has been incrementally developing approaches for many years, learning from other jurisdictions where such tables are now standard management practice (e.g. Bering Sea, USA). The presentation is attached as annex 6.

A key communication tool within this framework is the use of ecosystem “report cards,” which summarize complex ecosystem information into accessible, decision-oriented formats. These report cards present trends, current status, and potential projections of key indicators, helping managers quickly understand ecosystem conditions and associated risks. Importantly, indicators are not used in isolation but are linked to management objectives, risk categories, and potential management responses. The way the linking is done varies across fisheries, taking a more explicit approach in some tropical fisheries and more informal context-setting for decisions in others. Formal links across multiple ecosystem components are occurring in association with a push to move to multispecies harvest strategies and the implementation of a Climate Risk Framework. The clear links ensure that ecosystem information is directly relevant to decision-making, rather than remaining purely descriptive or scientific.

Overall, the Australian model highlights the value of integrating ecosystem indicators into broader advisory frameworks, where they inform stock assessments, contextualize management decisions, and support the evaluation of trade-offs. Its strength lies in making ecosystem considerations operational and actionable through clear linkages between indicators, risks, and management responses, providing a practical pathway for advancing EAFM within complex fisheries systems without requiring exhaustive monitoring, assessment, and reporting programs (which would be beyond Australia’s current capacity to service).

2.2.3 EAFM IMPLEMENTATION IN THE ICES AREA

Eider Andonegi presented the ICES approach to implementing EAFM centered on the development of ecosystem overview reports, which provide a structured and operational framework for ecosystem-informed advice. These reports synthesize information at the ecoregion scale and explicitly link human activities and pressures to ecosystem components and their observed state, thereby establishing clear causal pathways between drivers and ecosystem change. A key feature is the use of “activities–pressures–impacts” frameworks, which systematically map how different

sectors (e.g., fisheries, shipping, climate drivers) affect ecosystem components such as habitats, fish communities, and food webs.

ICES ecosystem overviews are designed to integrate information across sectors and disciplines, combining ecological, environmental, and socio-economic considerations into a single evidence base. They include descriptions of ecosystem status, trends, and key signals, alongside identification of dominant pressures and their impacts. This integrated perspective supports a broader understanding of ecosystem dynamics beyond single-species assessments and facilitates coherence across management domains.

Importantly, these reports are not purely descriptive but aim to clearly articulate management implications. Through their structured format, they highlight risks, identify key issues requiring attention, and provide contextual advice that can inform decision-making. Within the broader ICES Framework for Ecosystem-Informed Science and Advice (FEISA), indicators are combined with risk-based approaches to translate ecosystem knowledge into advice products aligned with management objectives. This makes the ICES model a strong example of how to operationalize EAFM by linking pressures, ecosystem state, and management responses in a transparent and policy-relevant manner. The presentation is attached as annex 7.

2.2.4 KEY LESSONS FOR T-RFMOS FROM OTHER REGIONS

Across the case studies presented, a consistent set of practical lessons emerged for tRFMOs seeking to advance EAFM implementation.

First, synthesis is essential: while many organizations have developed extensive suites of ecosystem indicators, their effectiveness depends on combining them into coherent outputs, such as ecosystem summary reports, risk tables, or integrated overview frameworks, rather than presenting them in isolation.

Second, visualization plays a critical role in improving communication and usability; tools such as heat maps, report cards, and structured diagrams (e.g. activities–pressures–impacts frameworks) help translate complex information into formats that are relatively easy to interpret by managers and stakeholders.

Third, narrative context is necessary. Quantitative indicators alone are insufficient without clear explanations of what trends mean, what is driving observed changes, and what the potential implications are for fisheries and ecosystems. Case studies demonstrated that combining indicators with concise interpretative narratives significantly enhances their relevance.

Finally, and most importantly, a clear link to management is key. Indicators become truly operational only when they are embedded within decision-making frameworks, whether through risk-based approaches, performance evaluation in MSE, or structured advisory outputs that explicitly connect ecosystem status to potential management responses.

Together, these lessons highlight that the challenge is not only in developing indicators but also in ensuring they are communicated, interpreted, and applied in ways that directly support decision-making within tRFMOs.

In summary, four common lessons emerged:

- Synthesis is essential: Indicators must be combined into coherent outputs, rather than presented individually.
- Visualization matters: Tools such as heat maps and report cards enhance interpretability.
- Narrative context is critical: Quantitative indicators must be accompanied by clear explanations of the underlying mechanisms and impacts.
- Link to management is key: Indicators are most effective when they inform decision-making frameworks.

3 Ecosystem and Climate Indicators for Tuna RFMOs

Following the tRFMO presentations, participants discussed existing indicator frameworks and their practical application. This section synthesizes discussions from the workshop on the development, selection, interpretation, and application of ecosystem and climate indicators to support the implementation of EAFM in tRFMOs.

Across tRFMOs, a wide range of ecosystem and climate indicators has been developed over the past two decades. As discussed above, the key challenge identified is not the lack of indicators but their limited operational use. A critical distinction emerged between ecosystem indicators (describing state and trends) and ecosystem performance indicators (evaluating whether management measures achieve ecosystem objectives). While the former are widely available, the latter remain largely undeveloped across tRFMOs.

In general, although they can be limited in capturing complex ecosystem dynamics, empirical indicators were often favored due to simplicity and reproducibility; however, model-based indicator usefulness was also acknowledged. A key point was the importance of ensuring transparency and reproducibility of indicators, particularly identifying the assumptions behind their calculations. Participants emphasized that too many indicators reduce effectiveness, with recommendations to limit core indicators to a manageable number (e.g., approximately 10 or fewer). Thus, there was consensus on the need to move toward fewer, more informative indicators, supported by clear interpretation frameworks.

3.1 Types of Indicators

Indicators used across tRFMOs can be broadly grouped into three categories:

- Fisheries indicators include metrics such as catch, effort, and CPUE proxies.
- Environmental and climate indicators include variables such as sea surface temperature, ocean heat content, dissolved oxygen, primary productivity, and climate indices (e.g., ENSO).
- Ecosystem indicators that provide the broader ecological perspective on the system, its structure and function; this may include bycatch rates, species composition, trophic structure, the abundance of specific indicator species and biodiversity metrics.

The integration of climate indicators was identified as a critical component of EAFM, given the strong influence of environmental variability on tuna ecosystems. These indicators provide important context for understanding changes in stock status, particularly where environmental drivers affect recruitment, distribution, and productivity. They can also act as early warning signals of ecosystem change, supporting the development of climate-informed management strategies.

However, their interpretation remains challenging. Climate indicators are externally driven and often operate on spatial and temporal scales that do not align with fishery management frameworks. In addition, relationships between climate variables and ecosystem responses are frequently complex and non-linear, making it difficult to translate observed changes into clear management responses.

Given these limitations, participants emphasized that climate indicators are best used to provide context for biological and fisheries indicators, rather than as direct triggers for management action. They are particularly valuable in supporting risk-based approaches, helping to identify vulnerabilities, interpret uncertainty, and inform longer-term planning, even if their role in short-term decision-making remains limited.

More generally, for all types of ecosystem and climate indicators, participants emphasized the importance of combining leading indicators (early warning signals) with lagging indicators (ecosystem responses) to better capture ecosystem dynamics. These indicators have generally been selected based on data availability and ease of calculation, rather than a formalized framework linking them to ecosystem objectives — despite the latter being key when possible.

Strengths and Limitations of Current Indicator Framework

Current indicator systems have several strengths, particularly for empirical indicators. These include simplicity, transparency, reproducibility, and broad coverage of ecosystem components. These attributes support credibility and allow for consistent application over time.

However, several key limitations were identified. Indicators are often presented individually rather than as part of an integrated framework. Interpretation and implications of indicator trends is frequently unclear, limiting their usefulness for decision-making. The proliferation of indicators can overwhelm decision-makers, reducing clarity and usability.

Most importantly, there is a weak linkage between indicators and management processes, with few indicators having defined baselines, thresholds, or reference points to inform management. To function effectively as performance metrics, indicators should preferably include some form of references against which progress/management can be assessed. However, this may not necessarily require absolute values; in some cases, directional trends may be used or appropriate. This suggests that the treatment of indicators may need to differ from the reference-point approaches traditionally used in single-species management. In any case, these limitations highlight that the effectiveness of indicators depends not only on their scientific robustness but also on their usability, interpretability, and relevance to management.

From Monitoring to Management

A central theme of the workshop was the need to transition from monitoring-oriented indicators to operational, management-oriented indicators. Monitoring indicators describe ecosystem status and trends but do not directly support decision-making. In contrast, operational indicators could be explicitly linked to management objectives, ideally including baselines, reference points, or thresholds that can inform management actions. These indicators could be embedded within decision-making frameworks, whether through risk-based approaches, performance evaluation in management strategy evaluation (MSE), or structured advisory outputs that explicitly connect ecosystem status to potential management responses.

Participants agreed that most current indicators remain at the monitoring stage. Moving toward operational indicators requires defining what constitutes a “good” or “undesirable” ecosystem state, identifying meaningful levels of change, and linking indicators to advisory frameworks such as harvest strategies and MSE.

In the short term, ecosystem indicators are unlikely to function as direct decision rules. However, they can play an important role as performance indicators within MSE frameworks, where they are used to evaluate the ecosystem impacts of candidate management procedures. Additionally, it was also suggested they can be used to evaluate ecosystem impacts when proposing new CMMs.

Case studies highlighted that indicators are most effective when synthesized into clear, decision-oriented outputs (e.g., report cards or risk tables) and embedded within coherent interpretation frameworks linked to management decisions.

3.2 Indicator Selection Criteria

The workshop identified a common set of criteria for selecting indicators (Juan Jorda et al., 2019), including scientific robustness, sensitivity to change, feasibility, transparency and reproducibility, and policy relevance. The criteria for indicator selection among tRFMOs was similar (table 2). All tRFMOs developed a structured framework identifying several key general criteria:

- **Scientific robustness:** Indicators should be based on sound scientific principles and reflect meaningful ecological processes.
- **Sensitivity to change:** Indicators should respond detectably to changes in ecosystem conditions or pressures.
- **Feasibility:** Indicators should be calculable using available data and within existing resource constraints.
- **Reproducibility and transparency:** Methods should be clearly defined and reproducible across time and by different analysts.
- **Policy relevance:** Indicators should ideally be directly linked to management objectives or concerns.

While these criteria are widely recognized, they are not always applied systematically across tRFMOs.

A central theme of the discussion was the trade-off between ideal and practical indicators. Ideal indicators are often scientifically comprehensive and better able to capture complex ecosystem processes, but they tend to be data-intensive and difficult to implement consistently. Data limitations are significant, particularly for ecosystem and socioeconomic indicators. In contrast, practical indicators are simpler and more feasible to apply across tRFMOs, and easy to communicate and interpret, although they may provide a less complete representation of ecosystem dynamics.

Data limitations remain a persistent constraint, particularly for ecosystem and trophic indicators, and waiting for “perfect” data would unnecessarily delay progress. Participants therefore emphasized the importance of adopting a pragmatic approach, using the best available indicators while acknowledging their limitations. It was also noted that even relatively simple indicators can provide significant value if they are consistently applied, clearly interpreted, and effectively communicated to decision-makers.

Transparency was emphasized as particularly important, including clear documentation of data sources, methods, and assumptions, and distinguishing between empirical and model-based indicators. Moreover, the workshop underlined that the indicator calculation needs to be reproducible with the data sources ideally publicly available to allow validation of estimations. In some cases, data could be available for RFMO Secretariats regularly but not to the public due to data confidentiality. In those cases, RFMO Secretariat should be able to reproduce the indicators regularly.

Table 2. Indicator selection criteria across tRFMOs.

INDICATOR SELECTION CRITERIA		
WCPFC	ICCAT/IOTC	IATTC
Science and data based	Scientific basis	Ecosystem relevance
Characterize the states and trends of ecosystems with respect to fishing activity and/or climate (including reference levels and baselines)	Ecosystem relevance	Grounded in science and data
Reflect well-defined processes underlying fishing activity and fishery responses to climate	Responsiveness to pressure	Sensitivity to response to relevant drivers (e.g., fisheries)
Responsive to changes attributable to fishing pressure and climate (i.e., minimal time-lags and capability to provide early warning)	Possibility to set targets	Cost-effective
Estimable on a routine basis with a historical data time-series available	Early warnings	Reproducible
Cost-effectiveness	Quality of sampling methods	Direct management value
Scalable across national, sub-regional and regional scales or have knowledge about spatial scales.	Knowledge of reliability at specific spatial scales	Inform actionable targets
Linked to existing WCPFC models and decision-making processes (e.g., MSE)	Cost effective	
Can be routinely estimated by members without reliance on the Science Service Provider - SPC	Existing databases	

There was also discussion on the need to clearly define what constitutes “change” in an ecosystem indicator, including potential use of thresholds, trends, or variability metrics. Participants discussed a range of approaches, including the use of trend-based interpretation (e.g., increasing or decreasing trends), threshold-based approaches defining acceptable ranges, deviations from historical baselines, and variability metrics such as anomalies relative to long-term means. However, most current tRFMO indicators rely primarily on trend analysis, with limited use of explicit baselines and thresholds or reference points to inform management. The absence of clearly defined reference levels or directional benchmarks was identified as a major barrier to the operational use of indicators in management, as it limits the ability to determine management actions based on the indicator.

3.3 Harmonization Across Tuna RFMOs

Participants explored opportunities to harmonize ecosystem and climate indicators across tRFMOs, recognizing this as a key step toward strengthening the implementation of EAFM at a global scale. Harmonization was seen as a means to improve comparability of ecosystem status across regions, enhance efficiency in indicator methodological development, and foster collaboration and data sharing among tRFMOs. It was also noted that greater alignment in indicator frameworks could support more consistent reporting to international processes and initiatives related to biodiversity and ocean governance. There was strong support for developing shared methodologies, data repositories, and collaborative platforms to facilitate cross-tRFMO work.

Participants emphasized that harmonization should not be interpreted as strict standardization. Tuna ecosystems, fisheries, data availability, and institutional contexts vary across ocean basins and tRFMOs. Accordingly, the workshop participants agreed to pursue alignment where practical while maintaining regional flexibility. This approach balances the benefits of common frameworks with the need for adaptation to ensure relevance and feasibility.

Several categories of indicators were identified as strong candidates for cross-RFMO harmonization. These included bycatch indicators (e.g., those related to sharks, turtles, and seabirds), FAD-related indicators (e.g., FAD density and impacts on species composition), and key environmental/climate indicators (e.g., sea surface temperature anomalies and productivity indices). These indicators were considered particularly suitable because they are relevant across regions, supported by existing data, already being estimated, and aligned with common management concerns shared by all tRFMOs.

Despite the clear benefits, several challenges to harmonization were identified. These include differences in data availability and quality across regions, variability in ecosystem structure and fisheries characteristics, institutional differences in membership, mandates and priorities, and resource constraints that may limit the capacity of some tRFMOs to implement harmonized approaches. Addressing these challenges will require sustained collaboration, capacity building, and realistic expectations regarding the pace of progress.

To advance harmonization in a practical manner, participants proposed a stepwise approach. This would begin with the identification of a small set of core indicators common to all tRFMOs, followed by the development of shared methodologies and definitions to ensure consistency. Regional adaptation would then be incorporated to account for ecological and operational differences.

Collaborative platforms — such as shared data repositories and joint working groups — would be established to support ongoing coordination and knowledge exchange.

A key theme emerging from the discussions was the need to balance scientific complexity with operational usability. While more complex, model-based indicators can provide deeper insights into ecosystem processes, they are often more difficult to communicate and implement within tRFMO processes. Conversely, simpler indicators are more accessible and easier to harmonize, but may not fully capture ecosystem dynamics. Participants therefore agreed that an effective harmonized framework should adopt a layered approach. This would include a core set of simple, empirical indicators for routine reporting and communication, complemented by a smaller number of integrated or model-based indicators to support more in-depth analysis. Such an approach allows indicator frameworks to remain both practical and scientifically robust, while meeting the needs of different audiences and decision-making contexts.

The group agreed that the small set of core candidate indicators for the harmonization process include:

- Indicator(s) that inform the "Bycatch" component of EAFM (e.g., sharks, turtles, seabirds)
- Indicator(s) that inform "FAD" fisheries (e.g., FAD density, impacts on species composition)
- Indicator(s) that inform environment/climate and their impact on population productivity (e.g., recruitment, SST anomalies, productivity indices)

Following this harmonization exercise of core set of indicators, the workshop agreed that indicators should be incorporated into communication tools such as Ecocards and risk tables, and integrated into management advice summary templates to evaluate their practical usefulness.

3.4 Communication Across tRFMOs

Participants emphasized that improved communication is essential to bridge the gap between scientific outputs and policy-relevant advice.

A key message from the workshop was that indicators must not be presented in isolation or as purely technical outputs. Instead, they should be synthesized into clear, accessible formats that align with the needs, expectations, and time constraints of Scientific Committees and Commissions. Tools such as ecosystem report cards, risk tables, Ecocards and ecosystem summary reports were highlighted as particularly effective in enhancing interpretability and usability. These tools allow multiple indicators to be synthesized and visualized in a structured way and illustrate how indicators can be explicitly linked to management objectives, risk categories, and potential management responses — enabling managers to quickly grasp ecosystem status, trends, and potential areas of concern. For example, Ecocards, as developed within some tRFMOs, were recognized as a promising approach.

Across all approaches, the importance of narrative context was strongly emphasized. Quantitative indicators alone are insufficient unless accompanied by clear explanations of what observed trends mean, what is driving those trends, and what their potential implications are for fisheries and ecosystems. Narrative summaries help translate scientific findings into actionable insights,

providing managers with the necessary context to interpret indicator results and consider appropriate responses.

Participants also highlighted that effective communication requires early and continuous engagement between scientists and managers. In many RFMOs, limited dialogue and differing expectations have contributed to a disconnect between indicator development and management uptake. Strengthening these interactions — through workshops, intersessional processes, and targeted communication products — was seen as essential to ensuring that indicators are both understood and trusted. Concrete examples of few indicators included clearly in management advice summaries are critical to explain trends, drivers, and implications to managers aligned with Commission needs and time constraints.

In summary, the workshop participants agreed that communication tools are not just supportive but also central to operationalizing EAFM. Indicators are most effective when they are synthesized into clear, coherent outputs; supported by concise narrative interpretation; and explicitly linked to management considerations. Tools such as report cards, risk tables, ecosystem summaries, and Ecocards can therefore play a key role in integrating ecosystem information into RFMO management advice.

Building on the identification of candidate indicators for harmonization — particularly bycatch, FAD-related, and climate indicators — the workshop agreed to develop a pilot “executive summary” product. This product would draw on existing best practices and combine risk tables with qualitative, and, where feasible, quantitative management-relevant interpretation within an Ecocard-style format. The objective of this pilot exercise is to test how a small, harmonized set of core indicators can be effectively communicated to managers in a concise, decision-oriented format, thereby strengthening the uptake of ecosystem information within tRFMO advisory processes.

3.5 Future Steps and Collaboration

Across all discussions, there was strong support for a pragmatic, incremental approach to advancing EAFM. Rather than attempting to fully operationalize ecosystem indicators in the short term, participants recommended starting with a small set of core indicators — particularly those related to bycatch, FAD impacts, and climate — testing and refining them, and progressively integrating them into advisory frameworks such as Ecocards.

Progress toward operationalization requires clearer interpretation frameworks, including defining what constitutes meaningful change in indicators. The absence of references, baselines or thresholds, or agreed methods for interpreting trends remains a major barrier to their use in decision-making. Addressing this gap is essential to strengthen the link between indicators and management responses. Several approaches were discussed, including the use of trend-based signals, deviations from historical baselines, variability metrics (e.g., standard deviations), and process-based indicators such as the frequency of extreme events or structural shifts. Developing practical and transparent methods for interpreting change was identified as a key step toward operationalization.

Data-related considerations were also central to the discussion. Participants highlighted the importance of ensuring transparency in data sources and methods, and promoting reproducibility through the use of accessible data and standardized workflows. The development of metadata

catalogues documenting indicator construction, assumptions, and limitations was identified as a useful practice. At the same time, it was recognized that data limitations should not prevent progress; rather, indicators can help identify key data gaps and guide future data collection and research priorities.

The role of spatial scale was also emphasized. Ecosystem indicators may exhibit different patterns across regions, and large-scale averages can obscure important local dynamics. The use of ecoregions or subregional analyses was identified as a promising approach to better capture ecosystem variability, although challenges remain in aligning these spatial frameworks with stock assessment units and management boundaries.

Participants agreed that an effective indicator framework should adopt a layered approach, combining a core set of simple indicators for routine reporting with a smaller number of integrated or model-based indicators for more detailed analysis. This approach allows indicator frameworks to remain both practical and scientifically robust, while addressing the needs of different audiences.

3.6 Ecosystem/Climate Indicator Session Recommendations

Building on the discussions held during the ecosystem/climate indicator session of the workshop, participants agreed on a set of priority recommendations to advance the development, harmonization, and operational use of ecosystem and climate indicators within tRFMOs. The following recommendations reflect a pragmatic and stepwise approach, aimed at strengthening the integration of ecosystem information into management advice while accounting for existing data, capacity, and institutional constraints:

- **Prioritize a limited set of core indicators** by developing and agreeing on a small number (approximately 3-5) of key ecosystem and climate indicators across tRFMOs.
- **Apply consistent indicator selection criteria**, ensuring indicators are scientifically robust, sensitive to change, feasible, transparent, reproducible, and relevant to policy.
- **Adopt a pragmatic approach to indicator development**, using the best available data while recognizing limitations, rather than delaying progress in pursuit of ideal indicators.
- **Advance harmonization across tRFMOs**, by aligning a core set of indicators (e.g., bycatch, FAD-related, and climate indicators) while allowing for regional flexibility.
- **Incorporate spatial considerations**, such as ecoregions or subregional analyses, to better capture ecosystem variability, noting potential considerations associated with the spatial framework underpinning current stock assessments.
- **Strengthen indicator interpretation frameworks**, including the development of reference points, thresholds, or agreed approaches (e.g., trends or variability bounds) to support decision-making.
- Use indicators to **identify key data gaps and guide future data collection and research priorities**.

- Ensure **transparency, reproducibility, and accessibility** of indicators, including clear documentation of methods and development of metadata catalogues.
- Follow a **stepwise, incremental implementation pathway**, testing and refining indicators through pilot applications (e.g., Ecocards) before full integration into advisory processes.
- **Integrate ecosystem and climate indicators into advisory processes**, ensuring they are presented alongside stock assessment results to support more holistic management advice or, for example, integrating them into MSE and MPs as performance metrics to assess ecosystem impacts.
- **Improve communication and usability** by synthesizing indicators into decision-oriented products such as Ecocards, report cards, risk tables, and concise executive summaries tailored to managers.
- **Adopt a layered indicator framework**, combining a core set of simple indicators for routine reporting with more complex or model-based indicators for in-depth analysis.
- **Strengthen collaboration and shared tools**, including the development of common methodologies, data platforms, and collaborative mechanisms to support cross-tRFMO work.
- **Enhance science-management dialogue**, including through intersessional engagement, workshops, and targeted capacity-building activities.
- Strengthen **capacity and resource allocation** to support long-term development and application of ecosystem indicators and their integration to decision-making processes.
- **Expand indicator frameworks**, including the development of socioeconomic indicators to complement ecological and climate indicators.

These recommendations provide a practical approach for advancing the operational use of ecosystem and climate indicators in support of EAFM.

4 Ecosystem Traits Index (ETI) Indicator

Days 3 and 4 of the workshop were dedicated to the introduction, evaluation, and discussion of the Ecosystem Traits Index (ETI) (Fulton and Sainsbury, 2025). Keith Sainsbury introduced the ETI as an integrative ecosystem indicator for the implementation of EAFM in tRFMOs (Annex 8). This session marked a transition from the primarily empirical indicators discussed earlier in the workshop toward model-based, system-level indicators capable of capturing ecosystem structure and function.

The ETI was presented as a tool designed to synthesize complex ecosystem information into a single metric reflecting overall ecosystem condition. It builds on ecosystem modeling frameworks and aims to provide a broader perspective on ecosystem dynamics than is possible through individual indicators or single-species assessments. While empirical indicators remain essential for monitoring specific components of the ecosystem, the ETI was introduced as a complementary approach that integrates multiple dimensions of ecosystem structure, resilience, and trophic functioning. To date the calculation of the ETI has primarily relied upon Ecopath with Ecosim (EwE), but the approach is generalizable to other ecosystem models or even datasets in systems that have appropriate and comprehensive datasets available.

The objectives of this session were to:

- Present the conceptual basis and methodology of the ETI
- Review its application to the tuna pelagic ecosystem across multiple ocean regions (Western and Central Pacific Ocean: WCPO; eastern Pacific Ocean: EPO; Atlantic Ocean: AO; and Indian Ocean: IO)
- Evaluate its strengths and limitations as a management-relevant indicator for tRFMOs
- Identify requirements and pathways for implementation within tRFMO advisory processes

4.1 Conceptual Basis of the ETI

The ETI was developed in response to the recognized limitations of single-indicator approaches. While individual indicators can provide valuable insights into specific ecosystem components, they often fail to capture interactions among species, food-web dynamics, and the cumulative effects of fishing and environmental pressures. The ETI addresses this gap by integrating multiple ecosystem characteristics into a single index that reflects the structure and functioning of the ecosystem as a whole.

The ETI combines three main components:

- **Ecosystem topology (hub index):** Identifies key species and connectivity within the food web, highlighting species that play central roles in ecosystem functioning (Fulton and Sainsbury, 2024)

- **Resilience and redundancy:** Reflects the system's capacity to absorb disturbances, including the presence of alternative pathways and functional diversity (Gao et al., 2016)
- **Food-web distortion/fishing pressure (Green Band):** Measures the impact of fishing relative to ecosystem productivity, indicating whether exploitation levels are within sustainable bounds (Fulton et al., 2025)

Together, these components provide a composite measure of ecosystem robustness and structural integrity. The ETI is grounded in network theory and focuses on structural integrity. It responds to cumulative ecosystem changes but does not distinguish between specific drivers such as fishing or environmental variability. These characteristics underscore both its strength as an integrative indicator and its limitation in terms of attribution.

The ETI produces a continuous score representing a gradient from more degraded or simplified ecosystems (i.e., low values) to more complex, resilient and functional systems (i.e., higher values). However, interpretation remains challenging. Values report on the status of an ecosystem given its inherent structure and content. While it is comparable across systems, ETI is more typically considered through time within a system; noting changes over time may reflect both natural variability and fishing pressure or other forms of disturbance. Participants emphasized that ETI should be interpreted cautiously and in context, particularly when used alongside other indicators or single stock assessment results, as the relationship between ETI and management objectives is not yet fully defined.

4.2 Modeling Approaches and Data Requirements

Dr. Beth Fulton provided a detailed overview of the modeling framework underpinning the ETI (Annex 9) and the requirements to calculate ETI and related indicators (Annex 10). The ETI is primarily derived from ecosystem models, particularly Ecopath with Ecosim (EwE), although other modeling approaches (e.g., size-based or trait-based models) may also be applicable. EwE models require data on biomass, diet composition, production, consumption, fisheries catch, effort and fishing mortality, and environmental drivers, and allow for the simulation of trophic interactions and energy flows.

For the regional application of the ETIs (see next section), an EwE was developed/updated for each tRFMO region: the Warm-pool of the WCPO and the three tropical areas of IATTC, ICCAT, and IOTC (see next section). A summary of EwE specifications and input data for each region is provided in Table 3.

Significant data challenges were identified for tRFMOs EwEs, including limited diet data (particularly for pelagic species), uncertainty in biomass estimates for non-target species, and incomplete historical time series for most regions. As a result, models often rely on assumptions, extrapolations, or the incorporation of “expert knowledge,” which can influence the robustness of EwE, and hence ETI, outputs. While these challenges are not new to ecosystem modelers and there are best-practice methods for addressing them, it is important to support newer uses in the adoption of those methods so that sensitivities and uncertainties are clear. Participants emphasized the importance of transparency, sensitivity analyses, and ongoing model refinement.

Table 3. Summary of EwE Model Development Inputs and Characteristics

EwE Component / Input	WCPO Warm Pool	IATTC – ETP	ICCAT – TAO	IOTC – TIO
Model Area	Tropical oligotrophic warm pool pelagic ecosystem; mesopelagic to surface focus	Eastern Tropical Pacific ecosystem	Tropical Atlantic Ocean, oceanic waters excluding continental shelf 0–500 m depth	Tropical Indian Ocean, oceanic waters excluding continental shelf, 0–500 m depth
Temporal Coverage	Fisheries time series from ~1952 onward	Original model (2003); updated with 1970–2021 data, fishing data from 1979	Ecopath base period 2000–2003; Ecosim fitted 2000–2022	Ecopath base period 2000–2003; Ecosim fitted 2003–2022
Functional Groups	65 functional groups	39 functional groups	36 functional groups	35 functional groups
Key Biological Structure	Age-structured tunas; sharks; rays; whales; turtles; forage fish; plankton; gelatinous groups	Ontogenetic tuna stages; sharks; rays; marine mammals; seabirds; forage fish; plankton and detritus	Mature/immature tuna stages; sharks; whales; seabirds; plankton; discards	Mature/immature tuna stanzas; vulnerable species; and lower trophic level groups
Fishing Fleets Included	5 fisheries: longline (LL), purse seine PS (FAD/FSC), pole-and-line (PL/BB), national fisheries	5 fleets	17 fleet categories including PS-FAD/FSC, LL, Baitboat (BB), Hand Line (HL), Gillnet (GN) and Others (OTH)	15 fleets including PS-FAD/FSC/unclassified, LL, BB, GN, line, miscellaneous fisheries, and one fleet representing FAD ghost fishing
Biomass Inputs	Monitoring programs and fisheries stock assessment datasets	Stock assessment inputs and update of biological parameter updates	Surveys, stock assessments and literature	Surveys data, stock assessment and literature
Diet Information	Ecosystem trophic structure datasets	Diet matrix from 1990s–2000s	Literature and trophic ecology expert validation	Literature and trophic ecology expert validation

Catch Inputs	Observer and logbook datasets	Revised longline catches; annual catch updates	ICCAT fisheries statistical datasets plus observer bycatch data	IOTC catch series and observer data
Main Ecosim Ecosim Drivers / Calibration	Fisheries time series and climate drivers; future refinements planned with updated CMIP simulations	Calibration to new biomass and catch time series for target and bycatch species	Driven by fishing effort, fishing mortality, discards proportion, primary production and sea water temperature; calibrated to biomass and catch time series	Driven by discards mortality rate, discards proportion, fishing effort, primary production, and sea water temperature; calibrated to biomass and catch time series
Key Model Features	Multiple progressively refined models through time; bottom-up controlled tropical pelagic ecosystem	Update improved ontogenetic linkages among tuna stages and rebalanced model structure	Tropical tuna catches >82% represented within model area; ready to include climate projection scenarios (SSP126/370/585)	>86% of tropical tuna catches occur within model area; harmonized structure with ICCAT TAO model

Historical reconstruction of fisheries data for non-target species was highlighted as a key limitation across tRFMOs, with datasets such as FishMIP and Sea Around Us identified as potential sources to support reconstruction efforts.

Participants highlighted the importance of ensuring consistency in the definition of functional groups across regions in EwE modelling, as these groupings underpin ecosystem model structure and can influence resulting outputs and, consequently, ETI estimations. Although testing of the approach has shown it to be robust to the forms of taxonomic aggregation typically required in creating ecosystem models for large regions, participants highlighted the importance of consistent and ecologically meaningful groupings, avoiding excessive aggregation or fragmentation.

Achieving comparability across tuna RFMOs requires not only harmonized approaches to grouping species but also adequate representation of key ecosystem components, including tuna species, forage fish, and top predators. At the same time, participants recognized the need to balance ecological realism with practical constraints, noting that increasing model complexity must be carefully weighed against data availability and quality to avoid introducing additional uncertainty.

Data limitations and underlying assumptions were identified as critical considerations in the development and application of ecosystem models. Participants emphasized the importance of transparently in model construction and documenting all assumptions — including data sources, parameter choices, and methodological decisions — to ensure credibility and reproducibility. Conducting sensitivity analyses was also highlighted as essential for understanding how model outputs respond to uncertainty and for identifying key drivers of results. In addition, participants stressed the need for models to be regularly updated as new data become available, allowing for continuous improvement in model accuracy and relevance to management. Improving reproducibility through shared workflows, code repositories, and standardized protocols was identified as a priority for advancing ETI applications across RFMOs.

4.3 Regional Applications of ETI

Applications of the ETI were presented for the Western and Central Pacific Ocean (WCPO) Warm Pool, Eastern Pacific Ocean (EPO) tropical area, Atlantic Ocean tropical area, and Indian Ocean tropical area (Table 4). These case studies demonstrated that ecosystem structure and dynamics vary significantly across regions and that ETI results must be interpreted within their specific ecological context.

For example, results showed that different regions have different hub species and structural characteristics, reflecting regional variability (Table 4). In general, ETI values remained relatively stable despite changes in fishing pressure, highlighting the complexity of ecosystem responses and the nature of the way tuna fisheries interact with large open water ecosystems. These applications demonstrated both the potential and limitations of ETI as a management-relevant indicator. Participants agreed ETI should complement, not replace, simpler ecosystem indicators.

Table 4. Summary of Ecosystem Trait Index (ETI) calculations and results across tuna RFMOs.

ETI Component / Result	WCPO Warm Pool	IATTC – ETP	ICCAT – TAO	IOTC – TIO
Hub Species / Functional Groups	Sharks, epi- and mesopelagic fish, mollusks, crustaceans, and zooplankton groups	Yellowfin, bigeye, sharks, dolphins, mesopelagic fish, zooplankton and phytoplankton groups	Pelagic sharks, small epi-/mesopelagic fishes, gelatinous plankton, macro- and meso-zooplankton	Small mesopelagic fishes, pelagic crustaceans, small epipelagic fishes, gelatinous plankton
Gao Index Result	Ecosystem consistently robust and resilient	Ecosystem remained within resilient zone	Ecosystem remained within resilient zone	Ecosystem in resilient state with high flow heterogeneity and low perturbation sensitivity
Green Band Result	Distortive pressure present but largely acceptable	Distortive fishing pressure identified	Target and vulnerable groups inside or below the green-band threshold, with some exceptions above	Vulnerable and target groups mostly sustainably exploited, hub groups underexploited
ETI Result	Desirable state, but functional integrity under distortive pressure	High-medium or medium integrity	High integrity, with a steady improvement over time	High integrity
Main Ecosystem Interpretation	System change occurring but still within acceptable state	Stable system within acceptable state	Stable system within acceptable state	Stable system within acceptable state
Key Management Signal	Avoid further decline as environmental change increases pressure	Continued management and monitoring required for sustainability	Continued management required	Continued management required

Main Gaps / Weaknesses	Spatial variability and climate forcing uncertainties	Update diet matrices, biomass inputs, artisanal fisheries and historical reconstructions	Data scarcity for non-assessed species; uncertainty analysis needed	Uncertainty in diets, biomass, catch, fishing effort, and lower trophic level knowledge
Next Steps	Extend fisheries time series and refine climate drivers, and better spatial representation	Extend historical time-series, improved datasets, and Ecospace/ecoregional ETI applications	Extend historical time-series, conduct uncertainty analysis and future scenarios	Extend historical time-series and improve ecosystem datasets

4.3.1 WESTERN AND CENTRAL PACIFIC OCEAN (WCPO)

The WCPO warm pool ecosystem is characterized by high productivity and complex trophic interactions. ETI values remained relatively stable over time despite changes in fishing pressure (Figure 1). This was interpreted as an indication of resilience linked to high biodiversity and redundancy of the system, although participants cautioned that stability in the index does not necessarily imply the absence of ecosystem change. The identification of key hub species included certain forage fish and mid-trophic predators.

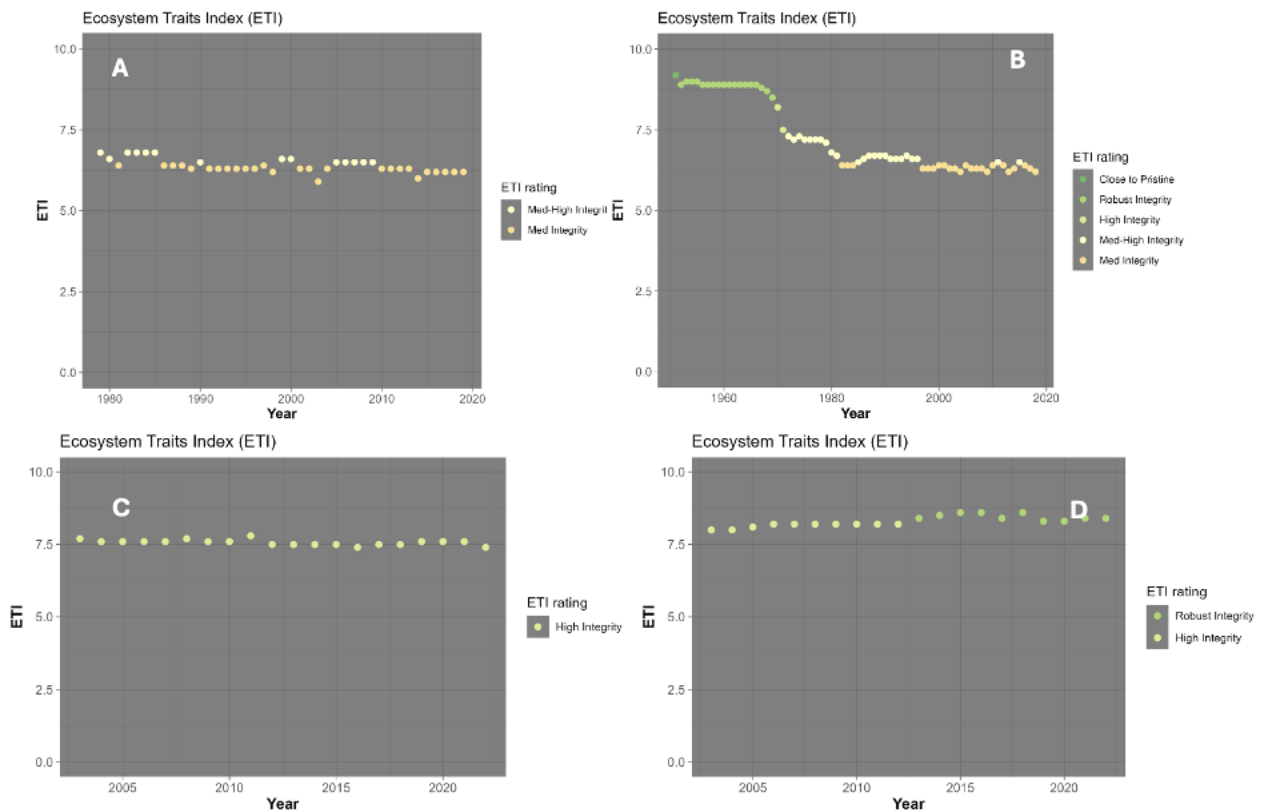


Figure 1. Preliminary ETI estimations for the (A) WCPO Warm Pool, (B) Tropical Eastern Pacific Ocean, (C) Tropical Indian Ocean, and (D) Tropical Atlantic Ocean.

4.3.2 EASTERN PACIFIC OCEAN (EPO)

In the EPO, where environmental variability such as ENSO plays a strong role, ETI values exhibited greater temporal variability over time, reflecting the combined influence of climate and fishing pressure (Figure 1). The group noted that the time series started in 1975 while the data availability extends to the 1950s. Due to the strong influence of environmental drivers on ecosystem structure, this case illustrated the importance of considering climate context when interpreting ETI results

4.3.3 ATLANTIC OCEAN (ICCAT REGION)

Applications in the Atlantic highlighted regional differences in ecosystem structure across sub-areas and identified key hub species, including pelagic sharks and mid-trophic organisms. ETI results showed a relatively stable ecosystem that steadily improved its status over time; however, the time series is short and limited to the most recent period (2003-2022) (Figure 1). Participants noted that the Atlantic case highlighted the potential for ETI to support comparative analyses across regions, although differences in model structure must be carefully considered.

4.3.4 INDIAN OCEAN (IOTC REGION)

In the Indian Ocean, ETI results suggested a stable resilient ecosystem, although with higher levels of uncertainty compared to other regions (Figure 1). Similar to the Atlantic case, the Indian Ocean time series is short and limited to the most recent period (2003-2022). This uncertainty largely reflects data limitations and model assumptions, which affect the robustness of any derived estimates. Across regions, differences in hub species, functional group structure, and environmental drivers further highlighted the importance of regional context when interpreting ETI outputs.

The Indian Ocean case also demonstrated the sensitivity of ETI to both fishing pressure and environmental variability, while underscoring key constraints related to data availability and model development. These findings emphasize the need for continued capacity building and improved data inputs to support the reliable application of model-based indicators in this region.

4.3.5 CROSS-REGIONAL INSIGHTS

A notable cross-regional finding was that these pelagic ecosystems appear structurally resilient, potentially due to the limited exploitation of forage species (Figure 2). However, participants highlighted that the development of fisheries targeting forage species (e.g., mesopelagic species) could significantly alter ecosystem structure and reduce resilience, emphasizing the need to acquire data from non-tRFMOs across shared regions to obtain a comprehensive view of the ecosystem's state, exposure to exploitation and disturbance, and the potential need for precautionary management (Figure 3). For example, the resilience of the WCPO Warm Pool system decreases, and the ETI is estimated as a "likely collapse," when mesopelagic hub species are fished unsustainably. In contrast, the resilience of the system remains at similar levels and the ETI is only slightly reduced when tuna fishing effort is increased by a factor of 10 (Figure 3).

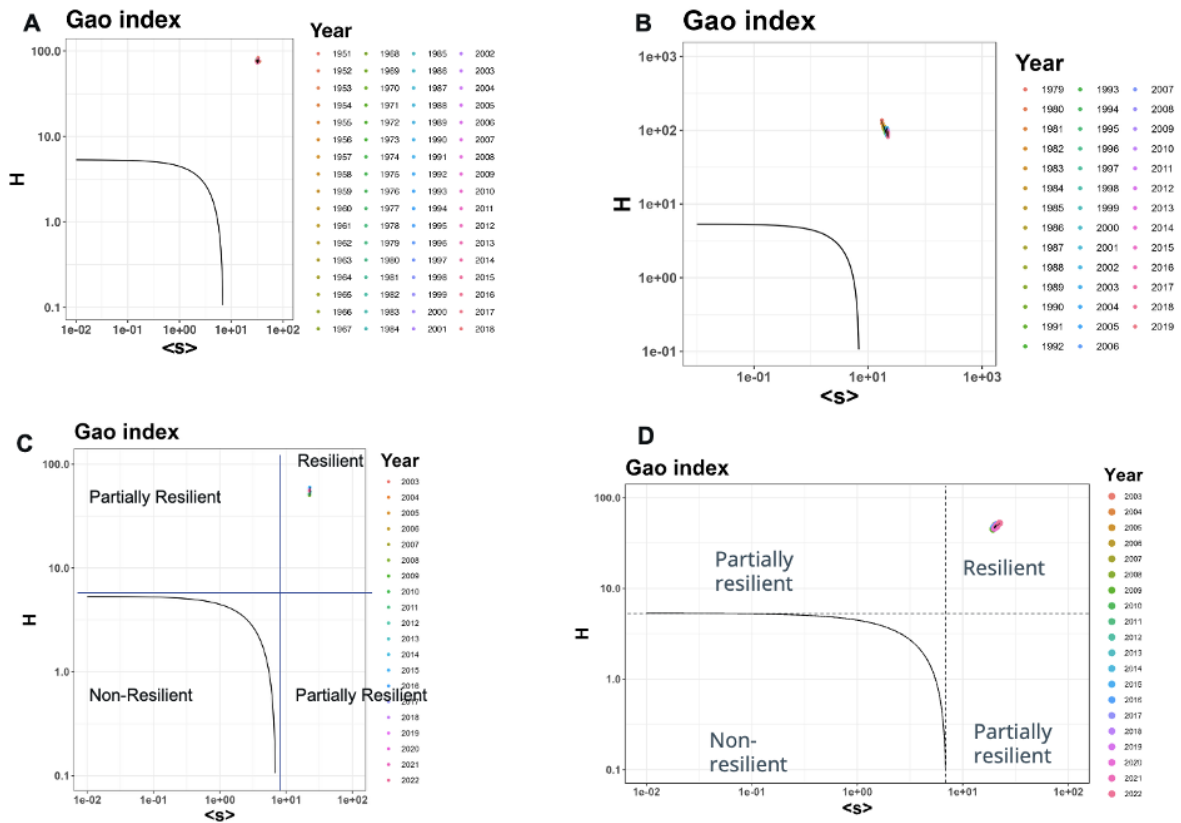


Figure 2. Preliminary Resilience (Gao Index) estimations for the (A) WCPO Warm Pool, (B) Tropical Eastern Pacific Ocean, (C) Tropical Atlantic Ocean, and (D) Tropical Indian Ocean.

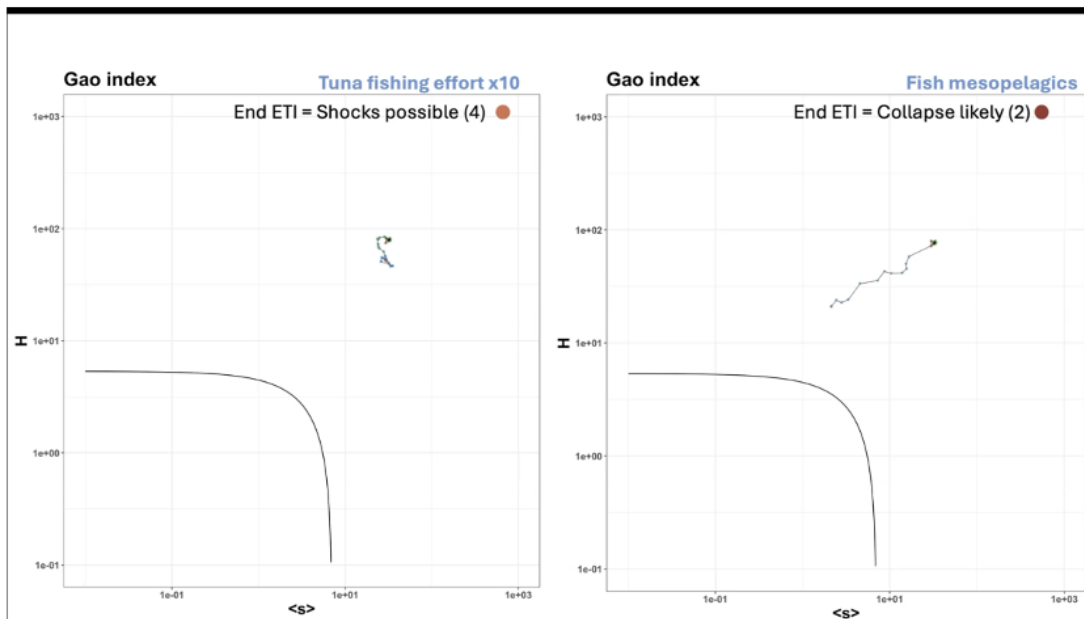


Figure 3. Resilience (Gao Index) estimations for the WCPO Warm Pool when (left) tuna fishing effort is increased by 10 and (right) mesopelagic fishes are caught unsustainably.

Across all regions, several common observations emerged. Ecosystems differ markedly in their structure and dynamics, and ETI can help identify key species and trophic pathways within food webs. However, interpretation requires careful consideration of regional context, including ecological characteristics, data availability, and model assumptions. While comparisons across regions are possible, they must account for differences in model structure and parameterization. This is a lesson for EAFM in general, as ecosystems are idiosyncratic, making cross comparisons less straightforward. It is also why universal (globally relevant) reference points may not be available for all ecosystem types.

A comparative synthesis of key limitations, required updates, and priority improvements for the application of EwE and ETI across tuna RFMOs is provided in Table 5. The table highlights common challenges, including data limitations, the need for model updates and improved parameterization, and uncertainties associated with model structure and assumptions. It also identifies priority areas for strengthening model performance and supporting more consistent application of ETI across regions. This comparison reinforces the importance of continued model development, improved data inputs, and enhanced collaboration across tRFMOs to support robust and comparable ecosystem assessments.

Table 5. Comparative summary of key limitations, required updates, and priority improvements for the application of Ecopath with Ecosim (EwE) models and the Ecosystem Traits Index (ETI) across tRFMOs.

WCPFC	IATTC	ICCAT	IOTC
✓ Sanity checks in each step for EwE development	✓ Sanity checks in each step for EwE development	✓ Sanity checks in each step for EwE development	✓ Sanity checks in each step for EwE development
✓ Update EwE	✓ Update EwE	✓ Update catch series	✓ Update catch series
✓ Super hub spp group investigation	✓ Extend timeseries backwards	✓ Extend timeseries backwards	✓ Extend timeseries backwards
✓ Extend timeseries forward (using recent SAs)	✓ Sensitivity analysis	✓ Sensitivity analysis	✓ Spatial variation, EwE with different regions or Ecospace
✓ Sensitivity analysis	✓ Spatial variation north/south	✓ Spatial variation	✓ No top predator as hub species (check the reason)
✓ Include spatial variation – use of Seapodm	✓ Pacific wide	✓ Sensitivity of the model to diet matrices	✓ Importance of forage species
✓ Pacific wide	✓ Included information of spp-s of other RFMOs	✓ Sensitivity of the years used in the unexploited/green band	✓ Included information of
✓ Included information for			

spp-s managed by other RFMOs			spp-s of other RFMOs
---------------------------------	--	--	-------------------------

4.4 Strengths of ETI

Participants highlighted several key strengths of the ETI, particularly its ability to provide an integrated view of ecosystem structure and function. Unlike single-species or component-based indicators, the ETI captures the complexity of trophic interactions and energy flows within the food web, offering a more holistic understanding of how ecosystems respond to fishing pressure and environmental variability. This integrative perspective allows for the identification of key “hub” species, those that play central roles in maintaining ecosystem connectivity, as well as potential vulnerabilities within the system.

Participants also noted that the ETI has strong potential as a communication tool. By synthesizing complex ecosystem dynamics into a single, integrated metric, it can provide a clear and accessible message to managers about overall ecosystem functioning and structure. This contrasts with many ecosystem indicators derived from ecosystem models, which, while scientifically robust, might be often less intuitive and more difficult to communicate effectively in decision-making contexts. In this sense, the ETI can serve as a powerful bridge between complex ecosystem science and management, enhancing the visibility and usability of ecosystem considerations within RFMO processes.

In addition, the ETI offers potential for comparative analyses across regions, enabling insights into differences in ecosystem structure, resilience, and response to pressures among ocean basins. While such comparisons require careful interpretation, they can support broader assessments of ecosystem status and inform cross-tRFMO discussions. These attributes make the ETI a valuable complement to simpler, empirical indicators, contributing depth and system-level context within a layered indicator framework for EAFM

4.5 Limitations and Challenges

Several technical challenges must be addressed before the ETI can be widely applied within RFMO processes. These include improving data quality and availability; reducing uncertainty in model inputs; refining model structure, particularly the definition of functional groups; extending the studied period; and conducting systematic sensitivity and uncertainty analyses. The ETI is most informative when calculated for longer time periods so change through time can be assessed. Key areas of uncertainty, such as diet composition and trophic linkages, were identified as particularly influential for model outputs. Participants emphasized that rigorous sensitivity testing and validation are essential to ensure the robustness and credibility of ETI results. In addition, the standardization of modeling approaches across regions — along with improved reproducibility through shared workflows, documentation, and open data practices — was identified as a critical priority to support broader uptake and comparability.

Capacity constraints were also recognized as a significant barrier, particularly for tRFMOs with limited technical and financial resources to develop and maintain ecosystem models. Addressing

these constraints will require sustained investment in capacity building, including targeted training, improved data access, and collaborative model development across institutions and regions.

4.6 Interpretation of ETI as a Management Tool

Participants recognized the ETI as a promising tool for providing an integrated view of ecosystem structure and function. Its ability to capture trophic interactions, identify key species, and reflect system-wide dynamics was highlighted as a key strength, particularly in the context of EAFM.

The ETI has relatively high data requirements and relies on model assumptions that can influence results if not applied with care, making it sensitive to data quality and potentially to model structure. This may reduce user confidence if not clearly documented and transparently explained, increasing the risk that ETI is perceived as a “black box” indicator. Compared to simpler empirical indicators, the ETI can also be less transparent and more difficult to interpret. Although, as mentioned above, the ETI has strong potential as an ecosystem-integrated communication tool, its complexity can also present communication challenges, particularly for non-technical audiences. Without clear interpretation frameworks by management, its direct application to management decisions is limited. Participants noted that communicating ETI outputs in a clear and policy-relevant manner is a challenge, especially given the complexity of the underlying models. Furthermore, there is currently limited experience to link ETI values or trends to specific management actions, which constrains its immediate applicability within decision-making frameworks. The workshop agreed that this is an area requiring future research.

A key priority is therefore to improve the interpretation of ETI and related ecosystem indicators (e.g., GOA index, green-band indicators) in terms that are clear and meaningful for management. This includes clarifying how indicator values relate to ecosystem status (e.g., resilience, shifts, or potential collapse), what these ecosystem status mean, their relationship to commonly used empirical indicators (such as stock status), and their implications for management considerations. Previous testing of ETI across multiple ecosystems provides a useful basis for developing such interpretation frameworks, but these have largely focused on demersal systems. Extending this work to pelagic ecosystems will require further development of ecosystem models across tRFMOs, followed by synthesis of results into practical guidance on how to interpret and use the ETI index scores.

Participants agreed that the ETI should complement, rather than replace, existing empirical indicators by providing an integrated, ecosystem-level perspective that adds context to observation-based metrics. While empirical indicators remain essential for routine monitoring and reporting, the ETI was seen as valuable for supporting deeper analysis of ecosystem structure, interactions, resilience, and risk-based approaches within EAFM. However, participants emphasized that further development is needed — particularly in relation to interpretation, communication, and model robustness — before the ETI can be routinely applied within tRFMO advisory processes. As such, its integration should be gradual, beginning with scientific committee review and validation before being communicated to decision-makers in simplified, policy-relevant formats.

Periodic updates of the ETI were considered sufficient, rather than annual reporting, given the complexity of model development and the relatively slow pace of ecosystem change.

4.7 Key Messages from ETI Session

The workshop highlighted that the ETI represents an important step toward integrated ecosystem assessment in tRFMOs. It provides a promising, integrative indicator that captures ecosystem structure and function in a way that complements existing indicators and supports a more holistic understanding of fisheries impacts. Its application also demonstrates the value of model-based approaches for analyzing complex ecosystem dynamics and interactions that cannot be fully captured through empirical indicators alone.

However, significant challenges remain, particularly in relation to data requirements, model uncertainty, and the communication of results to management audiences. A key conclusion from the workshop was that the ETI should be applied within a layered indicator framework, alongside empirical indicators, to balance simplicity and interpretability with analytical depth. Such an approach allows indicators to be tailored to different purposes, supporting both routine communication and more detailed ecosystem analysis.

Initial results suggest that tuna ecosystems may appear generally resilient, although this interpretation requires careful contextualization as important caveats were highlighted regarding interpretation. ETI results may not align with single-stock advice; for example, an ecosystem may appear stable while specific stocks require reduced fishing mortality. Therefore, ETI should not be used to override species-specific management advice. Instead, ideally, its individual components should be considered (e.g., status of a stock versus the Green band) to check for the need for stock specific interventions, with the ETI then best interpreted as an ecosystem-level diagnostic indicator that can qualitatively inform management advice and potentially contribute to the development of ecosystem-related reference points. Participants stressed the importance of translating ETI outputs into plain language to ensure that their meaning is clearly understood by managers.

From a modeling perspective, participants emphasized the need to update existing ecosystem models and improve input data quality. Sensitivity testing was identified as essential, particularly for diet matrices, model structure, spatial coverage, and key assumptions. Ensuring robustness requires transparent documentation, reproducibility, and rigorous scientific review within RFMO Scientific Committees before broader application.

In terms of its role in RFMO advice, ETI should be used in a qualitative ecosystem context alongside stock assessments and management procedures, rather than as a direct basis for determining harvest levels. A structured communication pathway was proposed, linking ecosystem model development to ETI outputs, followed by Scientific Committee review and subsequent communication to the Commission.

4.8 Future Directions and Collaboration

Participants agreed on a structured pathway for advancing the ETI. This includes strengthening and updating existing ecosystem models, improving data inputs and historical reconstructions, and exploring complementary modelling approaches such as size-based models (see table 6). Developing shared terminologies and definitions, methodologies, data platforms, and collaborative mechanisms across tRFMOs will be essential to support these efforts.

Particular emphasis was placed on improving the interpretability of ETI values for managers and testing how different management actions across target, bycatch, and key functional groups influence ETI outcomes. This will help ensure that ETI can meaningfully contribute to ecosystem-based management while remaining scientifically robust and relevant to policy.

There was strong support for enhancing cross-tRFMO collaboration, including joint technical work, shared repositories, and coordinated funding proposals. International processes, including emerging biodiversity frameworks, were identified as opportunities to support this work and demonstrate progress in ecosystem-based fisheries management.

Ultimately, the success of the ETI will depend on its ability to provide clear, policy-relevant insights that can be integrated into RFMO decision-making processes. This will require not only technical development but also sustained efforts to improve communication, build capacity, and strengthen the link between science and management.

5 Synthesis, Recommendations, Action Plan and Cross-Cutting Conclusions

Building on the technical exchanges from Days 1–4, discussion on the final day aimed to consolidate key findings, identify priority actions, and define a structured workplan to advance the development of ecosystem and climate indicators for EAFM implementation.

Participants agreed that, although significant progress has been made in incorporating ecosystem considerations into scientific work, these efforts remain insufficiently integrated into RFMO decision-making processes. A central objective of the session was therefore to move beyond diagnosis and toward actionable recommendations that can support the operationalization of EAFM, emphasizing the need for a coordinated, pragmatic approach that balances scientific ambition with institutional feasibility.

5.1 Synthesis of Key Findings

5.1.1 STATUS OF EAFM ACROSS RFMOS

The workshop confirmed that all tRFMOs have made meaningful progress in incorporating ecosystem considerations into their work. These efforts include the development of ecosystem and climate indicators, implementation of various EAFM-related management measures (e.g., bycatch mitigation), and increasing attention to issues such as fish aggregating devices (FADs) and environmental variability.

However, this progress remains uneven and largely implicit. Across tRFMOs, ecosystem elements are often implemented through individual measures rather than as part of a coherent EAFM strategy. As a result, ecosystem considerations are present but not systematically embedded in management processes.

Participants agreed that the current situation can be characterized as one in which EAFM elements exist but are not yet operationalized. A key gap lies in the absence of clear pathways linking ecosystem information to management decisions, limiting the practical impact of existing scientific work.

5.1.2 ROLE AND LIMITATIONS OF CURRENT INDICATORS

A central conclusion of the workshop was that the challenge is not the lack of ecosystem and climate indicators, but rather their limited use in decision-making contexts. Many indicators have been developed across tRFMOs, yet they are often not prioritized, lack clear interpretation frameworks, and are not explicitly linked to management objectives or actions.

As a result, indicators tend to be used primarily for descriptive purposes, providing contextual information rather than informing decisions. This limits their effectiveness and reduces their visibility within tRFMO processes. Participants emphasized that the key question is not what indicators exist, but how they can be used effectively within advisory and management frameworks. The workshop

also noted that many indicators are presented at SC, but not shown at the commission level which complicates efficient communication between science and management.

5.1.3 COMMUNICATION AS A CENTRAL CONSTRAINT

Communication emerged as one of the most significant cross-cutting constraints. Scientific outputs are frequently highly complex, insufficiently synthesized, or not clearly linked to management questions. In many cases, indicators are presented without adequate interpretation, making it difficult for managers to understand their implications. Participants also noted that there is often insufficient time, and in some cases insufficient priority, during tRFMO Commission meetings to address ecosystem science and how such information could be incorporated into decision-making processes.

Participants highlighted that improving communication is essential for enhancing the uptake of ecosystem information and supporting informed decision-making. Tools such as ecosystem report cards, Ecocards, and risk tables were identified as effective mechanisms for translating complex information into accessible and policy-relevant formats.

Strengthening communication was also seen as a means of bridging the gap between scientists and managers, which remains a persistent challenge across tRFMOs.

5.1.4 INTEGRATION INTO MANAGEMENT FRAMEWORKS

A major gap identified across all discussions is the limited integration of ecosystem indicators into core management processes, including MSE, harvest strategies, and the advisory outputs of Scientific Committees.

Participants agreed that without such integration, indicators will remain informational rather than operational. Moving toward operational use requires embedding ecosystem indicators within existing decision-making frameworks — for example, as performance metrics in MSE and as components of risk-based advice. This transition represents a fundamental shift from monitoring ecosystem conditions to actively using ecosystem information to inform management decisions.

5.1.5 ROLE OF ETI AND MODEL-BASED INDICATORS

The ETI was recognized as a promising integrative tool that can provide system-level insights into ecosystem structure and functioning. Its ability to synthesize complex interactions into a single metric was seen as particularly valuable for communication and comparative analysis.

However, participants agreed that the ETI is not yet ready for routine application within tRFMO advice. Key limitations include data requirements, model uncertainty, and the absence of clear interpretation frameworks. As such, the ETI should currently be used as a complementary tool, supporting deeper analysis and providing ecosystem context rather than serving as a direct basis for management decisions.

5.2 Cross-Cutting Themes

Several cross-cutting themes emerged consistently across all sessions.

First, there is a need for prioritization. While many indicators exist, only a small subset should be selected for routine use, ensuring clarity and usability within time-constrained decision-making processes. Therefore, there is a need to reduce the number of indicators to a small, manageable set that can be consistently applied and clearly interpreted.

Second, participants emphasized the importance of balancing simplicity and complexity. Effective frameworks should combine simple, empirical indicators for communication with more complex, model-based indicators for analysis, reflecting a layered approach to ecosystem assessment.

Third, harmonization across tRFMOs was identified as both feasible and beneficial. Shared approaches to key indicators — particularly those related to bycatch, FAD impacts, and climate variables — can enhance comparability and efficiency while supporting collaboration, as well as inform the best way to incorporate them in communication tools (e.g., Ecocards, risk tables) to inform management decisions.

Fourth, capacity constraints remain a significant barrier. Limitations in data, expertise, and funding affect all aspects of indicator development and application, particularly for ecosystem modeling.

Finally, collaboration was recognized as a key enabler. Strengthening inter-tRFMO collaboration can support knowledge sharing, reduce duplication, advance indicator development more efficiently and accelerate progress toward operationalizing EAFM.

5.3 Recommendations

The workshop identified a set of priority recommendations to advance the development and operational use of ecosystem and climate indicators within tRFMOs.

These include prioritizing the development of a small set of core indicators, improving communication tools such as Ecocards and risk tables, and integrating ecosystem indicators into management advice and MSE frameworks. Participants also emphasized the importance of strengthening collaboration and data sharing across tRFMOs, continuing the development and testing of the ETI, and enhancing capacity building and access to funding. These recommendations are accompanied by an agreed workplan to address some of those recommendations and identified priority issues across tRFMOs, including collaborative actions that can be implemented in the near term using existing capacities, as detailed in the following section.

Operationalization of Indicators

- A key overarching recommendation is to move from descriptive indicator frameworks toward operational systems that directly support decision-making — for example, through their integration into MSE and harvest strategies as performance metrics or exceptional circumstances.

- Maintain the complementary role of **surveillance/sentinel indicators**, which can provide trends and early warning signals without necessarily triggering immediate management action.
- Promote the use of both **empirical and model-based indicators** as complementary components within a layered indicator framework.

Indicator Selection and Prioritization

- Develop and apply **agreed indicator selection criteria** within each tRFMO, ensuring indicators are scientifically robust, feasible, transparent, and policy relevant.
- Prioritize the development of a **small set of core indicators** among tRFMOs, supported by additional indicators in an annex where appropriate (core + annex approach).
- Explore harmonized core indicators across tRFMOs with regional flexibility.
- Initiate pilot testing of a **limited number of harmonized core indicators** across tRFMOs, including:
 - Bycatch indicators
 - FAD-related indicators
 - Environmental indicators (e.g., larval habitat suitability, SST-based indicators)
 - The Ecosystem Traits Index (ETI)

Integration into Management Processes

- Establish **clear pathways for integrating ecosystem indicators into tRFMO advisory and decision-making processes**, including Scientific Committees, MSE frameworks, and Commission discussions.
- Ensure that ecosystem considerations are incorporated into management advice by, for example:
 - Providing **qualitative ecosystem information alongside stock assessment and management advice**
 - Evaluating ecosystem impacts when proposing CMMs, including potential disproportionate ecosystem effects
 - Developing integrated summary tables (e.g., risk tables, Ecocards) combining stock assessment results, ecosystem indicators, and, where relevant, industry perspectives

Communication and Uptake

- Strengthen the use of **standardized communication tools** to improve interpretability and uptake by managers, including:
 - Ecosystem report cards and Ecocards
 - Risk tables linking ecosystem indicators with stock status and management advice
 - Concise executive summaries incorporating ecosystem considerations tailored to Commission needs
- Promote **harmonized definitions, formats, terminology, and presentation** approaches across tRFMOs to facilitate consistency and understanding.
- Enhance visibility and accessibility of ecosystem information through **tRFMO websites and reporting platforms**.

Science–Management Interface

- Strengthen **dialogue between scientists and managers**, including engagement and intersessional discussions to ensure indicators are relevant, understood, and usable.
- Report progress regularly to **Scientific Committees**, allowing for iterative review, refinement, and eventual uptake at Commission level.

Harmonization and Collaboration

- Advance the development of **harmonized core indicators across tRFMOs**, while allowing for regional flexibility in application.
- Strengthen **inter-tRFMO collaboration** including:
 - Definitions and terminology for indicators
 - Sharing methodologies, tools, and data
 - Coordinating scientific efforts and workshops
 - Encouraging participation of experts across tRFMO processes
- Continue enhancing capacity building on ecosystem and climate indicator development across tRFMO stakeholders.

Broadening Indicator Frameworks

- Explore the development and use of **socio-economic indicators** alongside ecosystem indicators to support more comprehensive EAFM implementation.

- Promote collaboration with economists and social scientists, including through existing working groups and interdisciplinary initiatives.

These recommendations reflect a common understanding that advancing EAFM in tRFMOs requires not only improved indicators, but also clear pathways for their integration, effective communication, and strengthened collaboration across scientific and management communities.

5.4 Action Plan

Participants proposed a phased action plan to guide implementation of these recommendations above.

In the short term, priorities include identifying and agreeing on common terminology and definitions, a core set of indicators, improving communication tools and providing template examples of executive summaries integrating information from those core indicators, enhancing transparency and documentation, and initiating cross-RFMO coordination mechanisms as well as refining and updated the ETI estimations.

In the medium term, efforts should focus on integrating indicators into MSE frameworks and advisory processes more formally through discussions at tRFMO Scientific Committees, expanding the use of risk-based approaches, advancing ETI development, and developing shared data platforms and modeling tools.

In the long term, the goal is to fully operationalize EAFM within tRFMO decision-making, establish routine use of ecosystem indicators in advice more formally through discussions at tRFMO Scientific Committees and Commission levels, and maintain integrated ecosystem modeling frameworks supported by sustained collaboration and capacity.

Priority Actions identified by the workshop

- Agree to common terminology and definitions
- Identify and agree on a **core set of ecosystem and climate indicators**
- Initiate pilot testing of a **limited number of harmonized core indicators across tuna RFMOs**, including:
 - Bycatch indicators
 - FAD-related indicators
 - Environmental indicators (e.g., larval habitat suitability, SST-based indicators)
 - The Ecosystem Traits Index (ETI)
- Develop or refine **pilot communication tools** (e.g., Ecocards) and risk-based approaches using as examples the core indicators harmonized across tRFMOs

- Develop procedures to integrate the core indicators into management **advisory processes**, such as:
 - Integrate indicators into MSE frameworks and advisory processes
 - Expand the use of risk-based approaches
- Advance **ETI development for tRFMOs**, including validation and standardization
- Develop **shared data platforms and modeling tools**
- Improve **documentation and transparency** of selected indicators
- Initiate **cross-tRFMO coordination mechanisms**

Participants were informed that the EAFM component of the Common Oceans Tuna Project will be extended, with additional funding available through May 2027 to support the short-term priority actions identified above during the workshop. This funding is intended to facilitate targeted progress toward the operationalization of EAFM through ecosystem and climate indicators.

In summary, the work will focus on the development and pilot testing of a harmonized set of core ecosystem and climate indicators, including their application across spatial scales, definition of baselines, and integration into management processes through tools such as Ecocards, risk tables, and executive summary formats for presentation to tRFMO Scientific Committees. In parallel, further development of the ETI will be undertaken, including validation, refinement of its interpretation framework, and preparation of outputs to support its application across tRFMOs (see short term activities for ETI in Table 6). These activities will culminate in a follow-up workshop (planned for early 2027 in Hobart), which will provide an opportunity to review progress, advance technical developments, and discuss pathways for incorporating these tools into tRFMO decision-making processes.

Table 6. Priority tasks, timelines, and sequencing for the further development and validation of the Ecosystem Traits Index (ETI) across tuna RFMOs. This table summarizes the key tasks identified by the workshop to advance the development and application of ETI across tuna RFMOs. Tasks are categorized by indicative timeframe (short-term or long-term) and region, reflecting their relative priority and feasibility within current capacities and the new FAO project. Short-term actions focus on immediate priorities, including validation of preliminary ETI estimates, further model development, expanded application across regions, refinement of interpretation frameworks, improvement of model inputs and documentation, and preparation of communication outputs. The table is intended to guide implementation planning, support prioritization of resources, and facilitate coordinated progress across RFMOs.

			AREA			
Theme	Task	Priority	Warm Pool	EPO	AO	IO
Transparency/ reproducibility	Create a central documentation repository for work undertaken to date	Short term	X	X	X	X
	Agree to common terminology/definitions					
Different Model Types	Evaluate range of trophic models (e.g., size-based) for calculating ETI as an alternative to EwE given resources available	Medium term	X (preliminary exploration of alternative models -> feasibility study)			

EwE/ETI model inputs	Procedures for mapping tRFMO data to EwE	Short term	X led by WCPFC (guidelines and methods on how to do the extraction of data, transferable to other RFMOs)	X	X	X
	- Space, time, and species - Procedures for doing this					
	Update EwE/ETI data:	Short term	X	X (tropical)		
	- Data by fishery/area - Recalculate whole time series – methods - Spatial domain and spatial structure (that accommodates each tRFMO's spatial structure) - Important non-tRFMO fisheries		Use Seapodym for tropical spp-s	Potentially expand to N/S 20 degree	X (tropical)	X (tropical)
EwE/ETI Model structures	HUB species:	Short term	X	X	X	X
	Investigate the Super HUB groups (sharks-WCPFC, mesopelagics, etc)					
	Diet matrix -Sensitivity analysis for EwE/ETI	Short term	X (student work to balance different EwE models with different diet matrices)	X	X	X

	Diet matrix - DNA transition	Longer term	X			
	Sensitivity of ETI to model/data after model consolidation	Short term	X	X	X	X
Further development and update ETI calculations	Update ETI calculations • Separate heat map/etc. from ETI (sanity test) • Stress testing	Short term	X	X	X (explore plug-in development within Ecopath to automatically get index and diagnostics from the EwE software)	X (explore plug-in development within Ecopath to automatically get index and diagnostics from the EwE software)
Further EwE developments	Build in EcoSpace	Medium term	X	X	X	X
ETI Communication and advice	Investigate options for incorporating ETI outcomes into management advice Consider value of linking to harvest strategies as a performance indicator (ecosystem-level harvest control rule)	Medium term	X	X	X	X

5.5 Conclusions

The workshop concluded that tRFMOs are at a critical transition point in the implementation of EAFM. While substantial progress has been made in developing ecosystem indicators and advancing scientific understanding, the primary challenge now lies in translating this knowledge into practical management tools.

Achieving this transition will require prioritization and simplification of indicator frameworks, improved communication and usability, integration into existing management processes, and sustained collaboration across RFMOs.

A key message emerging from the workshop is that EAFM implementation is not constrained by a lack of science, but by the need for structured, transparent, and institutionally feasible pathways to integrate that science into decision-making. The group also agreed that the ETI index represents an important step toward more integrated ecosystem assessment, but should be developed alongside, and not replace, simpler ecosystem/climate indicators.

Participants expressed strong support for continuing the collaborative process initiated through the workshop. Regular joint workshops, shared methodological development, and ongoing dialogue between scientists and managers were identified as essential components of future progress.

The outcomes of this workshop provide a clear and actionable roadmap for advancing ecosystem indicators within tRFMOs. They also represent an important contribution to the broader global effort to operationalize the Ecosystem Approach to Fisheries Management in tRFMOs.

References

- Fuller L., J. Lopez, S. Griffiths, D. Crear, A. Aires-da-Silva, M.J. Juan-Jordá, V. Allain, and H. Murua. 2024. Review of T-RFMO ecosystem research to inform a workplan on Ecocards for the EPO. IATTC Document WGEB-02-02.
- Fuller L., J. Lopez, S. Griffiths, D. Crear, J.-F. Pulvenis and A. Aires-da-Silva. 2025. Progress of the Ecocard workplan: establishing the purpose and developing a framework. IATTC Document EB-03-04.
- Fulton, E.A. and K.J. Sainsbury (2024) Food web structure, the hub index and identifying species of ecological significance. *Ecological Indicators* 166. <https://doi.org/10.1016/j.ecolind.2024.112378>
- Fulton, E.A. and K.J. Sainsbury (2025) The Ecosystem Traits Index is proposed as a composite index of ecosystem robustness for use in marine resource management. *Nature Sustainability* 15: 32281. <https://doi.org/10.1038/s41598-025-15322-z>
- Fulton, E.A., K. Sainsbury, C. Bulman, C. Novaglio, J. Porobic, D. Hayes, E.I. van Putten, L.X.C. Dutra, L. Thomas, W. Norris, C. Pert, A. Willock, S.C. Montenegro, L. Garay- Narvaez, S. Hernández Concha, A. Hernández Saso, K.S. Mohamed, T.V. Sathianandan, S. Kuriakose, E. Varghese, T.M. Najmudeen, S. Vasudevan, M. Anish, S.S. Salim, I. Mandro, S. Zador, I. Ortiz, A. Whitehouse, K. Aydin, W. Tweit, D. Evans. 2025. The Green Band: Using Production and Catch to Judge Distortive Pressure on an Ecosystem. *BioRxiv*. <https://doi.org/10.1101/2025.06.09.658403>.
- Gao, J., Barzel, B. & Barabási, A.-L. Universal resilience patterns in complex networks. *Nature* 530, 307–312. <https://doi.org/10.1038/nature16948>.
- Juan-Jordá M.J., H. Murua, H. Arrizabalaga, and A. Hanke. 2018a. A template for an indicator-based ecosystem report card for ICCAT. SCRS/2017/140. *Collect. Vol. Sci. Pap. ICCAT* 74 (6): 3639-3670.
- Juan-Jordá M.J., H. Murua, and E. Andonegi. 2018b. An indicator-based ecosystem report card for IOTC -An evolving process. *IOTC-2018-WPEB14-20*. 17 p.
- Juan-Jordá, M. J., H. Murua, P. Apostolaki, C. Lynam, A. Perez-Rodriguez, J. C. Baez-Barrionuevo, F. J. Abascal, R. Coelho, S. Todorovic, M. Uyerra, E. Andonegi, and J. Lopez. 2019a. Selecting ecosystem indicators for fisheries targeting highly migratory species. Final Report. European Commission. Specific Contract No. 2 EASME/EMFF/2015/1.3.2.3/02/SI2.744915 under Framework Contract No. EASME/EMFF/2016/008. pp. 1-395.
- Juan Jordá M.J., A.-E. Nieblas, H. Murua, P. De Bruyn, S. Bonhommeau, M. Dickey Collas, M. Dalleau, F. Fiorellato, D. Hayes, I. Jatmiko, P. Koubbi, M. Koya, M. Kroese, F. Marsac, P. Pepin, U. Shahid, P. Thoya, S. Tsuji, A. Wolfaardt. 2020. 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, 29 August- 1 September 2019. *IOTC-2019-WPEB15-INF01*.
- Juan-Jordá M.J., H. Murua, G. Diaz, P. Obregon, L. Kell, D. Alvarez-Berastegui, A. Eider, R. Coelho, T. Sachiko, D. Ochi, A. Domingo, D. Die, O. Yates, I. Tai, J. Bell, P. Tugores, and A. Hanke. 2022a. Report of the 1st Meeting of the Sub-Group on the Ecosystem Report Card. SCRS/2022/104. *Collect. Vol. Sci. Pap. ICCAT* 79 (5): 152-164.
- Juan-Jorda, M., Nieblas, A., Tsuji, S., Marsac, F., Chasso, E., Hayes, D., Shahid, U., Khan, M., Andonegi, E., de Bruyn, P., Fiorellato, F., Thoya, P., Green, M., Kitakado, R., Nelson, L., Ramos-Alonso, L., Martin, S., Moss, J., Lopetegui-Eguren, L., Murua, H. 2022b. Report of the Second IOTC Ecoregion Workshop on "The Identification of Regions in the IOTC Convention Area to Inform the Implementation of the Ecosystem Approach to Fisheries Management." *IOTC-2022-WPEB18-22*.
- Juan-Jordá, M.J., Murua, H., Idárraga-Garcés, V., Andonegi, E. 2024. Ecosystem Fisheries Overviews - Assessing the applicability of IOTC candidate ecoregions as a spatial framework for developing ecosystem-based advisory products. *IOTC-2024-WPEB20(AS)-24*.
- Lopez J., M.H. Román, C.E. Lennert-Cody, M.N. Maunder, N. Vogel, L.M. Fuller, S. Caillot. 2026. Floating-object fishery indicators: a 2025 report. IATTC Document FAD-10-01.

Annex 1

WCPFC APPLICATION OF EAFM - Mandate

INTRODUCTION

- Overview of WCPFC relevant mandates, resolutions, and ongoing RFMO processes relevant to EAFM implementation
- Role of ecosystem and climate indicators in EAFM implementation and climate-resilient management progress

MANDATE

- WCPFC Convention text does not explicitly include the application of the Ecosystem Approach to Fisheries Management
- Does explicitly include references to ecosystems
- *Preamble: Conscious of the need to avoid adverse impacts on the marine environment, preserve biodiversity, maintain the integrity of marine ecosystems and minimize the risk of long-term or irreversible effects of fishing operations.*
- *Main text: Article 5 Principles and measures for conservation and management*
 - *(d) assess the impacts of fishing, other human activities and environmental factors on target stocks, non-target species, and species belonging to the same ecosystem or dependent upon or associated with the target stocks;*

MANDATE

- Scientific Committee
- Article 12 Functions of the Scientific Committee
 - *encourage and promote cooperation in scientific research, taking into account the provisions of article 246 of the 1982 Convention, in order to improve information on highly migratory fish stocks, non-target species, and species belonging to the same ecosystem or associated with or dependent upon such stocks in the Convention Area.*
- Article 13 Scientific services
 - 2 (b) conduct assessments of highly migratory fish stocks, non-target species, and species belonging to the same ecosystem or associated with or dependent upon such stocks, within the Convention Area;
 - 2 (c) assess the impacts of fishing, other human activities and environmental factors on target stocks and species belonging to the same ecosystem or dependent upon or associated with the target stocks

IMPLEMENTATION

- Conservation and Management Measures
 - Sharks
 - Seabirds
 - Turtles
 - Cetaceans
 - Mobulid Rays
 - Marine Pollution
 - FADs
- Resolutions
 - Climate Change
- Harvest Strategies
 - Single and multi-species

IMPLEMENTATION

- Sharks

- Key Shark Species
- Status Assessment
- Shark Research Plan
- Non retention
- No finning
- Gear restrictions
- Safe handling

- Seabirds, Turtles, Cetaceans, Mobulid Rays

- Non retention
- Gear restrictions
- Mitigation
- Safe handling

- FADs, Marine Pollution

- Design (non-entangling)
- Encourage Biodegradable
- Number Active limits

ROLE OF ECOSYSTEM AND CLIMATE INDICATORS

- Ecosystem Status
- Supportive rather than decision orientated
 - No significant impact
 - Consistent with best practice (e.g. FAO code of conduct for responsible fishing; International Plans of Action)
 - Community expectations
 - Inform Harvest Strategies
 - Change in productivity
 - Evidence for exceptional circumstances
 - Trend rather than absolute
 - Empirical rather than model based
 - Singular rather than integrative

tRFMO PHILOSOPHY

- Standards are evolving not static
- tRFMO's need to evolve to meet those expectations
 - Traditionally single species/issued focussed
 - Evolve conventions/CMM's that adopt EAFM
 - Evolve EAFM tools to decision responsiveness
 - reference points or thresholds that signal ecosystem change
 - evaluate management options

WCPFC APPLICATION OF EAFM - Scientific Approach

INTRODUCTION

- Existing WCPFC ecosystem and climate indicators
- Scientific objectives of indicator development (diagnostic, explanatory, predictive)
 - Fisheries indicators (e.g., catch rates, effort)
 - Physical oceanographic indicators (e.g., SST, oxygen, productivity)
 - Biological and ecosystem indicators (e.g., forage species, bycatch, biodiversity)
- How indicators are currently used to tracking ecosystem change and supporting EAFM
- Strengths and weaknesses of indicators: Limitations, uncertainties, and appropriate interpretation of indicators

SCREENING CRITERIA

- science and data based;
- characterize the states and trends of WCPFC marine ecosystems with respect to fishing activity and/or climate (including reference levels and baselines);
- reflect well-defined processes underlying fishing activity and fishery responses to climate;
- responsive to changes attributable to fishing pressure and climate (ie. minimal time-lags and capability to provide early warning);
- estimable on a routine basis with a historical data time-series available;
- cost-effectiveness;
- scalable across national, sub-regional and regional scales;
- linked to existing WCPFC models and decision-making processes (for inclusion in MSE scenarios, validation of predictions and testing of model assumptions);
- can be routinely estimated by members without reliance of the SSP.

System/Ocean Basin Condition Indices

Oceanography

- ENSO strength
- PDO strength
- North Pacific Circulation
- Southern Annular
- Indian Dipole
- Warmpool Area

Habitat Compression

- Large Marine Heatwaves
- Tuna spawning habitats
- Micronekton trend
- Primary productivity
- Oxygen depletion

Model Coherence

- Recruitment indices
- Distributional shifts
- Nutrient pump
- Isotope cycling

Feature/Sub-Regional Condition Indices

Oceanography

- East Australia Current
- New Caledonia jet
- Warmpool

Habitat Compression

- Heatwaves
- Acidification events
- Localised spawning
- PP change
- Microbiome
- Effort shiftS

Model Coherence

- Sub-regional HSI

Local/EEZ Condition Indices

Oceanography

- SSH trend
- SST trend
- Anoxic events

Habitat Compression

- Micronekton depletion
- Refuge
- Catch composition
- Fat composition
- Trophic composition

Model Coherence

- CSIRO tuna forecast

Develop and test indicators

- Interpretability
- Appropriate and relevant reference levels
- Predictive capability and reliability
- Robustness to data availability
- Management relevance
- Accepted

Management Decision Inputs

Exceptional Circumstances

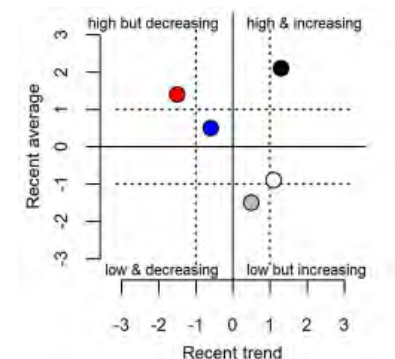
- Outside tested MSE conditions
- Outside 5-point rolling average
- Outside defined thresholds

Regional & National Outlooks

- Average to favourable conditions
- Unfavourable conditions
- Report Cards

Climate Tracking

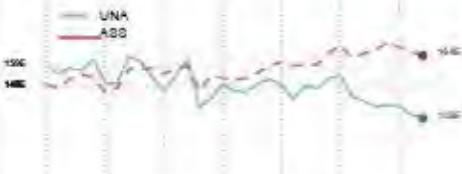
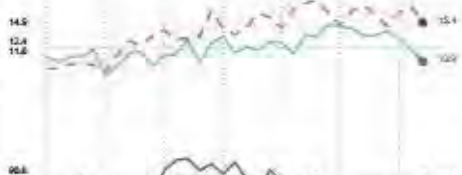
- Within climate trajectory
- Proximity to trigger points
- Report Cards

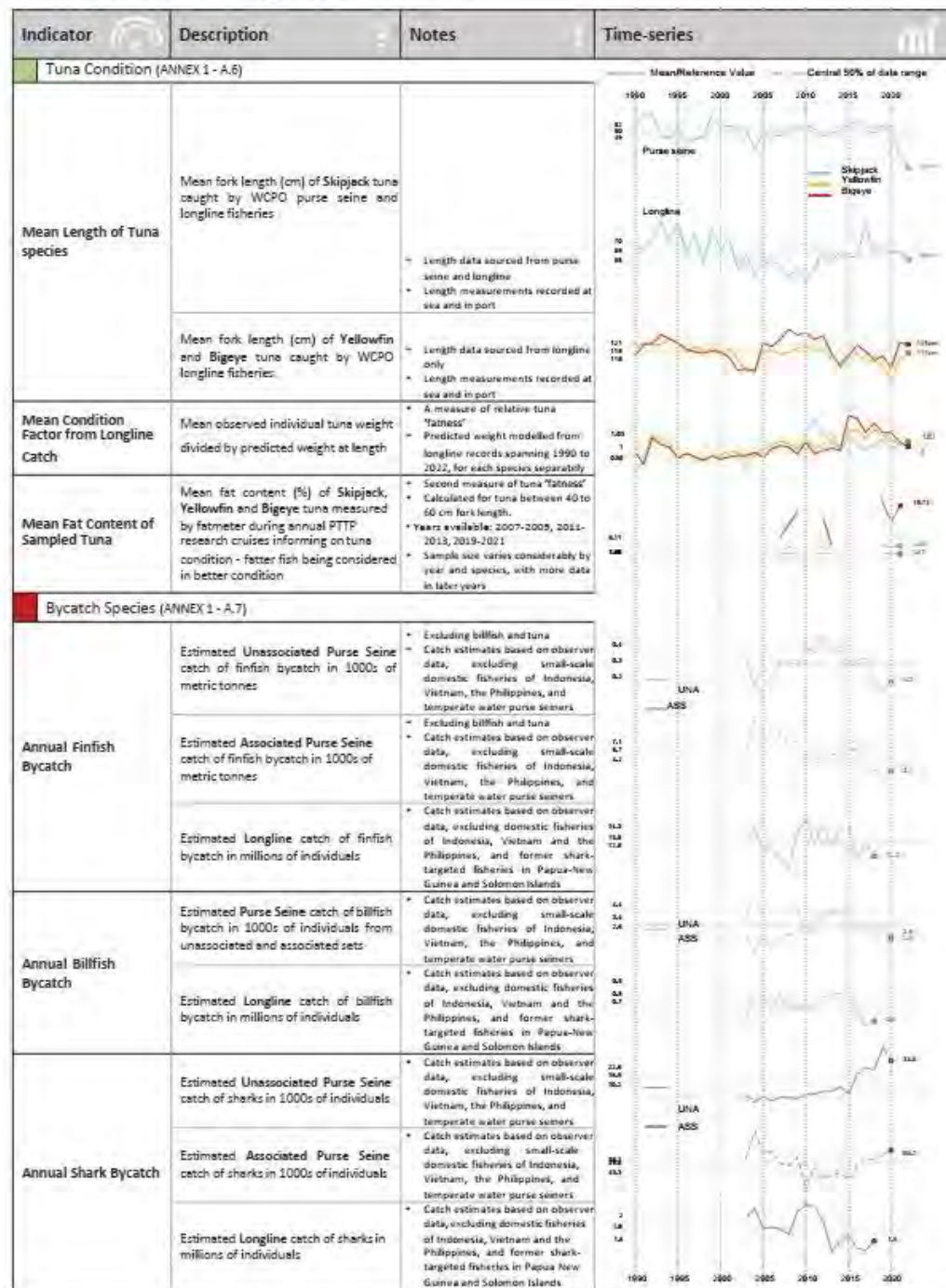


WCPFC CANDIDATES

Report Card 1. Environment Indicators

Indicator	Description	Notes	Time-series
Sea Surface Temperature Anomalies (ANNEX 1 - A.1)			
Annual SST Anomaly	Mean annual SST anomaly (°C) across WCPO area	- Derived from ocean models - WCPO area western limit of 130°E - Anomaly from mean temperature 1993-2021	Mean/Reference Value — Central 50% of data range 1990 1995 2000 2005 2010 2015 2020
	Mean annual SST anomaly (°C) across WCPO equatorial zone	- Derived from ocean models - Equatorial zone 5°S-5°N - Anomaly from mean temperature 1993-2021	
Nov-Apr Warm-pool SST Anomaly	Mean annual SST anomaly (°C) within warm-pool extent	- Derived from ocean models - Warm-pool defined by mean Nov-Apr temperature > 29°C	
Warm-pool Indices (ANNEX 1 - A.2)			
Mean Size of Warm-pool	Approximate size of warm-pool in millions of km ²	- Derived from ocean models - Warm-pool defined by mean Nov-Apr temperature > 29°C	
Eastern Limit of Warm-pool Boundary	Longitude of strongest sea surface salinity boundary	- Derived from ocean models - Boundary defined as largest change over 10° distance	
Mean Warm-pool Mixed Layer Depth	Mean depth (m) of the mixed layer within warm-pool	- Derived from ocean models - Layer over which water temperature is homogenous	
Climate Indices (ANNEX 1 - A.3)			
Oceanic Niño (ONI) and Interdecadal Pacific Oscillation (IPO) Index	ONI indicates SST anomalies in the Niño 3.4 region during Nov-Jan each year IPO represents long-term oscillation between El Niño favourable and La Niña favourable phases	- ONI values > 0.5 indicative of El Niño events, values < -0.5 indicative of La Niña - IPO values > 0 indicative of more El Niño events, < 0 indicative of more La Niña events - Time series from 1993-2021	

Indicator	Description	Notes	Time-series
Annual Tuna Catch (ANNEX 1 - A.4)			
Annual Tuna Catch	Total Skipjack catch for entire WCPFC-CA, in millions of tonnes	- Data from all fishing gears combined - See Hare et al. (2023) [SC19/SA-WP-06] for a compilation of all fishery indicators for skipjack	
	Total Yellowfin catch for entire WCPFC-CA, in 100,000 of tonnes	- Data from all fishing gears combined - See Hare et al. (2023) [SC19/SA-WP-06] for a compilation of all fishery indicators for yellowfin	
	Total Bigeye and Albacore catch for entire WCPFC-CA, in 100,000 of tonnes	- Data from all fishing gears combined - Data for albacore pertains to the South Pacific stock only - See Hare et al. (2023) [SC19/SA-WP-06] for a compilation of all fishery indicators for bigeye and South Pacific albacore	
Fishing Effort (ANNEX 1 - A.5)			
Annual, Longitudinal Centre of Purse Seine Effort	Mean longitudinal centre of gravity of purse seine effort	- Purse seine effort is disaggregated into unassociated (UNA) and associated (ASS) sets - Associated sets include those made on drifting FADs as well as drifting logs and debris	
Annual Area of Fishing Effort	Total area occupied by Purse Seine fleet annually, in millions of km²	- The sum of the area of 1° x 1° cells with at least one purse seine set, aggregated annually - Purse seine effort is disaggregated into unassociated and associated sets	
	Total area occupied by Longline fleet annually, in millions of km²	The summed area of 5° x 5° cells with at least one longline set, aggregated annually	
Effort in High Seas Areas	Annual proportion of Purse Seine sets made in High Seas areas within the WCPFC-CA	- High Seas areas comprise the 11,12,13,14,15,16,17,18,19,H4,H5 regions - Proportions calculated relative to the total numbers of sets made, for unassociated and associated sets separately	



STRENGTHS & WEAKNESSES

- Strengths
 - Cost-effective
 - Repeatable by all RFMO members (Data rather than model driven)
 - Familiar/Simple framework for testing
 - Focus on “trends & variance” rather than absolute values
 - Advise on magnitude of change
 - Restricted to a few rather than many
- Weaknesses
 - Spatial variability
 - Indirect
 - Difficult to integrate (RFMO becomes the principal EAFM tool)

Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



Context Setting, Commission Perspective – Tuna RFMO EAFM Implementation: IATTC

Jon Lopez, Leanne Fuller, Dan Crear

Annex 2

Overview of Commission Mandates

- Absence of any explicit reference to EAFM in the IATTC normative framework
 - in the 2003 Antigua Convention, which entered into force in 2010,
 - in any instrument adopted by the Commission since 2010 or previously
- However, the Antigua Convention and these instruments:
 - do include EAFM elements
 - are generally interpreted and considered as referring implicitly to EAFM in terms of contents and implementation
 - they take account the two-way relationship between fisheries/stocks and ecosystems/environment

Antigua Convention

- Under the Antigua convention, the IATTC is responsible for ensuring the “long-term conservation and sustainable use of the stocks of tunas and tuna-like species **and other associated species of fish taken** by vessels fishing for tunas and tuna-like species in the eastern Pacific Ocean (EPO)”
- Article IV. “Where the status of target stocks or **non-target or associated or dependent species** is of concern, the members of the Commission shall subject such stocks and species to enhanced monitoring in order to review their status and the efficacy of conservation and management measures. They shall revise those measures regularly in the light of new scientific information available.”
- Article VII. “adopt, as necessary, conservation and management measures and recommendations **for species belonging to the same ecosystem** and that are affected by fishing for, **or dependent on or associated with, the fish stocks covered by this Convention**, with a view to maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened

Strategic planning

- Absence of a strategic vision and objectives specifically referring to EAFM and its implementation
- However, inclusion in the IATTC strategic vision and objectives of specific references to the environment and the ecosystems, with sections on “*Interactions among the environment, the ecosystem, and fisheries*” in the IATTC Strategic Science Plan [2019–2023](#), updated in 2025 ([2026–2030](#)) e.g.,:
 - The scientific staff’s mission is “*to undertake state-of-the-art scientific research to inform sound management advice, aiming at the conservation and sustainable use of the marine species and ecosystems covered by the Antigua Convention*”.
 - The scientific staff’s vision includes, among others, the following two elements:
 - “*Minimizing mortality of unutilized bycatch species, thus reducing impacts on the ecosystem*”
 - “*Minimizing the impacts of fishing on the integrity and functioning of the ecosystem, while maintaining profitable and sustainable use of target species*”

Subsidiary body: Ecosystem and Bycatch Working Group

- In 2022 the existing Working Group on Bycatch was replaced with an Ecosystem and Bycatch Working Group (EBWG), with new and expanded terms of reference (Resolution [C-22-06](#));
- Functions (some summarized) -
 - Relationship between bycatch and target species
 - Relationship between species and the environment across different spatiotemporal scales
 - Evaluation and recommendation of:
 - i. **bycatch mitigation and reduction measures** as well as **resilience and adaptation plans** for fisheries and target species in a **dynamic environment**, including, but not limited to, adaptive management and **climate change** impact and adaptation plans;
 - ii. conservation and management measures and recommendations **for species belonging to the same ecosystem** and that are impacted by fishing for, or dependent on or associated with, the fish stocks covered by the Antigua Convention, with a view to maintaining or restoring, as appropriate populations of such species above levels at which their reproduction and sustainability may become seriously threatened;

Subsidiary body: Ecosystem and Bycatch Working Group

- Functions (some summarized; cont.) -
 - Evaluation and recommendation (cont.) of:
 - iii. measures and best practices, as appropriate, to avoid, reduce and minimize waste, discards, catch by lost or discarded gear, catch and mortality of non-target species (both fish and non-fish species), effective methods for safe handling and release of non-target species, and **the effects** if fishing in the Convention Area on associated or dependent species and **habitats**, in particular **endangered species and sensitive habitats**;
 - iv. programs and/or standards for monitoring and data collections to support the Commission's **scientific investigations on ecosystem and bycatch topics**;
 - a. To the extent practicable, assist with the technical development, evaluation and promotion of selective, environmentally safe and cost-effective fishing gear and techniques for by-catch reduction and **minimization of ecosystem impacts**, as well as making recommendations to the Commission regarding related activities such as education, training, technology transfer and capacity building.

Subsidiary body: Ecosystem and Bycatch Working Group

- Functions (some summarized; cont.) -
 - In addition to reporting to the Scientific Advisory Committee (SAC) possibility to report directly to the Commission:
 3. The conclusions and recommendations adopted by the EBWG:
 - i. shall be submitted first of the Scientific Advisory Committee (SAC), for its consideration and endorsement and later submission to the Commission, as endorsed;
 - ii. may be submitted to the Commission directly, whenever they could not be considered and/or endorsed by the SAC or upon the request of the Commission itself.

Institutional Structure

- The institutional structure of the IATTC also includes its “Administration” (Antigua Convention, Art. XII).
 - Reorganization in 2019 and 2020 based on the second IATTC performance review focused on organizational aspects and human resources
 - Two substantive divisions, **Policy and Compliance** and **Scientific Research**
 - In the Scientific Research Division, a lead unit particularly **relevant for all matters related directly or indirectly to EAFM**: the Ecosystem and Bycatch program

Current status of EAFM implementation: Resolutions

- EAFM is not explicitly implemented but EAFM considerations are monitored
- Observers in the purse-seine fishery report interactions with non-target species, but also other activities
 - e.g., disposal of plastics trash at sea ([C-04-05](#)), FAD activity ([C-19-01](#))
- FAD research is conducted pursuant to several resolutions (including monitoring of indicators, biodegradable FADs and start of a voluntary FAD strandings program)
 - Resolutions: [C-25-07](#), [C-23-03](#), [C-23-04](#), [C-23-05](#)
- Resolution [C-24-10](#) on climate change was recently adopted, a workplan for climate-resilient fisheries is in process ([SAC-15-12](#)), first workshop held February 2025; second workshop planned for April 2026
- Adoption of EM minimum standards ([C-24-09](#))
- Resolution [C-25-08](#) on conservation measures for the protection and sustainable management of sharks was adopted (including BHRPs)
- An [EAFM Resolution](#) was proposed (not adopted) at IATTC's 103rd meeting (2025)

Current status of EAFM implementation: EAFM advice

- Advice on EAFM considerations is provided to the Commission:
 - Both the scientific staff and the SAC develop and submit recommendations to the Commission and either implement them or review them, once they are endorsed by the Commission
 - Other subsidiary bodies (e.g., the EBWG) also adopt recommendations and submit them to the SAC and/or the Commission for consideration and endorsement
 - Examples:
 - Dolphin Mortality Limits (DML) established for dolphin species annually
 - For identified vulnerable bycatch species, recommendations for mitigation measures are made:
 - Resolution [C-25-08](#) on conservation measures for the protection and sustainable management of sharks
 - includes guidelines for best handling and release practices for all fisheries recommended in [SAC-15-11](#)
 - a list of priority shark species for research and management recommended in [SAC-15-09](#)
 - Development of >40 FAD indicators (e.g., [FAD-09-01](#)) for a whole assessment of the fishery
 - Annual reporting of *Ecosystem Considerations* (e.g., [EB-03-01](#))
 - Development of an EcoCard Workplan ([EB-02-02](#)) and related progress reports ([EB-03-04](#); EB-04-03)



Questions

Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



Context Setting, Scientific Perspective – Tuna RFMO EAFM Implementation: IATTC

Jon Lopez, Leanne Fuller, Dan Crear

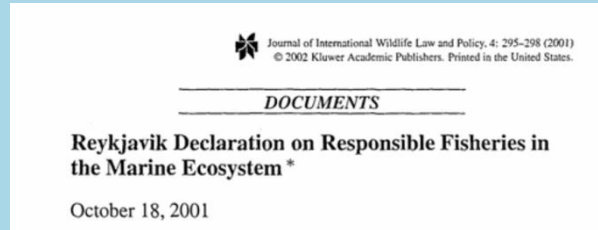
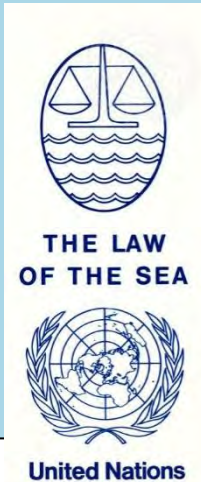
4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators, SPC, Noumea (New Caledonia), 02-06 March 2026

Current indicator framework and initiatives at the IATTC

- Several indicators being currently annually produced/considered by the staff for the Commission and its scientific bodies EBWG, FADWG and SAC:
 - Ecosystem/Ecological considerations: **Ecosystem Considerations Report**.
 - Fishery indicators: **Fishery Status Report**.
 - FAD indicators: several indicators, ranging from fishery to technological and biological – compiled in the **Floating object indicators** report.
 - Climate and environmental indicators: currently under consideration as part of the **CC workplan**.
- Many of these indicators will be selected to show in an eventual **Ecocard and Ecosystem Status Report**. See **Ecocard workplan** for details in this transition.

Current indicator framework and initiatives: EC report

- Annual reporting of *Ecosystem Considerations* (EC) since 2003, initiated by Dr. Robert Olson
- Created in response to development of the EAFM & prompted by:
 - [United Nations Convention on the Law of the Sea](#) (UNCLOS)
 - [Code of Conduct for Responsible Fisheries](#) (CCRF)
 - [Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem](#)
 - Adoption of the Antigua Convention (with references to *“non-target or associated or dependent species”* and *“species belonging to the same ecosystem and that are affected by fishing for, or dependent on or associated with, the fish stocks covered by this Convention.”*)

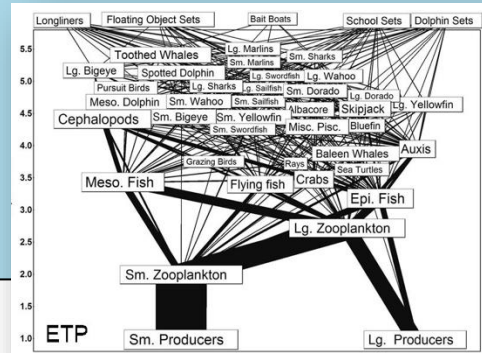


Current indicator framework and initiatives: EC report

- Published as a section in IATTC's Fishery Status Report annually
- Ensure ecosystem considerations are part of the Commission's agenda
- Purpose:
 - to broadly describe fisheries impacts on the ecosystem
- Initial focus (previous year only):
 - Summarized direct impacts of fisheries on species and species groups (bycatch)
 - Reviewed species not directly impacted by fisheries (e.g., prey groups: lanternfishes, flyingfishes)
 - Reviewed annual environmental conditions
 - Included research in the EPO by scientists external to IATTC



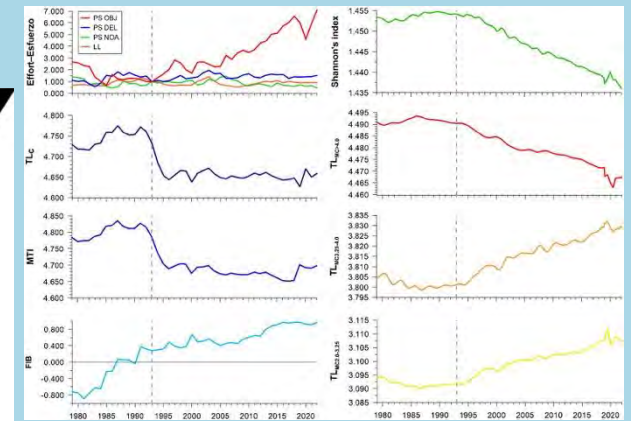
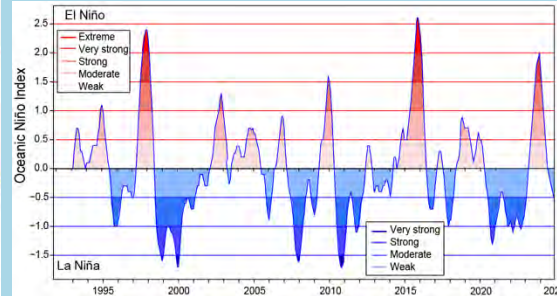
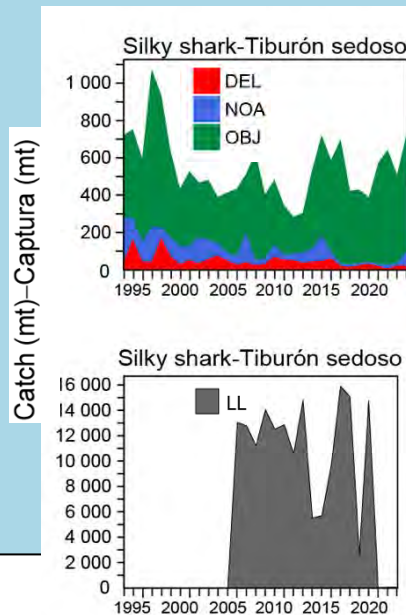
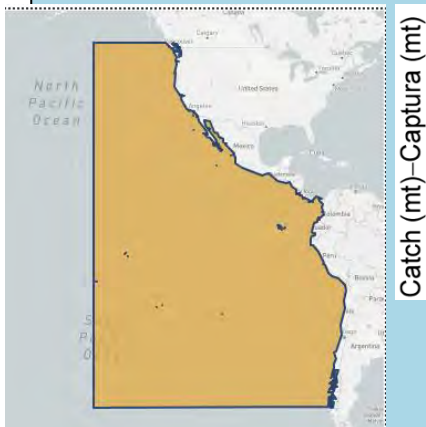
Direct associations



indirect associations

Current indicator framework and initiatives: EC report

- Contemporary changes to the EC report:
 - Time series of observed and/or reported **species-specific bycatch quantities**
 - Provides transparency and context to the relative magnitude of change
 - Inclusion of **minimum reported catches by LL**
 - Reporting of physical environment
 - Updates of analyses prioritizing vulnerable species & exploring hypothetical CMMs (EASI-Fish)
 - Inclusion of ecological indicators from the ETP Ecopath model

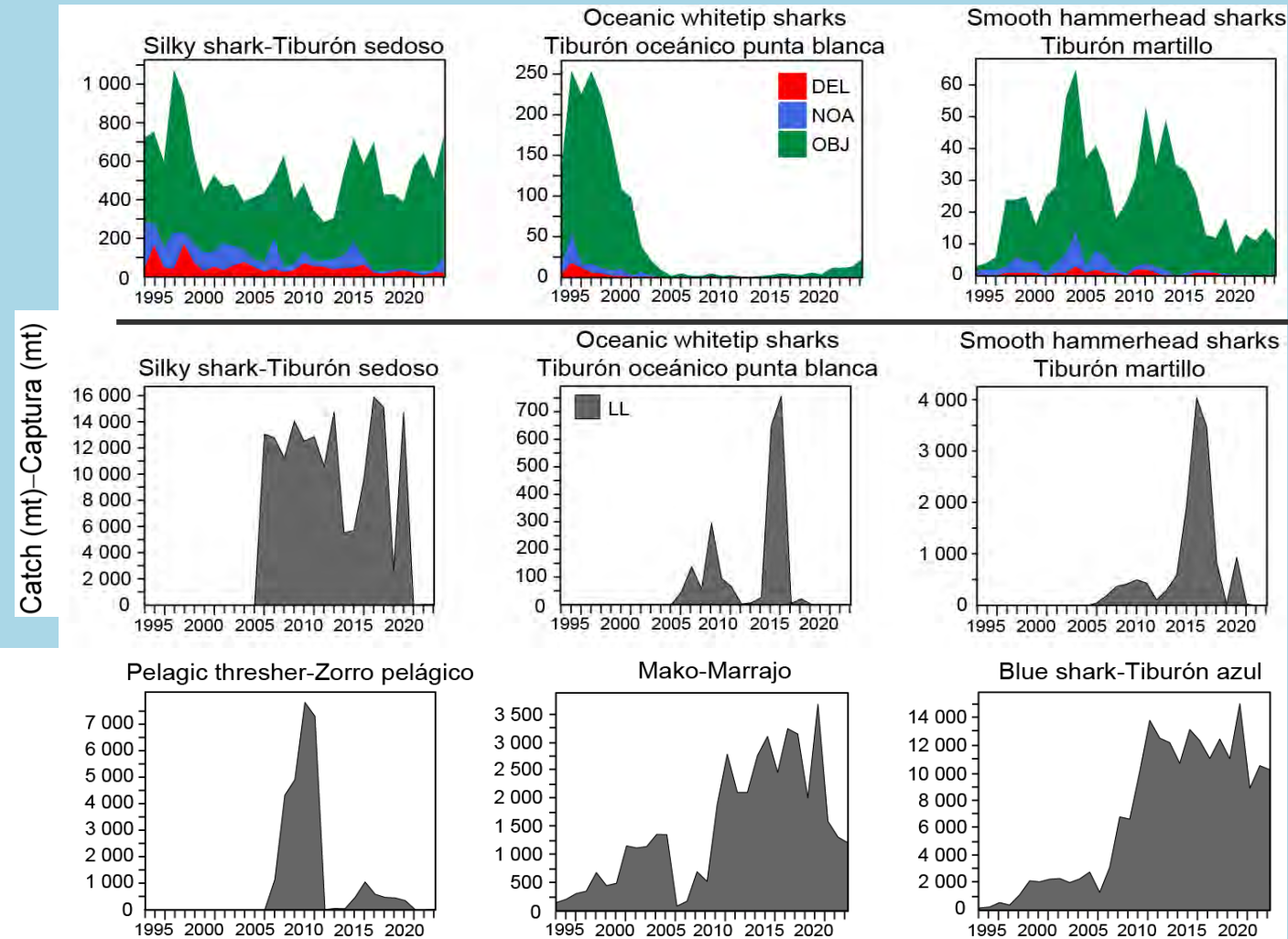


Current indicator framework and initiatives: EC report

- Data availability and quality varies by fishery
 - 100% observer coverage (PS SC-6), includes data on bycatch (see e.g., [EB-03-01](#); [IATTC Special Rpt. 25](#))
 - ~40% observer coverage in 2024 (PS SC 1-5; from TUNACONS), includes data on bycatch (see [WSDAT-02-01](#) & [-02](#))
 - 5% observer coverage (LL), limited data but includes bycatch
- Data sources for bycatch taxa in EC report include:
 - most comprehensive source (PS SC-6 observer data; time series available)
 - minimum reported catches by PS SC1-5 (not estimated totals; previous year only – no time series included yet; estimated totals may be possible for some of the common bycatch species in future e.g., dorado, silky shark)
 - minimum reported catches by LL observer data (not estimated totals; previous year only – no time series; insufficient for estimating bycatch totals (see [BYC-10 INF-D](#)))
 - minimum catches by longline vessels (“Task I” data)
 - obtained using “Task I” summarized data of gross annual removals (time series where available) data provision [specifications](#) (Res. [C-03-05](#)) – limited data on bycatch, only those reported to IATTC; time series included for some commonly-reported bycatch species

Current indicator framework and initiatives: EC report

- Shark example (similar plots are provided for other taxonomic groups – dolphins, sea turtles, rays, fishes):

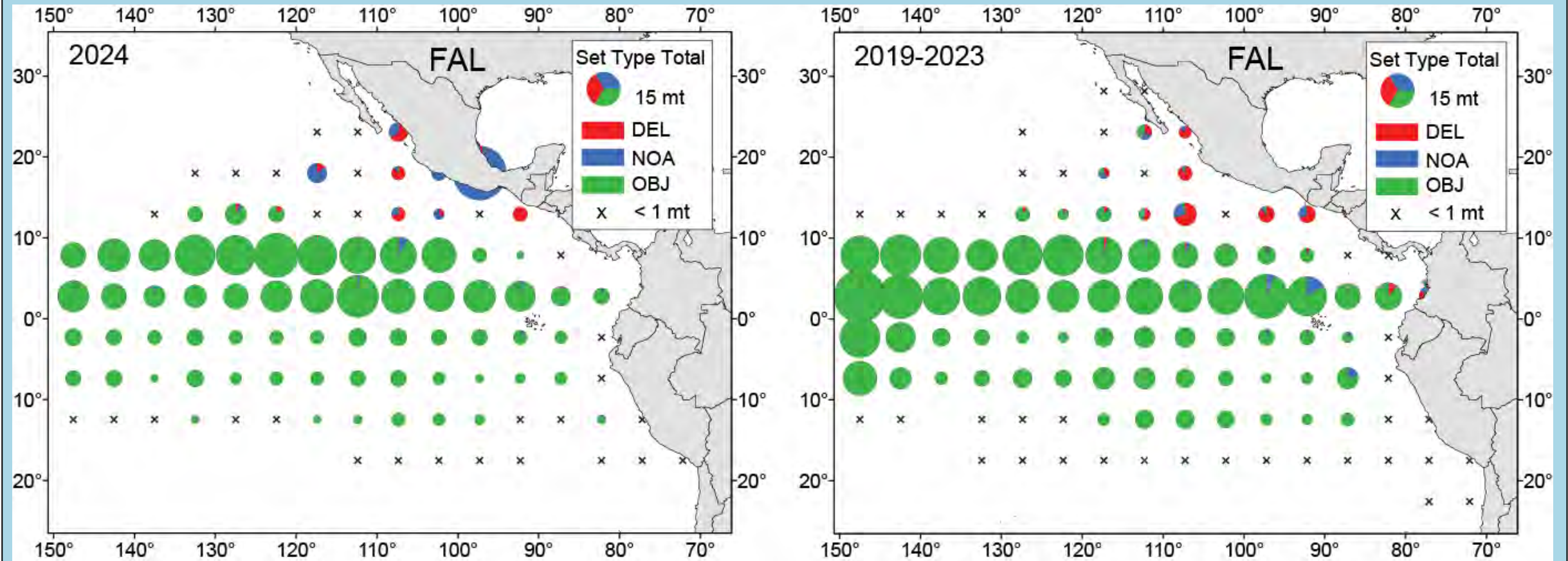


Purse-seine

Longline

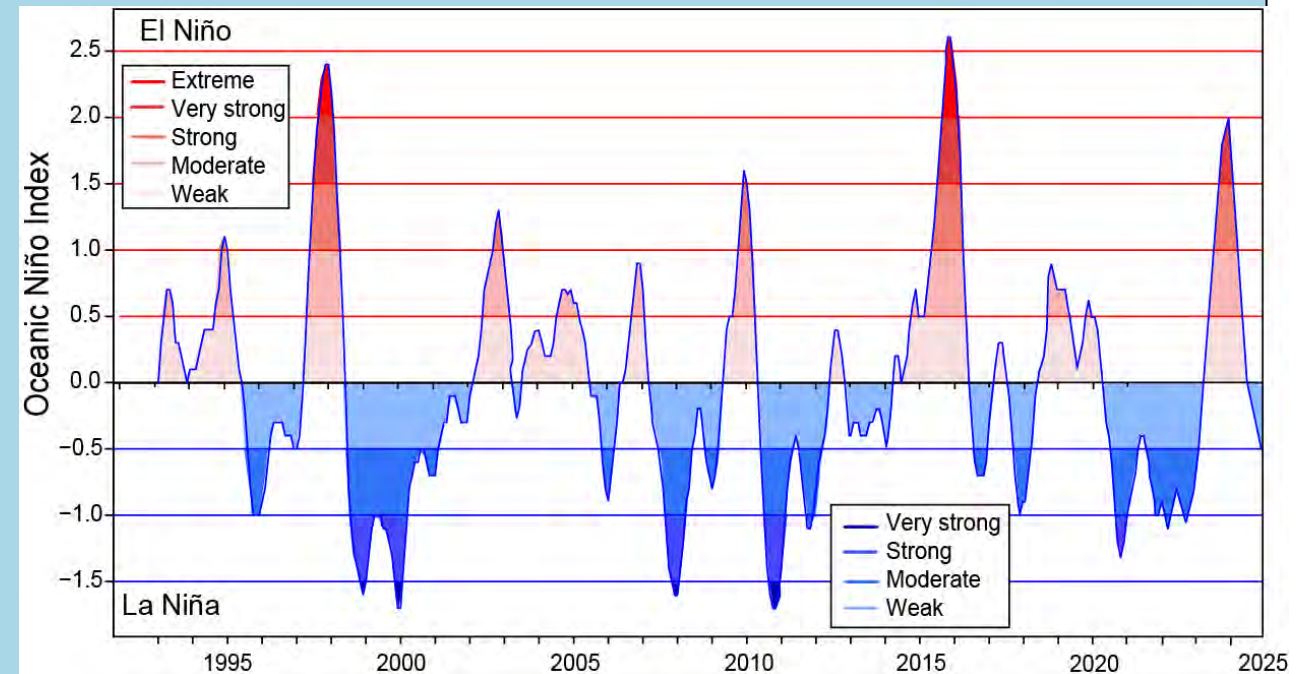
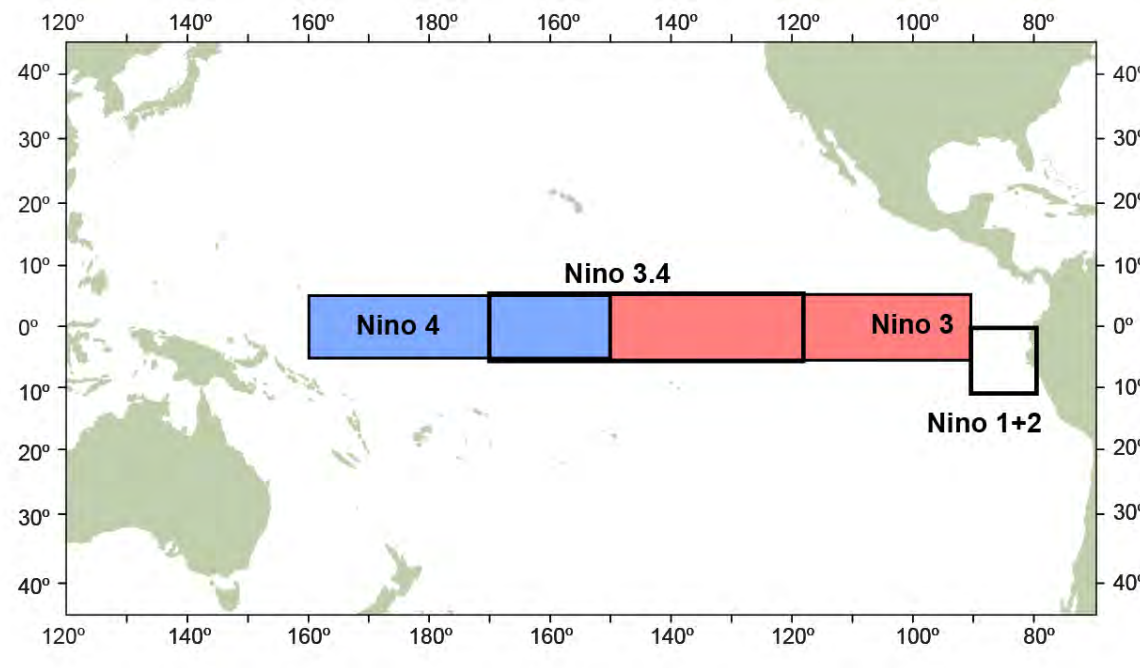
Current indicator framework and initiatives: EC report

- Spatial distribution of silky shark (most commonly reported shark species in the PS SC-6 observer data)



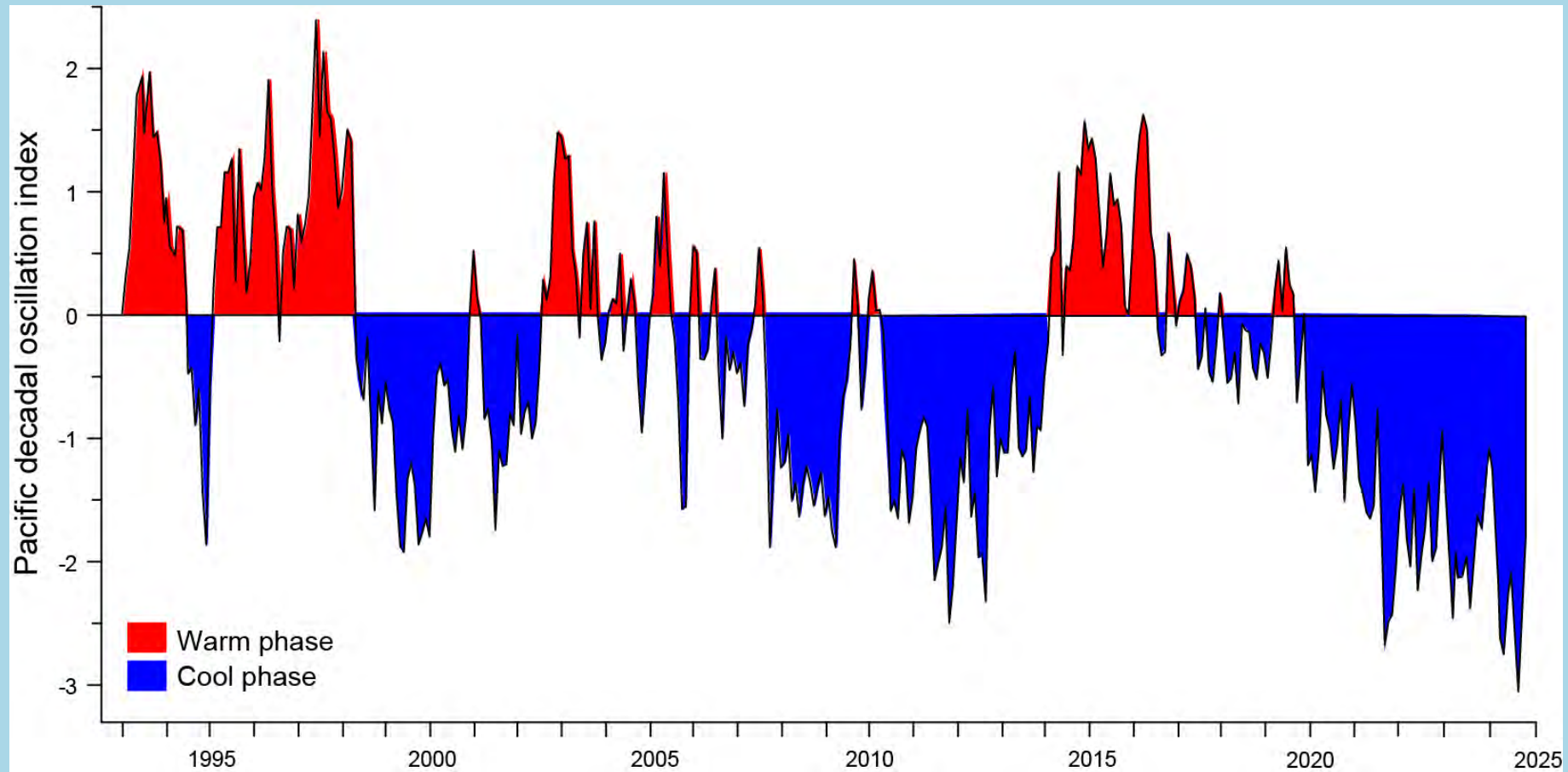
Current indicator framework and initiatives: EC report

- Physical environment
 - “Very strong” El Niño conditions started to weaken at the beginning of 2024 and transition to a neutral phase while the year ended in La Niña conditions



Current indicator framework and initiatives: EC report

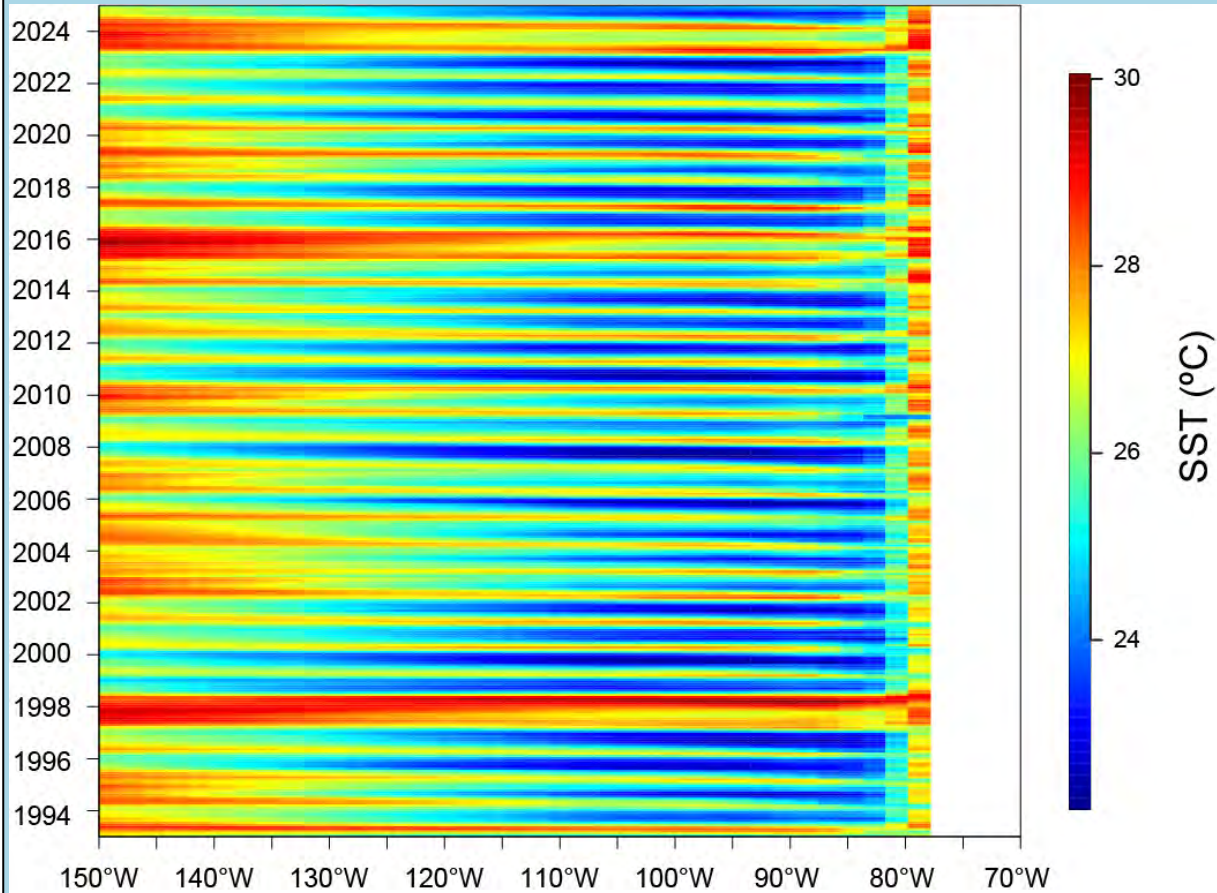
- Physical environment
 - PDO has been in a cool phase since early 2020



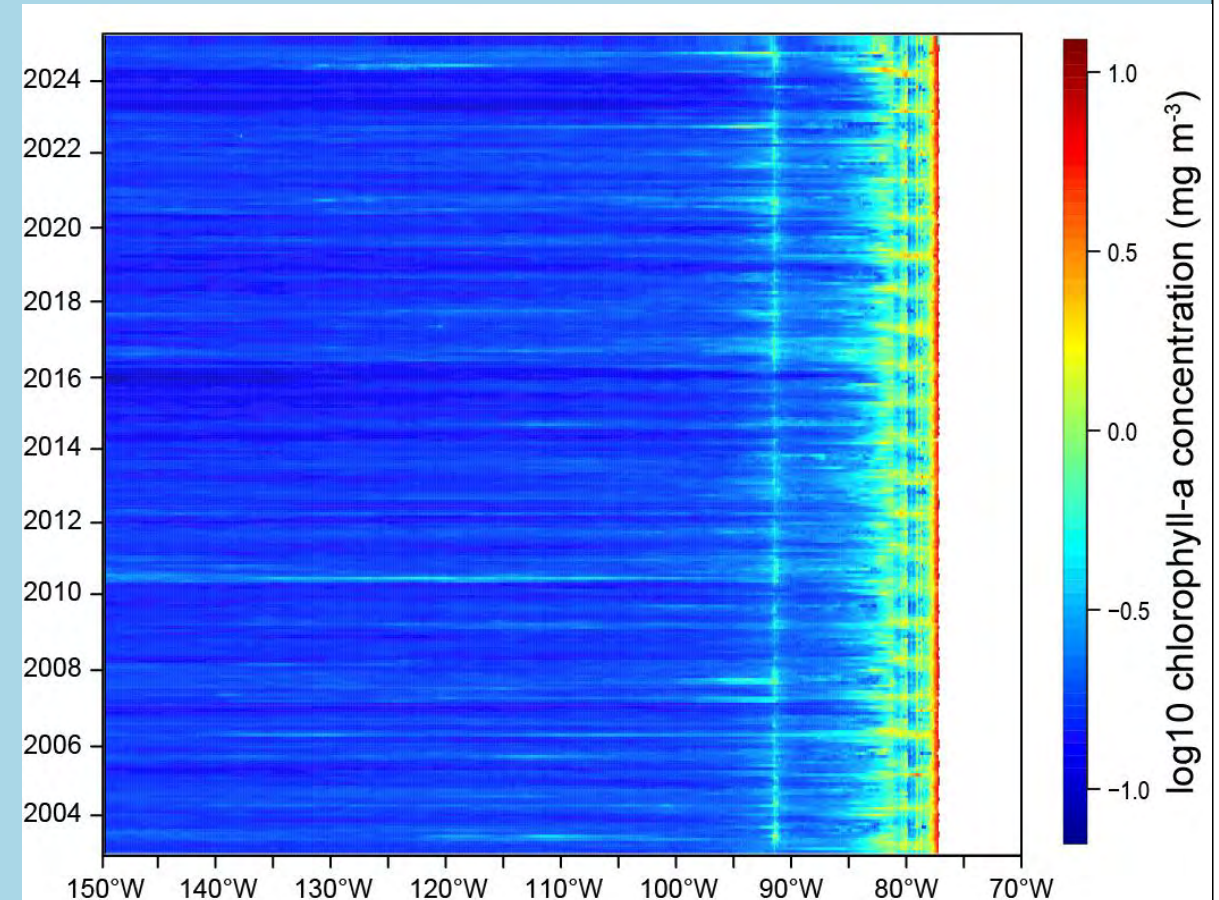
Current indicator framework and initiatives: EC report

- Physical environment

Sea Surface Temperature



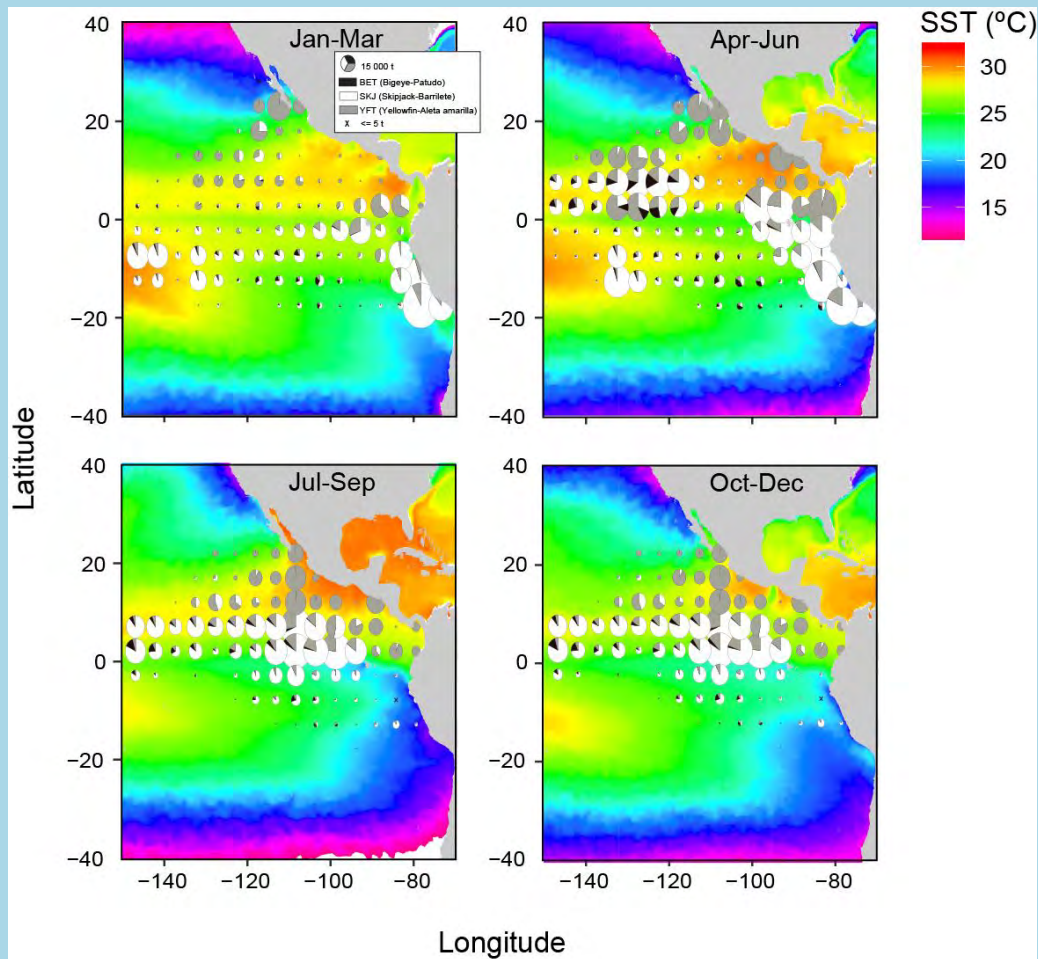
Chlorophyll-a



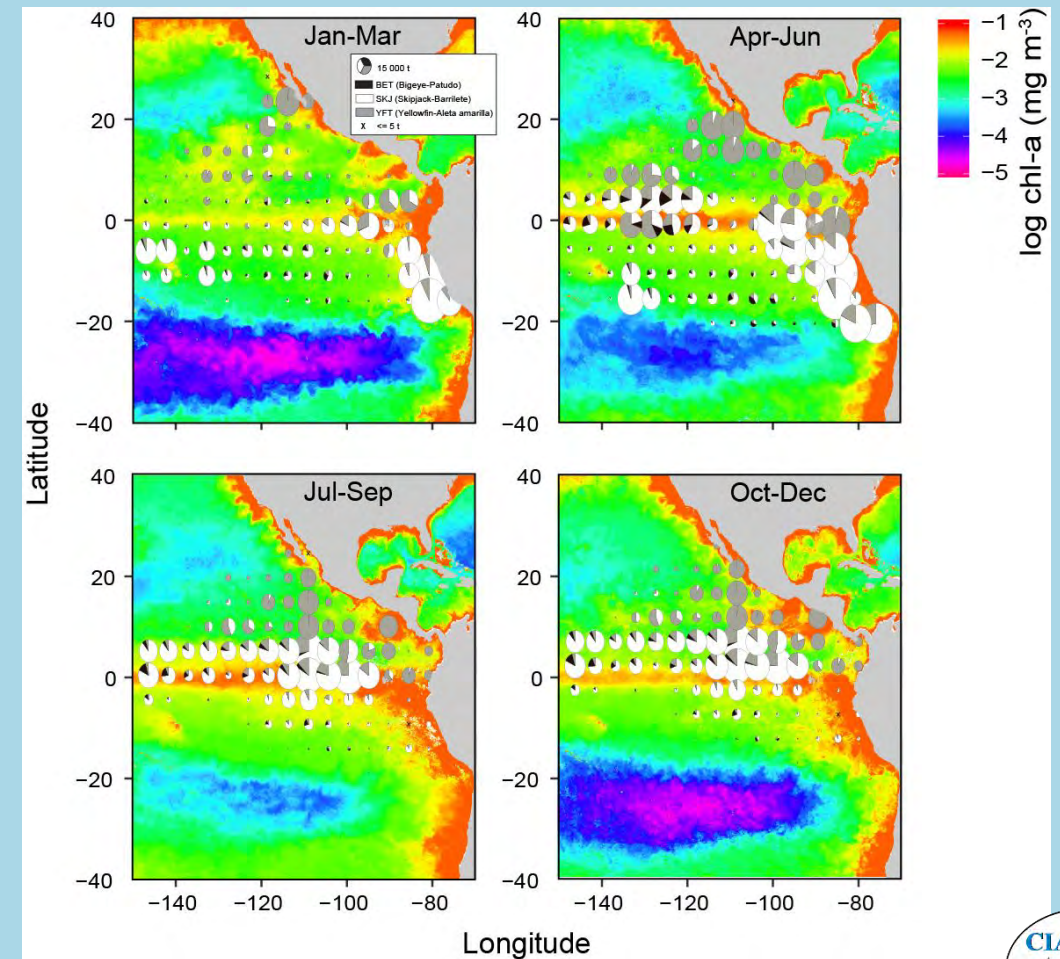
Current indicator framework and initiatives: EC report

- Physical environment

Sea Surface Temperature

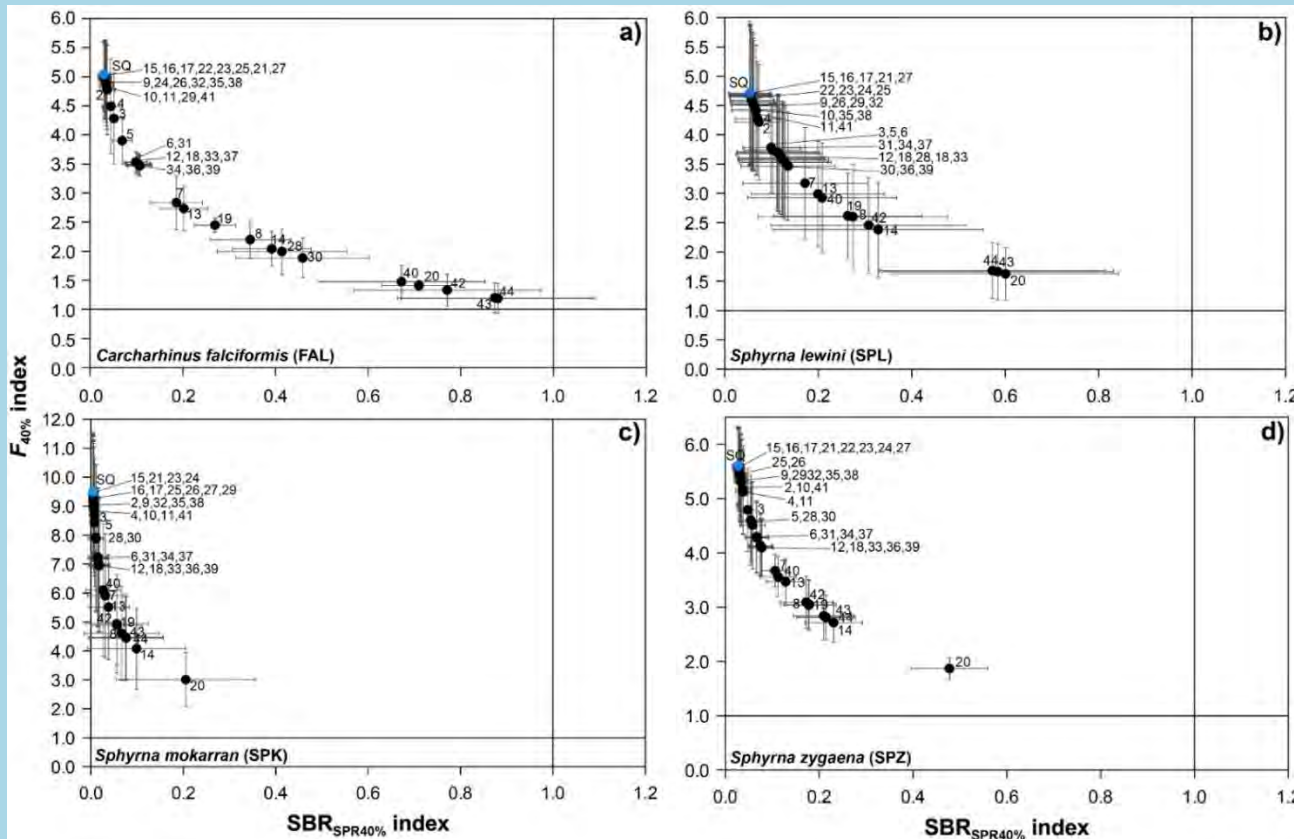


Chlorophyll-a



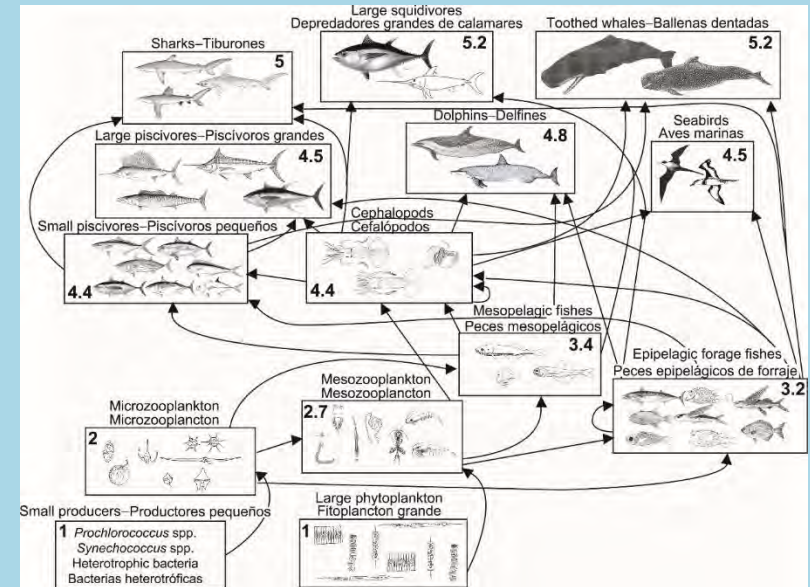
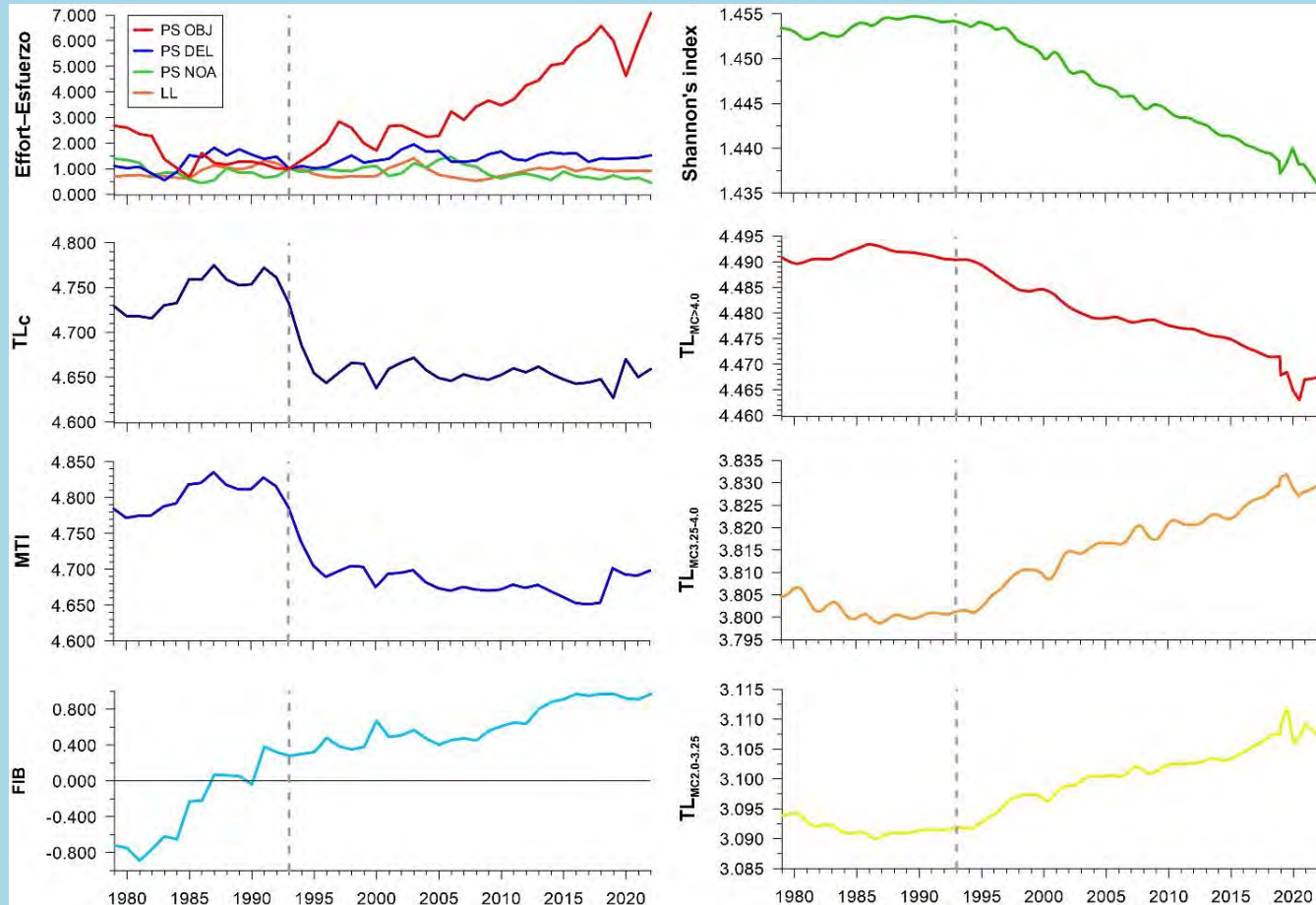
Current indicator framework and initiatives: EC report

- Exploration of hypothetical conservation and management measures
 - no updates to EASI-Fish in 2024, but noting the EC report includes a section to summarize updates as appropriate
 - details on these types of analyses are typically provided in separate documents (e.g., see [SAC-14-12](#))



Current indicator framework and initiatives: EC report

- Ecological indicators output from the ETP Ecopath Model
 - no updates in 2024, but noting the EC report includes a section to summarize updates as appropriate



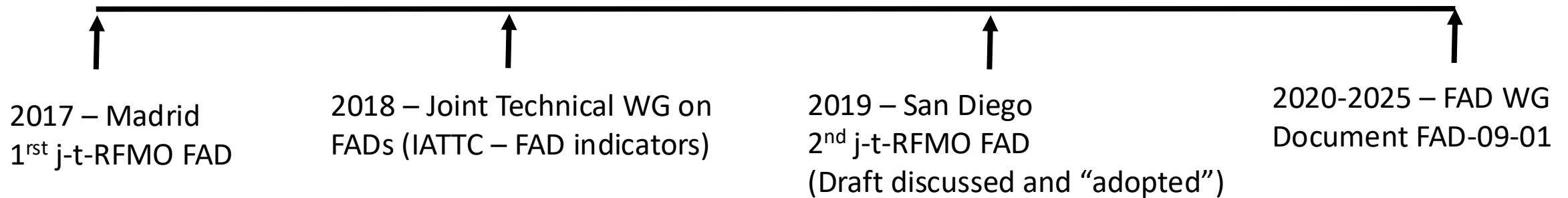
Current indicator framework and initiatives: FSR indicators

- Produced annually for the SAC and the Commission.
- Status of the main target species and fisheries of the IATTC (tuna, billfish and associated species).
- Catch by species and fleet.
- Also includes information of interest for management, e.g. size composition, capacity.
- Many indicators are spatial to support assessment and management needs as well.
- Data (*taken from SAC-16-01*):

The IATTC staff has collected and compiled data on the longline fisheries since 1952, on catches of yellowfin and skipjack since 1954, bluefin since 1973, and bigeye since 1975. The data in this report, which are as accurate and complete as possible, are derived from various sources, including vessel logbooks, on-board observer data, unloading records provided by canners and other processors, export and import records, reports from governments and other entities, and the IATTC species and size composition port sampling program.

Current indicator framework and initiatives: FAD indicators

- Multi-dimensional impacts of the fishery, it must be holistically monitored



Current indicator framework and initiatives: FAD indicators

Grouped in 8 categories (~50 indicators produced)

Indicator Type	Priority - Prioridad 1 Major – Mayor, 2 Moderate - Moderada, 3 Minor – Menor
Catch and effort	1
Activity	1
Buoy/FAD-use	1
Capacity	1
Technology	2
Ecosystem-Impact	2
Socio-Economico	3
Bio-Eco-Behavior	3

Data for FAD indicators

Five main datasets:

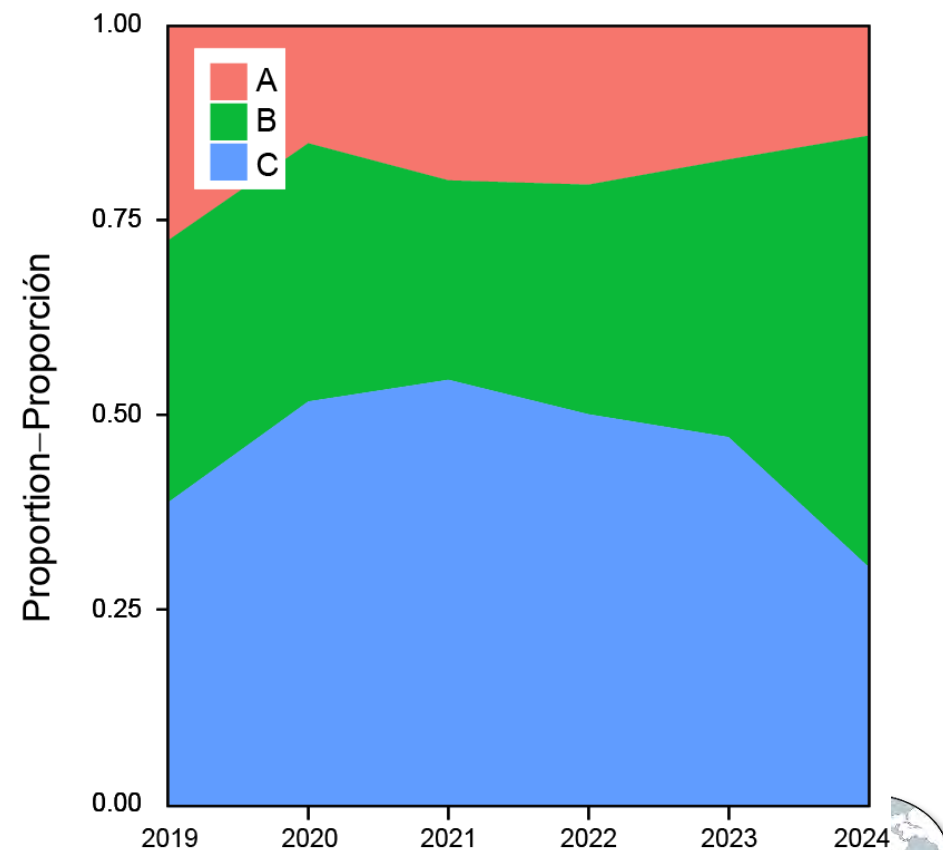
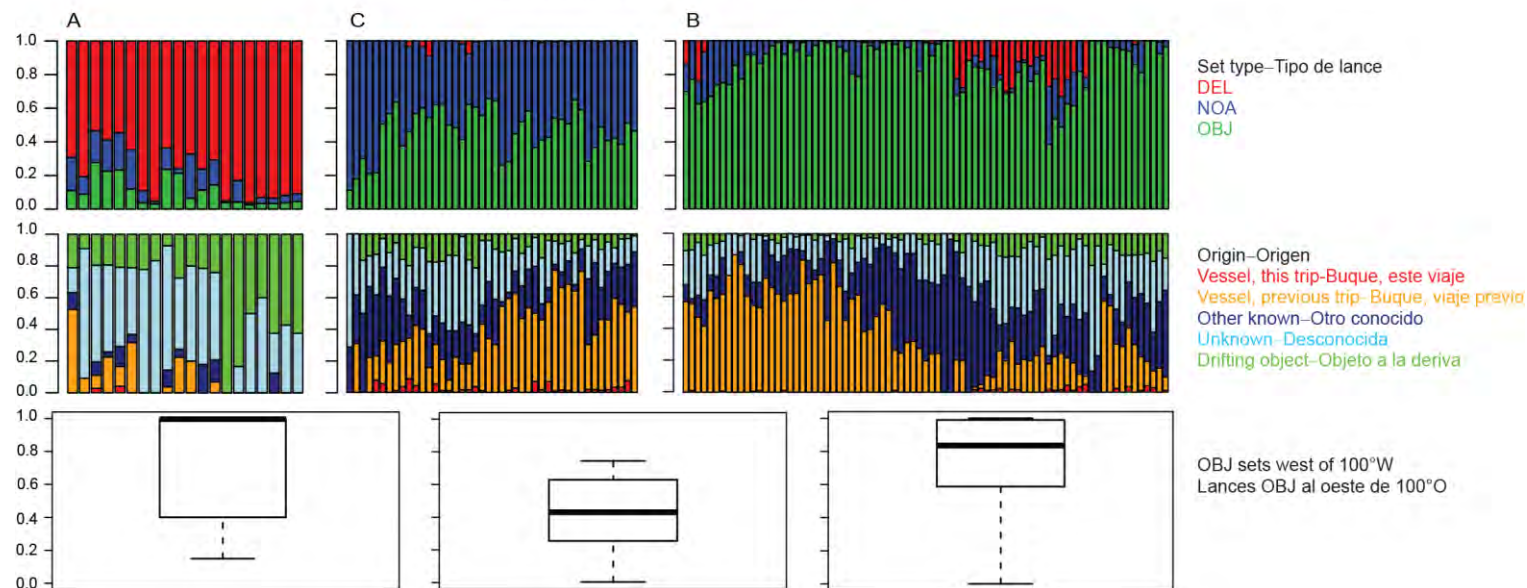
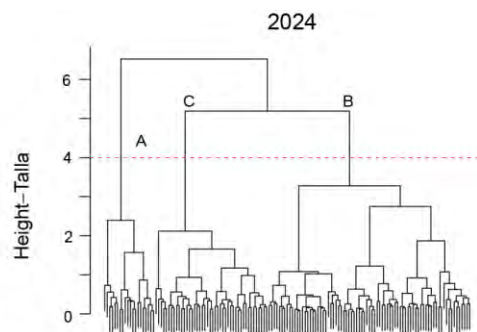
- a. 2019-2024 AIDCP **observer data** for Class-6 vessels [fleet behavior, activities, and technology].
- b. **Catch and effort** data for all vessels (Classes 1-6) [catch and effort]
- c. **Daily active buoy** data for >166 vessels (Classes 1-6) reporting since 2022. [buoy-based indices]
- d. 2022-2024 monthly **remote deactivation and reactivation** data for all vessels (Classes 1-6) [buoy indices]
- e. 2020-2024 **FAD form** data for all vessels without observers (Class 1-5)[activities]

Indicators by fleet segments

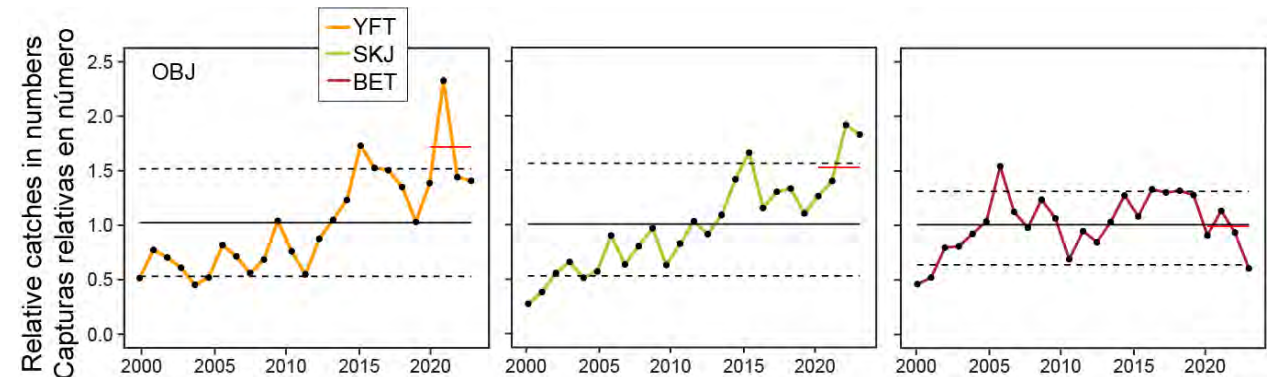
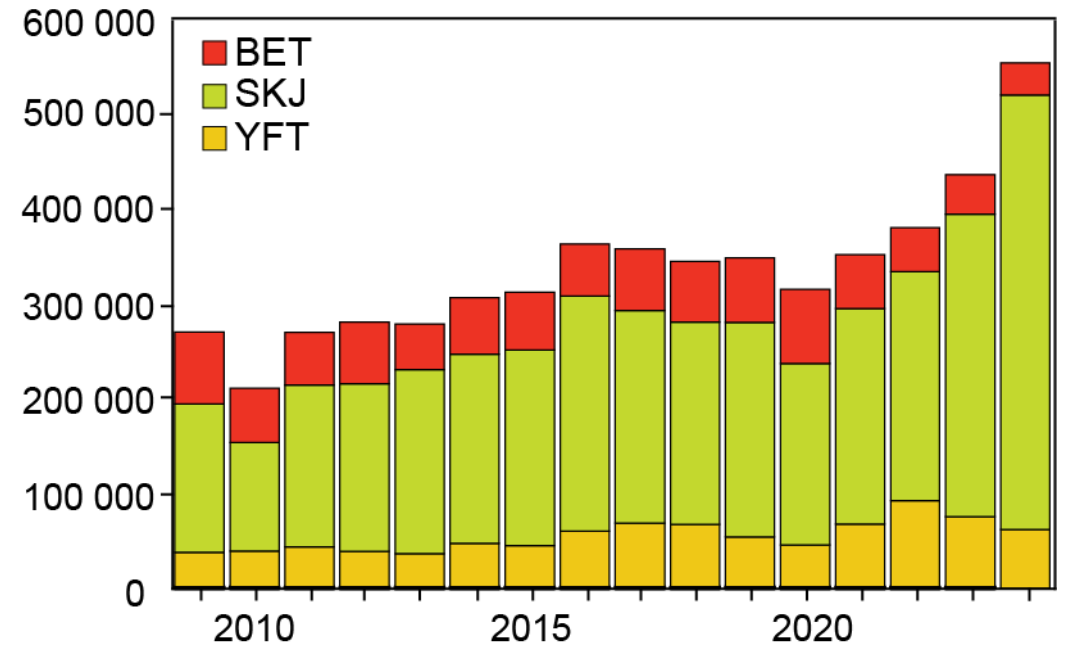
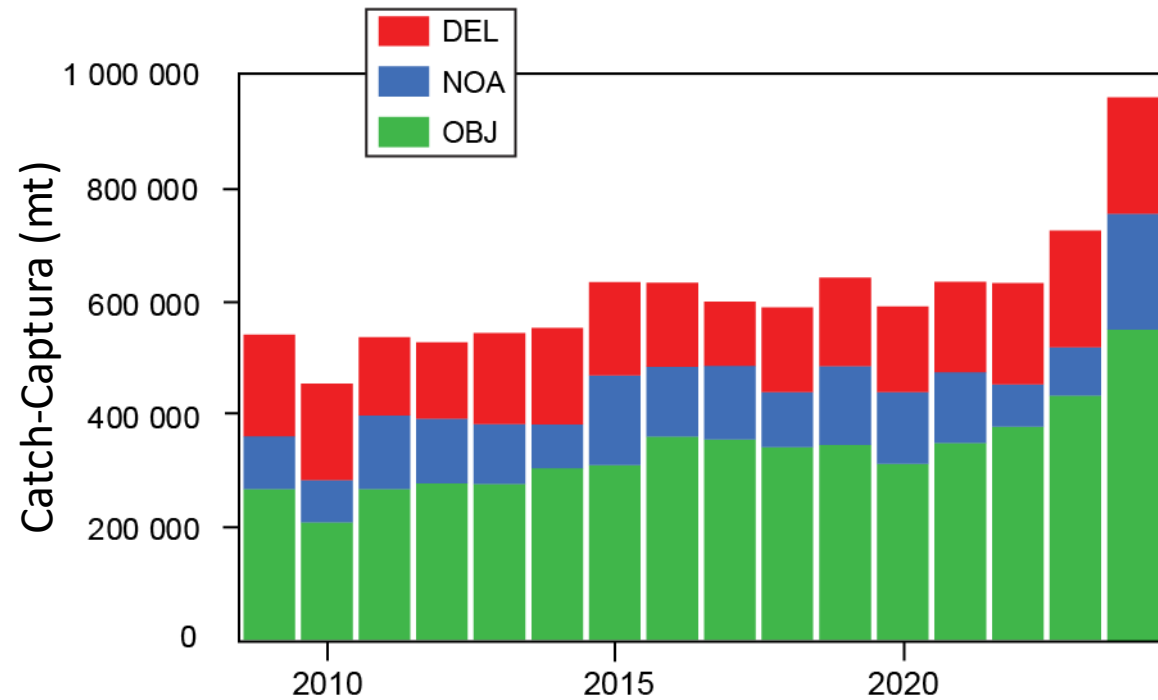
A = > 100W + DEL and opportunistic OBJ sets (23)

B = >100W + OBJ sets (monitored) (48)

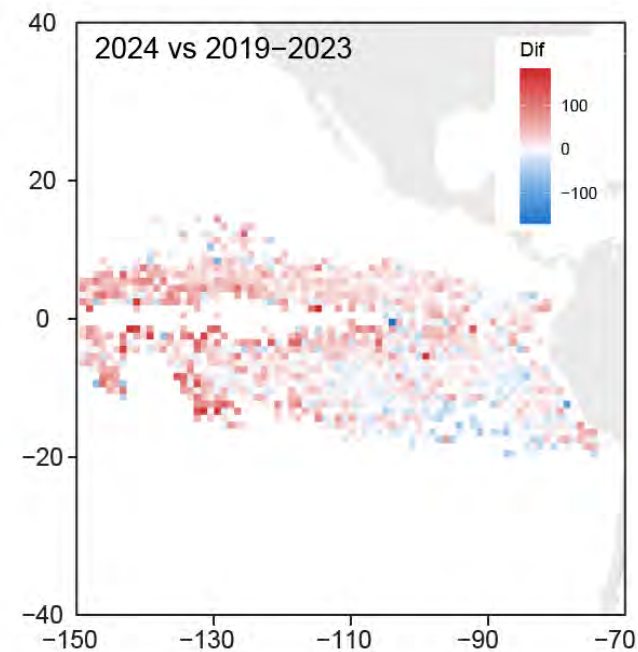
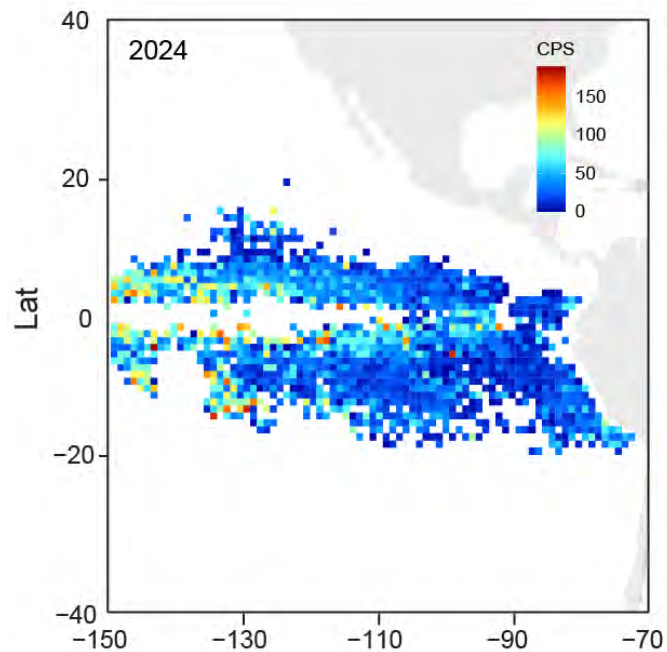
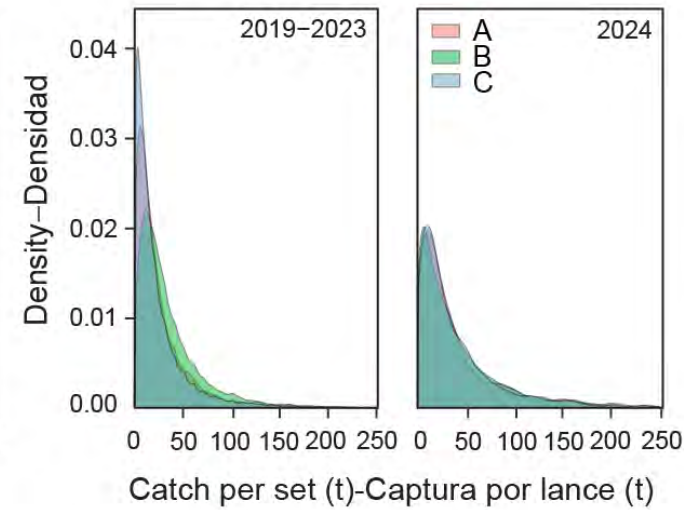
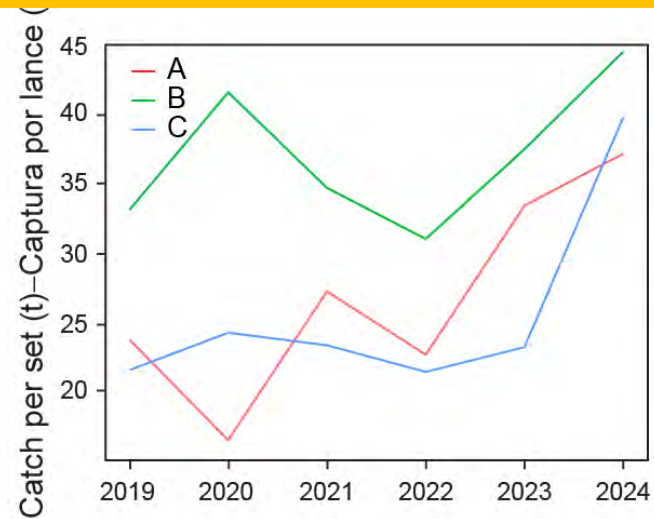
C = <100W + mix of set types (64)



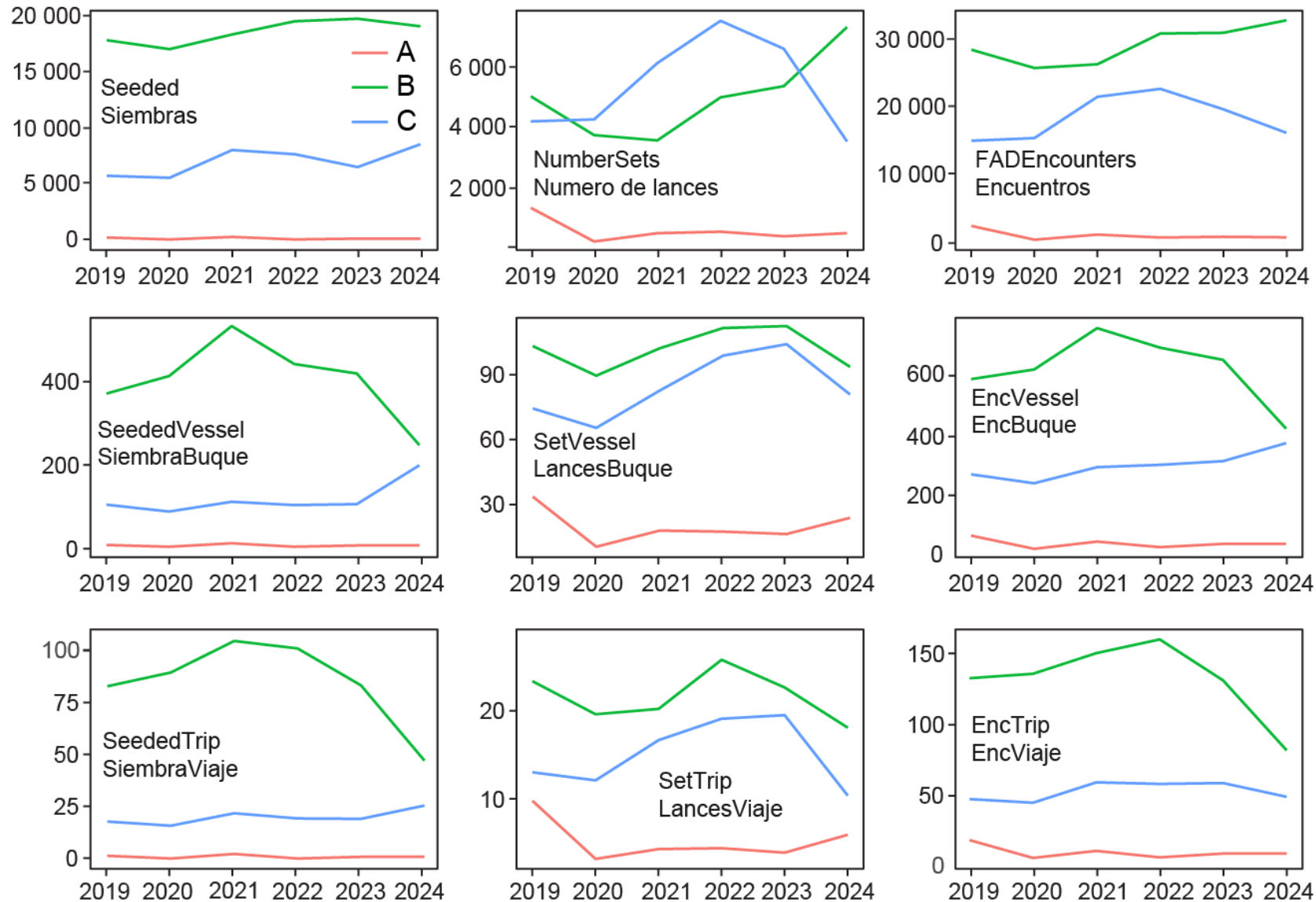
Catch by set type (and species)



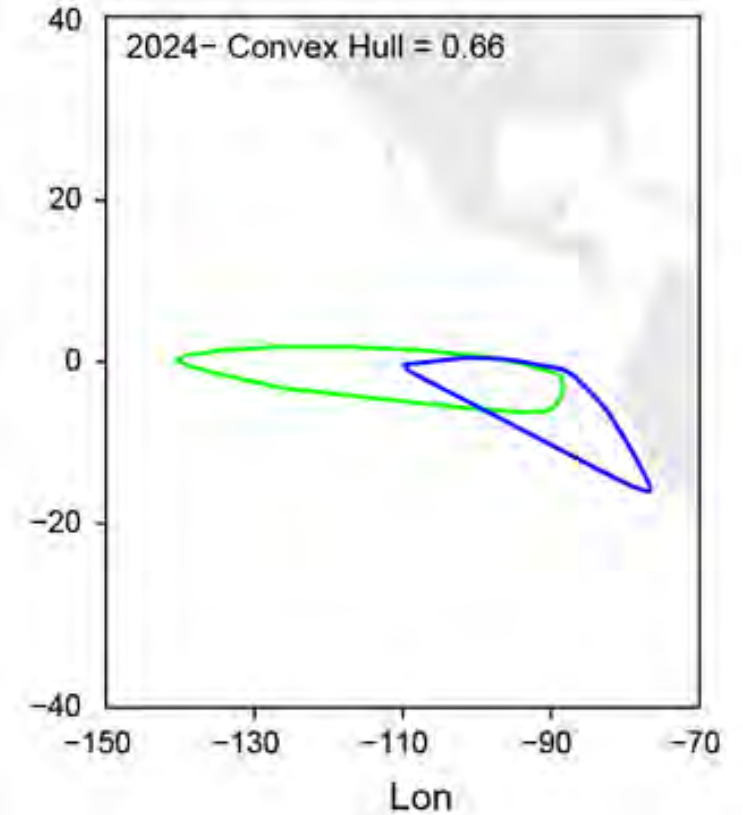
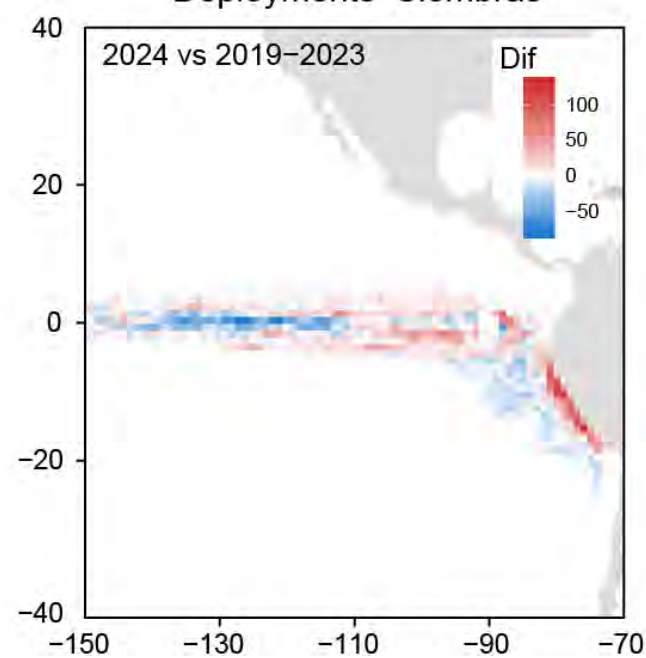
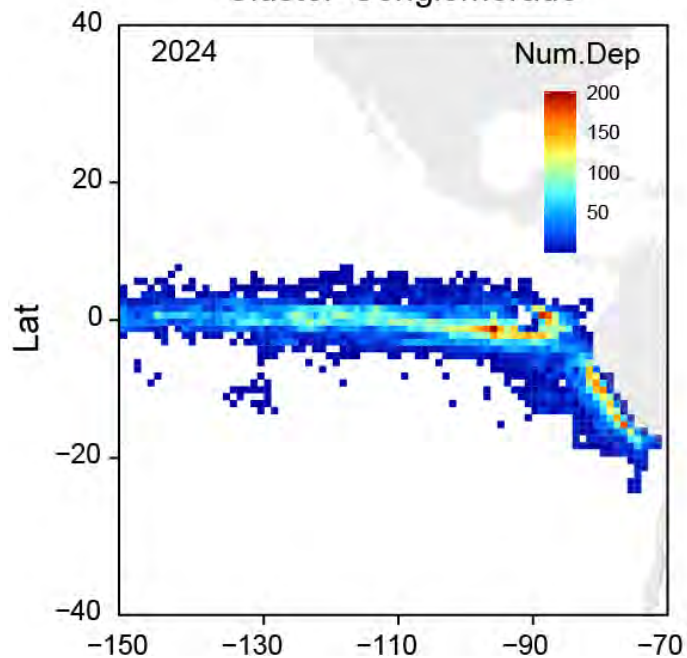
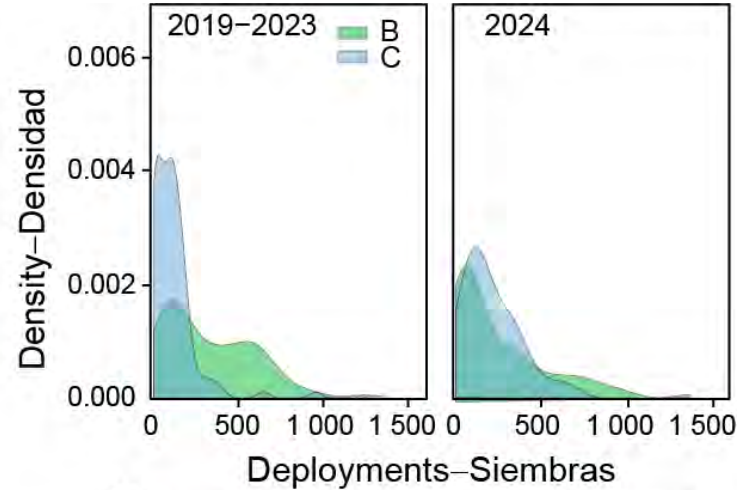
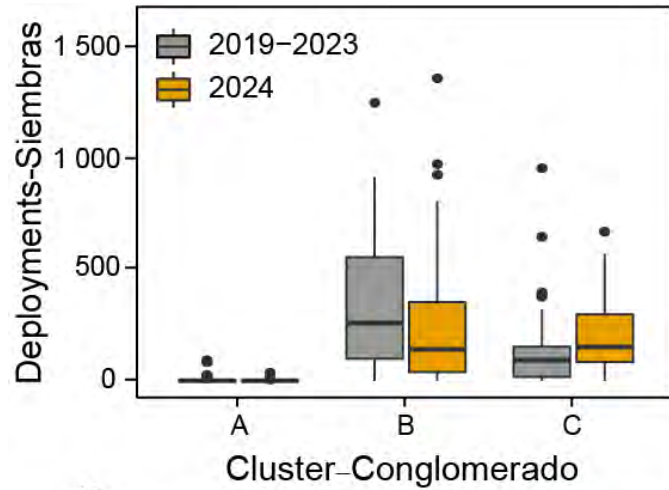
Catch per set by fleet segment



General OBJ activity evolution by fleet segment



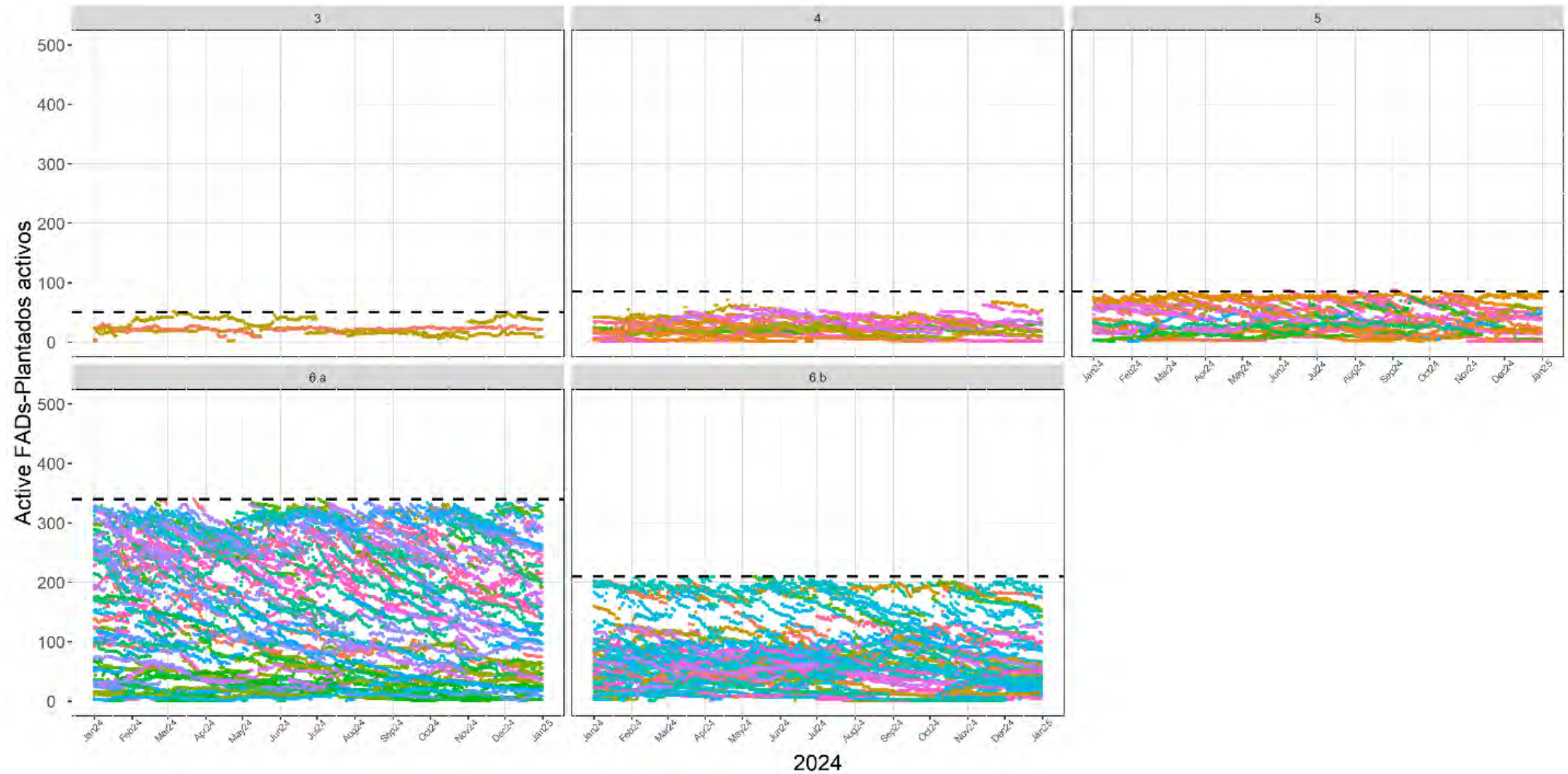
Deployments by segment



Daily active FADs

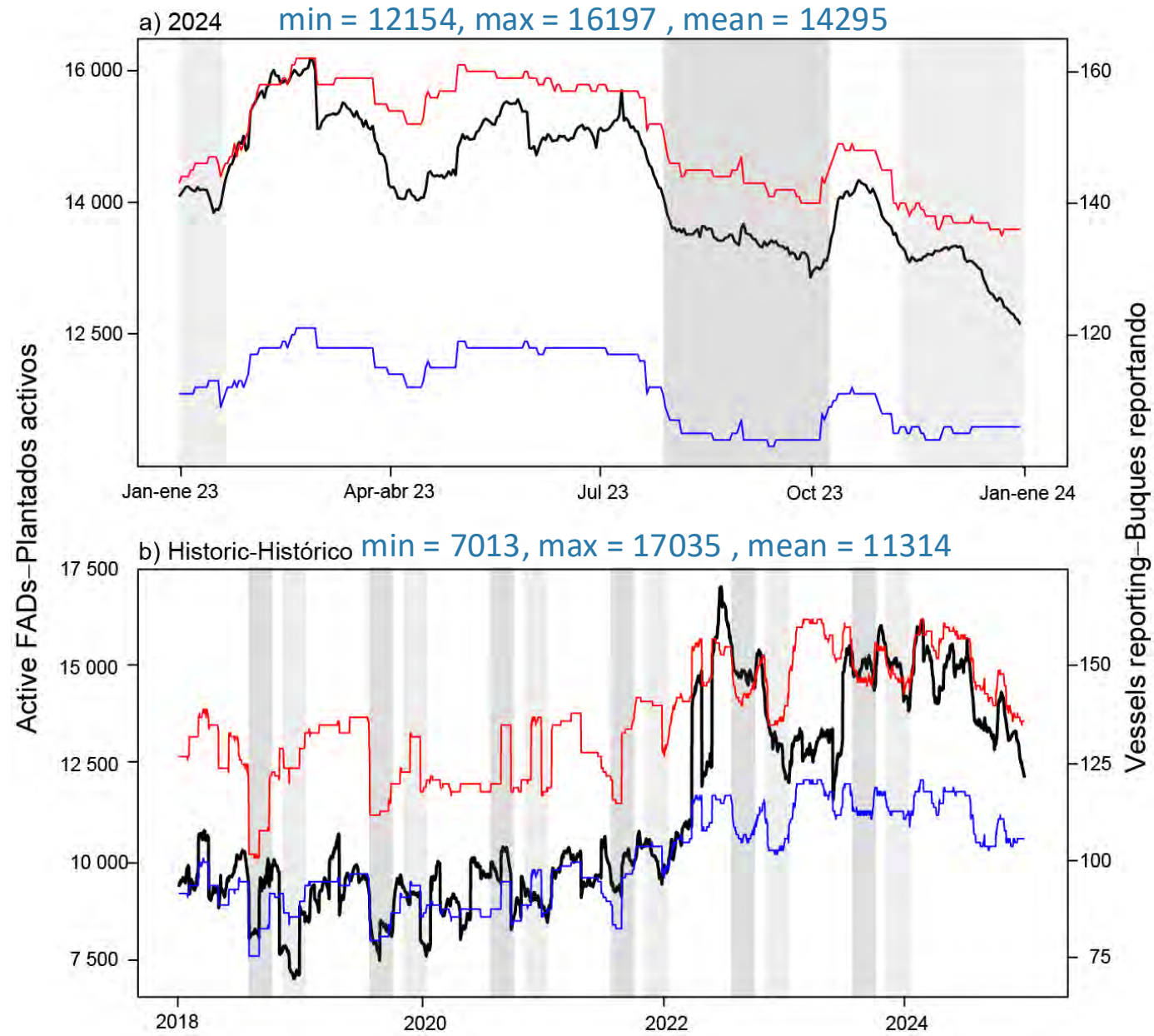
Res. C-21-04

(166 vessels)

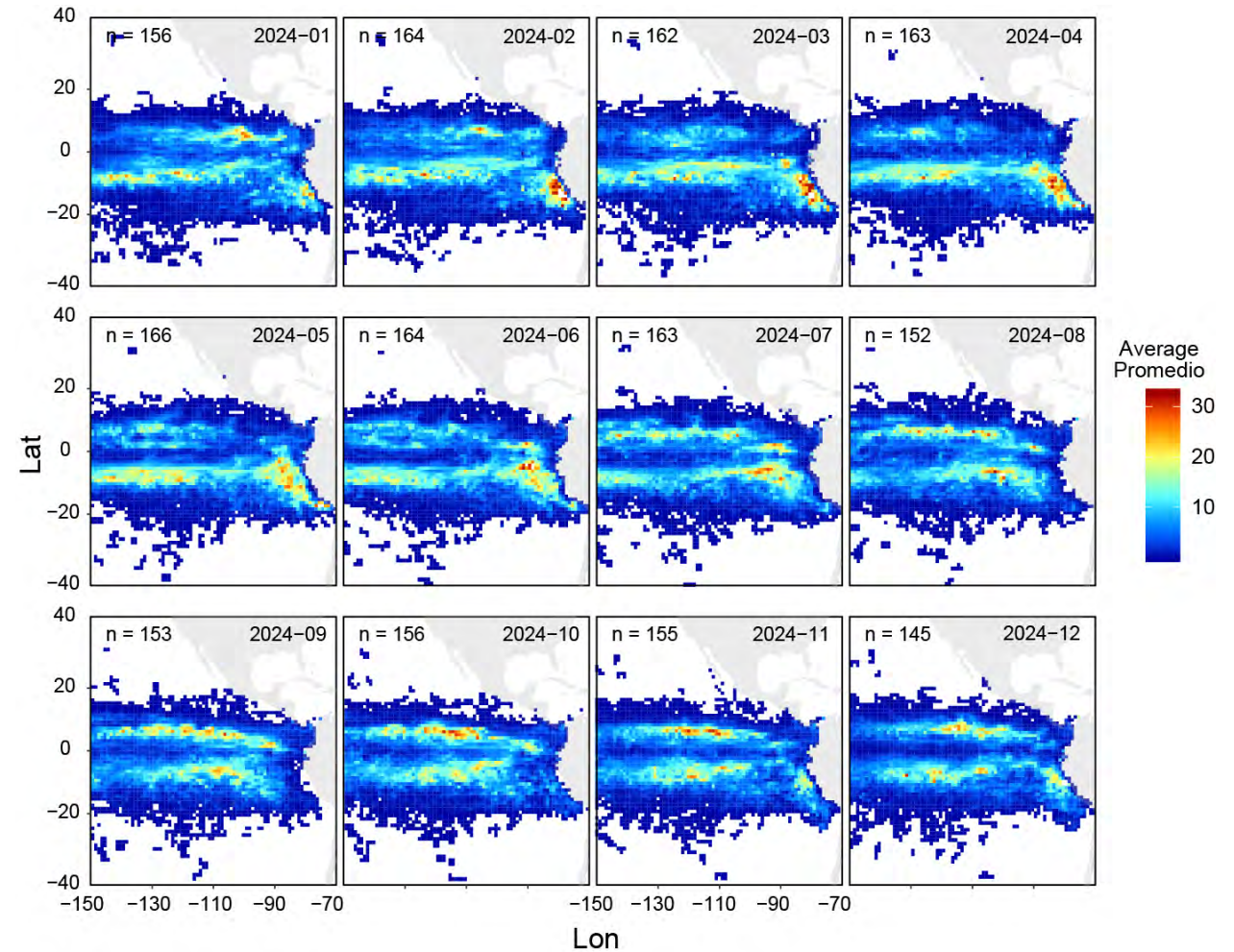
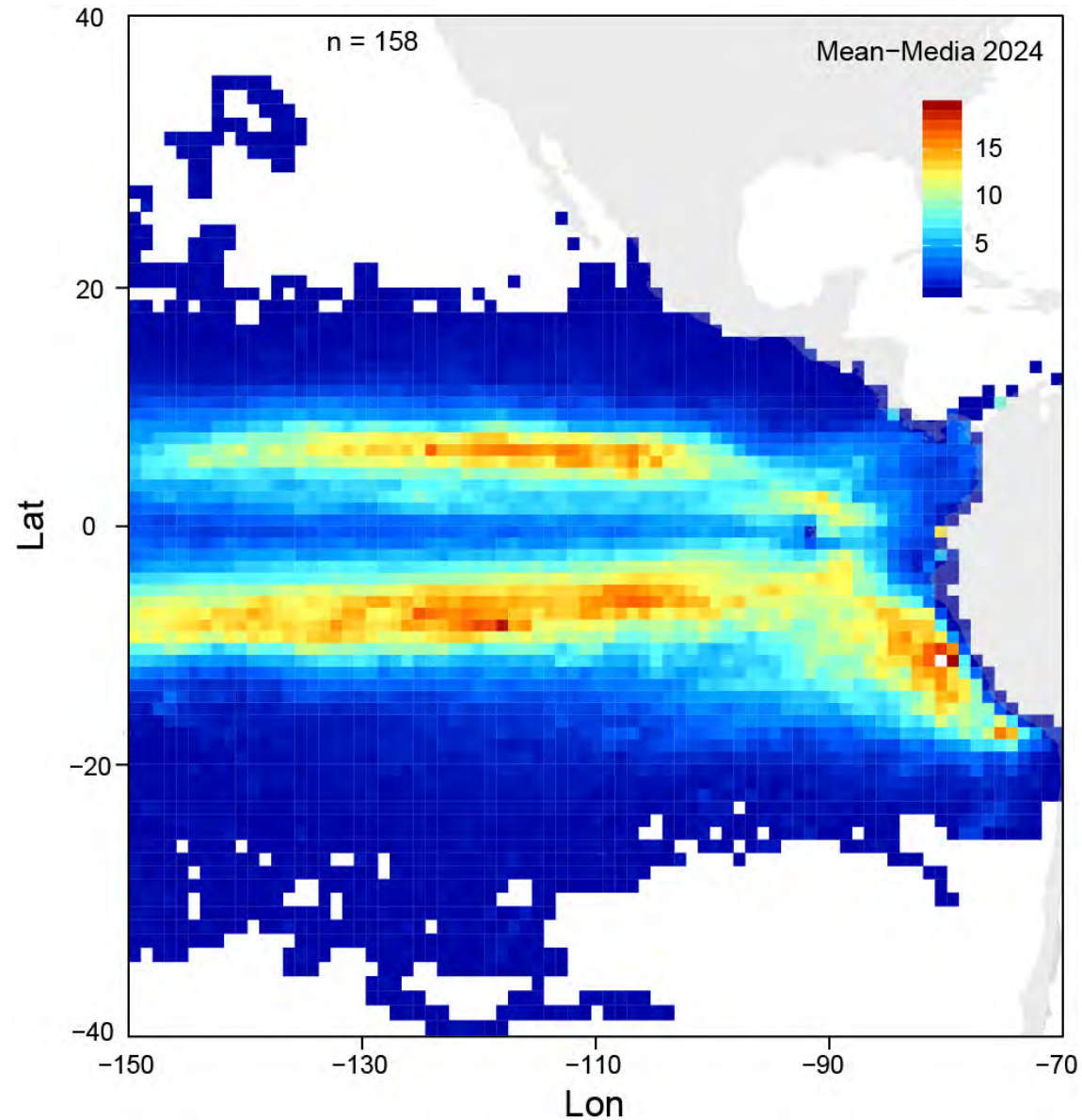


Daily total active buoys

166 vessels
(123 Class 6
43 Class 1-5)

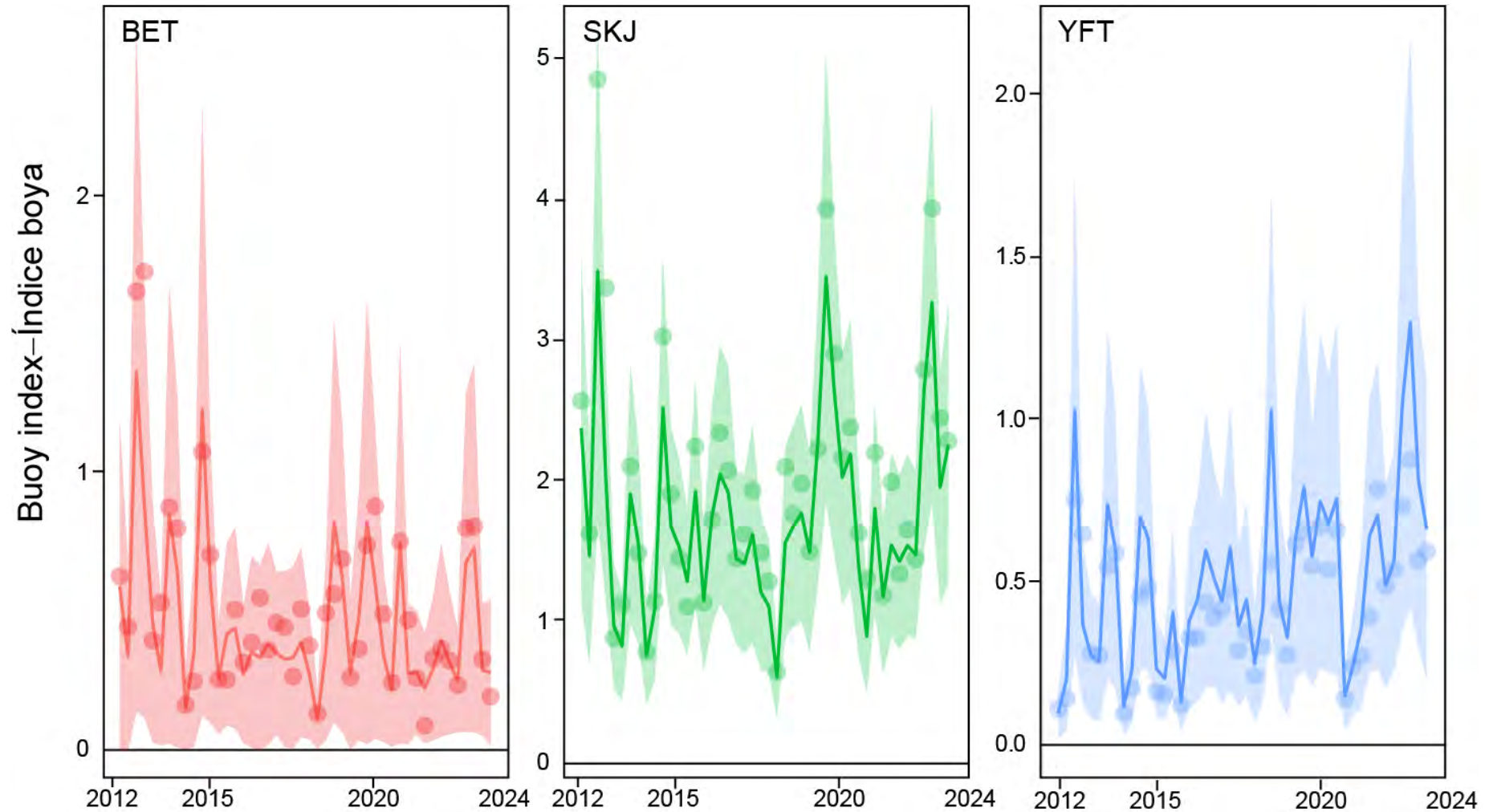


Active FADs densities



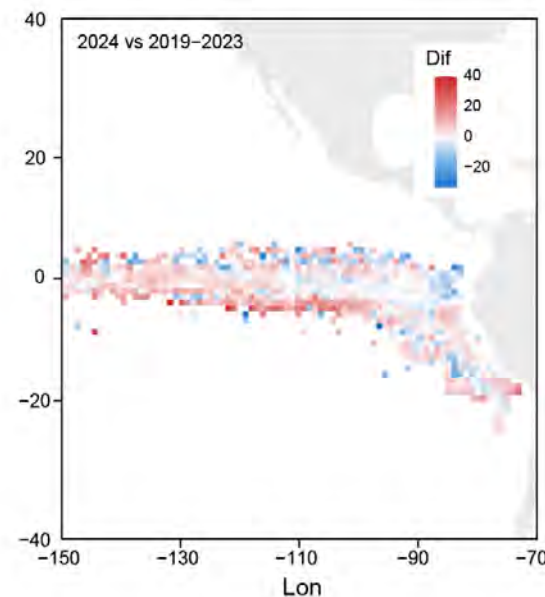
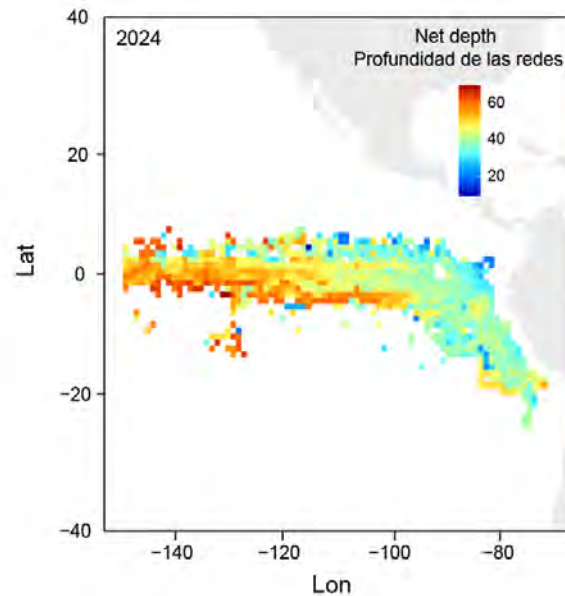
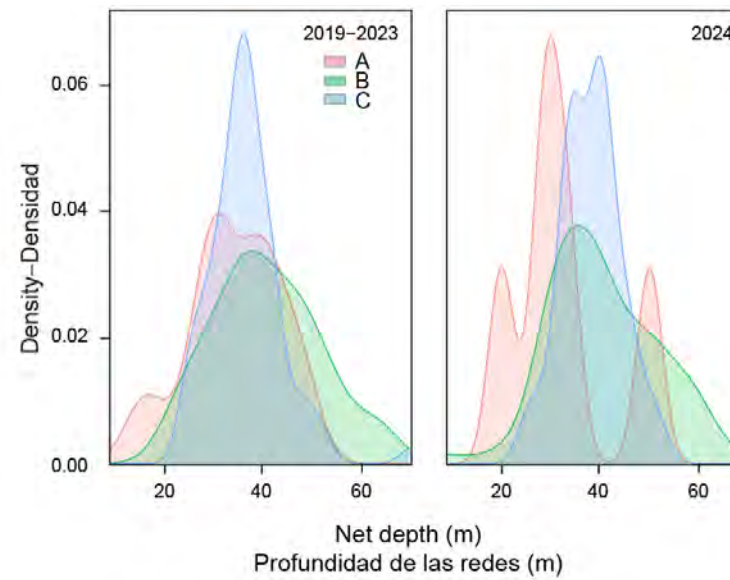
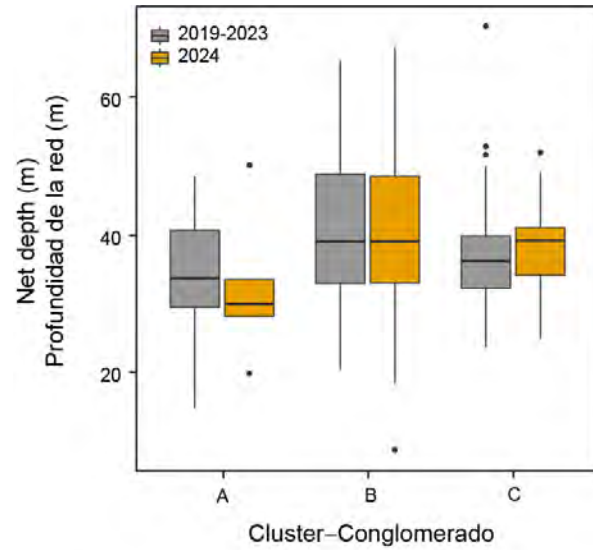
145-166 vessels-buques
13040-16005 FADs-DCPs

Buoy Abundance Index



FAD-08-03 – BAI indices
SAC-15-04 - SKJ assessment

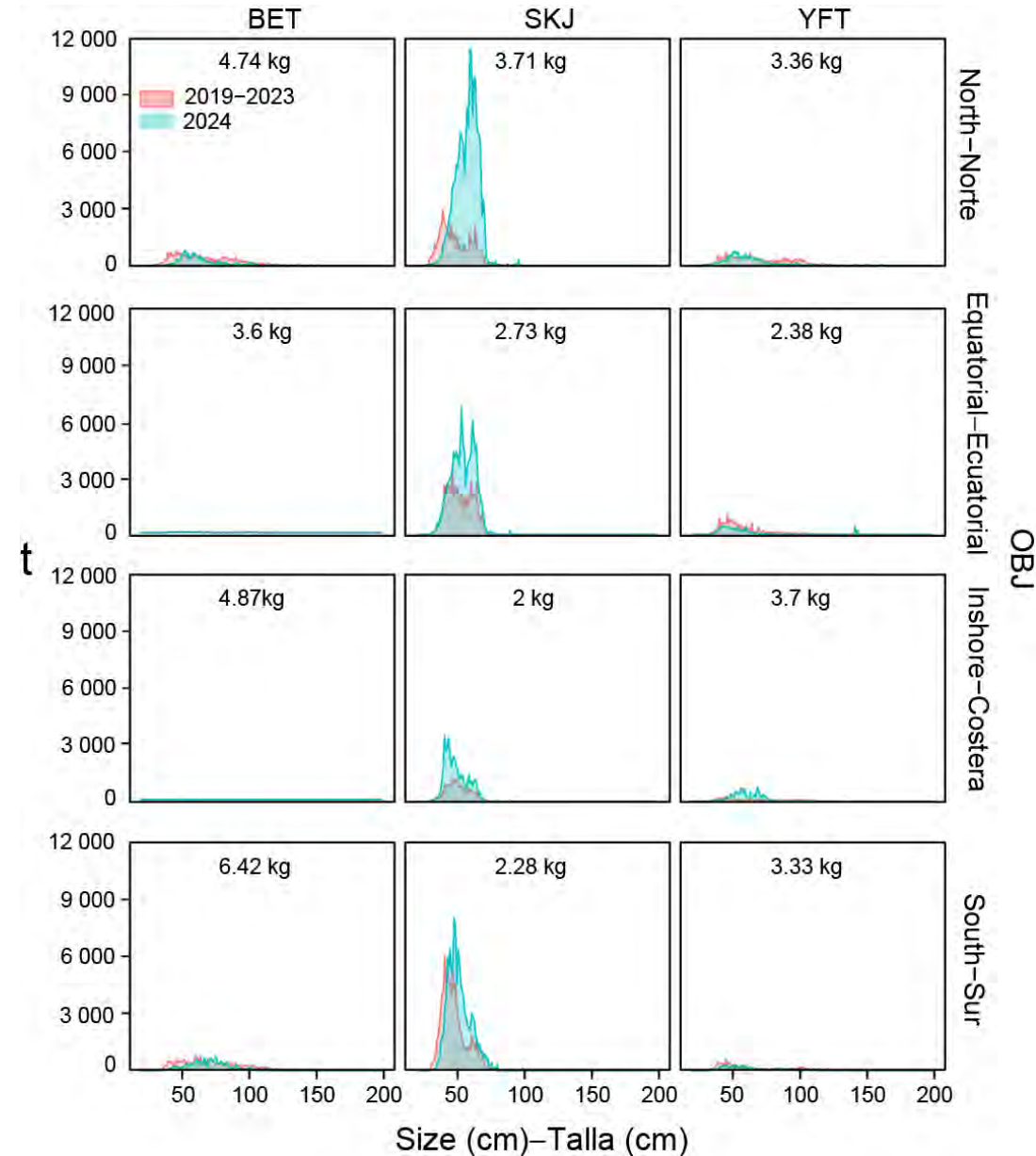
FAD depth (technology)



Onboard technology (technology)



Size composition of tuna (Biology)



Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



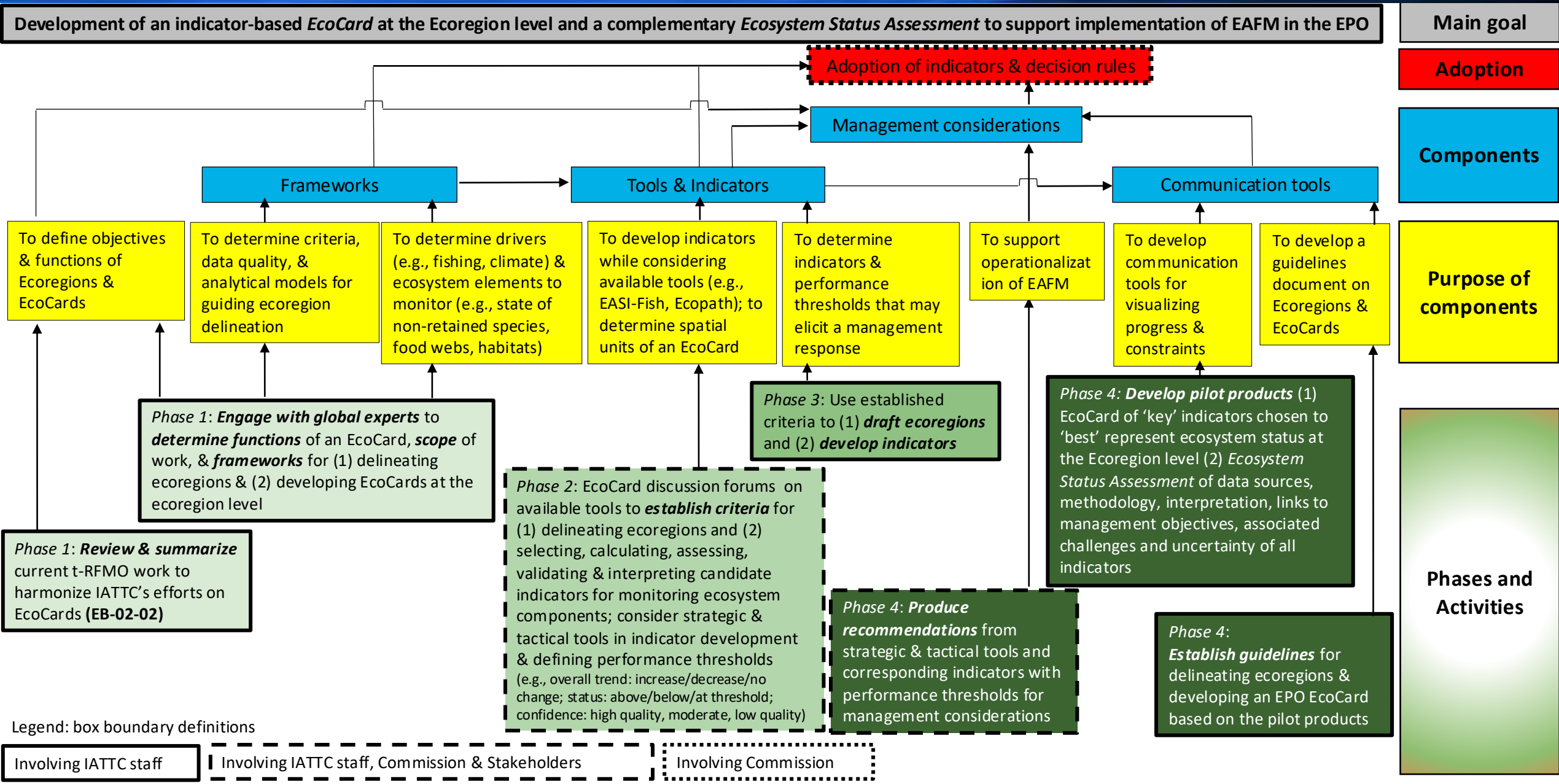
IATTC EcoCard Workplan

4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators, SPC,
Noumea (New Caledonia), 02-06 March 2026

Current indicator framework and initiatives: EcoCard Workplan

- Research expansion under Antigua Convention and IATTC's SSPs ([2019–2023](#); updated in 2025: [2026–2030](#))
- Consequences:
 - The EC report has increased in length and complexity
 - Report is not optimal for communicating ecosystem status
 - Transition to shortened agendas = reduced opportunities for detailed presentations
- Staff proposed a restructure of the EC report to improve communication (ecosystem-advice products)
 - Indicator-based Ecosystem Report Card or “*EcoCard*”
 - *Ecosystem Status Assessment*
- Reviewed and summarized available information on ecosystem research by each t-RFMO (see [EB-02-02](#))
- Proposed an IATTC EcoCard and Ecosystem Status Assessment workplan

Current indicator framework and initiatives: EcoCard Workplan

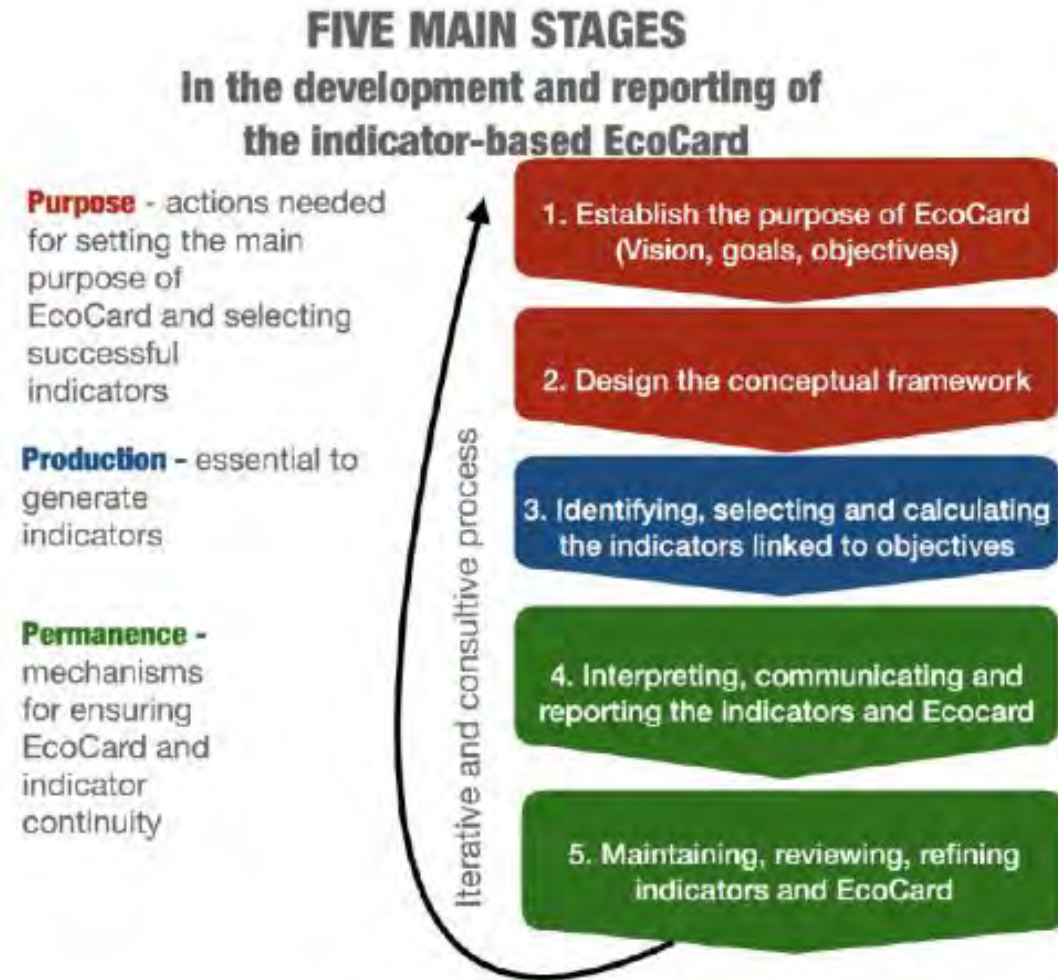


Current indicator framework and initiatives: EcoCard Workplan

[illegible]

Current indicator framework and initiatives: EcoCard Workplan

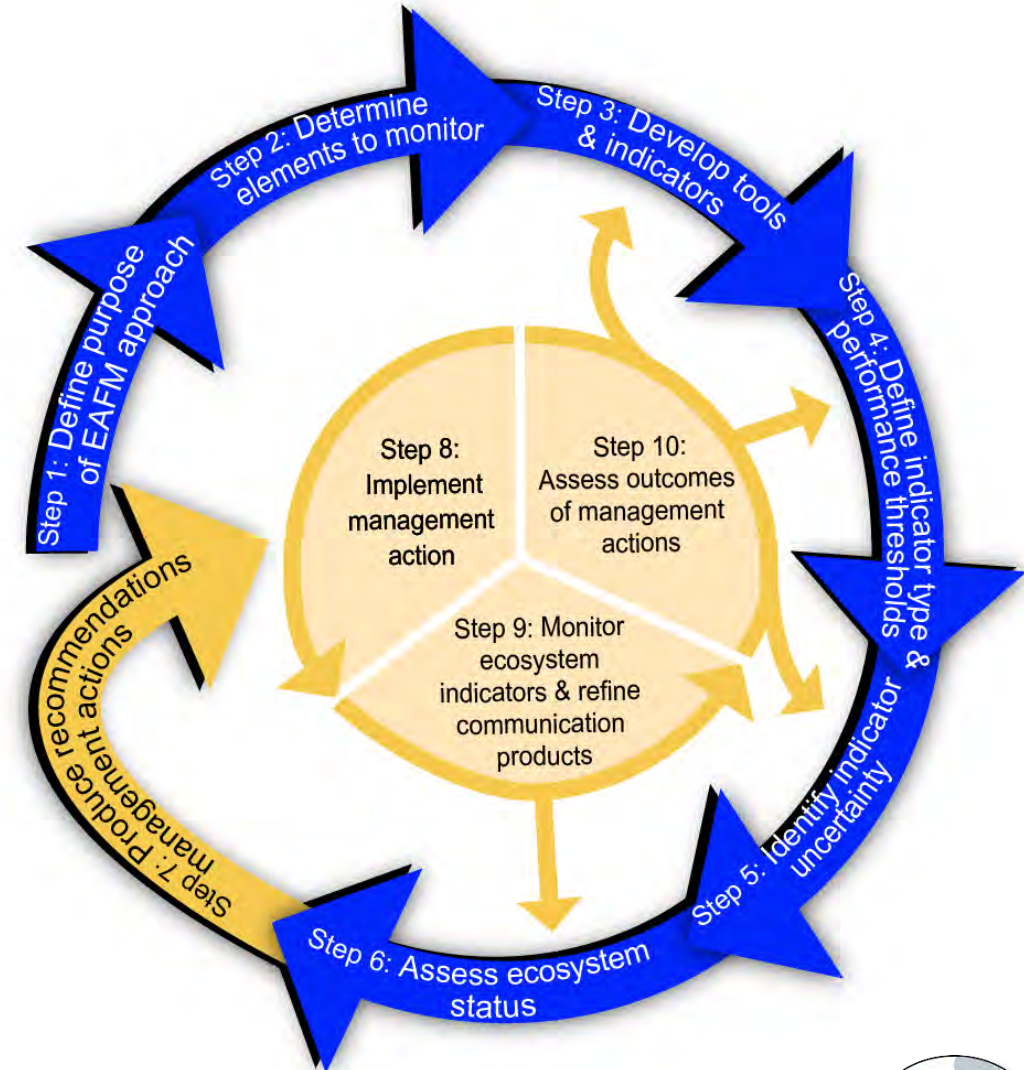
- Phase 1: Planning – completed tasks
 - Summarized ongoing t-RFMO work to harmonize IATTC's efforts ([EB-02-02](#)) (2024)
 - Followed ICCAT's 5 Main Stages to developing EcoCards
 - Step 1: Define purpose of EcoCard
 - **Goal:** to facilitate implementation of EAFM by improving ecosystem science advice for management through the development and application of tools and communication products
 - **Objective:** transition to an indicator-based *EcoCard* to increase awareness, communication and reporting of the state of different ecosystem components to facilitate prioritization of research and potential management intervention



Juan-Jordá, M.J., H. Murua, G. Díaz, P. Obregon, L. Kell, D. Alvarez-Berastegui, A. Eider, R. Coelho, T. Sachiko, D. Ochi, A. Domingo, D. Die, O. Yates, I. Tai, J. Bell, P. Tugores, and A. Hanke. 2022b. Report of the 1st Meeting of the Sub-Group on the Ecosystem Report Card. SCRS/2022/104. Collect. Vol. Sci. Pap. ICCAT 79(5): 152-164.

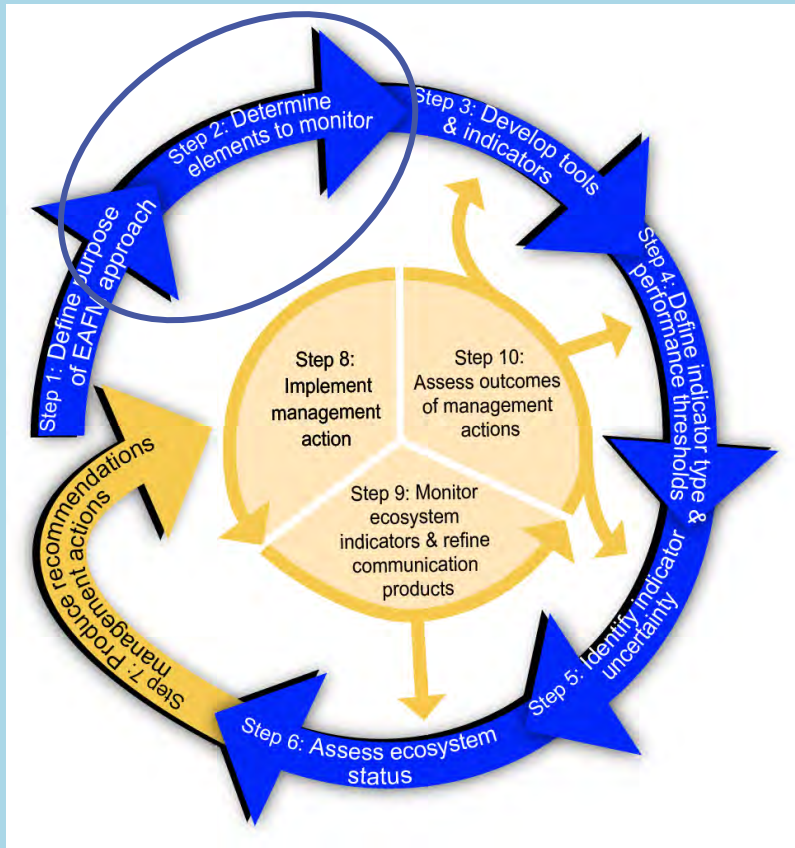
Current indicator framework and initiatives: EcoCard Workplan

- Phase 1: Planning – completed tasks
 - Created draft framework for ecosystem products internally (2024)
 - Collaborative and iterative approach between scientists and managers
 - Combination of [Juan-Jorda et al. \(2022\)](#) and NOAA's [Integrated Ecosystem Assessment loop](#)
 - Blue arrows: indicate scientific steps to provide ecosystem advice to the Commission
 - Yellow arrows: represent involvement by the Commission to determine potential management actions

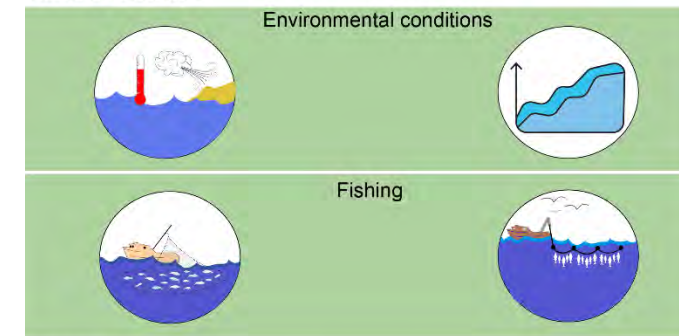


Current indicator framework and initiatives: EcoCard Workplan

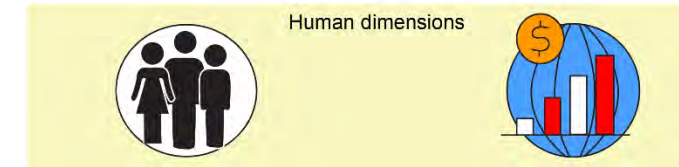
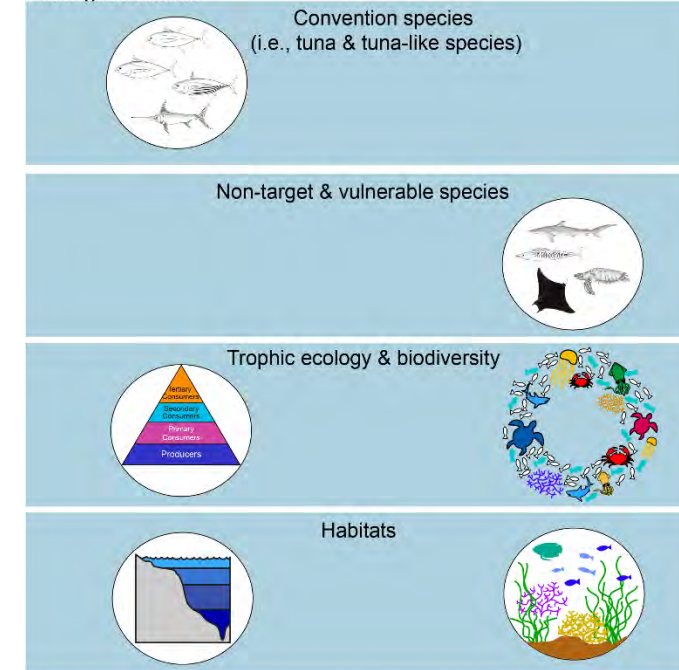
- Phase 1: Planning – completed tasks (cont.)
 - Step 2 of the staff's proposed conceptual framework
 - Created a visual dashboard of broad categories to monitor



Drivers/Pressures

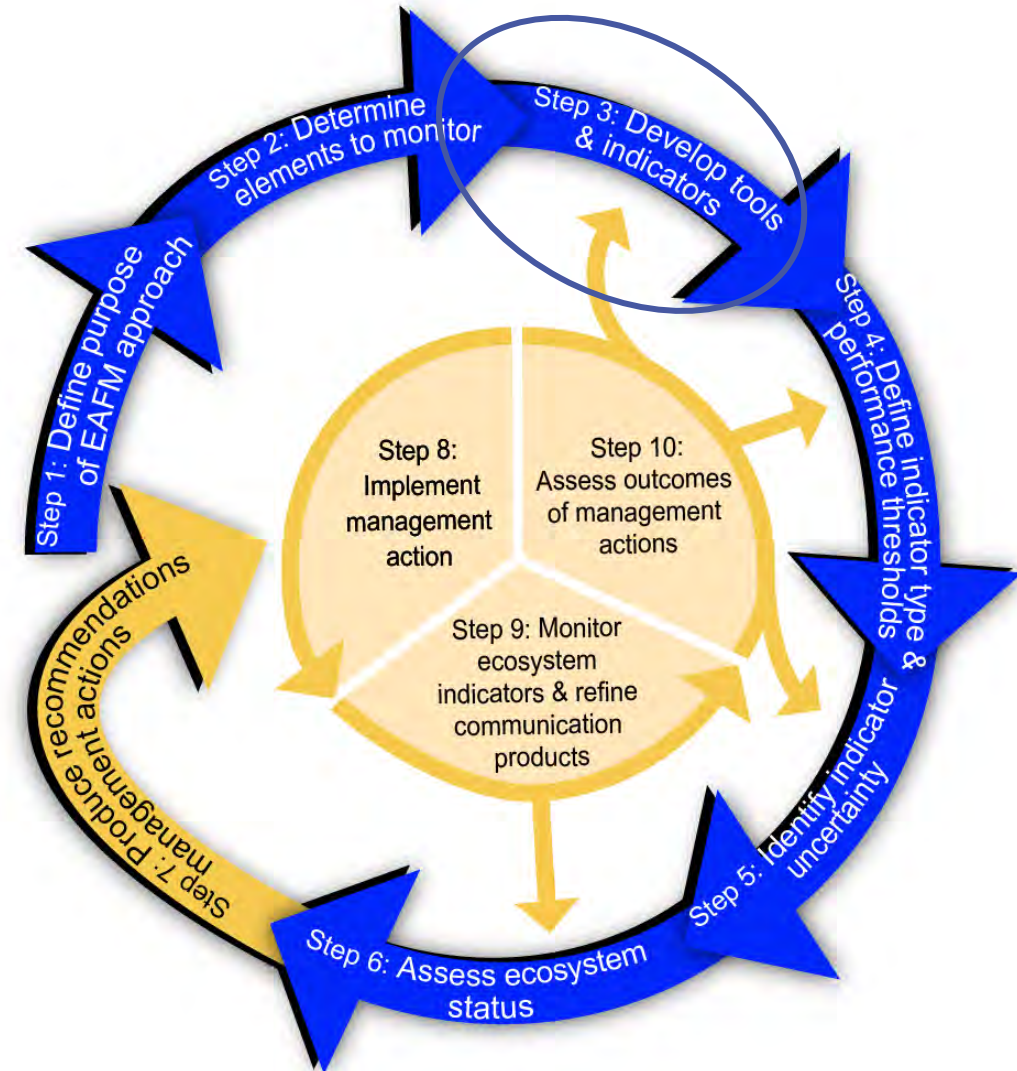


Ecological States



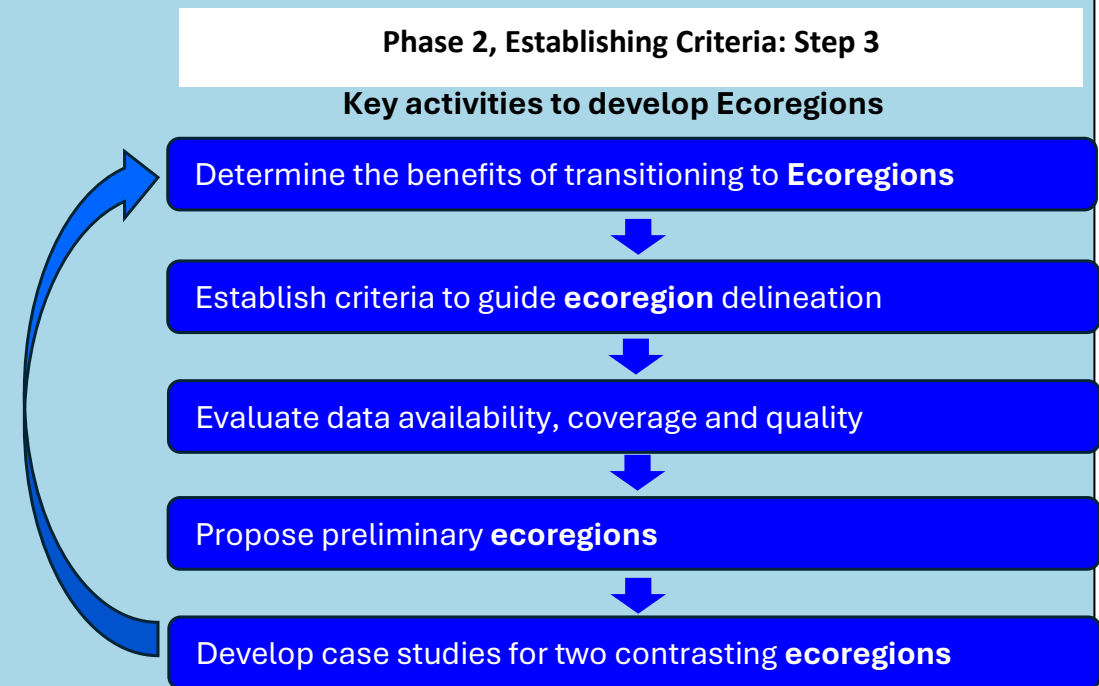
Current indicator framework and initiatives: EcoCard Workplan

- Phase 2: Establishing criteria – completed tasks
 - Step 3 of the staff's proposed conceptual framework
 - Focused on two main actions:
 - (1) exploring the use of **ecoregions** as a potential tool (see Step 3 of the conceptual framework), and
 - (2) **establishing preliminary criteria** for both delineating ecoregions and selecting or developing candidate indicators



Current indicator framework and initiatives: EcoCard Workplan

- Key activities for exploring ecoregions (adapted from ICCAT and IOTC: Juan-Jorda et al. 2022; Nieblas et al. 2022)
 - Determine the purpose and use of ecoregions:
 - provides a practical tool for structuring and guiding ecosystem advice through the development of regional EcoCards
 - Establish criteria to guide ecoregion development: 3 central topics
 - oceanography
 - species and assemblage distributions
 - fleet dynamics of tuna and tuna-like species
 - Evaluating data availability, quality and coverage
 - Proposing preliminary ecoregions
 - Developing case studies to illustrate potential application
 - consider two contrasting regions
 - e.g., one tropical, one subtropical



Current indicator framework and initiatives: EcoCard Workplan

Indicator criteria established in other organizations

t-RFMO/organization	Indicator Criteria	Data Criteria	Source
WCPFC	1. science and data based; 2. characterize the states and trends of WCPFC marine ecosystems with respect to fishing activity and/or climate (including reference levels and baselines); 3. reflect well-defined processes underlying fishing activity and fishery responses to climate; 4. responsive to changes attributable to fishing pressure and climate (i.e., minimal time-lags and capability to provide early warning); 5. estimable on a routine basis with a historical data time-series available; 6. cost-effectiveness; 7. scalable across national, sub-regional and regional scales; 8. linked to existing WCPFC models and decision-making processes (for inclusion in MSE scenarios, validation of predictions and testing of model assumptions); 9. can be routinely estimated by members without reliance of the SSP	Data should be publicly available and be quantitative, specific, and preferably directly measurable or observable. Data should be updated on a regular basis, preferable at least annually. Time-series used should be long-term (>10-years preferred). Data should have appropriate and adequate spatial coverage. Data should have sufficient signal-to-noise ratio to estimate measurement, process uncertainty, and detect significant change. Explanation of the limits of data must be documented.	(SPC-OFP <i>et al.</i> 2025)
ICCAT & IOTC	1. Scientific basis 2. Ecosystem relevance 3. Responsiveness to pressure 4. Possibility to set targets 5. Precautionary capacity/early warning 6. Quality of sampling methods 7. Cost effective 8. Existing/ongoing data	Not provided	(Juan-Jordá <i>et al.</i> 2019)
NOAA (Ecowatch)	1. Indicators should be theoretically sound, reliably represent key ecosystem attributes and hold up to peer review. 2. Indicators should have demonstrable importance to the ecosystem (e.g., keystone or structural architect species) and society (e.g., charismatic or subsistence species)) 3. Indicators should be relevant and understandable to management, to the public, and to policy makers 4. Indicators should be responsive, showing sensitivity to and reacting predictably to environmental variability and/or management or policy actions. 4a. The direction of response should be theoretically- or empirically-expected. 4b. When possible, indicators should provide early warning of ecosystem change. 5. Indicators should complement the indicators already served on the portal in ways such that they are not redundant	Data should be publicly available and be quantitative whenever possible. Qualitative information and expert opinion can provide context for quantitative indicators. Data should be specific, preferably directly measurable or observable. Data should be updated on a regular basis, preferably at least annually. Time-series should be long-term (>10-years preferred) and likely to extend for the foreseeable future. Data should have appropriate and adequate spatial coverage. Normal ranges of spatial (e.g. patchiness) and temporal (e.g. diel, seasonal, annual, and decadal) variation for data should be considered to ascertain status and trends. Data should have sufficient signal-to-noise ratio to estimate measurement, process uncertainty, and detect significant change.	(NOAA 2025)



Current indicator framework and initiatives: EcoCard Workplan

- Staff's proposed criteria to guide indicator selection, adapted from SPC, ICCAT, IOTC and NOAA's Ecowatch

Indicator Criteria	Criteria Definition
Ecosystem and/or Socio-Economic Relevance (operational* or surveillance)	Reflects key ecological processes or socio-economic factors relevant to the objectives and priorities of CPCs and the broader ecosystem context.
Reliable: Grounded in Science and Data (operational* or surveillance)	Appropriate for the measurement of a specific variable or construct and based on reliable scientific methods and data sources that describe established ecological, fisheries, or environmental principles and processes
Sensitivity to Response to Relevant Drivers (operational* or surveillance)	Responds detectably to changes in relevant drivers such as fishing activity, ecosystem dynamics, or environmental conditions, as such potentially serving as an indicator of ecosystem change.
Cost-Effective (operational* or surveillance)	Developing, monitoring and maintaining the indicator does not require excessive resourcing.
Reproducible (operational* or surveillance)	Can be repeatedly applied (e.g., annually) to monitor trends over time—ideally across long time series (>10 years).
Direct Management Value (operational* only)	Provides information that can directly inform the development of actionable targets for fisheries or ecosystem management decisions.
Inform Actionable Targets (operational* only)	Threshold values or reference points that signal when management action should be initiated.

¹ [SC21-EB-IP-01 \(2025\)](#)

² [Juan-Jorda et al. 2019 WCPFC-SC15-2019/EB-WP-12](#)

³ <https://ecowatch.noaa.gov/about> (see “Indicator Selection” tab)

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

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

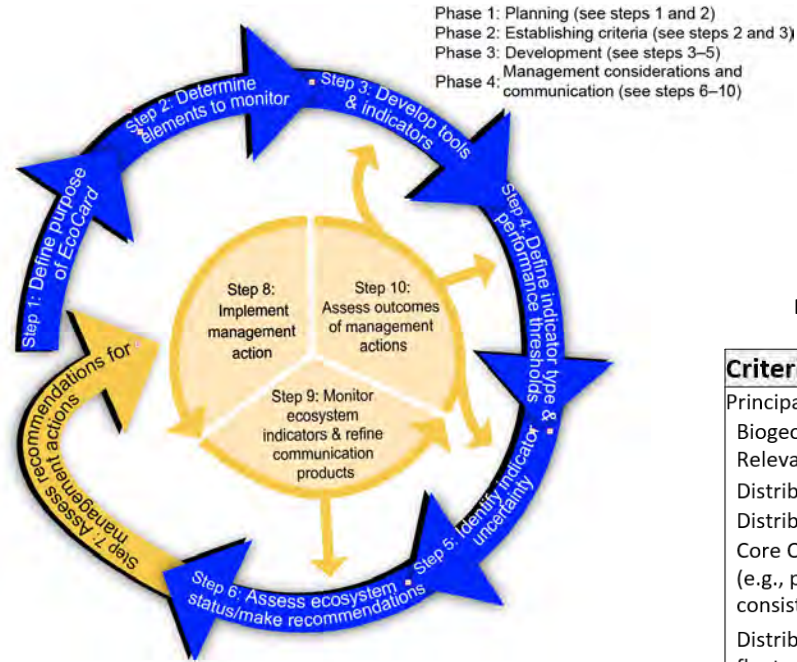
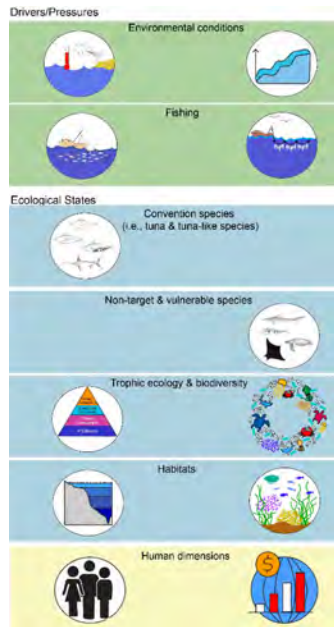
Current indicator framework and initiatives: EcoCard Workplan

- Staff's proposed **data criteria** to guide indicator selection
- Data criteria for both 'operational' and 'surveillance' indicators should:
 - a) have adequate temporal coverage, ideally spanning >10 years, and broad spatial coverage (e.g., across the EPO or region-specific within the EPO;
 - b) be specific and preferably directly measurable or observable, rather than relying on indirect proxies;
 - c) have sufficient signal-to-noise ratio, allowing reliable estimation of measurement and process uncertainty and detection of meaningful changes;
 - d) include documented caveats and limitations to ensure transparency and support interpretation;
 - e) be publicly available

Current indicator framework and initiatives: EcoCard Workplan

Phase 1, Planning: Step 2

Visual Dashboard: Elements to Monitor



Phase 2, Establishing Criteria: Step 3

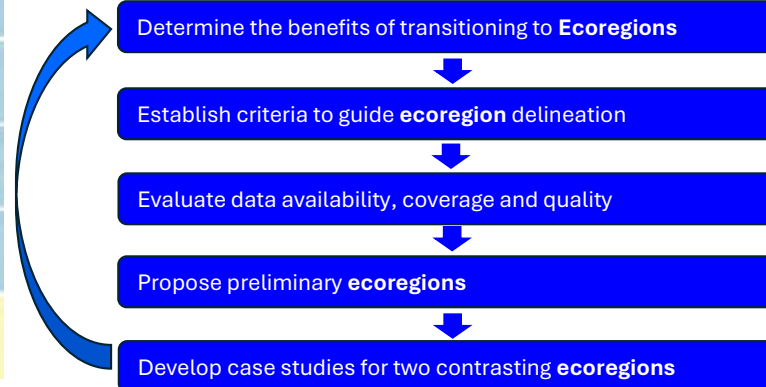
Criteria to guide Ecoregions

Principal factors to consider:

- Biogeography, Biochemistry and Oceanography Relevance
- Distribution of Species and Assemblages
- Distribution of Fleet Dynamics
- Core Qualities of Ecoregions (e.g., practicality, feasibility, adaptability, consistency, temporal resolution)
- Distribution of catches + overlap with species, fleets and biogeographic classifications of interest

Phase 2, Establishing Criteria: Step 3

Key activities to develop Ecoregions



Criteria to guide indicator selection

- Ecosystem and/or Socio-Economic Relevance (operational* or surveillance)
- Reliable: Grounded in Science and Data (operational* or surveillance)
- Sensitivity in Response to Relevant Drivers (operational* or surveillance)
- Cost-Effective (operational* or surveillance)
- Reproducible (operational* or surveillance)
- Direct Management Value (operational* only)
- Inform Actionable Targets (operational* only)

Current indicator framework and initiatives: EcoCard Workplan

- Next steps – Phase 3 (Development):
 - Present progress report on the Ecocard Workplan (Phase 2: Establishing Criteria) to the EBWG (June 2026)
 - Incorporate feedback
 - apply established criteria to draft preliminary ecoregions in the EPO
 - apply screening criteria to select and propose candidate indicators for case studies
 - develop case studies for two contrasting ecoregions (e.g., one subtropical, one tropical)

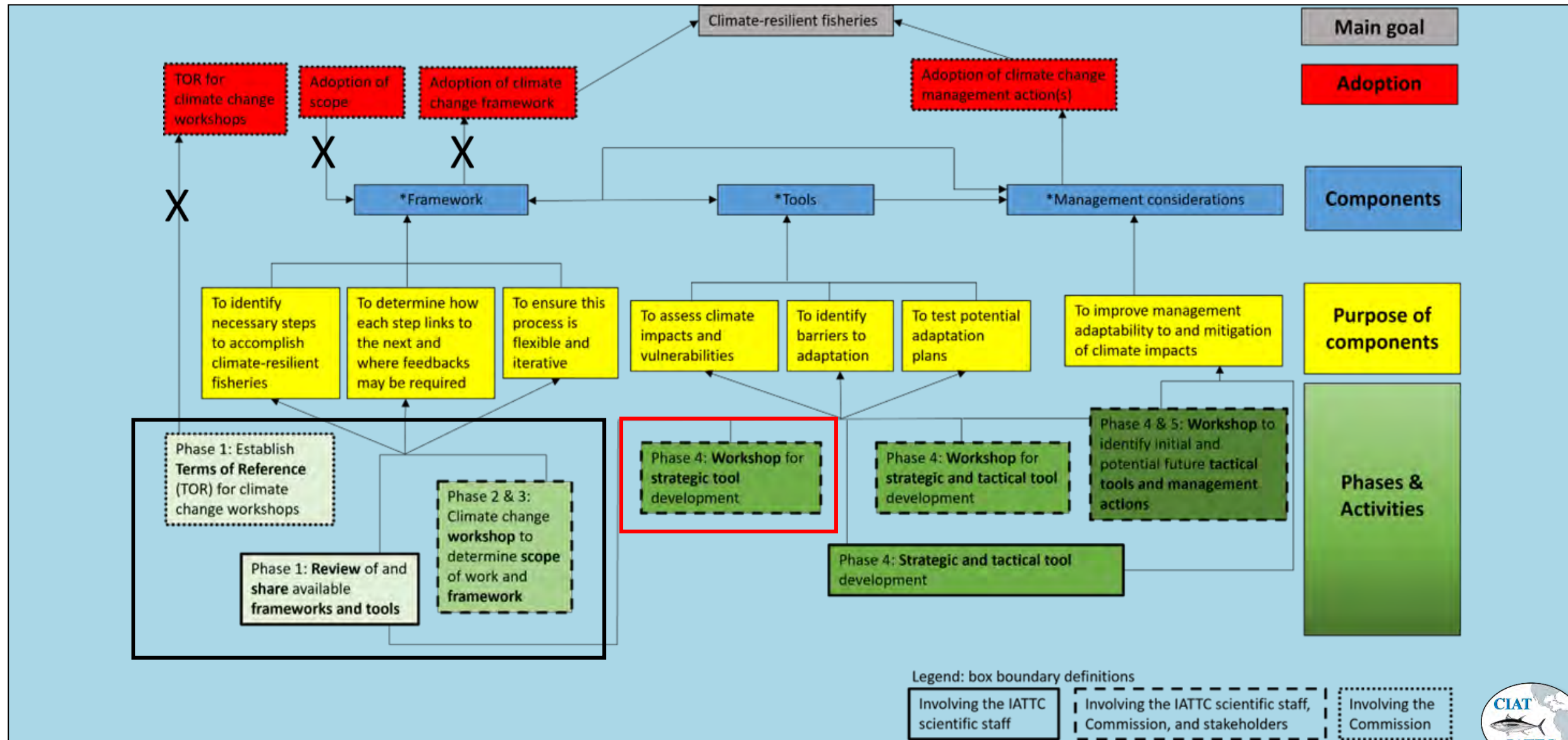
Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



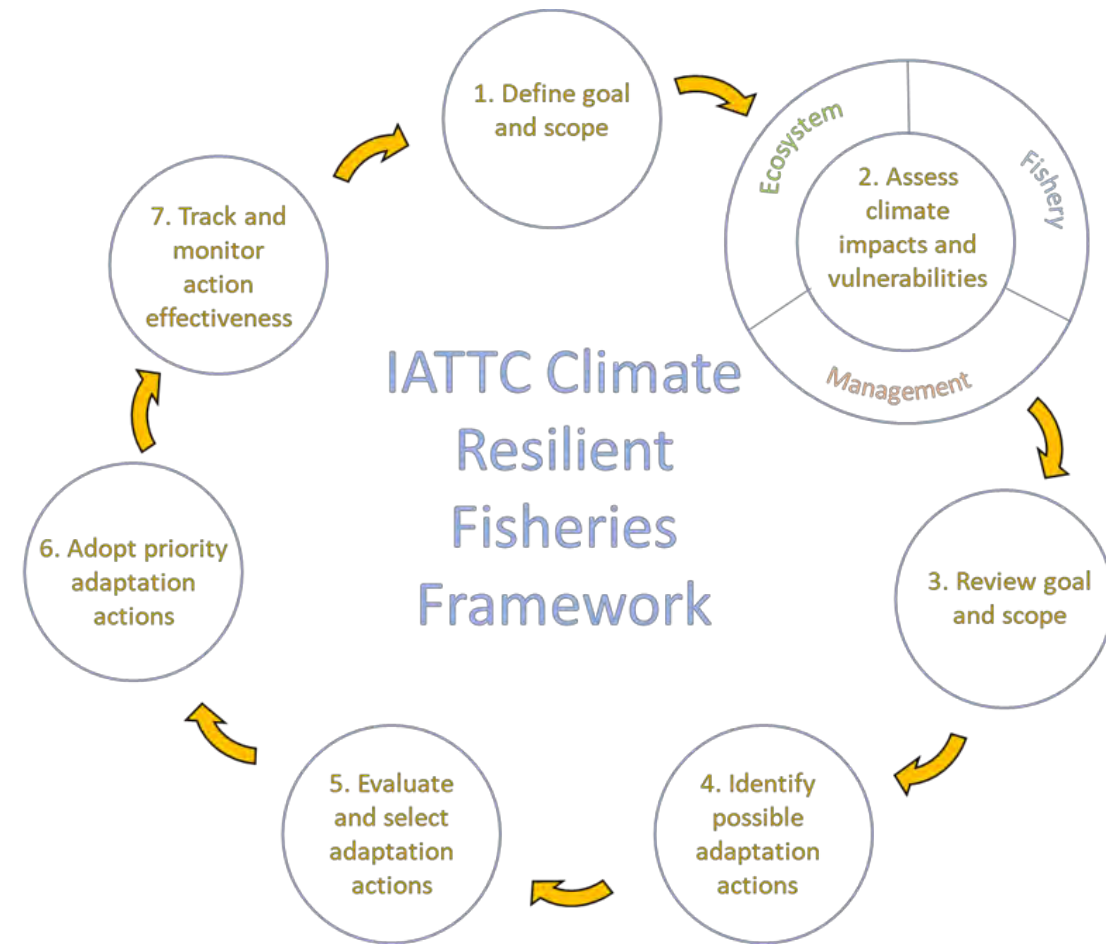
IATTC Climate Change Workplan

4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators, SPC, Noumea (New Caledonia), 02-06 March 2026

Current indicator framework and initiatives: CC Workplan

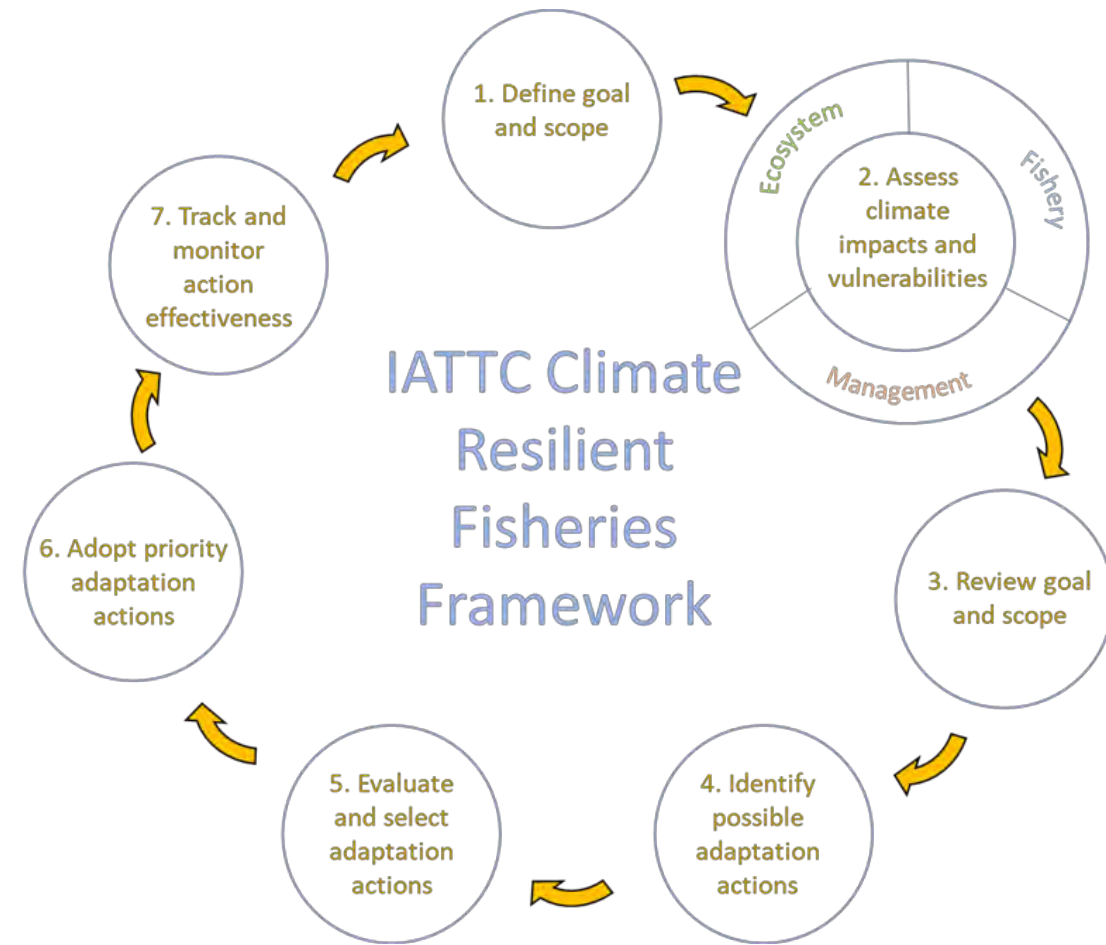


Current indicator framework and initiatives: CC Workplan



Tool	Assessment level	Pros	Cons	Recommended (Years)
Oceanographic data (historical and future conditions)	-Ecosystem/ ecological -Fisheries	- basis for many other climate and non-climate related tools -accessing data is free -historical data has updated to 2023 -no funding needed	-takes up a lot of digital storage	YES, continue doing (2024-2028)
Species distribution models (SDMs)	-Ecosystem/ ecological	- basis for many other climate and non-climate related tools -developed for some species already -expertise in house -can be done through academic collaborations to expand species list -no funding needed	-many target and bycatch species -requires computing power	YES, continue doing (2024-2028)
Physiological/laboratory experiments	- Ecosystem/ ecological	-have infrastructure in place (Achatines Lab) that is used for climate and non-climate related tools -access to live animals -expertise in house -can be done through academic collaborations	-time consuming -will require funds	YES, continue doing (2024-2028)
Indicators	-Ecosystem/ ecological -Fisheries	-already undergoing EcoCard workplan -ecosystem model already developed -collaborating with other tRMFOs -no funding needed	-a lot of potential indicators to choose from (surveillance vs operational) -IATTC lost ecosystem scientist	YES, continue doing (2024-2028)
Climate vulnerability assessments (CVAs)	-Ecosystem/ ecological -Fisheries	-provide overall vulnerability rank for specific species, habitat, or fishery that is comparable -conducted on all species or fisheries at once -CVAs are already developed by many groups that can be adapted (WCPFC is planning CVA) -participation of stakeholders at in person workshop	-time needed to adapt a CVA for IATTC -requires a lot of planning for in person workshop -potentially separate CVAs for ecological and fishery levels -will require funds	YES, ecosystem/ecological CVA to start (2027-2028)

Current indicator framework and initiatives: CC Workplan



Tool	Assessment level	Pros	Cons	Recommended (Years)
Climate change scenario planning	-Ecosystem/ ecological -Fisheries -Management	-can assess risk at all three levels -model/adapt to already successful scenario planning exercises -participation of stakeholders at in person workshop -funding acquired for this exercise	-time needed to adapt a CVA for IATTC -requires a lot of planning for in person workshops	YES, (2026-2027)
Ecosystem models	-Ecosystem/ ecological -Fisheries -Management	-can assess risk at all three levels -ecosystem model already developed -collaborating with other tRFMOs	-complex and requires a lot of data -IATTC lost ecosystem scientist	TBD
Climate-informed stock assessments	-Ecosystem/ ecological	-already have stock assessments developed for tunas -novel approaches are being developed to incorporate environmental variables -there are many ways stock assessments can be climate-informed -funds have been acquired to improve stock assessments	-some attempts have been made to incorporate -attempts to integrate environmental variables has occurred with minimal success	TBD
Management strategy evaluation (MSE)	-Ecosystem/ ecological -Fisheries -Management	-can assess risk at all three levels -bigeye MSE is almost complete -variety of ways to incorporate the environment into MSEs	-requires a lot of time and resources	TBD
Fisheries surveys	-Fisheries	-engages with stakeholders -fairly simple to initiate -could be paired with scenario planning	-requires large number of responses from fishers	YES, (2027)
Management surveys	-Management	-engages with stakeholders -one of only a few opportunities to assess management vulnerabilities -could be paired with scenario planning	-requires large number of responses from managers	YES, (2028)

Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



ETI Application in the IATTC

4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators, SPC, Noumea (New Caledonia), 02-06 March 2026

ETP Ecopath with Ecosim model

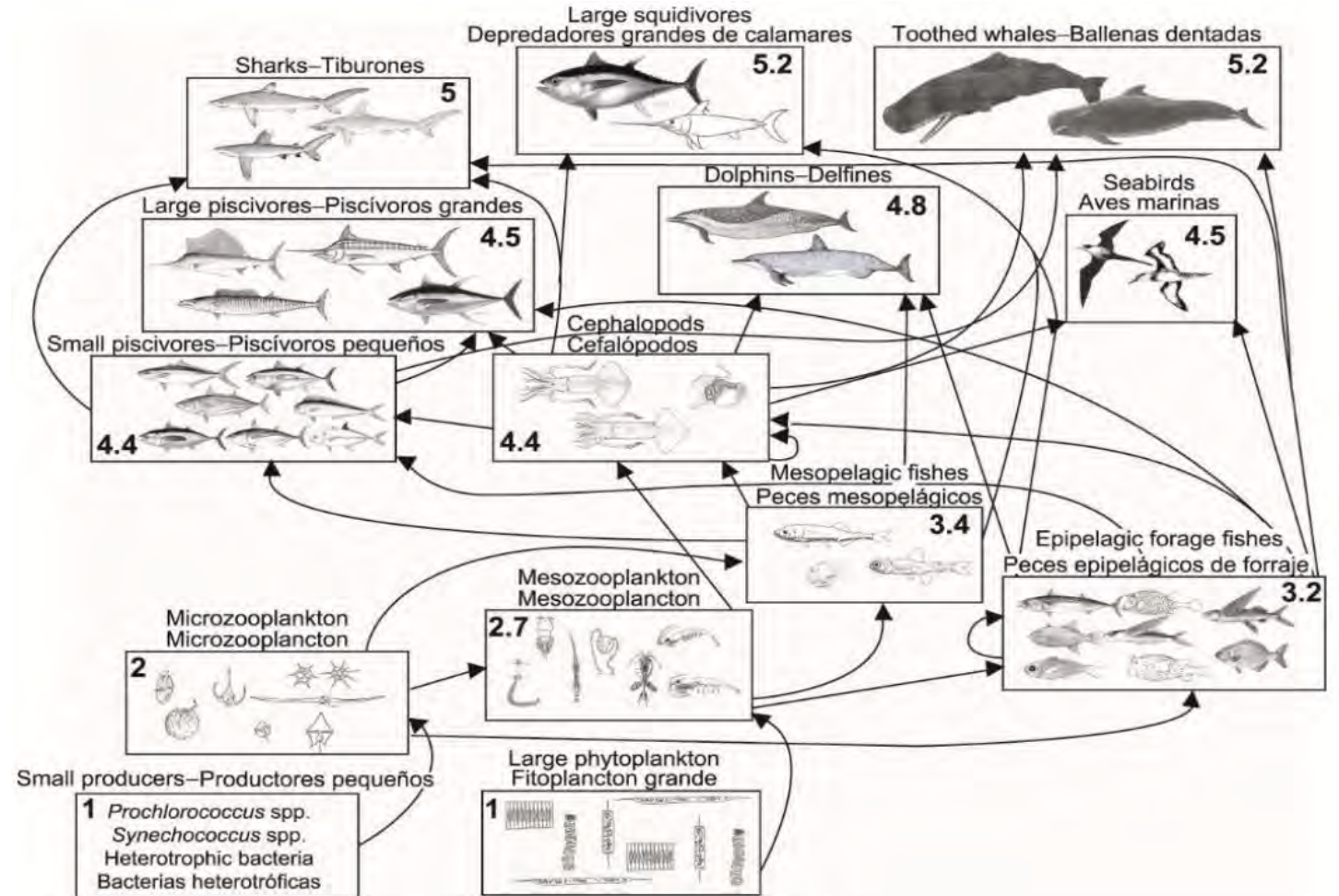
- In 2017, staff updated the ETP7 model with new data 1970-2014
- Since 2017, staff update ETP7 annually with catch and effort data and report on indicators in “*Ecosystem Considerations*” report (SAC-12-12)
- 2021 update (ETP-21) was required to:
 - Improve model structure to link ontogenetic stages (e.g., small and large YFT)
 - Update biological parameters with new information since 2003
 - Rebalance the model after including revised longline catch estimates (SAC-12-12)
 - Calibrate the model to new time series data available for target and bycatch species



ETP Ecopath with Ecosim model

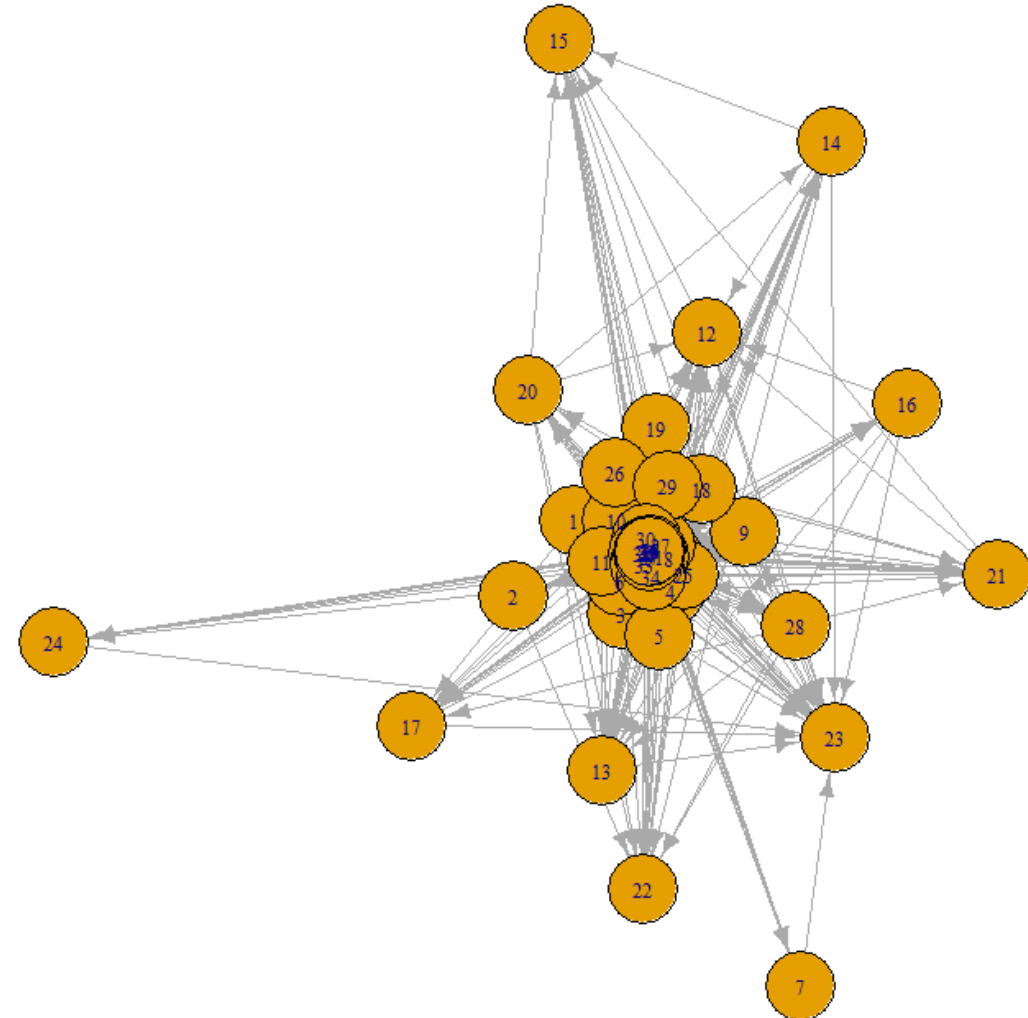
Diet matrix based
on 1990s-2000s

39 groups



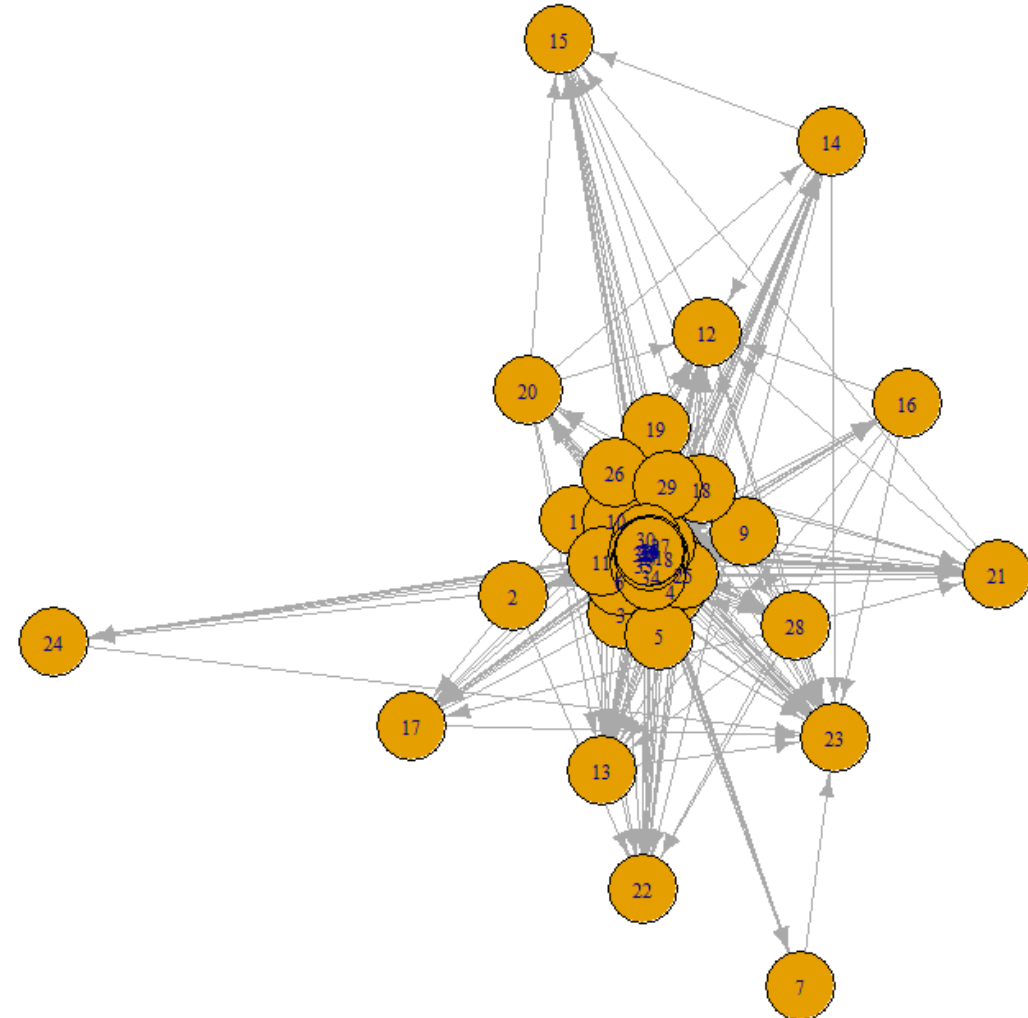
Hub Species: Network Analysis

1	Pursuit_Birds	20	Sm_Wahoo
2	Grazing_Birds	21	Lg_Wahoo
3	Baleen_Whales	22	Sm_Sharks
4	Toothed_Whales	23	Lg_Sharks
5	Spotted_Dolphin	24	Rays
6	Meso_Dolphin	25	Skipjack
7	Sea_Turtles	26	Albacore
8	Sm_Yellowfin	27	Auxis
9	Lg_Yellowfin	28	Bluefin
10	Sm_Bigeye	29	Misc. Pisc
11	Lg_Bigeye	30	Flying_fish
12	Sm_Marlins	31	Misc_Epi_Fish
13	Lg_Marlins	32	Misc_Meso_Fish
14	Sm_Sailfish	33	Cephalopods
15	Lg_Sailfish	34	Crabs
16	Sm_Swordfish	35	Mesozooplankton
17	Lg_Swordfish	36	Microzooplankton
18	Sm_Dorado	37	Lg_Phytoplankton
19	Lg_Dorado	38	Sm_Producers
		39	Detritus

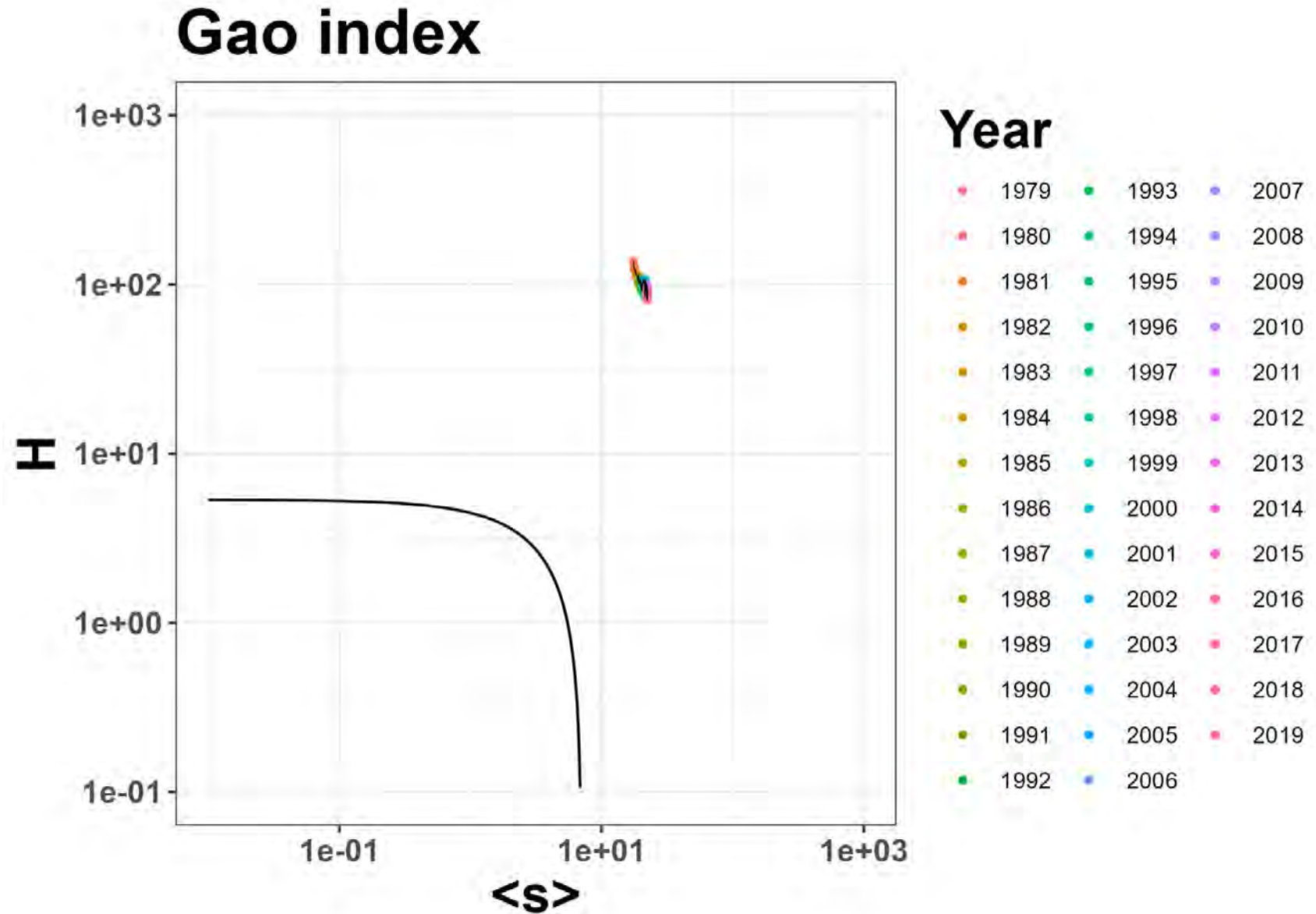


Hub Species: Network Analysis

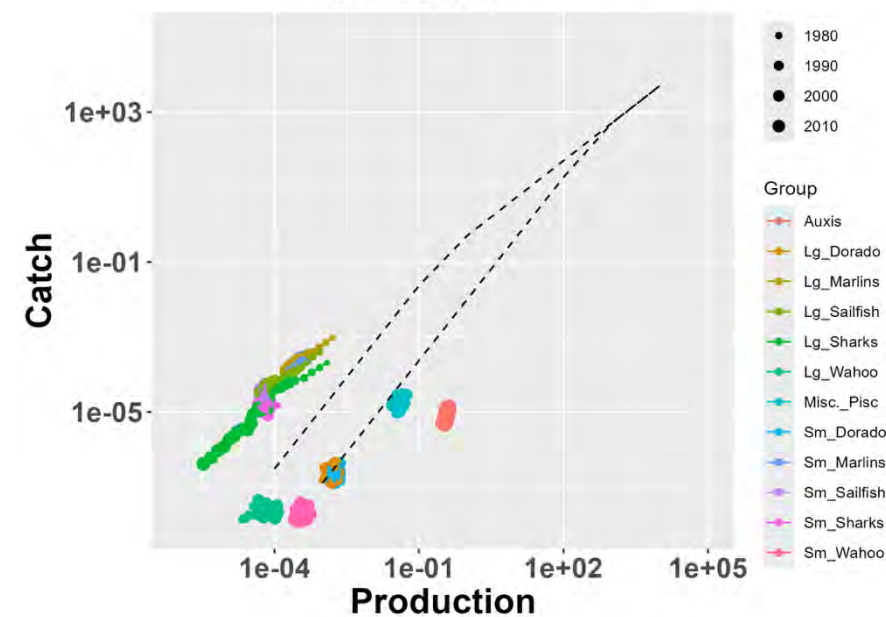
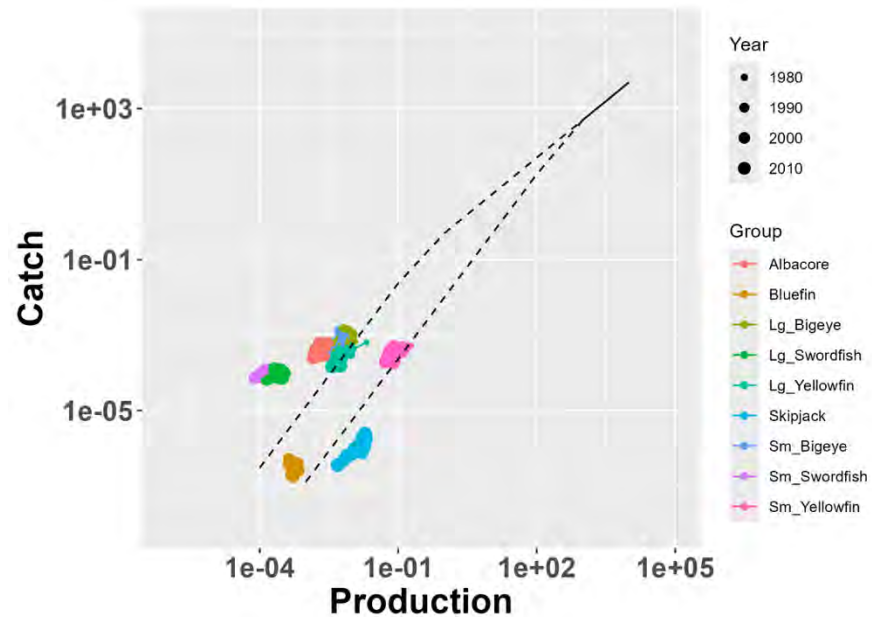
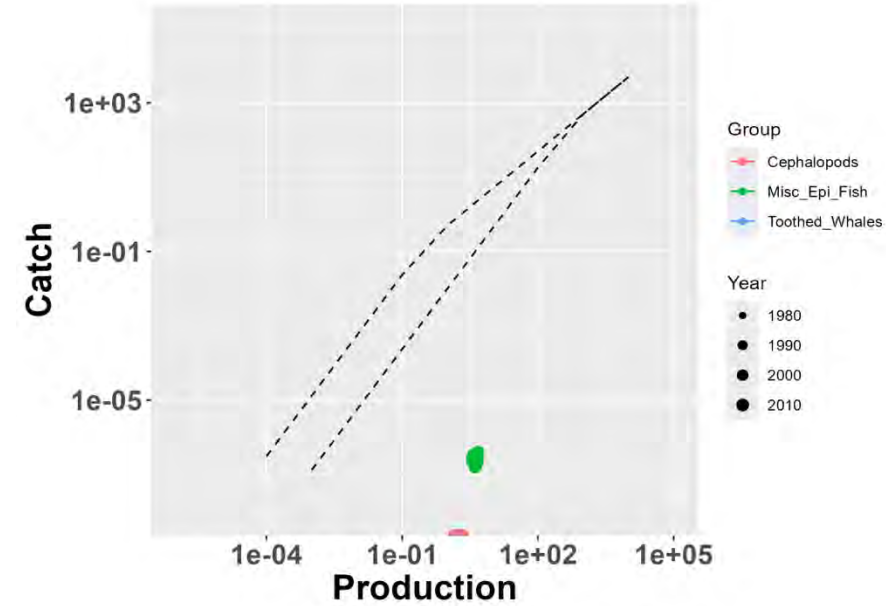
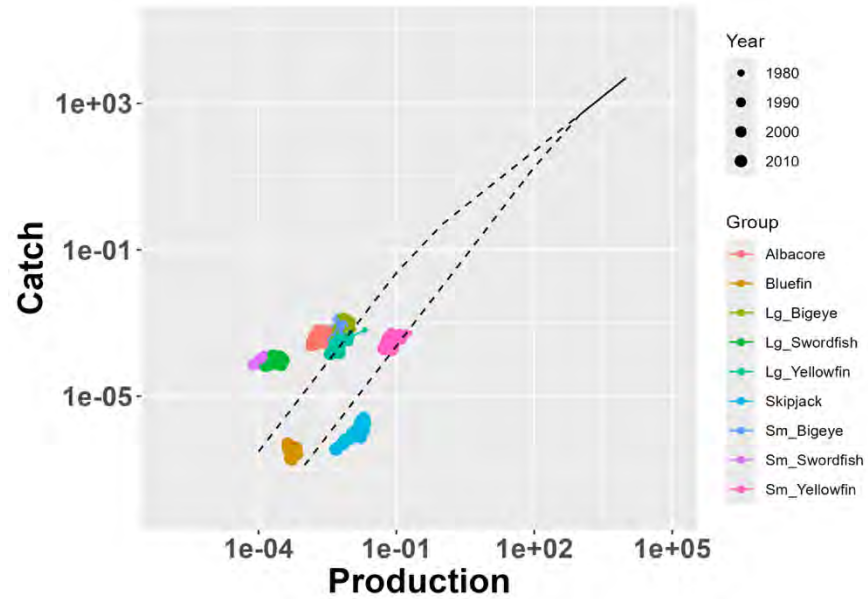
1	Pursuit_Birds	20	Sm_Wahoo
2	Grazing_Birds	21	Lg_Wahoo
3	Baleen_Whales	22	Sm_Sharks
4	Toothed_Whales	23	Lg_Sharks
5	Spotted_Dolphin	24	Rays
6	Meso_Dolphin	25	Skipjack
7	Sea_Turtles	26	Albacore
8	Sm_Yellowfin	27	Auxis
9	Lg_Yellowfin	28	Bluefin
10	Sm_Bigeye	29	Misc. Pisc
11	Lg_Bigeye	30	Flying_fish
12	Sm_Marlins	31	Misc_Epi_Fish
13	Lg_Marlins	32	Misc_Meso_Fish
14	Sm_Sailfish	33	Cephalopods
15	Lg_Sailfish	34	Crabs
16	Sm_Swordfish	35	Mesozooplankton
17	Lg_Swordfish	36	Microzooplankton
18	Sm_Dorado	37	Lg_Phytoplankton
19	Lg_Dorado	38	Sm_Producers
		39	Detritus



Gao Index (Network Resilience)

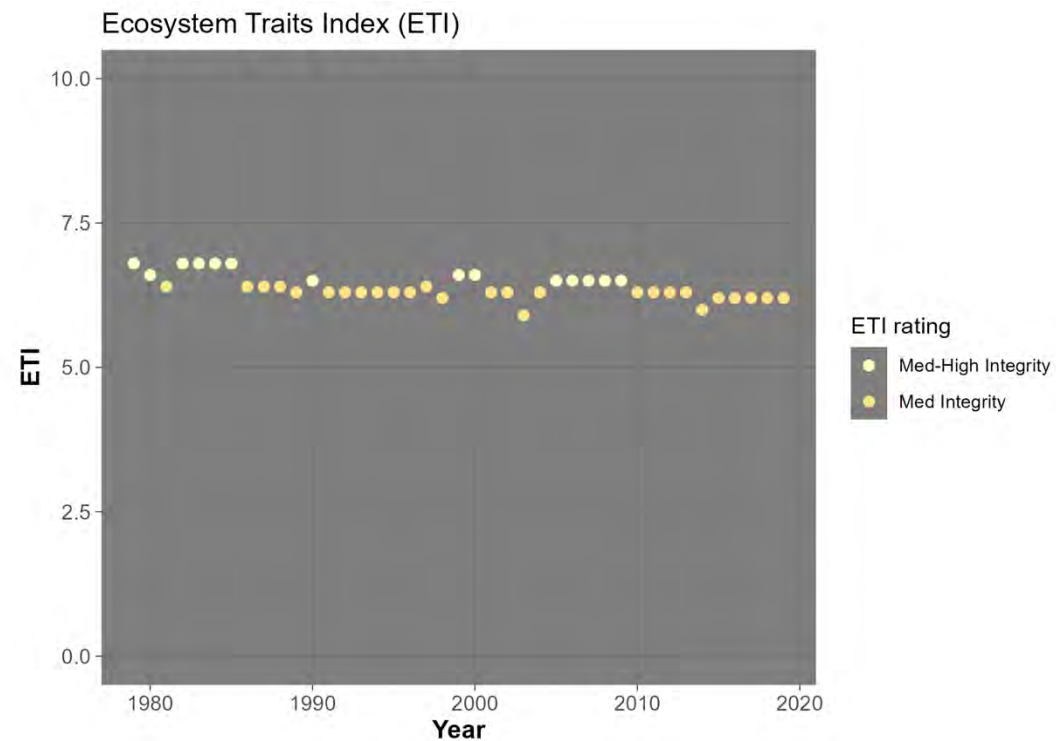
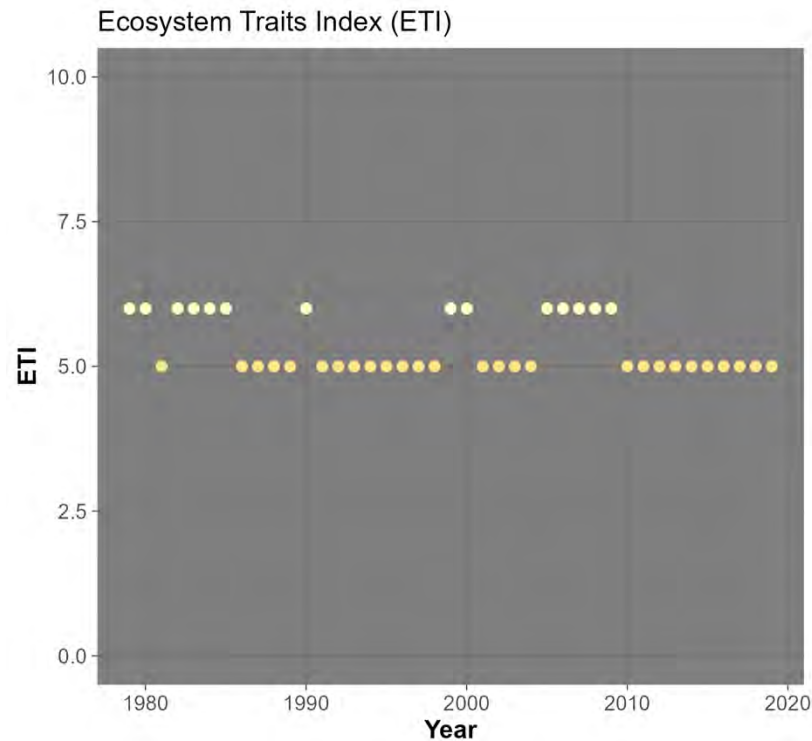


Green Band (Distortive Pressure)



ETI

ETI value	Qualitative Rating	Management Guidance
< 2.5	Collapse likely	Urgent Intervention: <i>Degraded structure and function</i>
2.5 – 3.7	Shocks likely	Requires immediate large-scale action; likely to take considerable time to recover
3.7 – 4.6	Shocks possible	Act: <i>At risk</i>
4.6 – 5.5	Low integrity	Requires attention; should respond rapidly to intervention
5.5 – 6.4	Medium integrity	Monitor: <i>Still stable</i>
6.4 – 7.3	Medium-High integrity	Continue monitoring; no changes required
7.3 – 8.2	High integrity	Stable: <i>Not at risk</i>
8.2 – 9.1	Very robust integrity	Continue monitoring; potential for increased activity (exploitation)
9.1 – 10	Close to pristine	
> 10	Pristine	

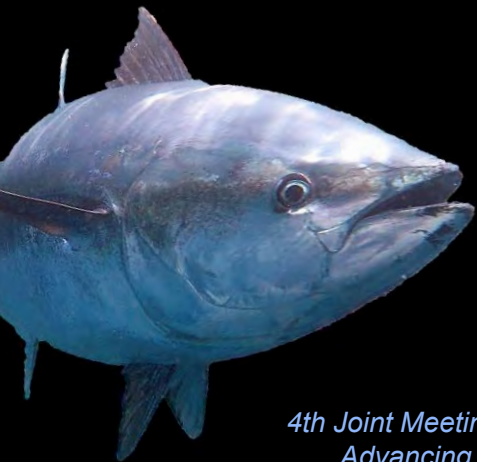




Questions

CONTEXT SETTING - tRFMO EAFM implementation ICCAT

Eider Andonegi (AZTI) – eandonegi@azti.es



OUTLINE

1. COMMISSION MANDATES,
RESOLUTIONS/RECOMMENDATIONS
AND ONGOING RFMO PROCESSES
2. THE ROLE OF ECOSYSTEM AND
CLIMATE INDICATORS TO INFORM A
CLIMATE-RESILIENT MANAGEMENT
PROCESS



MANDATE AND RELEVANT RESOL/RECOMM

Convention mandate → explicit reference to the EAFM

ICCAT Resolution 15-1 concerning the application of an ecosystem approach to fisheries management

When making recommendations pursuant to Article VIII of the Convention, the Commission **should apply an ecosystem-based approach to fisheries management**

In implementing an ecosystem-based approach to fisheries management, the Commission should, inter alia:

- consider the **interdependence of stocks** and species belonging to the same ecosystem or associated with or dependent upon target stocks;
- consider the **impacts of fishing, other relevant human activities, and environmental factors on target stocks, non-target species and species belonging to the same ecosystem** or associated with or dependent upon target stocks in the Convention area;
- **minimize negative impacts** of fishing activities on the marine ecosystem.

Convention mandate → explicit reference to the EAFM

- Amendment to the Convention Mandate (2019) - New Article IV: “The Commission and its Members, in conducting work under this Convention, shall act to:
 - (a) *apply the precautionary approach and an ecosystem approach to fisheries management in accordance with relevant internationally agreed standards and, as appropriate, recommended practices and procedures*
 - (b)....
 - ...”

MANDATE AND RELEVANT RESOL/RECOMM

Convention mandate → explicit reference to the EAFM

Bycatch species (seabirds, sea turtles, sharks and cetaceans)

- ❖ ICCAT Recommendation 25-07 concerning basking shark and great white shark caught in association with ICCAT-managed fisheries
- ❖ ICCAT Recommendation 25-08 amending Recommendation 22-11 on the conservation of the South Atlantic stock of shortfin mako caught in association with ICCAT fisheries
- ❖ ICCAT Recommendation 25-09 on the Experimental Use of Trap Lines

Convention mandate → explicit reference to the EAFM

FADs

- ❖ ICCAT Recommendation 16-01 on a multi-annual conservation and management programme for tropical tunas – Part IV Management of FADs
- ❖ ICCAT Recommendation 16-02 to establish an ad hoc working group on fish aggregating devices (FADs)
- ❖ ...

MANDATE AND RELEVANT RESOL/RECOMM

Convention mandate → explicit reference to the EAFM

Communication – very limited yet

- ❖ ICCAT Resolution 16-21 on the third meeting of the standing working group for enhancing the dialogue between fisheries scientists and managers
- ❖ Currently presented and discussed at the SCRS level, but little information provided to the COMM (if any)

Convention mandate → explicit reference to the EAFM

- The SCRS Science Strategic Plan (2015-2020) includes elements regarding EAFM:
 - 3.2 Enhance the EAFM
 - 3.3. Develop short term, medium and long-term objective to enhance ecosystem-based approaches
- New SCRS Science Strategic Plan in progress – include those and new elements

MANDATE AND RELEVANT RESOL/RECOMM

Convention mandate → explicit reference to the EAFM and Climate Change

ICCAT Resolution 22-013 on Climate Change

MANDATE AND RELEVANT RESOL/RECOMM

**Convention mandate → explicit reference to the EAFM and Climate Change
and BBNJ**

ICCAT Resolution 25-05 on the implementation of the United Nations Agreement on the Protection of Marine Biodiversity in Areas Beyond National Jurisdiction (BBNJ)

EAFM & CC (*and BBNJ related issues*) fall under the mandate of the **SUBCOMMITTEE ON ECOSYSTEMS AND BYCATCH (SCECO)**.

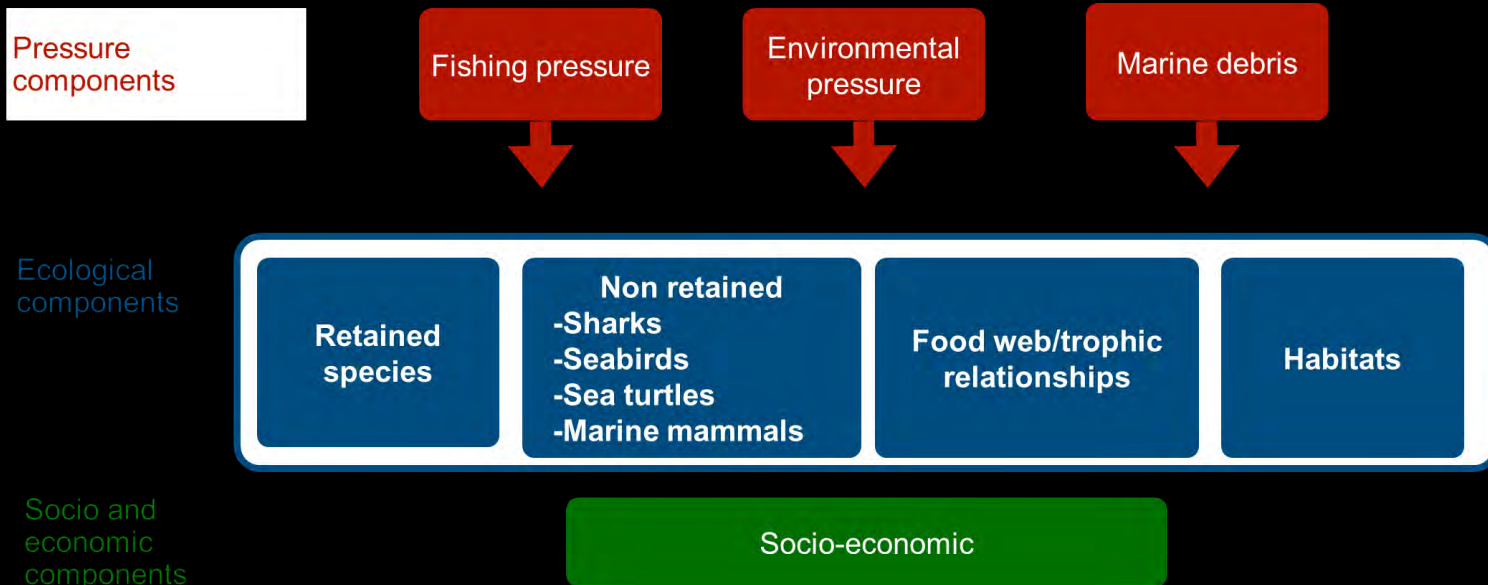
- Ecosystem impacts from ICCAT fisheries
- Impacts of environmental effects/climate change on ecosystems and fisheries.
 - Other WG can also discuss these topics under their agenda when relevant to their focus species

INSTITUTIONAL STRUCTURE

- Advice on “EAFM and CC considerations” is provided to the Commission via the recommendations made by the SCECO via the SCRS.
- The SCRS chair presents the recommendations and advice from the SCECO at the Commission meeting.
- Not EAFM neither CC are explicitly being implemented yet, however Recommendations and Resolutions addressing key elements already exist.

ROLE OF ECOSYSTEM & CLIMATE INDICATORS

Monitor pressure, ecological and socioeconomic dynamics - **EcoCARD**



ROLE OF ECOSYSTEM & CLIMATE INDICATORS

EcoCARD – progress in 2026

Goal/Timing	EcoCard Component	Objective	Contributor/s
No expectation of development in 2026	Retained species: Not assessed	Perform PSA for select retained unassessed species	
Update for 2026	Retained species: Assessed	Update BRATIO and/or FRATIO values from recent assessments and deal with F _{0.1} and MSE issue.	Alex/Eider
Update for 2026	Non-retained sharks (silky shark)	Increase the scope of the data used in the analysis. Include other gear types. Silky shark risk assessment based on SDM or vulnerability index.	Rui/Leire
Develop	Marine turtles	Perform risk assessment for loggerhead and leatherback turtles and indicator development Check progress of other tRFMOs.	Ochi/Andres
Develop	Seabirds (albatross/petrel)	Create vulnerability indicator based on overlap of species distribution with longline & purse seine fisheries. ICCAT and/or SEFRA data.	James/Sachiko/Sebastian/Helen
Develop	Marine mammals	Discuss collaborations with IWC and ICES. Following scoping exercise, develop index from Ecosim model of the tropical Atlantic.	Josu/Eider

Develop	Trophic structure, community and diversity indicators	Develop indicators from EwE to monitor the biomass structure, size structure and trophodynamics of the ecological communities in the tropical Atlantic in response to fishing pressure and environmental drivers.	Josu/Eider/Maria Jose
No expectation of development in 2026	Habitat	Create indicators to monitor climate-induced and fishing-induced habitat changes in ICCAT species.	
Update and develop for 2026	Socio economic	Develop indicators based on socio-economic data. Develop tool to extract the socio-economic data. Adjusted for inflation and per ton of catch.	Sachiko/Jose Carlos/Diego
Develop	Fishing pressure	Develop an indicator based on fishing effort or capacity.	Diego/TunaMed
Develop	Environmental pressure	Develop indicators that have a causal relationship with stock life history traits.	TunaMed/Diego/Maria Jose
Develop	Marine debris (abandoned, lost or otherwise discarded fishing gears (ALDFG))	Quantify annual ALDFG strandings.	Erin/Maitane

ROLE OF ECOSYSTEM & CLIMATE INDICATORS

EcoCARD – Climate related indicators

Table. Environmental indicators and their ecological relevance to ICCAT species.

<i>Indicators</i>	<i>Description</i>	<i>Species</i>	<i>Areas</i>	<i>Ecological Relevance</i>
Marine heatwaves and sea surface temperature anomalies	Frequency and intensity of heat waves and warming in key areas during early life ecology and reproductive aggregations along the Mediterranean Sea	Not species specific, affecting BFT, ALB, SWO	Spawning grounds, possible for juvenile feeding areas and YOY (identified for BFT)	Demonstrated effects of temperature on larval ecology (survival, growth). Methodologies at Juza et al., 2022
Interannual variability of the ocean dynamics shaping tuna habitats	Surface mixing properties associated with coherent Lagrangian structures during the reproductive season will be monitored from finite size Lyapunov exponents	Not species specific, affecting BFT, ALB, SWO	Spawning grounds	Habitat quality for tuna larval stages (Díaz-Barroso et al., 2021)
Climate velocity	Ratio of variability of temperature trends and spatial temperature gradients	Not species specific, affecting BFT, ALB, SWO	Spawning grounds, feed in areas, fishing grounds	For identifying areas more susceptible of being impacted by CC. Isotherm displacements. (Burrows et al., 2011)
Larval habitat spatial coverage trends	Effects of habitat variability on the expansion/contraction of suitable larval habitats	For BFT, ALB, SWO, calculated for species specific	Spawning grounds	Changes on habitat distributions forced by CC (Tugores et al., 2023)
Primary and secondary productivity	Primary production and secondary production trends	Not species specific, affecting BFT, ALB, SWO	Spawning grounds, possible for juvenile feeding areas and YOY (identified for BFT)	Identification of ecosystem productivity shifts, affecting larval and juvenile stadiums
Small pelagic productivity	Abundance trends of small pelagics in tuna key areas	Not species specific, affecting BFT, ALB, SWO	YOY areas and juvenile feeding grounds	Information on ecosystem productivity at higher trophic levels

ROLE OF ECOSYSTEM & CLIMATE INDICATORS

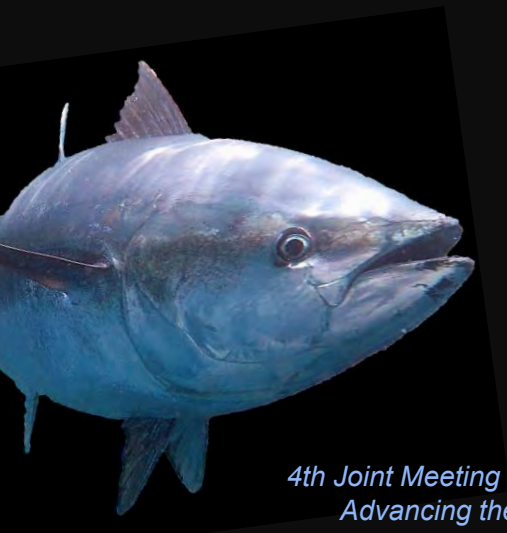
EcoCARD – Climate related indicators

Climate conditioned, risk equivalent advice by using climate indicators in MSE, both at OM or MP levels – first discussions

Climate and ecosystem informed advice from Ecosystem models

CONTEXT SETTING - Current Indicator Framework and initiatives in ICCAT

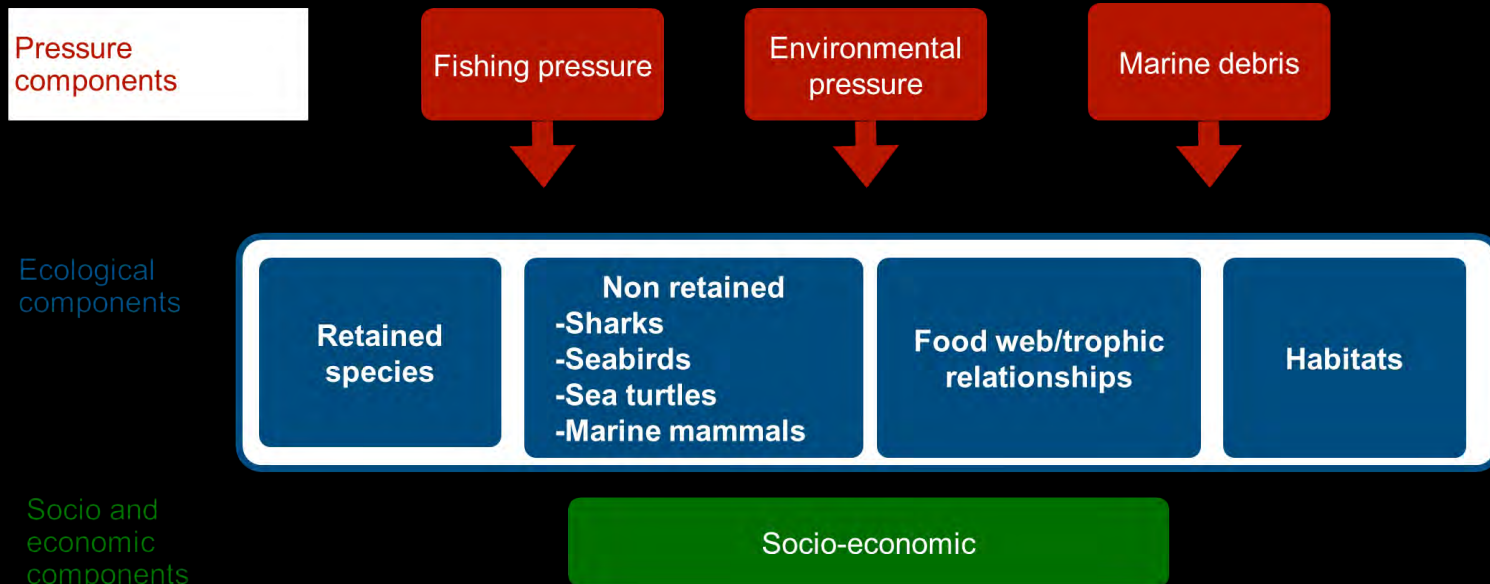
Eider Andonegi (AZTI) – eandonegi@azti.es



*4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management:
Advancing the Development of Ecosystem Indicators. 2-6 March 2026, SPC, Noumea (New Caledonia)*

INDICATOR FRAMEWORK AND INITIATIVES

PRODUCTS: The EcoCard



ROLE OF ECOSYSTEM & CLIMATE INDICATORS

EcoCARD – progress in 2026

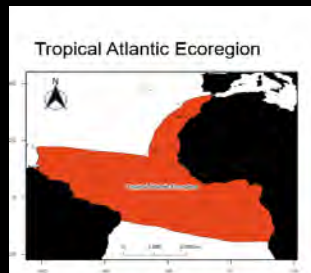
Goal/Timing	EcoCard Component	Objective	Contributor/s
No expectation of development in 2026	Retained species: Not assessed	Perform PSA for select retained unassessed species	
Update for 2026	Retained species: Assessed	Update BRATIO and/or FRATIO values from recent assessments and deal with F _{0.1} and MSE issue.	Alex/Eider
Update for 2026	Non-retained sharks (silky shark)	Increase the scope of the data used in the analysis. Include other gear types. Silky shark risk assessment based on SDM or vulnerability index.	Rui/Leire
Develop	Marine turtles	Perform risk assessment for loggerhead and leatherback turtles and indicator development Check progress of other tRFMOs.	Ochi/Andres
Develop	Seabirds (albatross/petrel)	Create vulnerability indicator based on overlap of species distribution with longline & purse seine fisheries. ICCAT and/or SEFRA data.	James/Sachiko/Sebastian/Helen
Develop	Marine mammals	Discuss collaborations with IWC and ICES. Following scoping exercise, develop index from Ecosim model of the tropical Atlantic.	Josu/Eider

Develop	Trophic structure, community and diversity indicators	Develop indicators from EwE to monitor the biomass structure, size structure and trophodynamics of the ecological communities in the tropical Atlantic in response to fishing pressure and environmental drivers.	Josu/Eider/Maria Jose
No expectation of development in 2026	Habitat	Create indicators to monitor climate-induced and fishing-induced habitat changes in ICCAT species.	
Update and develop for 2026	Socio economic	Develop indicators based on socio-economic data. Develop tool to extract the socio-economic data. Adjusted for inflation and per ton of catch.	Sachiko/Jose Carlos/Diego
Develop	Fishing pressure	Develop an indicator based on fishing effort or capacity.	Diego/TunaMed
Develop	Environmental pressure	Develop indicators that have a causal relationship with stock life history traits.	TunaMed/Diego/Maria Jose
Develop	Marine debris (abandoned, lost or otherwise discarded fishing gears (ALDFG))	Quantify annual ALDFG strandings.	Erin/Maitane

INDICATOR FRAMEWORK AND INITIATIVES

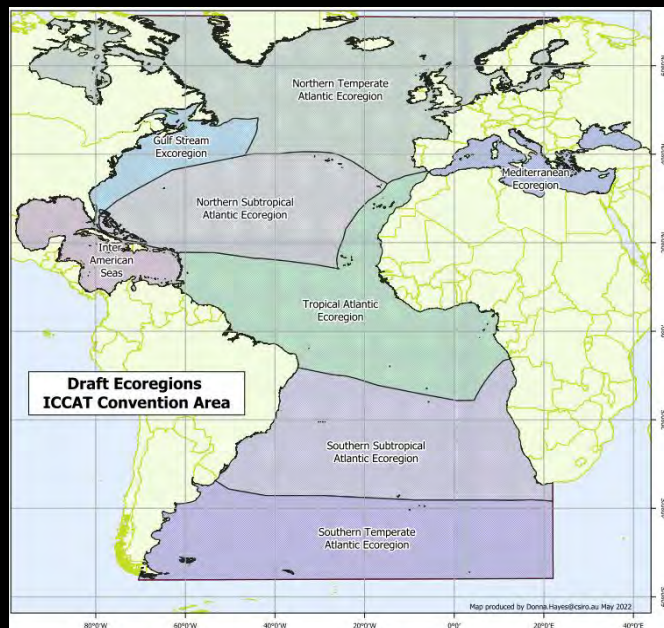
PRODUCTS: The Ecosystem Fisheries Overviews

SUMMARY of key signals (EcoCard)	ECOREGION DESCRIPTION	WHO IS FISHING <i>main countries- fleets</i> <i>main fisheries</i>	WHAT ARE WE FISHING <i>catches -landings and</i> <i>discards</i>
STATUS OF FISHERY RESOURCES <i>target species</i>	MIXED FISHERIES ADVISE <i>fisheries interactions</i> <i>species interactions</i>	FISHERIES MANAGEMENT <i>bycatch mitigation</i> <i>measures</i>	FISHERY MANAGEMENT PLANS
ENVIRONMENTAL & CLIMATE CHANGE EFFECTS	EFFECT OF FISHERIES ON THE ETP species & STATE OF ETP species <i>Shar/rays</i> <i>Seabirds</i> <i>Sea turtles</i> <i>Marine mammals</i>	EFFECT OF FISHERIES ON THE FOODWEB & STATE OF FOODWEB	SOCIO-ECONOMIC CONTEXT



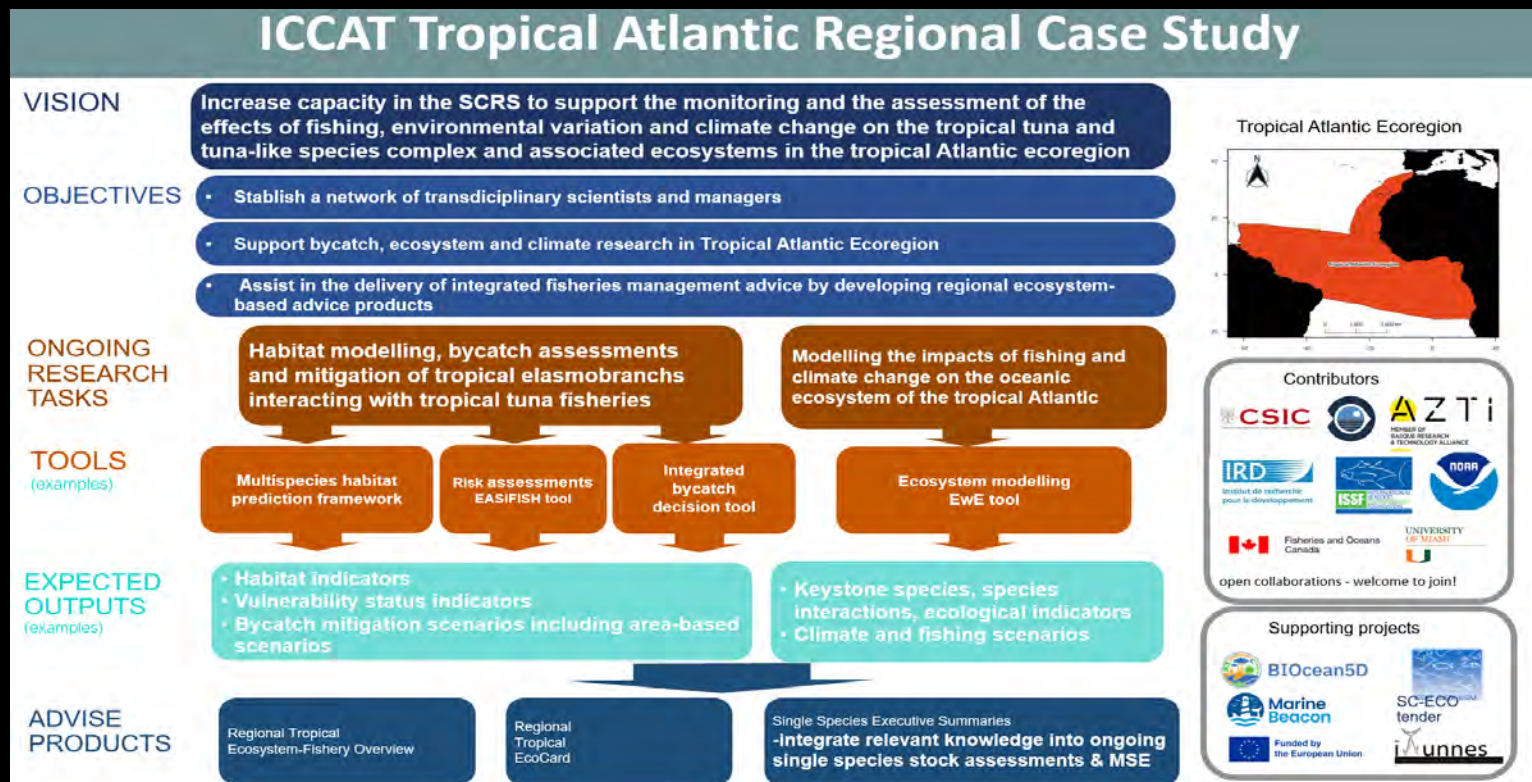
INDICATOR FRAMEWORK AND INITIATIVES

Initiative 1: Delineation of ecoregions - testing



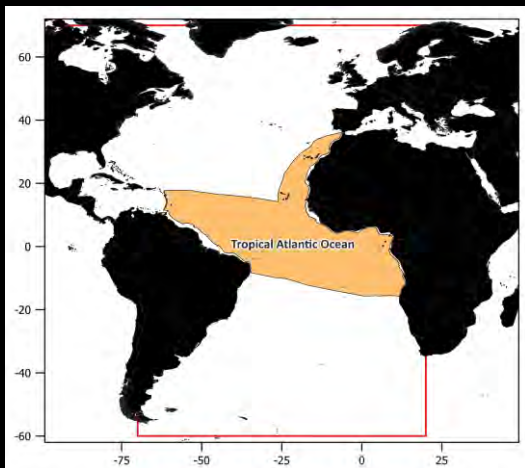
INDICATOR FRAMEWORK AND INITIATIVES

Initiative 2: Case Studies

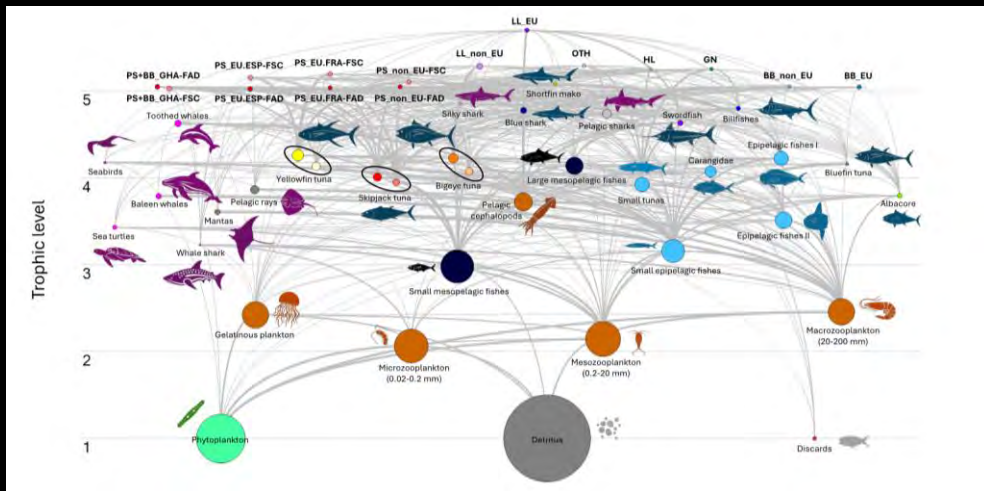


INDICATOR FRAMEWORK AND INITIATIVES

Initiative 3: Ecosystem modelling - TAO



Nº	Functional Group (FG)	Nº	Functional Group (FG)
1	Seabirds	19	Skipjack immature
2	Sea turtles	20	Albacore
3	Baleen whales	21	Bluefin tuna
4	Toothed whales	22	Small tunas
5	Whale shark	23	Carangidae
6	Mobulas	24	Epipelagic fishes I
7	Pelagic stingray	25	Epipelagic fishes II
8	Blue shark	26	Small epipelagic fishes
9	Shortfin mako	27	Large mesopelagic fishes
10	Silky shark	28	Small mesopelagic fishes
11	Pelagic sharks	29	Pelagic cephalopods
12	Swordfish	30	Gelatinous plankton
13	Billfishes	31	Macrozooplankton
14	Yellowfin mature	32	Mesozooplankton
15	Yellowfin immature	33	Microzooplankton
16	Bigeye mature	34	Phytoplankton
17	Bigeye immature	35	Detritus
18	Skipjack mature	36	Discards



INDICATOR FRAMEWORK AND INITIATIVES

Initiative 3: Ecosystem modelling - TAO

Indicator name	Value	Unit
Total biomass (excluding detritus)	36.673	t/km ²
Total primary production/Total respiration (Pp/R)	3.895	
Total primary production/Total biomass (Pp/B)	49.825	
Net system production (Pp-R)	1358.134	t/km ² ·year
System omnivory index (SOI)	0.217	
Finn's cycling index (FCI)	7.91	%
Finn's mean path length (PL)	2.731	
Mean transfer efficiency (TE)	11.161	%
Mean trophic level of the community (mTLco)	2.543	
Total catch	0.021	t/km ² ·year
Mean trophic level of the catch (mTLc)	4.161	
Primary production required to sustain the fisheries	2.307	%

Ecosystem health

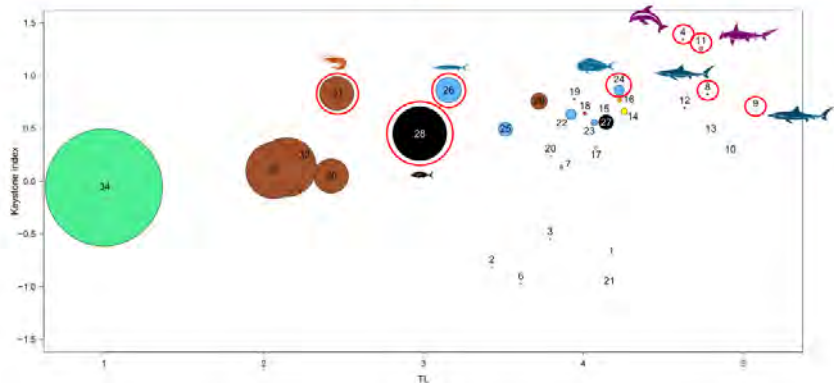
Ecosystem structure



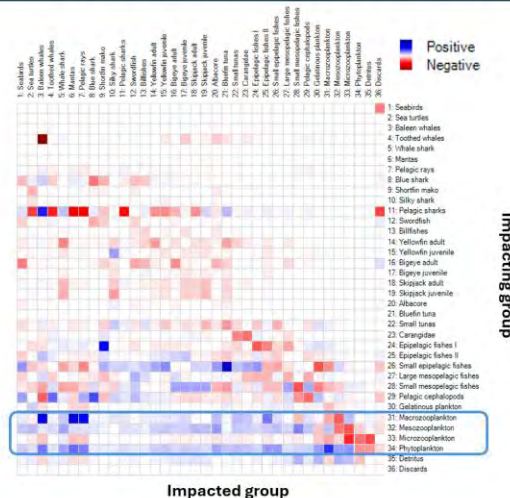
INDICATOR FRAMEWORK AND INITIATIVES

Initiative 3: Ecosystem modelling - TAO

Keystone species index



Mixed Trophic Impact – Functional groups



MEMBER OF
BASQUE RESEARCH
& TECHNOLOGY ALLIANCE

Impacted group

1. Seabirds
2. Sea turtles
3. Balaen whales
4. Leopard sharks
5. White shark
6. Manta
7. Shark rays
8. Shark
9. Bluefish
10. Spiny mako
11. Pelagic shark
12. Bluefish
13. Bluefish
14. Bluefish
15. Yellowtail
16. Bluefish
17. Spiny mako
18. Spiny mako
19. Spiny mako
20. Spiny mako
21. Spiny mako
22. Spiny mako
23. Spiny mako
24. Spiny mako
25. Spiny mako
26. Spiny mako
27. Spiny mako
28. Spiny mako
29. Spiny mako
30. Spiny mako
31. Spiny mako
32. Spiny mako
33. Spiny mako
34. Spiny mako
35. Spiny mako
36. Spiny mako

Impacting group

1. Seabirds
2. Sea turtles
3. Balaen whales
4. Leopard sharks
5. White shark
6. Manta
7. Shark rays
8. Shark
9. Bluefish
10. Spiny mako
11. Pelagic shark
12. Bluefish
13. Bluefish
14. Yellowtail
15. Yellowtail
16. Bluefish
17. Spiny mako
18. Spiny mako
19. Spiny mako
20. Spiny mako
21. Spiny mako
22. Spiny mako
23. Spiny mako
24. Spiny mako
25. Spiny mako
26. Spiny mako
27. Spiny mako
28. Spiny mako
29. Spiny mako
30. Spiny mako
31. Spiny mako
32. Spiny mako
33. Spiny mako
34. Spiny mako
35. Spiny mako
36. Spiny mako

Legend:

- Positive (Red square)
- Negative (Blue square)

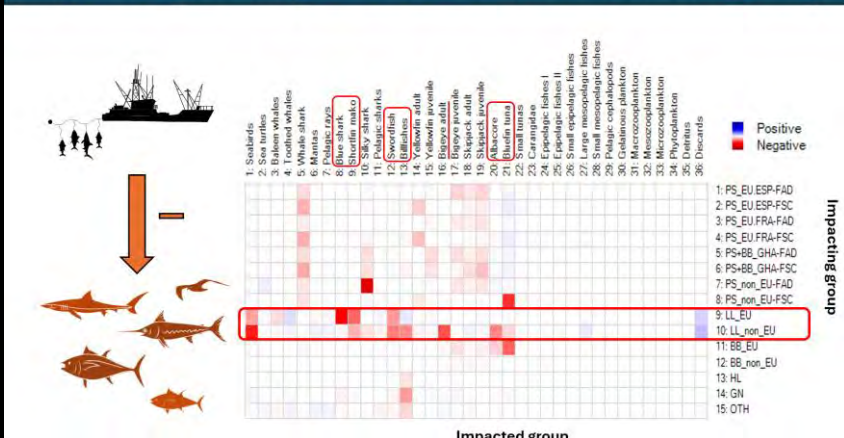
Figure 1: Conceptual diagram of the study design. The diagram illustrates the interactions between an 'Impacted group' and an 'Impacting group'. The 'Impacted group' (left) includes species such as Sea turtles, Bottlenose dolphins, White shark, Pelagic shark, Silky shark, Hammerhead shark, Bull shark, Yellowtail snapper, Yellowtail adult, Yellowtail juvenile, Bigeye snapper, Skipjack adult, Skipjack juvenile, Albacore, and Bluefin tuna. The 'Impacting group' (right) includes species such as Sea turtles, Bottlenose dolphins, White shark, Pelagic shark, Silky shark, Hammerhead shark, Bull shark, Yellowtail snapper, Yellowtail adult, Yellowtail juvenile, Bigeye snapper, Skipjack adult, Skipjack juvenile, Albacore, Bluefin tuna, Small tunas, Cownose ray, Epipelagic fishes I, Epipelagic fishes II, Small mesopelagic fishes, Large mesopelagic fishes, Small mesopelagic fishes, Pelagic cephalopods, Cephalopods, Macrozooplankton, Mesozooplankton, Microzooplankton, Phytoplankton, Detritus, and Diatoms. A central heatmap displays the interactions, with a red box highlighting a specific area of high positive interaction. A legend indicates that blue squares represent 'Positive' interactions and red squares represent 'Negative' interactions.

INDICATOR FRAMEWORK AND INITIATIVES

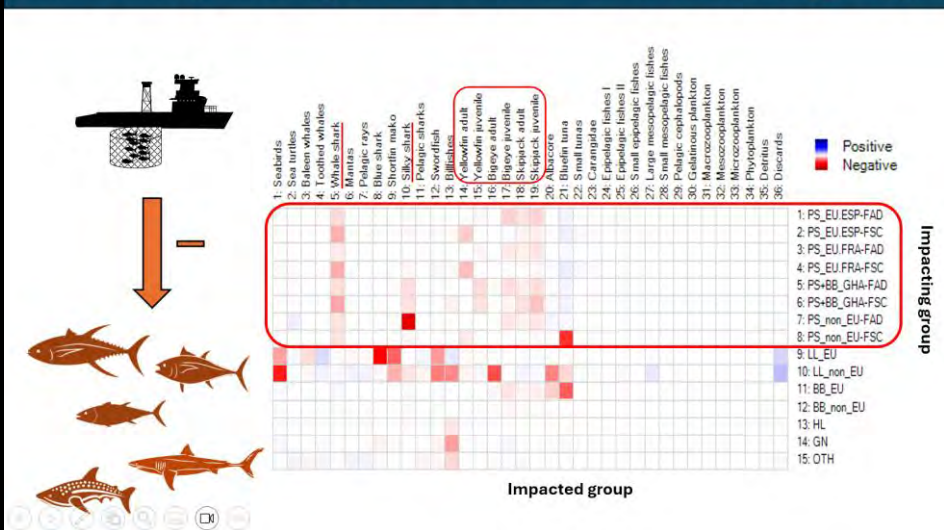
Initiative 3: Ecosystem modelling - TAO



Mixed Trophic Impact – Fleets vs Functional groups



Mixed Trophic Impact – Fleets vs Functional groups

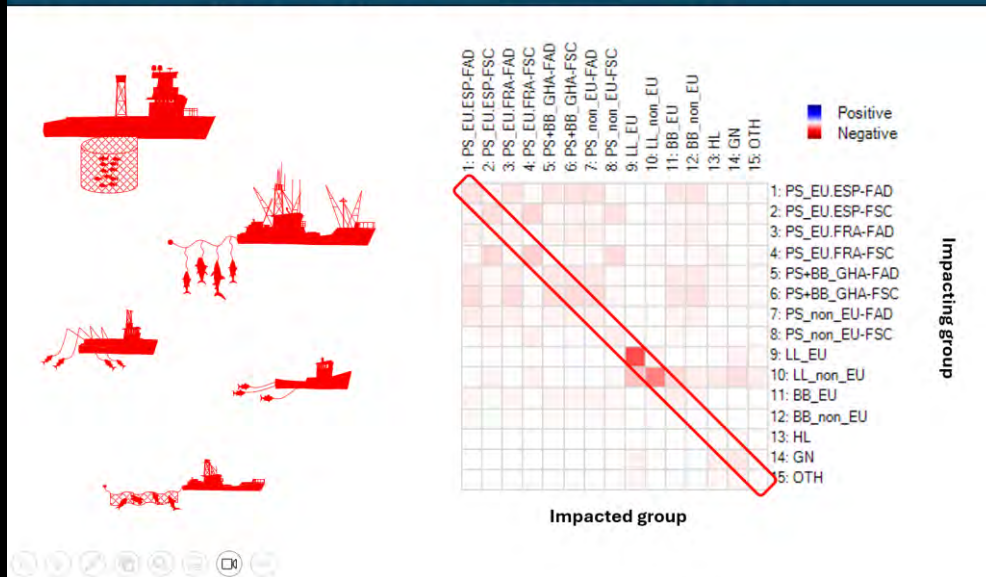


INDICATOR FRAMEWORK AND INITIATIVES

Initiative 3: Ecosystem modelling - TAO

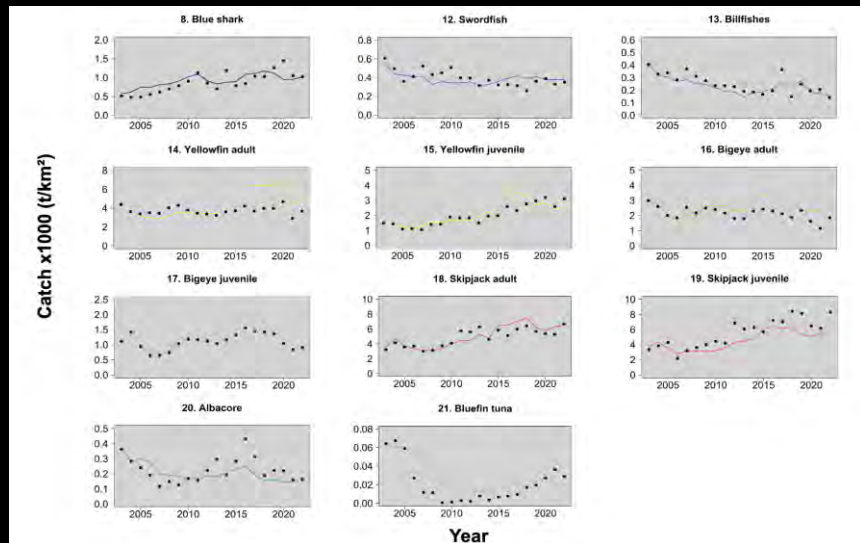
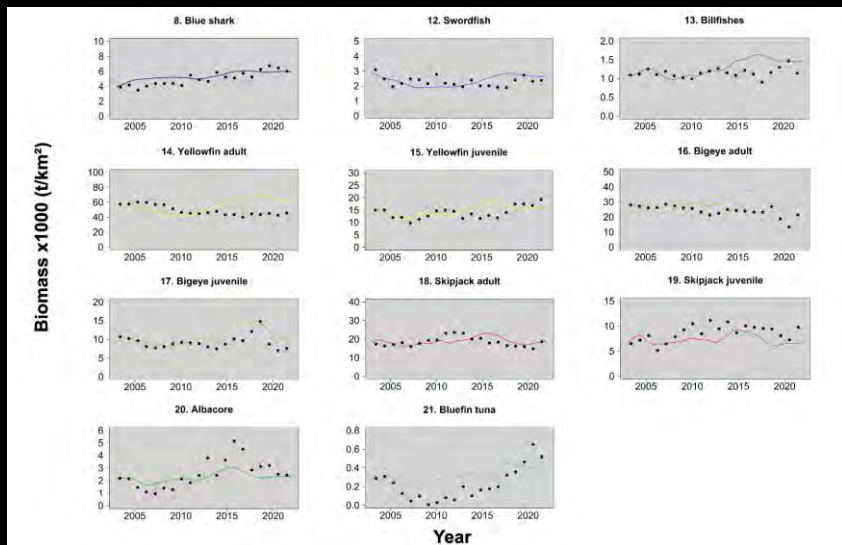


Mixed Trophic Impact – Fleets vs Fleets



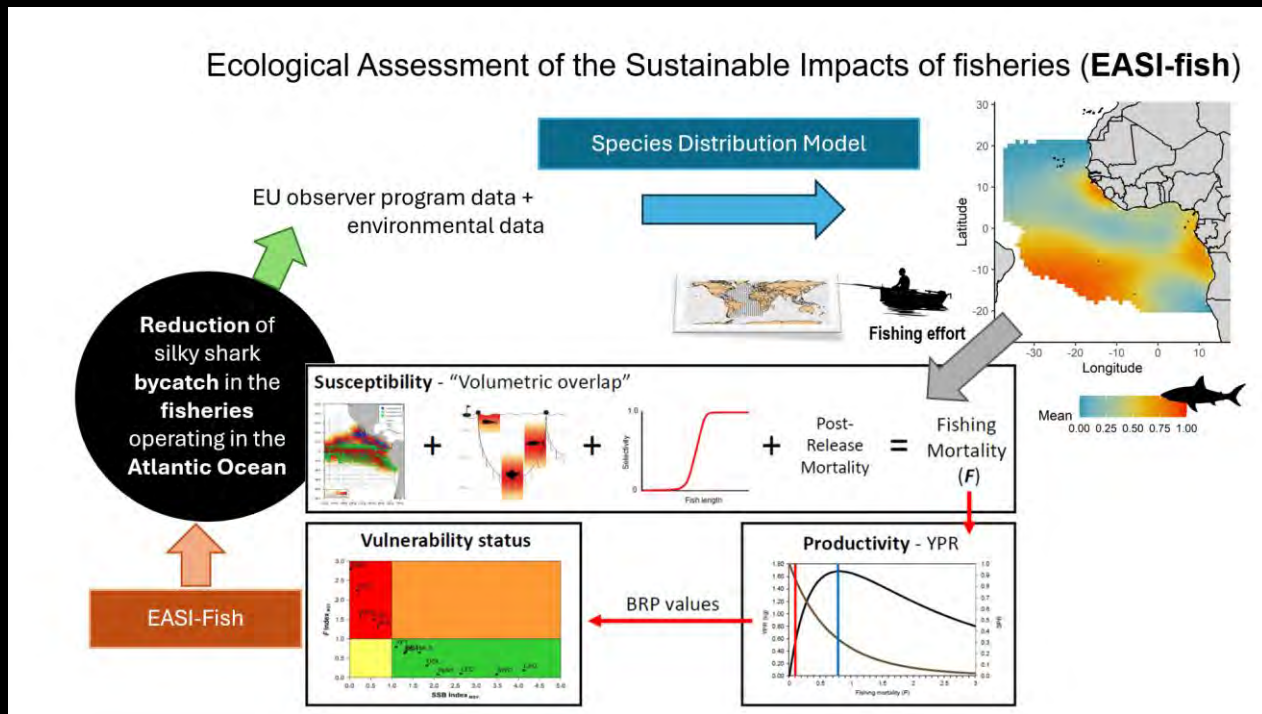
INDICATOR FRAMEWORK AND INITIATIVES

Initiative 3: Ecosystem modelling - TAO



INDICATOR FRAMEWORK AND INITIATIVES

Initiative 4: Risk assessment



Workplan 2026 - Ecosystems

1) Ecosystem Report Card Development: Priority 1

IN PERSON WORKSHOPS TO ADVANCE THE WORK ON THE ECOCARD IN 2026 - 2027

2) Work of the EcoCard subgroup: Priority 2

PLAN TO MEET IN MARCH

3) Development of a Risk Screening Tool: Priority 2

ADVANCES TO REVIEW IN 2026 , INCLUDE ML AND AI METHODS

4) Progress on Case Studies: Ongoing work – a lot expected for the Tropical Atlantic Ecoregion

5) ECOtest: Priority 3

6) Response to Commission requests. Goals and objectives for components of the EcoCard.

4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators

**2- 6 March 2026
SPC, Noumea (New Caledonia)**

Maria José Juan Jordá

Annex 4

CONTEXT SETTING

Tuna RFMO EAFM implementation

IOTC

COMMISSION LEVEL PROGRESS

- Overview of Commission relevant mandates, resolutions, and ongoing RFMO processes relevant to EAFM implementation
- Role of ecosystem and climate indicators in EAFM implementation and climate-resilient management progress

- The IOTC Convention Mandate **does not make explicit (or implicit) reference to “EAFM”**.
 - **IOTC mandates predates UNFSA**. It does not contains provisions related to ecosystem considerations.
- EAFM has not been explicitly pursued or requested by Commission to date in any CMM
 - but **8 CMMs make reference to “ecosystem approach or EAFM elements”** or examining the impact of various activities/conditions on ecosystems.
- IOTC has **not adopted a strategic vision and objectives to guide EAFM implementation**, yet:
 - In 2019, the **IOTC Commission adopted the Strategic Science Plan 2020– 2024** which **contains an objective for advancing ecosystems-based management advice**.
 - In 2024 the IOTC Scientific Committee adopted the **Strategic science plan 2025-2029** which contains an objective for advancing ecosystems-based management advice.

Data/analysis → WPEB → Scientific Committee → Commission → CMMs

- EAFM implementation “Data/bycatch/ecosystem/climate analyses” discussed at WPEB (Working Party of Ecosystem and Bycatch)
- Recommendations transmitted via Scientific Committee
- Commission integrates “selected elements” into CMMs
- No formal monitoring framework for EAFM implementation or monitor progress
- **The scientific architecture exists.** Ecosystem analyses are generated and discussed at the WPEB.
- Implementation remains indirect and case-specific, rather than structured under a formal EAFM monitoring framework.

- **“Ecosystem considerations” already embedded in management via multiple CMMs**
- Most ecosystem consideration are related to non-target species, climate change, Management Procedures and FAD management. For example:
 - **Resolutions adopted for the conservation of vulnerable taxa** - non-target species such as mobulid rays, various shark species, cetaceans and turtles
 - **Res 24/01** makes reference to taking into account scientific information on potential impacts from **climate change** on tuna stocks, bycatch and species belonging to the same ecosystem.
 - **Res 24/02 on dFADs makes reference to ecosystem impacts** caused by FADs and requires use of non-entangling FADs and move towards biodegradable materials in their construction
 - **Res 24/07 and 24/08 on a MP for SKJ/SWO** requests the SC to investigate approaches to incorporating a multi-species framework into future MPs and wider impacts in the ecosystem

- **Why Ecosystem & Climate Indicators Are Central to EAFM implementations**
 - Track ecosystem state and pressures
 - Detect climate-driven responses
 - Provide early warning signals
 - Inform precautionary management
 - Support climate-resilient MPs
- **Commission is receptive of “information”- not reactive - yet close to ZERO information gets there.**
- **Climate change resolution is accelerating change - “creating Commission awareness”**
- **Without structured indicators linked to management response, ecosystem considerations remain descriptive.**
 - Indicators are the operational bridge between ecosystem science and Commission decision-making.
 - The question is no longer whether ecosystem considerations matter.
 - The question is how to structure and interpret them systematically and are linked to advice.

- **Institutional Position**

- IOTC does not have an explicit EAFM mandate in its founding Agreement.
- However, ecosystem considerations are increasingly embedded through CMMs and the Strategic Science Plan.
- The Working Party on Ecosystems and Bycatch (WPEB) provides a structured scientific platform for ecosystem advice.
- EAFM is evolving institutionally rather than being formally mandated.

- **Ecosystem Considerations in Management**

- Ecosystem elements are already influencing management measures (e.g., vulnerable species, FAD impacts, climate references).
- Recent Management Procedure resolutions signal interest in multi-species and ecosystem integration.
- However, ecosystem advice is still issue-specific rather than embedded within a unified EAFM framework.

4th Joint Meeting of Tuna RFMOs on the Implementation of the Ecosystem Approach to Fisheries Management: Advancing the Development of Ecosystem Indicators

**2- 6 March 2026
SPC, Noumea (New Caledonia)**

Maria José Juan Jordá

CONTEXT SETTING

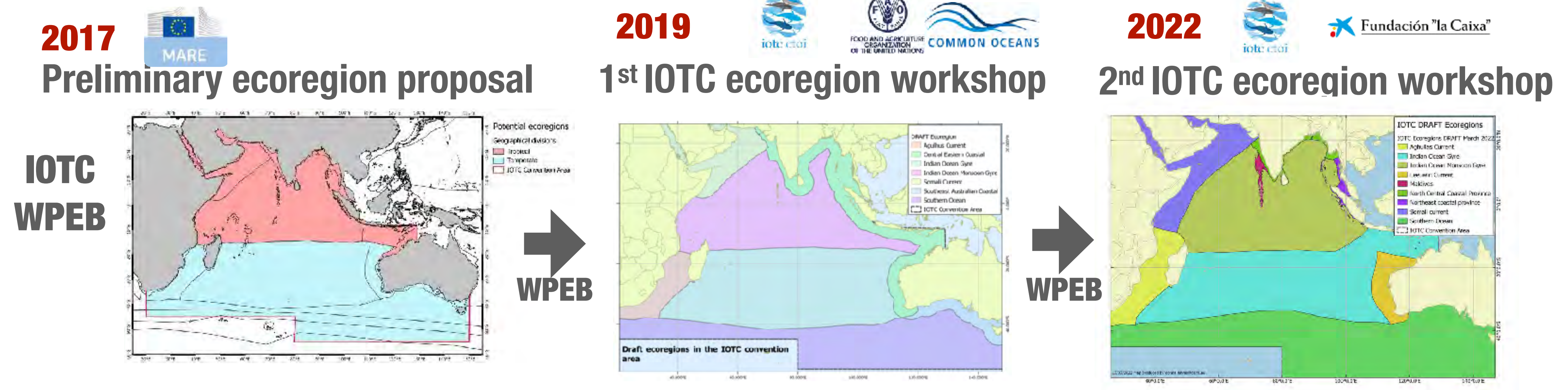
Current indicator framework and initiatives

IOTC

SCIENTIFIC COMMITTEE LEVEL

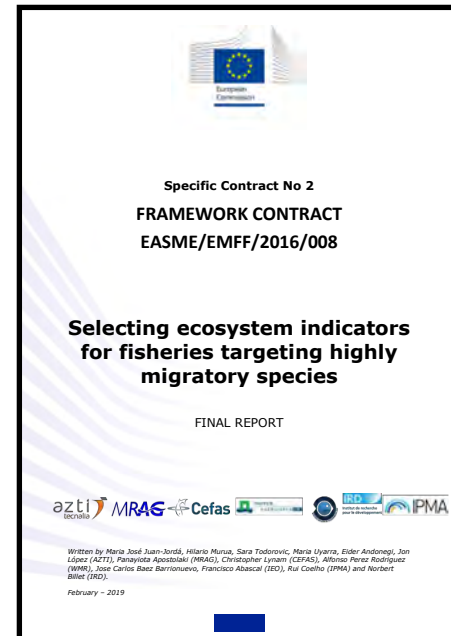
- **Updates from RFMO Scientific Committees and Working Groups on existing ecosystem and climate indicators**
 - Most of the work done and discussed at the WPEB
 - Example 1: Work on ecoregions has been further developed and is now being tested/validated
 - Example 2: indicator-based **EcoCard** tool
 - Example 3: development of the **Ocean Atlas** to visualize environmental and climate variation relevant to IOTC species and fisheries
 - Example 4: **Ecosystem-Fisheries Overviews**
 - Example 6: New **ecosystem modelling approaches** presented (Ecopath with Ecosim, APECOSM) to assess impacts of fishing in tropical Indian ocean
 - Example 5: Strengthened **FAD management** with passing of new Resolutions. Studies on impact of FADs in the Indian Ocean. Some retrieval of FADs before beaching- FADWATCH

- **Example 1: Work on ecoregions has been further developed and is now being tested/validated**



- Two regions/case studies selected for developing pilot products
- ecosystem based tools/products require spatial context — ecoregions provide that structure.

- **Example 2: indicator-based EcoCard process**



- **2016 WPEB12** - idea presented - tool - opportunity to lead the implementation of the EAFM in IOTC
- **2017 WPEB13** - recommended the development of an indicator-based ecosystem report card
- **2018 WPEB14** - A proposal for a process to develop the first ecosystem assessment and ecosystem report card in IOTC
- **2019 WPEB15** - great participation (EU- and non-EU IOTC scientists)
- **2020 WPEB16** - stopped
- **Regional case studies used to reactivate EcoCard**

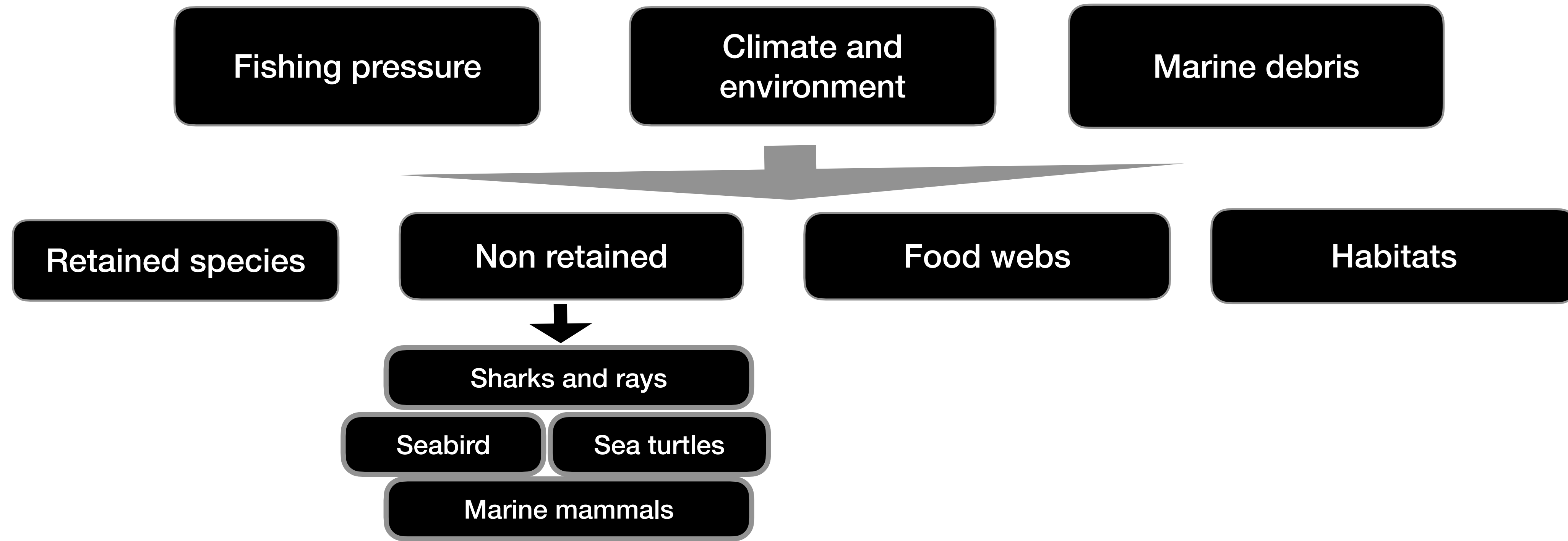
- **Example 2: indicator-based EcoCard tool**

1. Reporting framework relevant to IOTC fisheries

Ecosystem components:

Pressure components

State components (ecological)



- **Example 2: indicator-based EcoCard tool**

2. Group of assessors volunteer to lead the development of each ecosystem component

ECOSYSTEM COMPONENTS	ASSESSORS
Retained fish species: Assessed	Maria Jose Juan Joda , Hilario Murua, Henning Winker , Zhe Geng, Francis Marsac
Retained fish species: Not Assessed	Maria Jose Juan Jordá, Pascal Bach, Philippe Sabarros, Mariana Tolotti, Umair Shahid , Zhe Geng, Sandamali Herath
Non-retained sharks and rays	Rui Coelho, Pascal Bach, Philippe Sabarros, Mariana Tolotti , Umair Shahid, Zhe Geng, Sandamali Herath, Daniel Fernando, Jon Ruiz, Maitane Grande
Seaturtles	Umair Shahid, Jana Yonat Swimmer , Jerome Bourjea, Muhammad Khan
Seabirds	Ross Wanless , Catrina van der Merwe, Anton Wolfaardt
Marine mammals	Jeremy Kiszka Muhammad Khan
Foodweb/trophic relationships	Eider Andonegi , Maria José Juan Jordá, Philippe Sabarros, Muhammad Khan, Reza Shahifar, Jeremy Kiszka, Evgeny Romanov
Habitat of ecological significance	Maria José Juan Jordá, Muhammad Khan, Reza Shahifar, Francis Marsac Maitane, Iker
Fishing Pressure	Umair Shahid, Reza Shahifar , Mohammed Koya, Sandamali Herath
Marine debris	Iker Zudaire , Maitane Grande, Jon Ruiz
Ocean climate and environment	Marcis Marsac, Reza Shahifar

- **Example 2: indicator-based EcoCard tool**

3. General guidelines drafted to guide the work on each component:

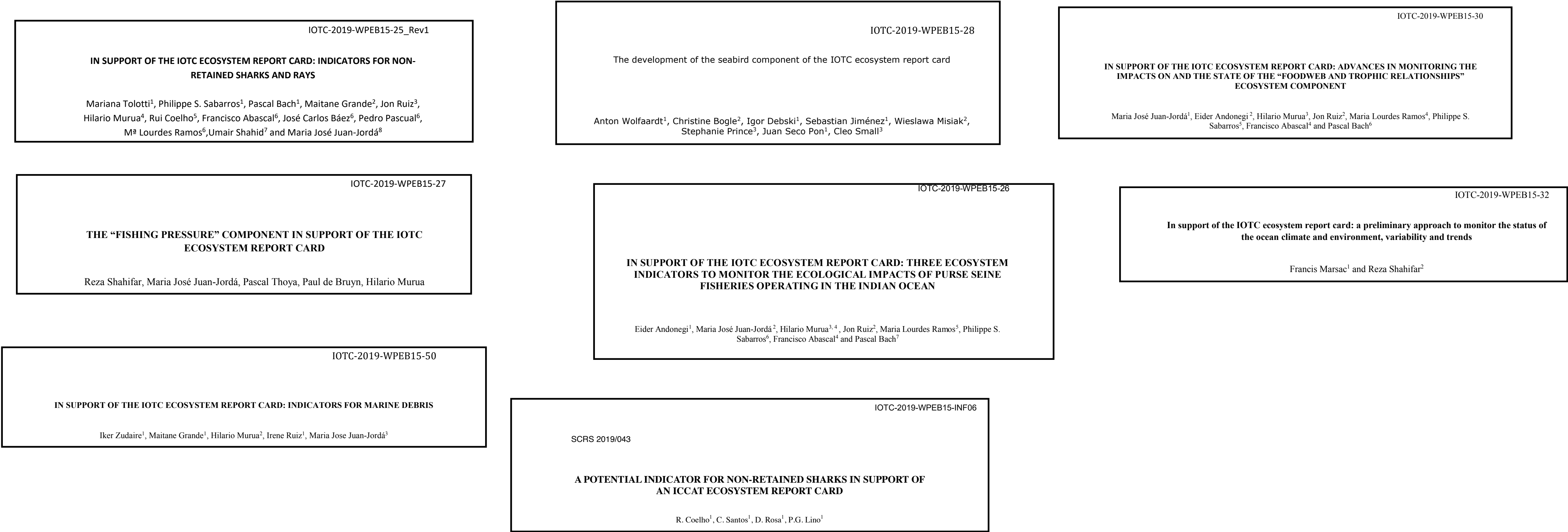
- Describe it. What does it mean to you?
- Propose conceptual and operational objectives
- Propose candidate indicators
- Pick some -develop and test them
- Future work

4. Group of assessors *work inter-sessionally* on their respective components, prepare IOTC papers, present and discuss in WPEB (9 paper presented in 2019)

5. Objective: Prepare first prototype Ecosystem Report Card (updated yearly)

it did not happen!!

- Example 2: indicator-based EcoCard tool



- **Example 3: development of an online digital ocean atlas for the Indian Ocean and a dedicated IOTC website on climate change and its impact of tuna fisheries**

PRODUCTS

System administration
audit trail of all operations

Animated maps
(along a range of months/years)

Data export
(in a variety of formats)

Maps

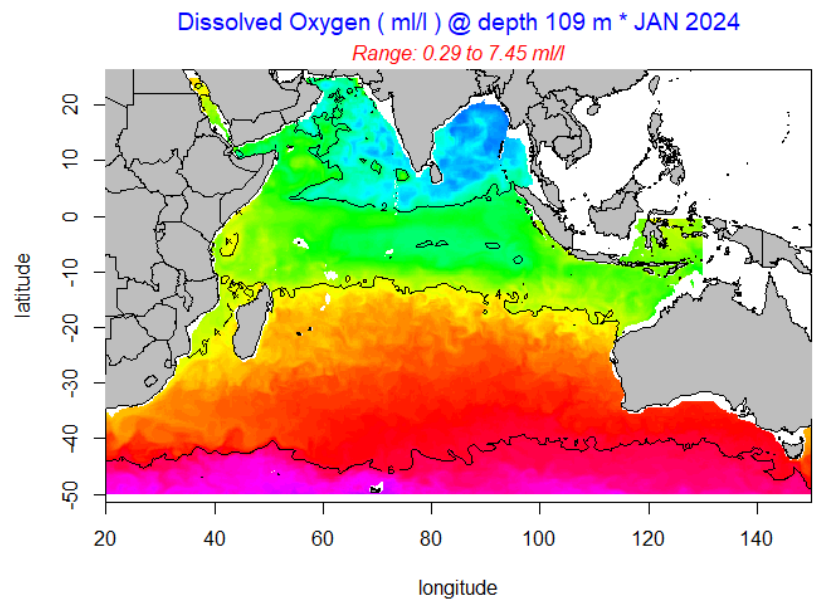
including

- EEZ contours
- Subarea selection

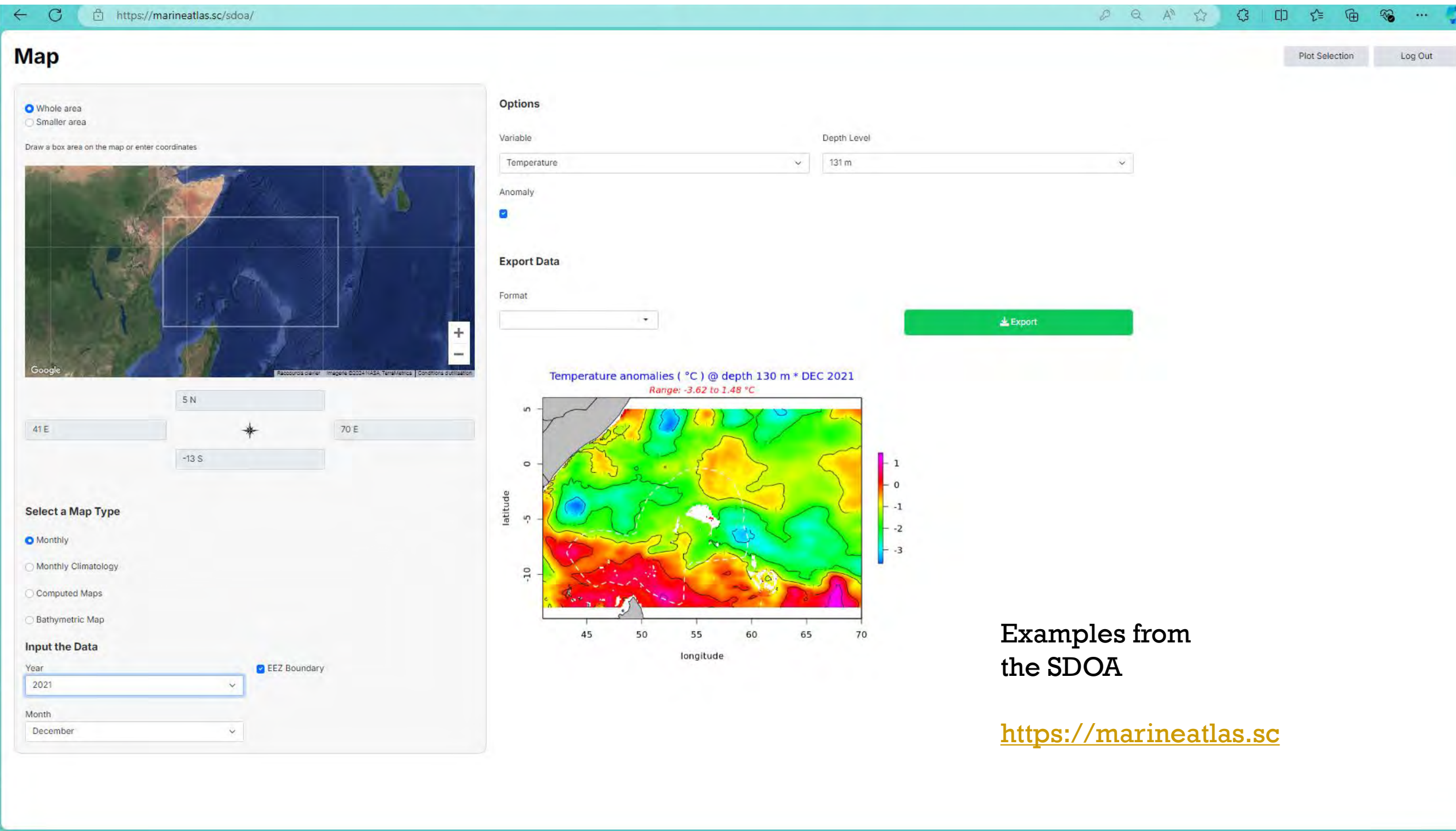
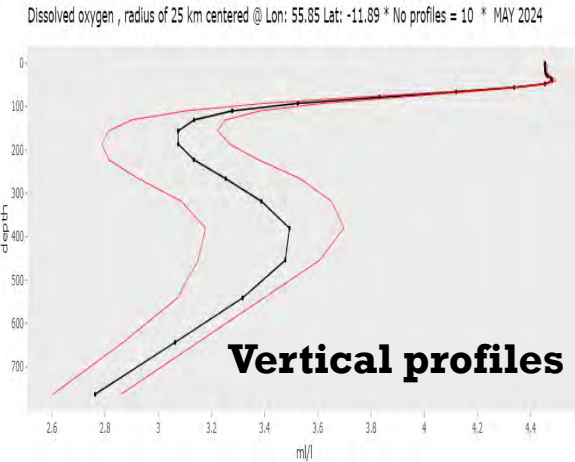
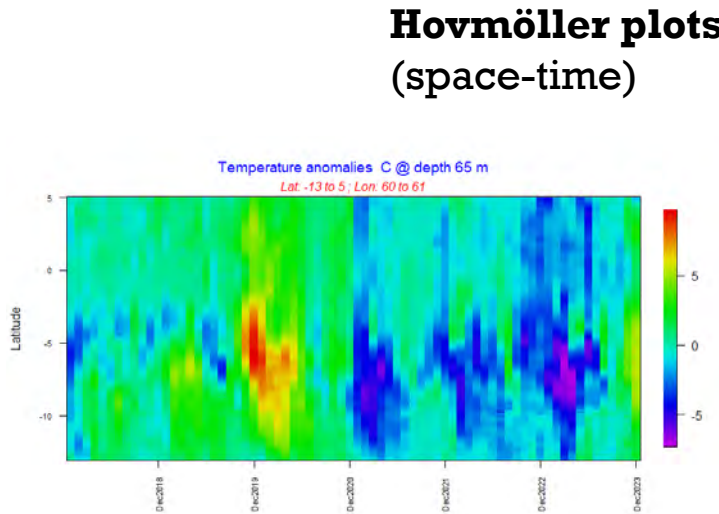
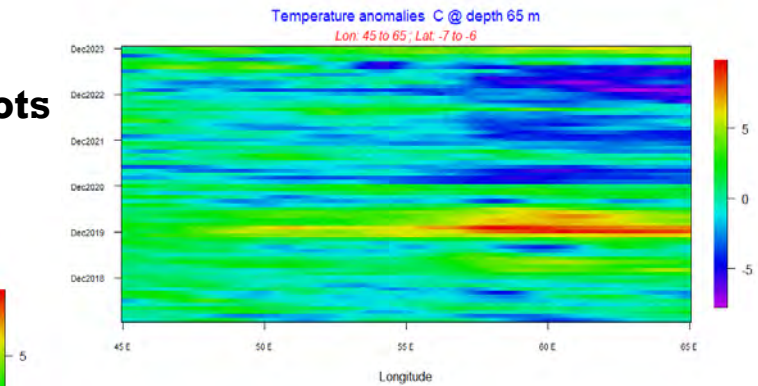
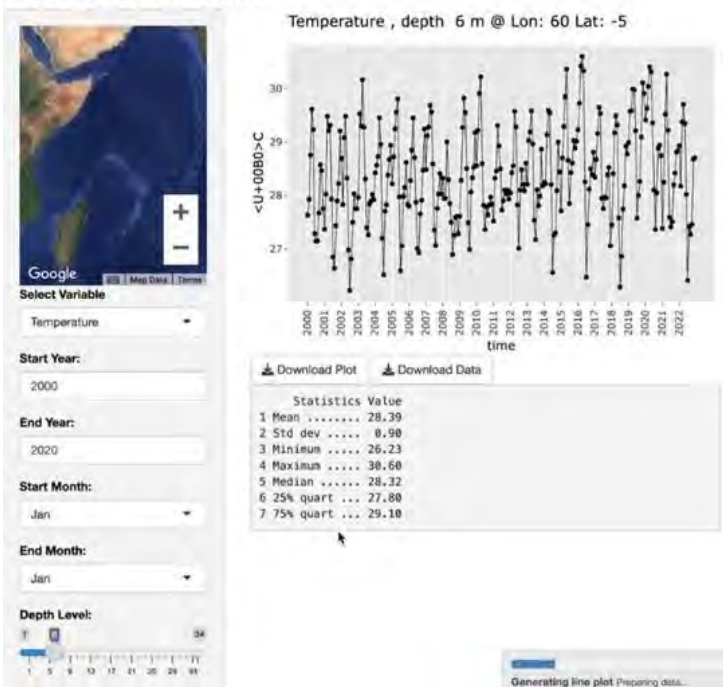
Line plots

including :

associated stats

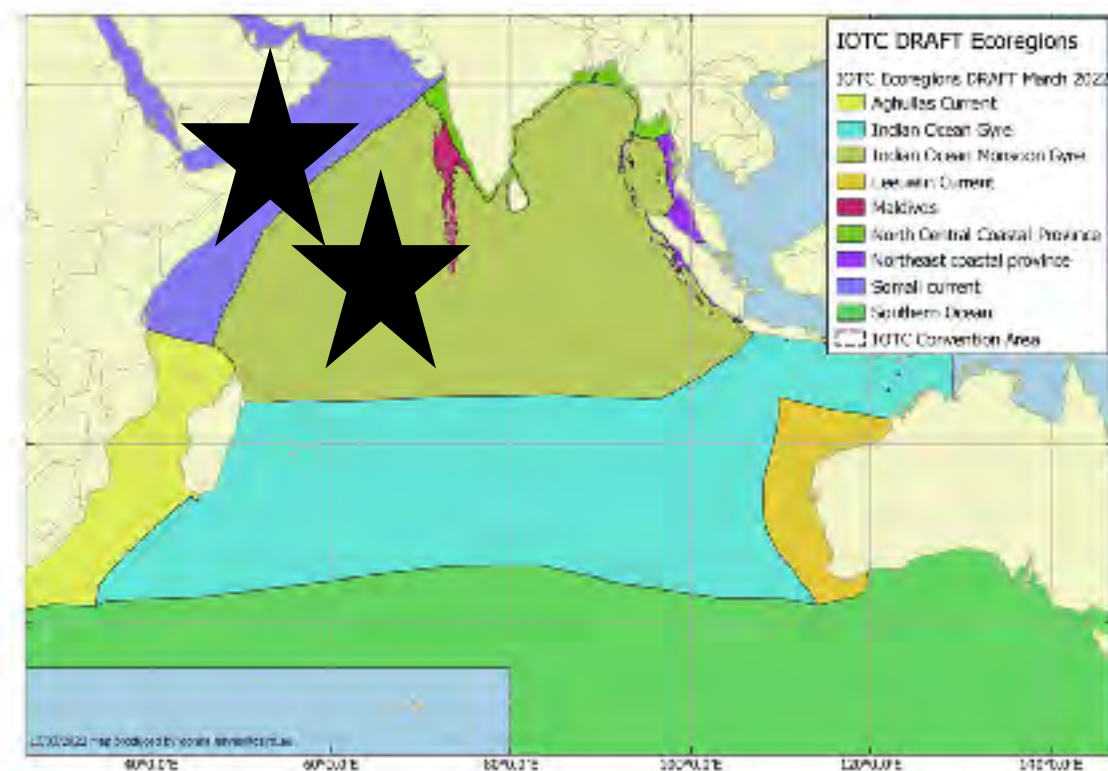


Line Plot Visualization



- S

2nd IOTC ecoregion workshop



The IOTC WPEB
selected to case
study regions

Ecosystem Fishery Overview

SUMMARY of key signals (EcoCard)	ECOREGION DESCRIPTION	WHO IS FISHING <i>main countries- fleets main fisheries</i>	WHAT ARE WE FISHING <i>catches -landings and discards</i>
STATUS OF FISHERY RESOURCES <i>target species</i>	MIXED FISHERIES ADVISE <i>fisheries interactions species interactions</i>	FISHERIES MANAGEMENT <i>bycatch mitigation measures</i>	FISHERY MANAGEMENT PLANS
ENVIRONMENTAL & CLIMATE CHANGE EFFECTS	EFFECT OF FISHERIES ON THE ETP species & STATE OF ETP species <i>Shar/rays Seabirds Sea turtles Marine mammals</i>	EFFECT OF FISHERIES ON THE FOODWEB & STATE OF FOODWEB	SOCIO-ECONOMIC CONTEXT

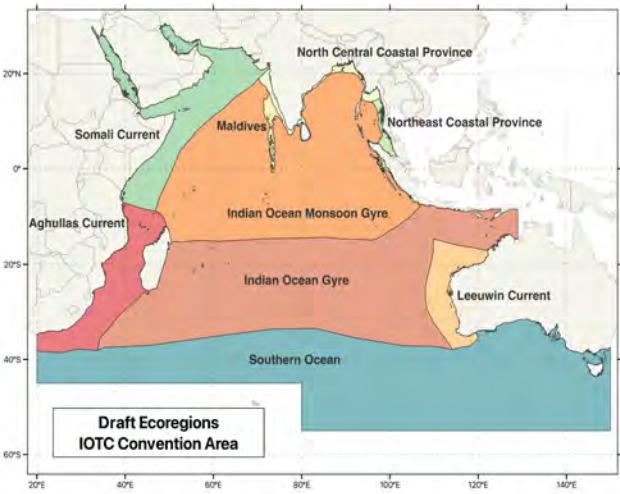
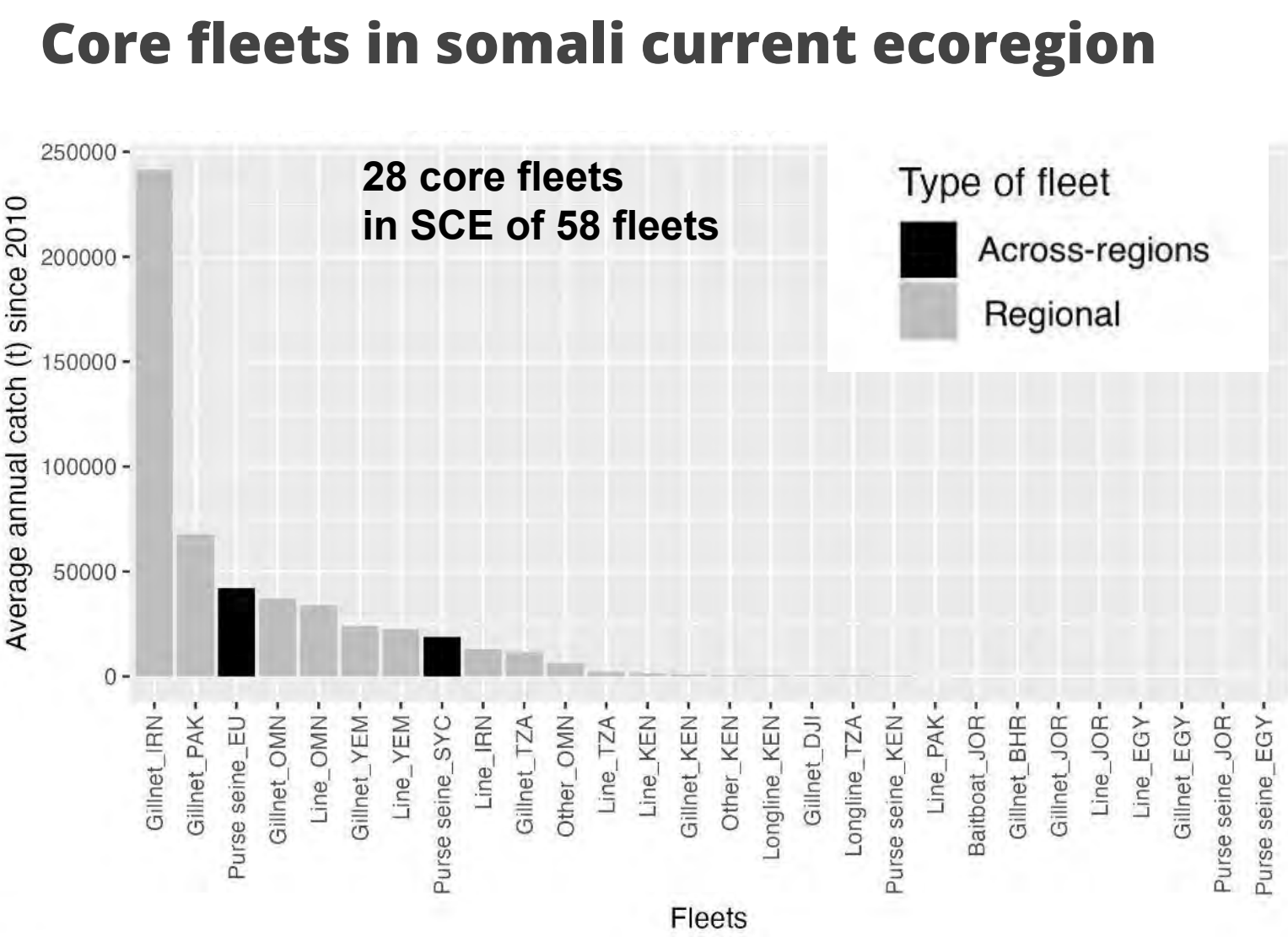
- EFOs as proof-of-concept products to assess whether ecoregions can serve as practical and informative units for organizing, synthesizing, and communicating ecosystem science in support of ecosystem-based advice.
- EFOs integrate information on the fisheries operating within each ecoregion, including fleet composition, catches and bycatch, foodweb interactions, and key environmental and climate drivers, as well as other relevant pressures.

• **Example 4: Ecosystem-Fisheries Overviews**

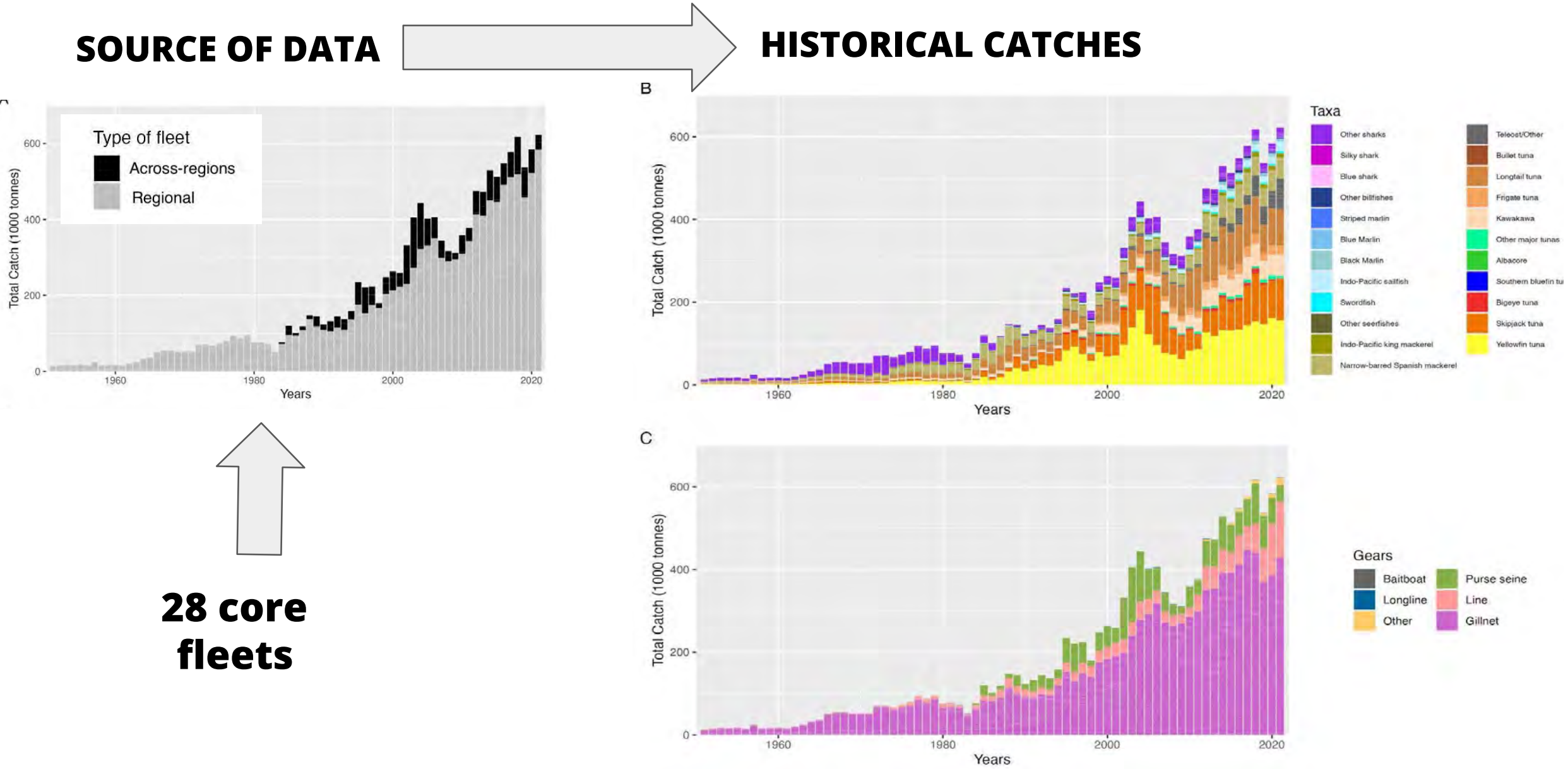
Ecosystem Fishery Overview			
SUMMARY of key signals (EcoCard)	ECOREGION DESCRIPTION	WHO IS FISHING main countries- fleets main fisheries	WHAT ARE WE FISHING catches -landings and discards
STATUS OF FISHERY RESOURCES target species	MIXED FISHERIES ADVISE fisheries interactions species interactions	FISHERIES MANAGEMENT bycatch mitigation measures	FISHERY MANAGEMENT PLANS
ENVIRONMENTAL & CLIMATE CHANGE EFFECTS	EFFECT OF FISHERIES ON THE ETP species & STATE OF ETP species Shark/rays Seabirds Sea turtles Marine mammals	EFFECT OF FISHERIES ON THE FOODWEB & STATE OF FOODWEB	ECOSYSTEM-LEVEL CONTEXT

SOMALI CURRENT ECOREGION - who is fishing?

SOMALI CURRENT ECOREGION - what are they catching?

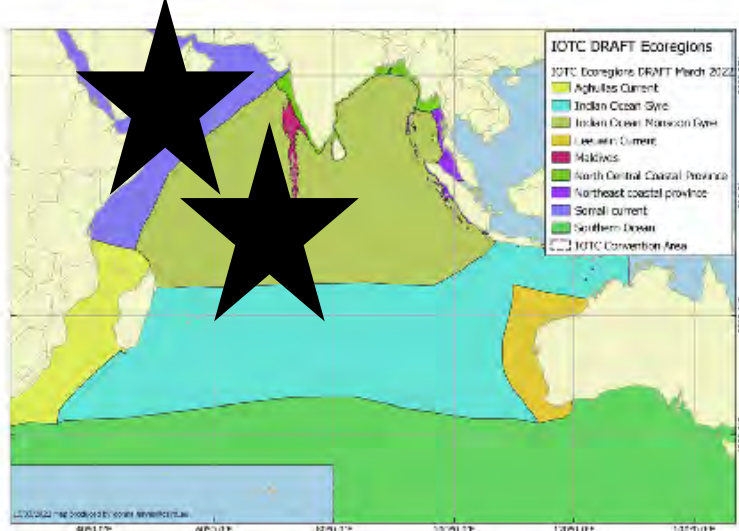


- Mix of GN, PS, LN, LL
- Majority are regional fleets
- Together contribute to 95% of total catch in the ecoregion



• Example 4: Ecosystem-Fisheries Overviews

2nd IOTC ecoregion workshop



FISHERY-ECOSYSTEM OVERVIEW

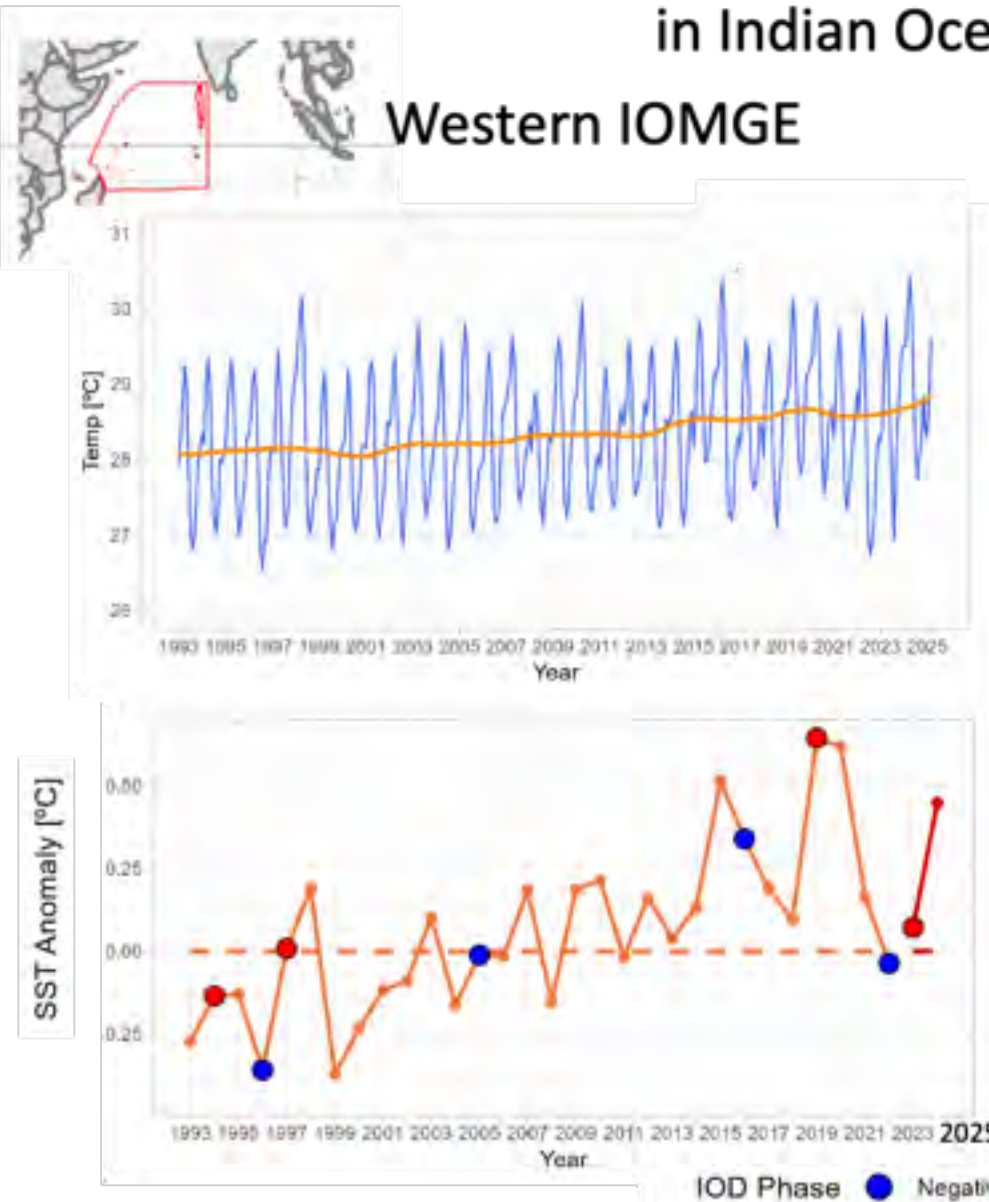
SUMMARY of key signals (EcoCard)	ECOREGION DESCRIPTION	WHO IS FISHING <i>main countries- fleets main fisheries</i>	WHAT ARE WE FISHING <i>catches -landings and discards</i>
STATUS OF FISHERY RESOURCES <i>target species</i>	MIXED FISHERIES ADVISE <i>fisheries interactions species interactions</i>	FISHERIES MANAGEMENT <i>bycatch mitigation measures</i>	FISHERY MANAGEMENT PLANS
ENVIRONMENTAL & CLIMATE CHANGE EFFECTS	EFFECT OF FISHERIES ON THE ETP species & STATE OF ETP species <i>Shar/rays Seabirds Sea turtles Marine mammals</i>	EFFECT OF FISHERIES ON THE FOODWEB & STATE OF FOODWEB	SOCIO-ECONOMIC CONTEXT

1

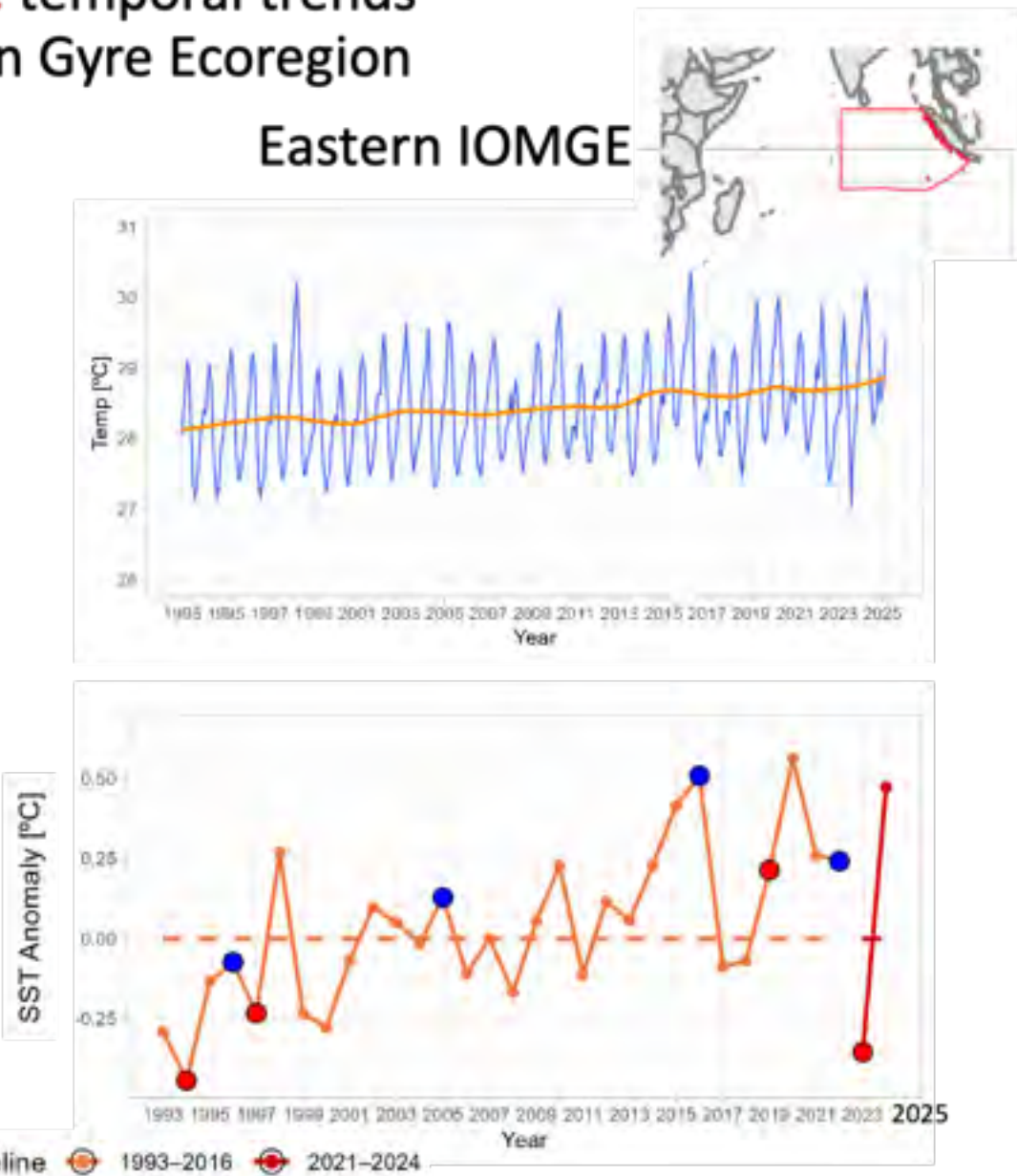
Results

IOTC-2025-WPEB21(AS)-37

Sea surface temperature temporal trends in Indian Ocean Monsoon Gyre Ecoregion



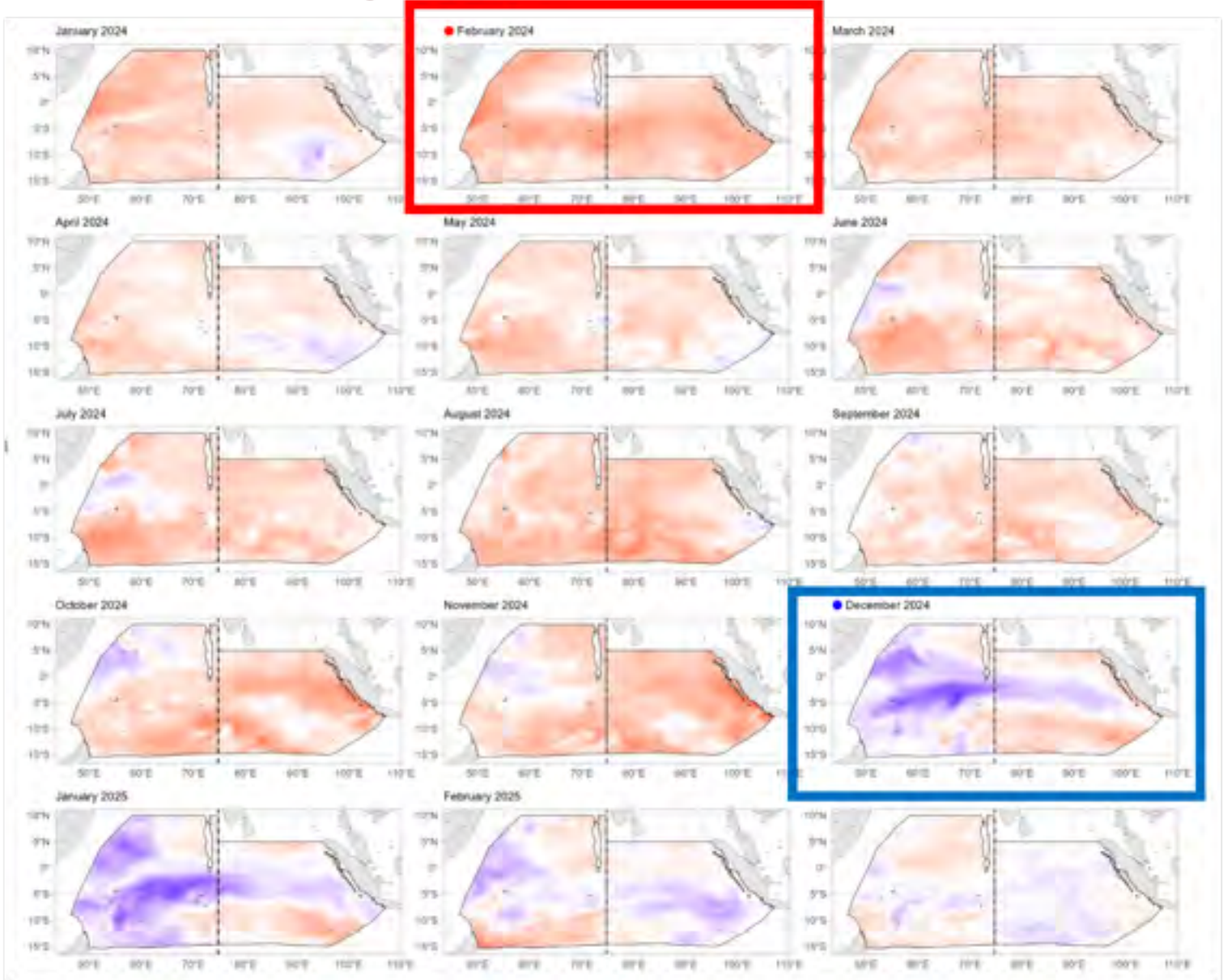
Eastern IOMGE



Results

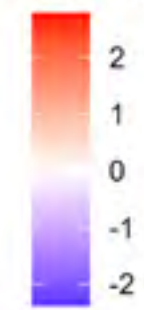
Sea surface temperature anomalies in Indian Ocean Monsoon Gyre Ecoregion

1



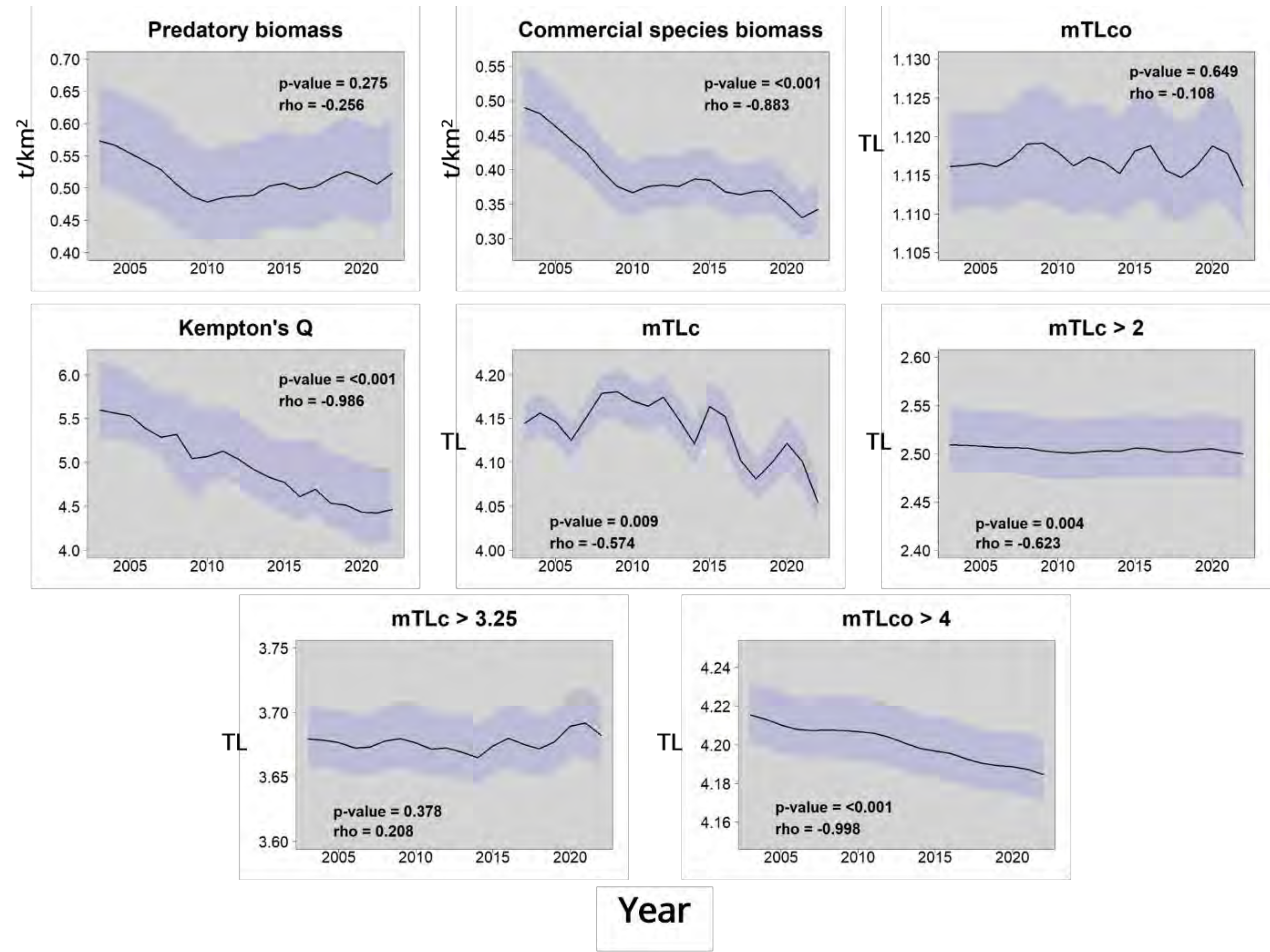
Last 15 months
2024 & Jan, Feb, March 2025

-2.4 to 2.8 °C
SST Anomaly [°C]



IOTC-2025-WPEB21(AS)-37

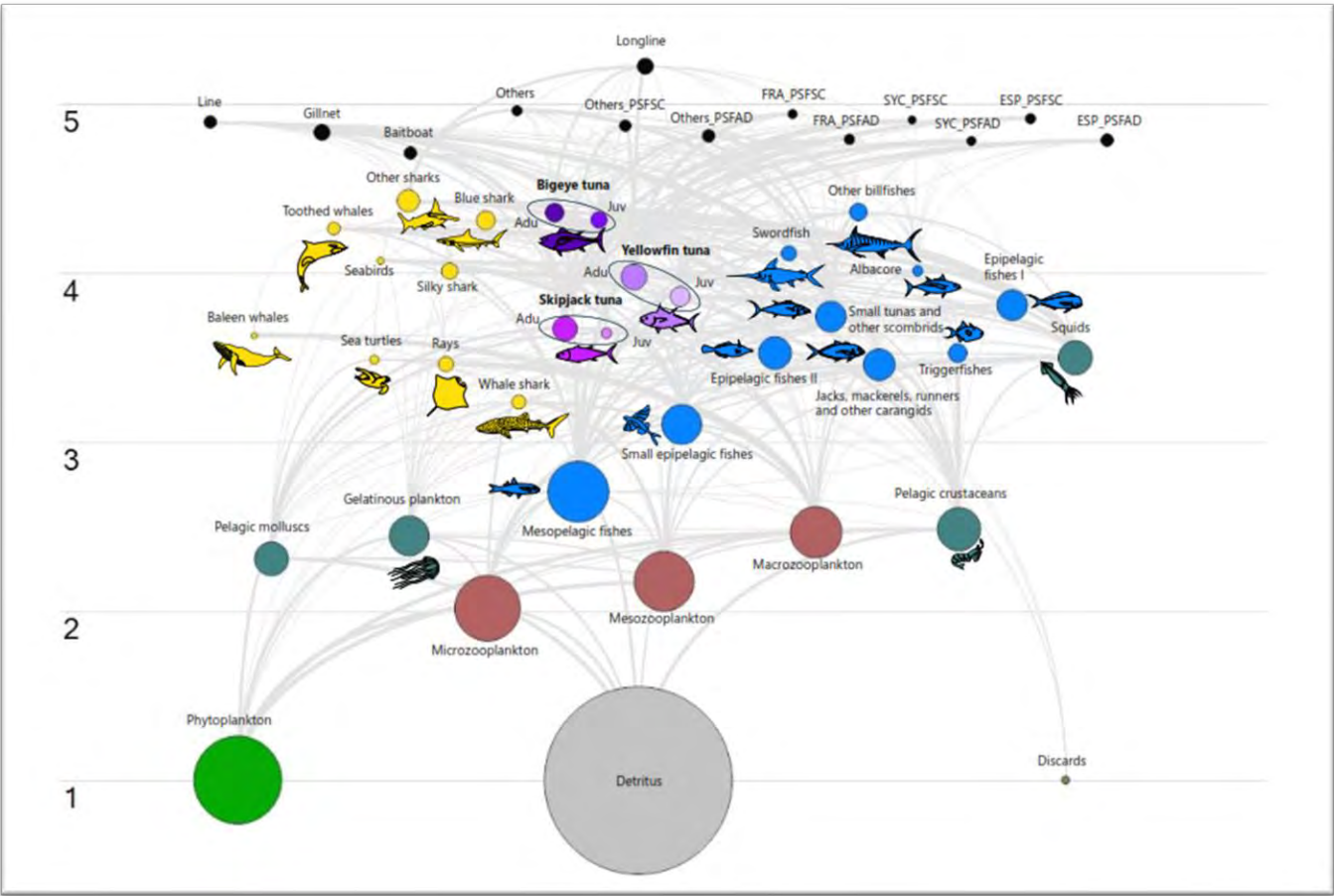
• Example 4: Ecosystem-Fisheries Overviews



FISHERY-ECOSYSTEM OVERVIEW

SUMMARY of key signals (EcoCard)	ECOREGION DESCRIPTION	WHO IS FISHING <i>main countries- fleets</i> <i>main fisheries</i>	WHAT ARE WE FISHING <i>catches -landings and discards</i>
STATUS OF FISHERY RESOURCES <i>target species</i>	MIXED FISHERIES ADVISE <i>fisheries interactions</i> <i>species interactions</i>	FISHERIES MANAGEMENT <i>bycatch mitigation</i> <i>measures</i>	FISHERY MANAGEMENT PLANS
ENVIRONMENTAL & CLIMATE CHANGE EFFECTS	EFFECT OF FISHERIES ON THE ETP species & STATE OF ETP species <i>Sharlrays</i> <i>Seabirds</i> <i>Sea turtles</i> <i>Marine mammals</i>	EFFECT OF FISHERIES ON THE FOODWEB & STATE OF FOODWEB	SOCIO-ECONOMIC CONTEXT

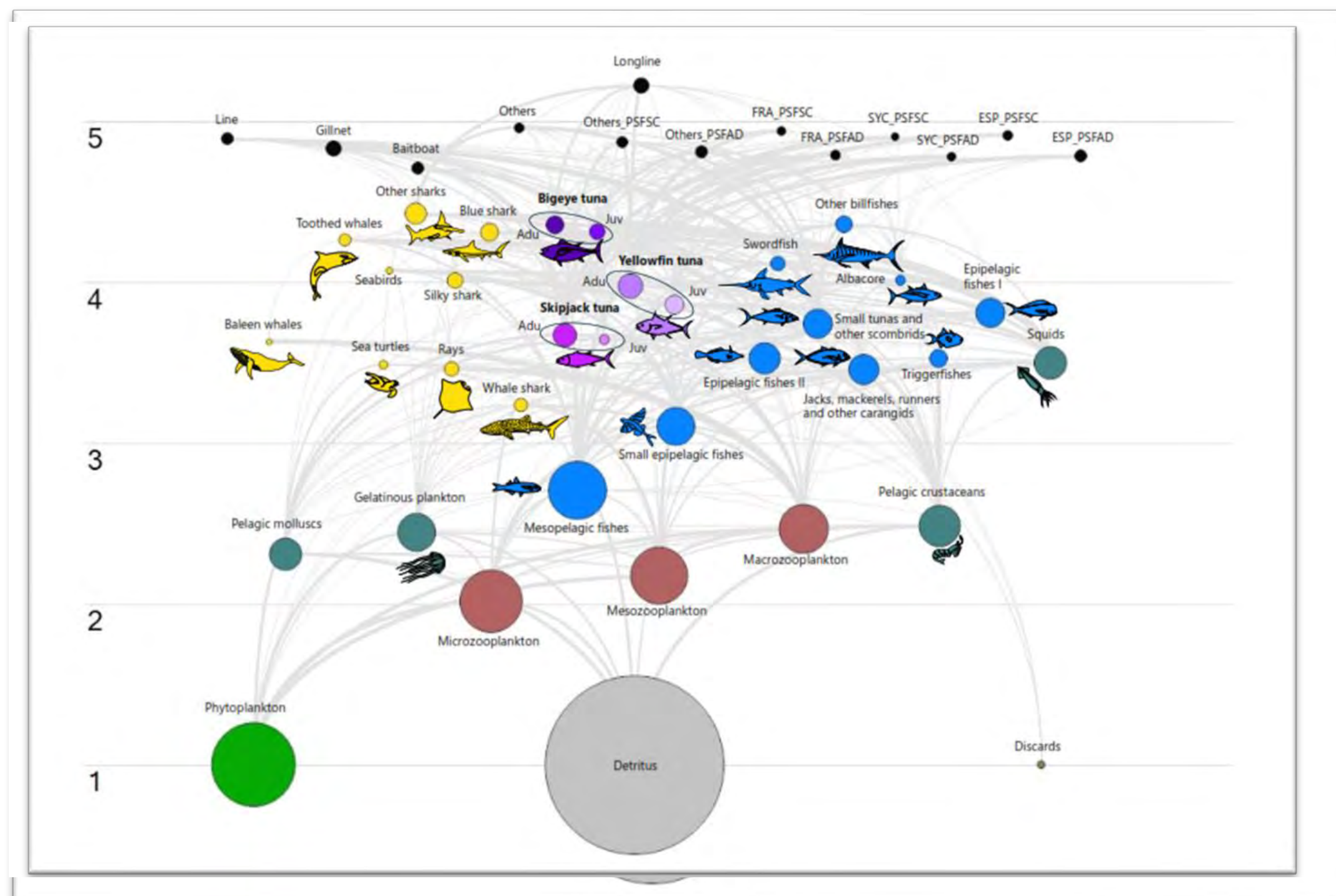
EwE Roger et al 2025



- **Example 6: New ecosystem modelling approaches presented (Ecopath with Ecosim, APECOSM) to assess impacts of fishing in tropical Indian ocean**

IOTC-2025-WPEB21(AS)-38

Hindcasting the food-web dynamics of the tropical Indian Ocean pelagic ecosystem over the last two decades

Roger Amate¹, Maria José Juan-Jordá², Xavier Corrales¹, Iker Zudaire³, Eider Andonegi¹

IMPACTS OF CLIMATE CHANGE - MARINE BIODIVERSITY - ECOSYSTEM MODELLING - PROPAGATION OF CLIMATE VARIABILITY - GLOBAL SCALE - PELAGIC ECOSYSTEM



Which processes structure global pelagic ecosystems and control their trophic functioning? Insights from the mechanistic model APECOSM.

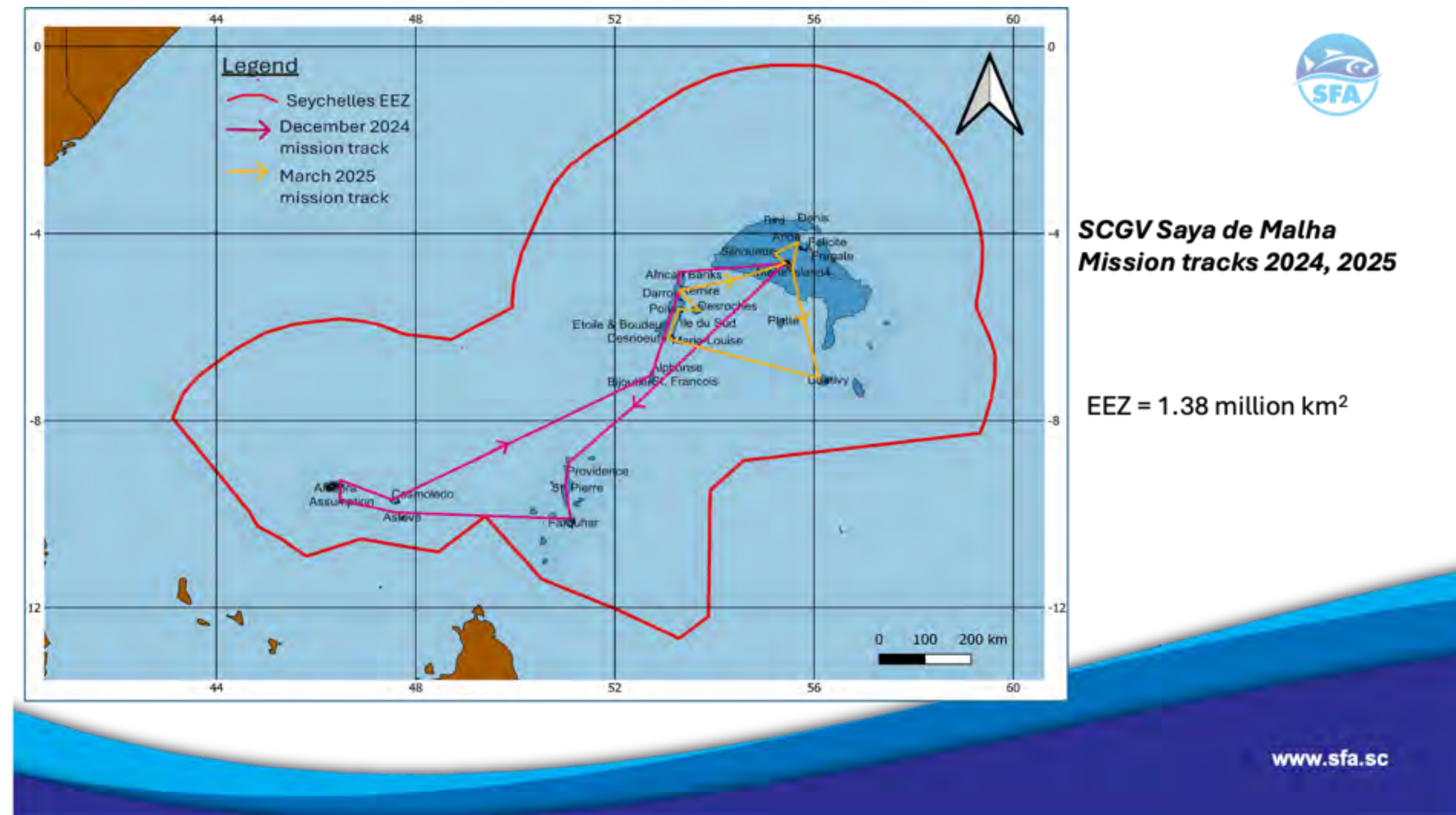
11 september 2025

Laureline Dalaut

Co-authors : Nicolas Barrier, Matthieu Lengaigne, Jonathan Rault, Alejandro Ariza, Mokrane Belharet, Adrien Brunel, Ralf Schwamborn, Mariana Travassos-Tolotti, Olivier Maury

IMPACTS OF CLIMATE CHANGE - MARINE BIODIVERSITY - ECOSYSTEM MODELLING - PROPAGATION OF CLIMATE VARIABILITY - GLOBAL SCALE - PELAGIC ECOSYSTEM

- **Example 5: Strengthened FAD management with passing of new Resolutions. Studies on impact of FADs in the Indian Ocean. Some retrieval of FADs before beaching- FADWATCH**



- Updates from RFMO Scientific Committees and Working Groups on existing ecosystem and climate indicators
 - Scientific objectives of indicator development (diagnostic, explanatory, predictive)
 - different tools/products ongoing generating observational and model-based indicators
 - Fisheries indicators (e.g., catch rates, effort)
 - Several EFO pilot studies ongoing with candidates indicators
 - Physical oceanographic indicators (e.g., SST, oxygen, productivity)
 - Ocean Atlas and EFO pilot studies ongoing with candidate indicators
 - Biological and ecosystem indicators (e.g., forage species, bycatch, biodiversity)
 - New ecosystem modelling approaches ongoing with candidate indicators

- How indicators are currently used to tracking ecosystem change and supporting EAFM
 - Ecosystem Indicators in IOTC: Emerging but Not Yet Operationalized
 - Indicator concepts (criteria, selection, spatial scales) discussed at WPEB
 - No formally agreed core indicator set
 - No defined thresholds or trigger mechanisms
 - Climate relance and signals beginning to enter advisory discussions
- Strengths and weaknesses of indicators: Limitations, uncertainties, and appropriate interpretation of indicators
 - Fragmented process not operationalized

- **Scientific Foundations Strengthened**
 - Development and testing of ecologically meaningful ecoregions.
 - Improved spatial visualization tools (e.g., Ocean Atlas).
 - Strengthened FAD monitoring
 - Emerging trophic modelling capacity (EwE in the tropical Indian Ocean).
 - Increasing integration of climate signals “awarenesses” in scientific discussions

- **Ecosystem and Climate Indicators: Current Status**
 - Indicator concepts are being discussed and developed.
 - No formally agreed core ecosystem or climate indicator set yet.
 - No structured interpretation framework or thresholds.
 - Indicators currently inform discussion rather than trigger management action.
 -

- **IOTC SC/WPEB slowly progressing**
 - The scientific architecture is strengthening.
 - Ecosystem considerations are increasingly visible in management (for selected issues - vulnerable taxa).
 - But full operationalization of EAFM remains incomplete.
 - The next frontier is integration and communications — not indicator proliferation.
 - Climate change makes this transition urgent.
 - Support **regional case studies** with concrete **products** to provide concrete examples to SC and Commission

EAFM in Canada, with a focus on the Maritimes Region

Alida Bundy

4th Joint Meeting of Tuna RFMOs on the Implementation of the
Ecosystem Approach to Fisheries Management: Advancing the
Development of Ecosystem Indicators 2- 6 March 2026, SPC,
Noumea (New Caledonia)



Annex 5

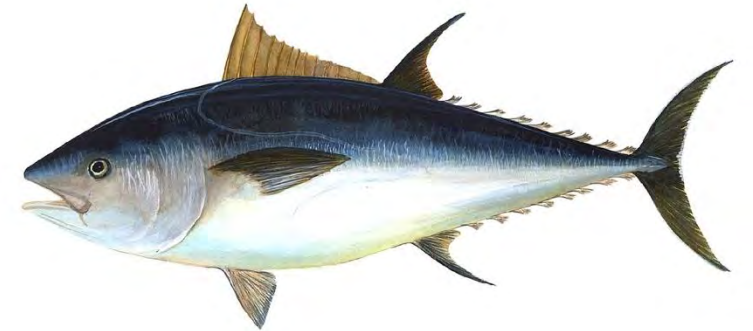


Fisheries and Oceans
Canada

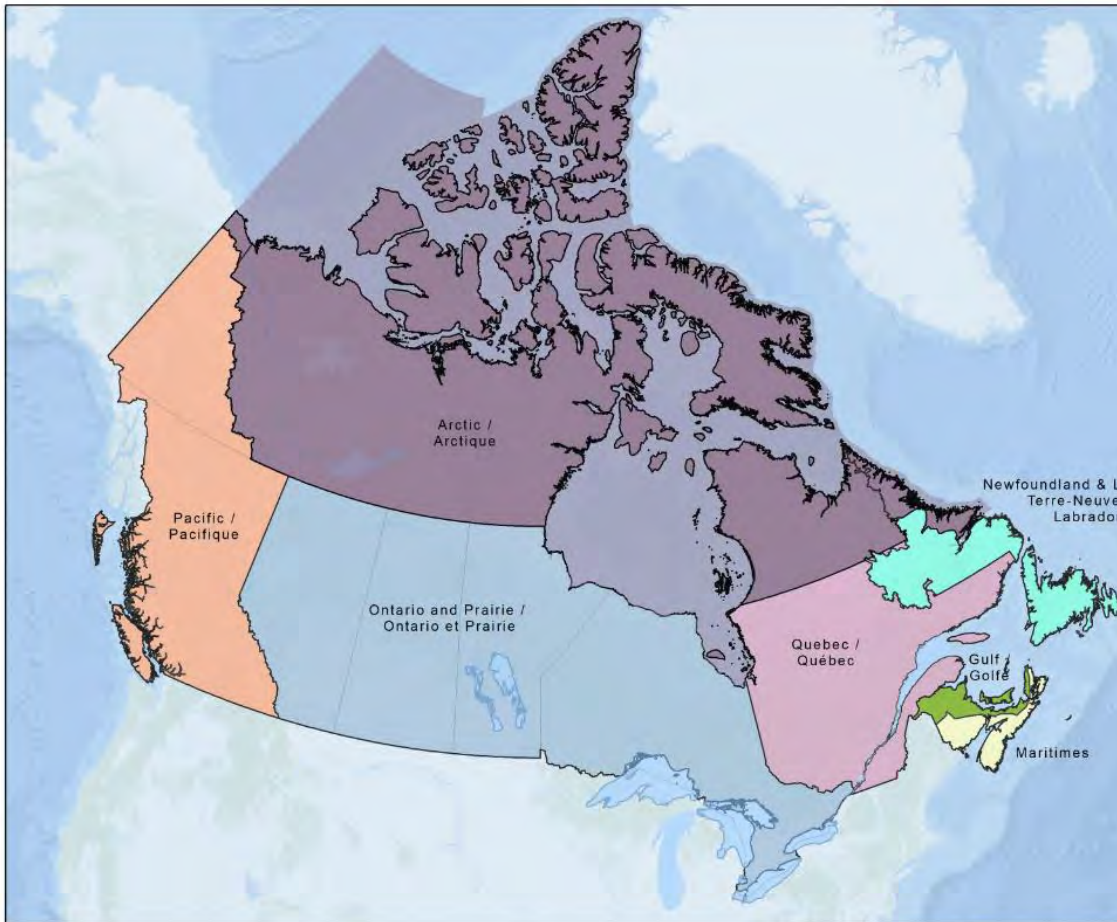
Pêches et Océans
Canada

Plan

- Fisheries and Oceans Canada
- National EAFM Initiative
- Ecological Indicators
 - Development
 - Spatial Behaviour
 - Exploring pressure/response and thresholds
- Ecosystem Summary Reports



Fisheries and Oceans Canada (DFO)



Oceans Act (1996, Amended 2019) – embraces an ecosystem approach and integrated management

“lead and facilitate the development and implementation of plans for the integrated management of all activities or measures in or affecting estuaries, coastal waters and marine waters that form part of Canada or in which Canada has sovereign rights under international law”

Fisheries Act (1985, Amended 2019)

“Except as otherwise provided in this Act, when making a decision under this Act, the Minister may consider, among other things, (a) the application of a precautionary approach and an ecosystem approach....”

Species at Risk Act (2002, Amended 2019)



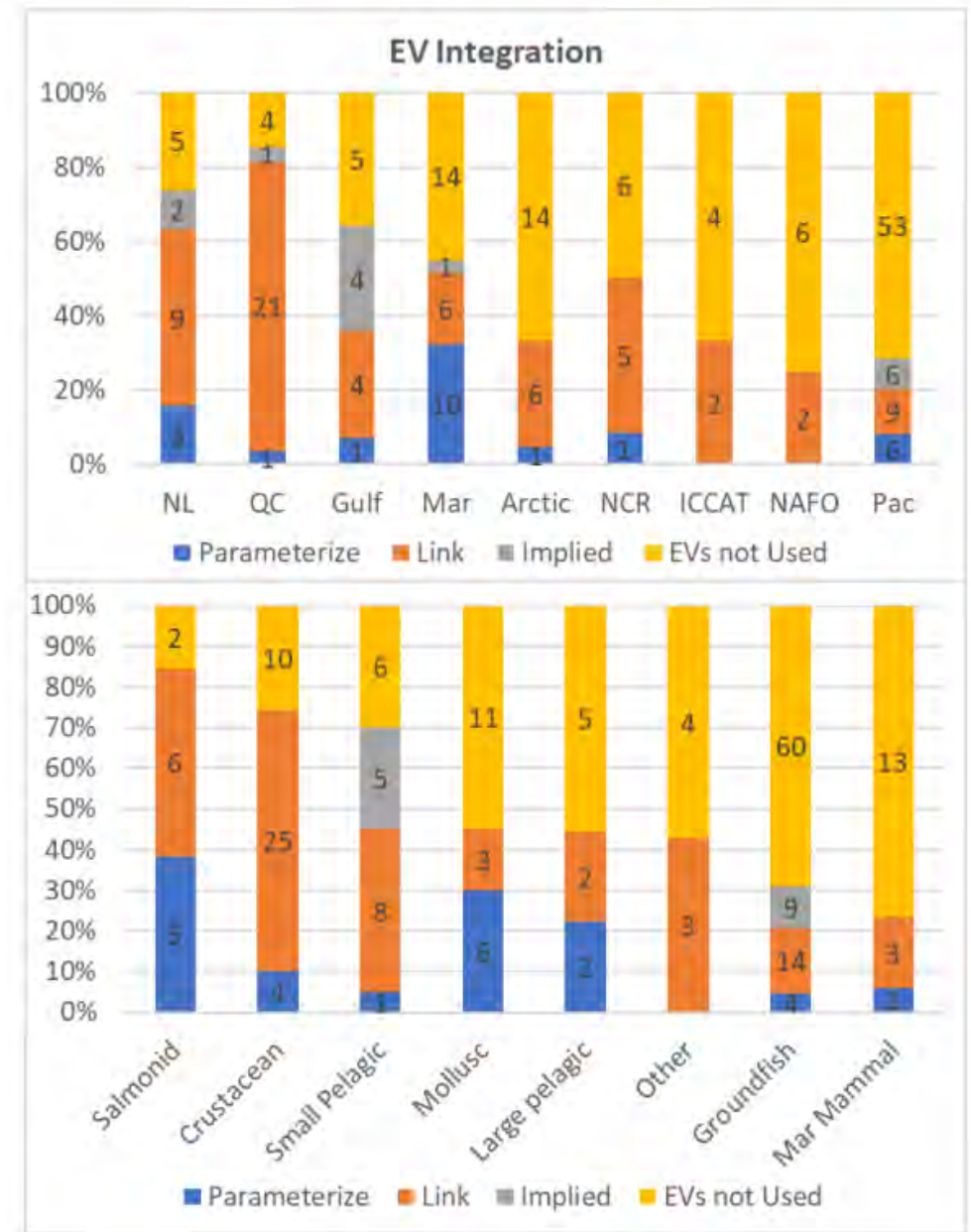
DFO's Ecosystem Approach to Fisheries Management

EAFM is a single-stock approach that enables the incorporation of ecosystem information into stock assessments, science advice, management recommendations, and integrated fishery management plans or other harvest strategies (i.e., the entire science-management cycle) to better inform stock and individual fishery-focused decisions



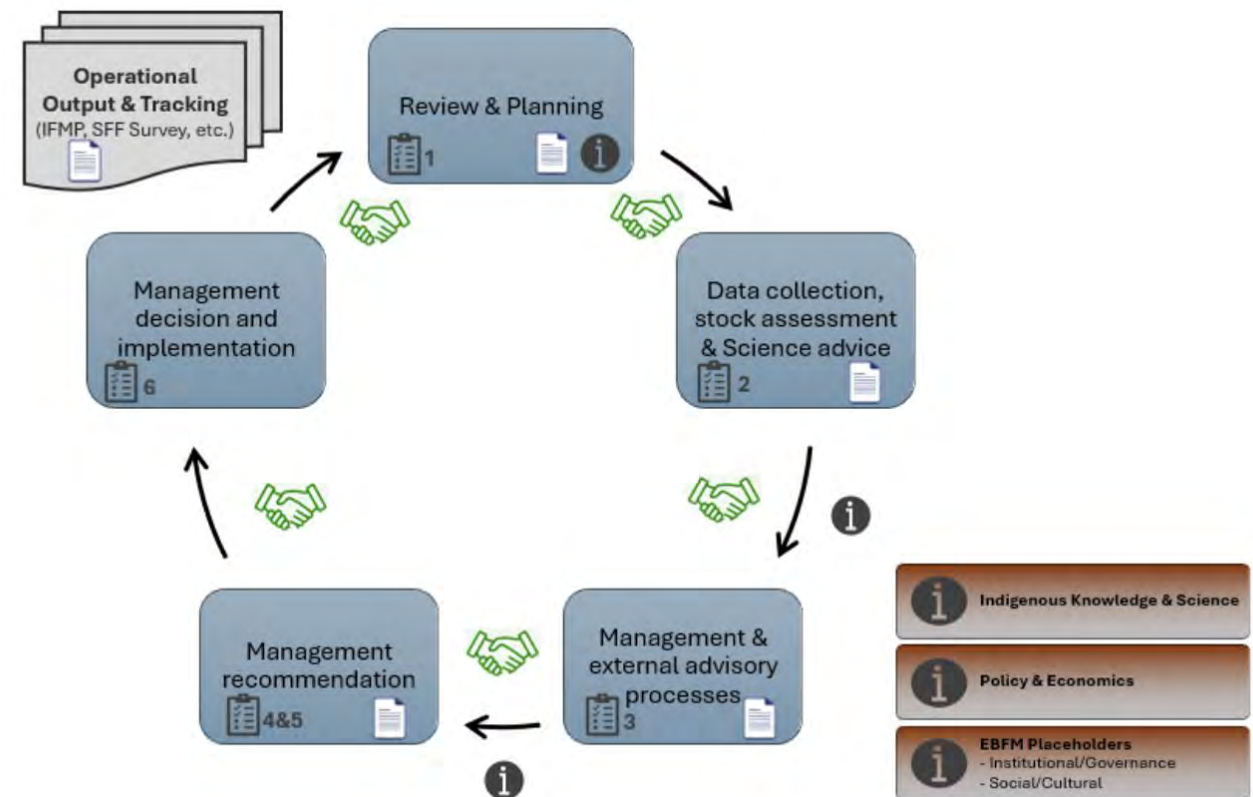
Gap Analysis

- Purpose: evaluate current state of integration of Ecosystem Variables (EVs) in stock assessments, expanding on ACCASP results.
- Approach: questionnaire-based input directly from scientists and managers responsible for individual stocks.
- Strong supportive responses for majority of 200+ stocks considered.
 - **48% of assessments consider EVs**
- Strongest impact on advice achieved by including EVs in assessment models.
- Data access, quality, capacity and resources are critical limitations.



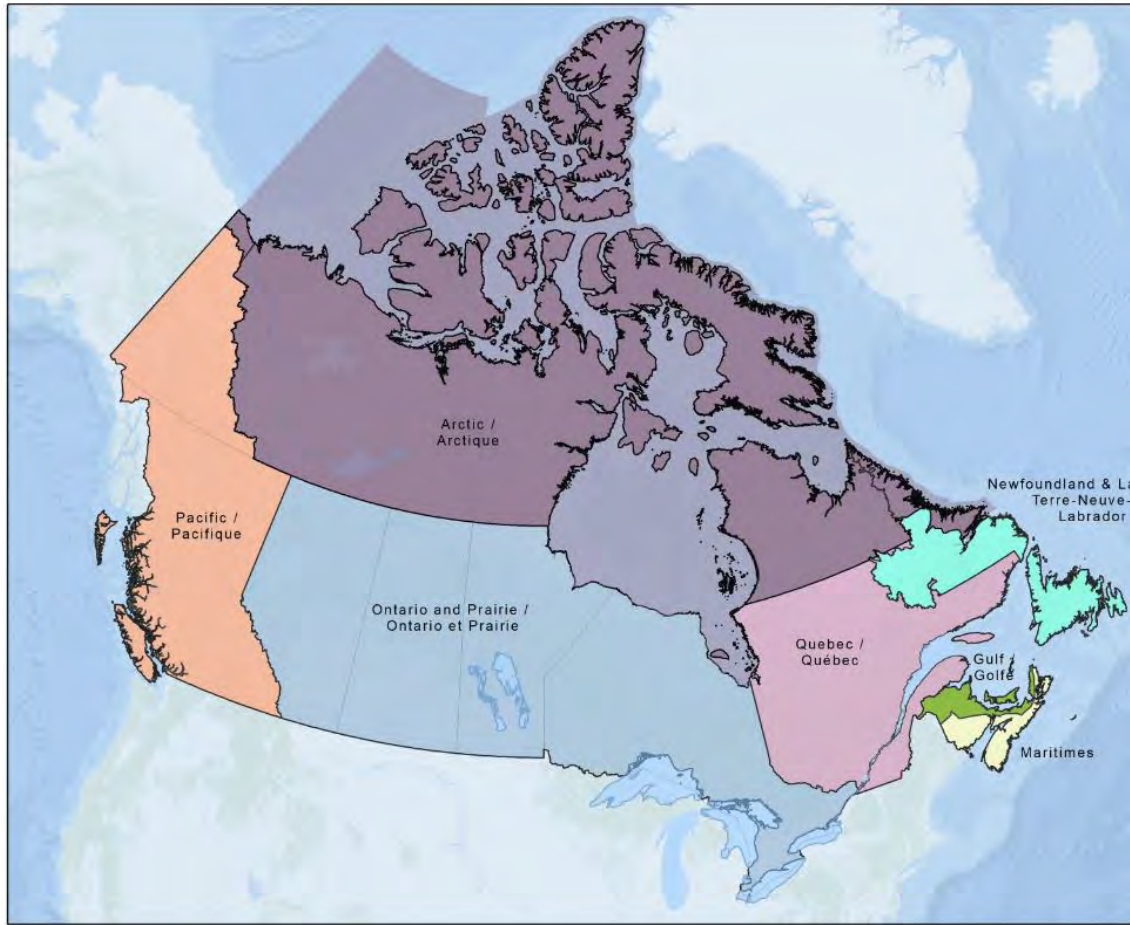
National EAFM WG outputs

- Strategic Plan
 - Public-facing, high-level strategy, objectives, and rationale
 - “What we Heard” reports
- Implementation Plan/EAFM Framework
 - Internal, general description of tactics and responsibilities for implementation
- EAFM Implementation Materials and Tools
 - [An Accounting of Integration of Environmental Variables in Fishery Stock Assessments in Canada](#) (Kulka et al. 2022)
 - EAFM Science Methods Toolbox
 - [EAFM Case Study Synthesis Report](#) (Pepin et al. 2023)
- **Ecosystem Summary Reports**



DFO Fisheries Management-Science EAFM Feedback Tool

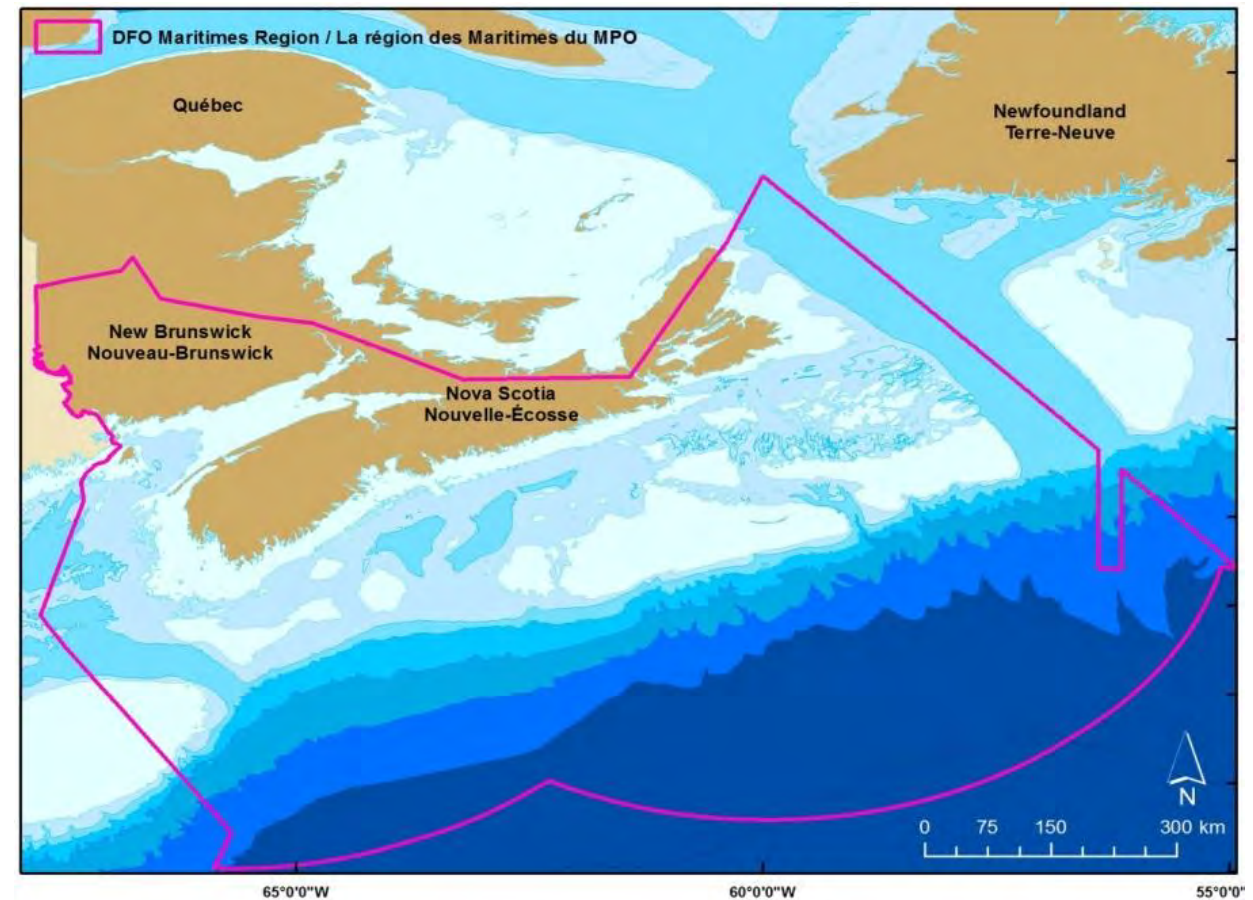
handshake symbols = opportunities for discussion of ecosystem variables



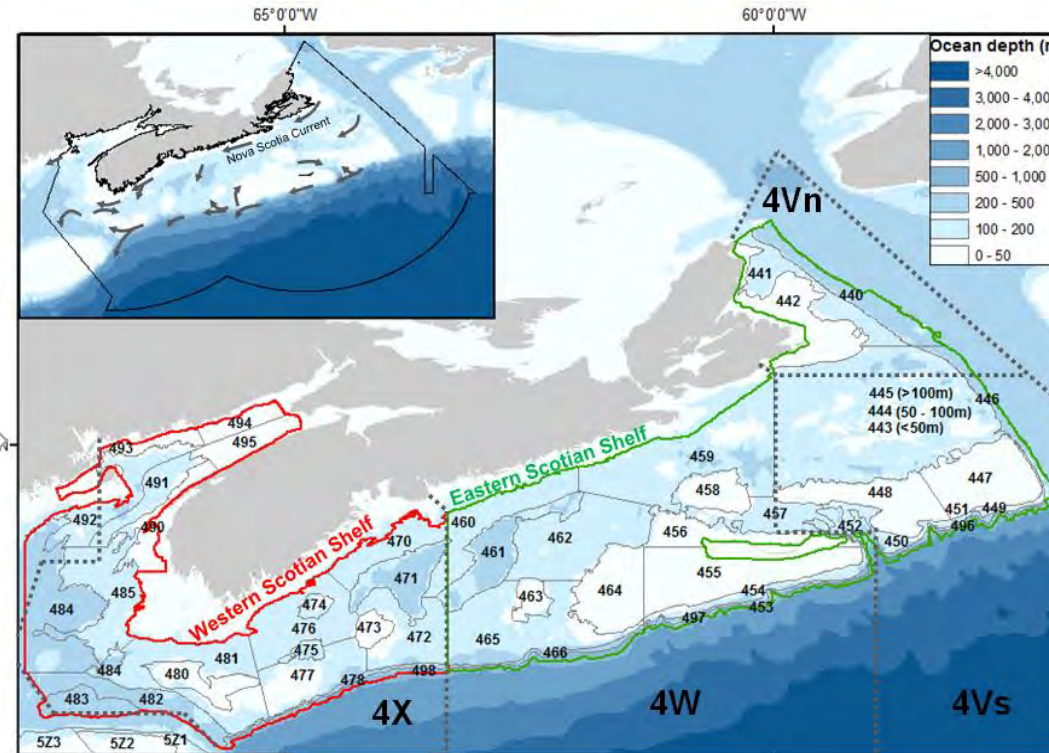
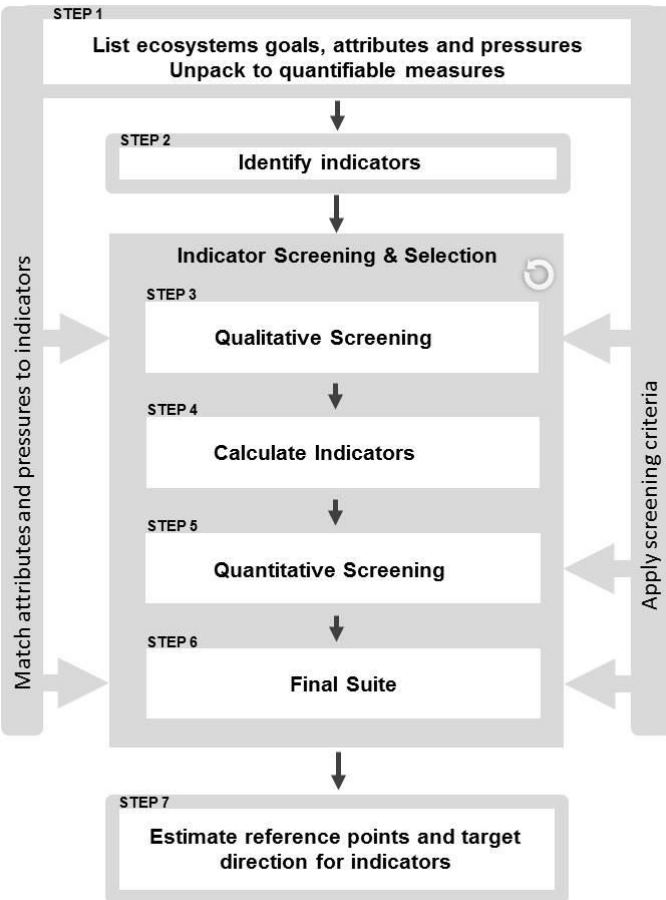
8,600 kilometres of coastline (<4% of Canada).

37% of the total landed value of Canadian commercial fisheries (2021); 70+ species harvested.

~ 70% of value from shellfish



Ecological Indicators

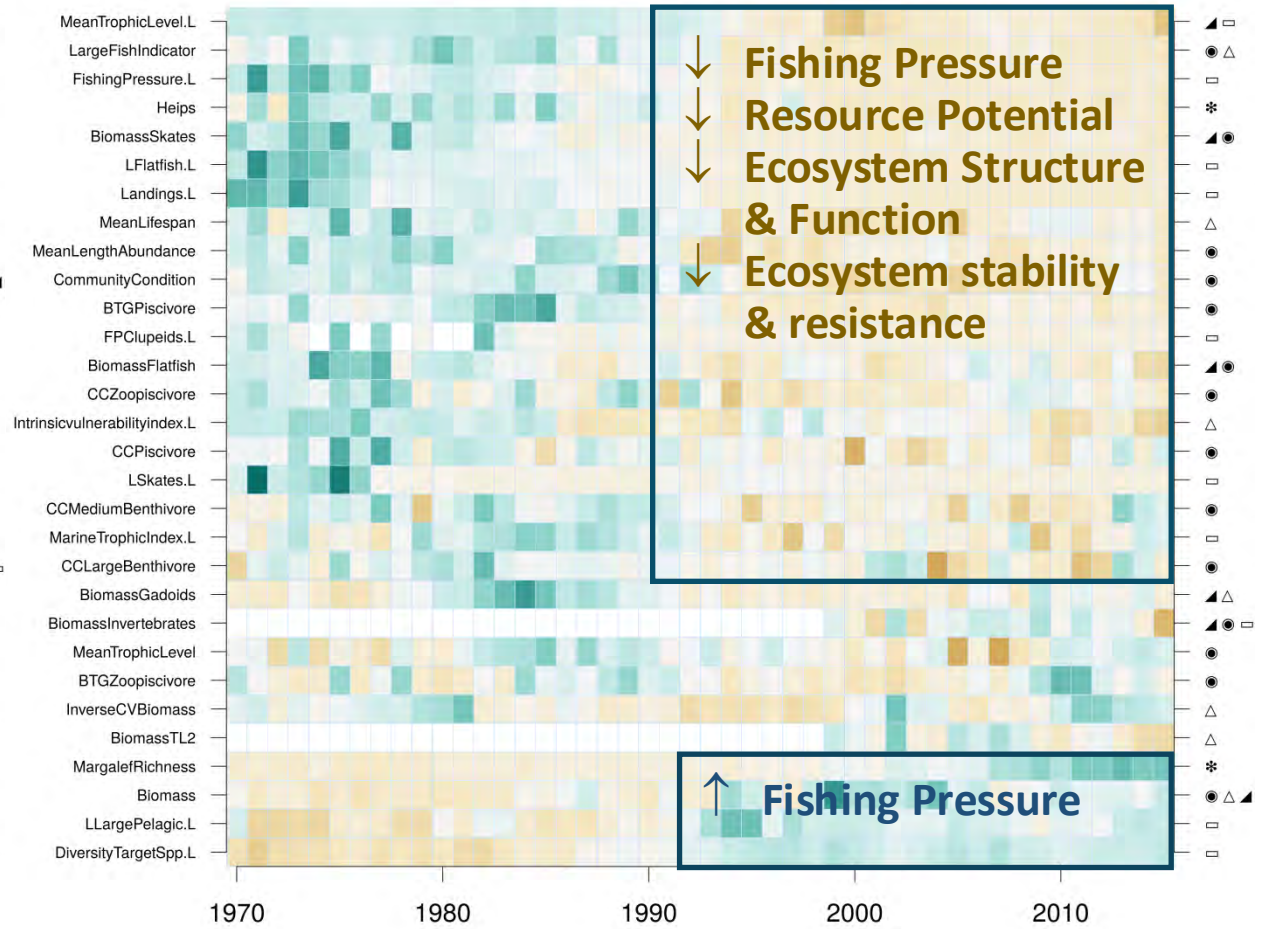
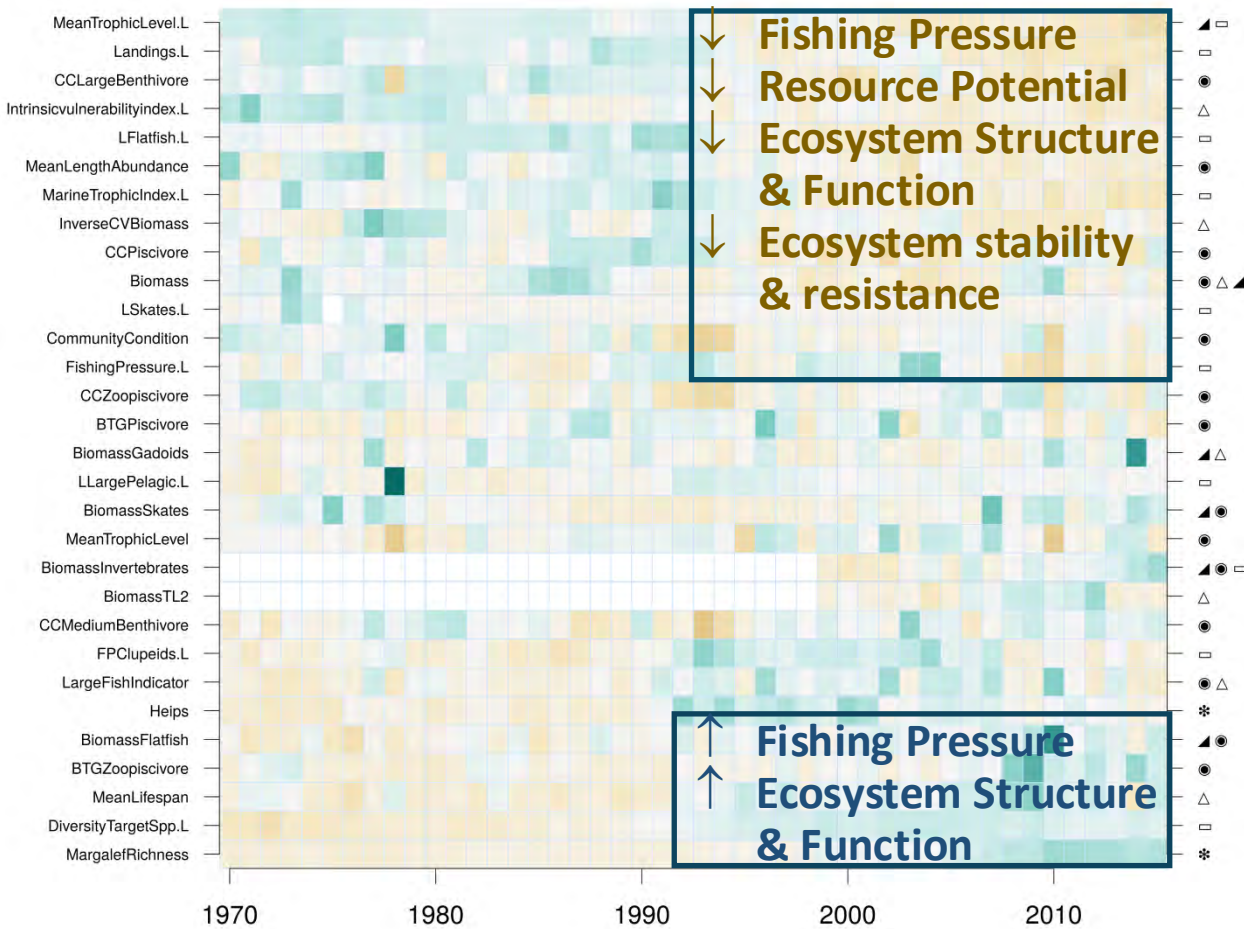


- Developed a guidance Framework for the selection and evaluation of indicators
- Focussed on the selection of a parsimonious and complementary indicators using clear, defensible criteria
- Applied the Framework to the Scotian Shelf bioregion, Canada, at multiple spatial scales
- Patterns of redundancy and complementarity among indicators were generally consistent at all spatial scales
- 30 indicators

- 4 ecosystem attributes & 1 pressure:
 - Biodiversity;
 - Ecosystem structure & function;
 - Ecosystem stability & resistance;
 - Resource potential
 - Fishing pressure

Western Scotian Shelf

Eastern Scotian Shelf



Time series of anomalies of the first principal component of a multivariate ordination of indicators

▲ = Resource potential; ● = ecosystem structure & function; △ = ecosystem stability & resistance; * = biodiversity;

□ = fishing pressure

Scotian Shelf has undergone large, negative changes at all spatial scales since 1970, with no sign of recovery

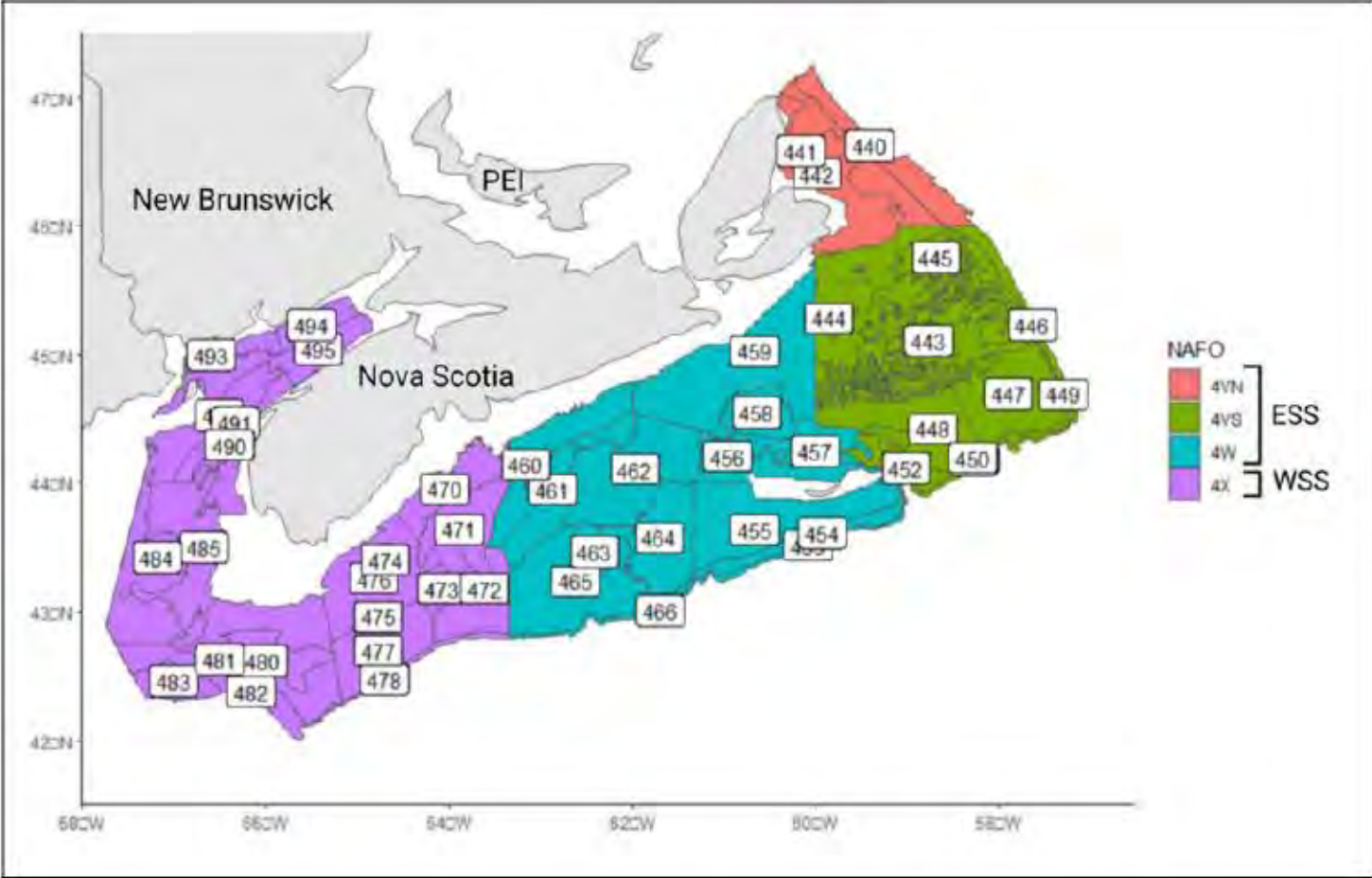
Fonya Irvine

SPATIAL COHERENCE OF ECOSYSTEM INDICATORS ACROSS THE SCOTIAN SHELF, CANADA

Spatial coherence of ecosystem indicators across the Scotian Shelf, Canada

3 main questions:

- (i) Is the spatial and temporal resolution of current data collection in the Scotian Shelf fine-grained enough to detect changes in key indicators at the strata level?
- (ii) How closely do fluctuations in time series at the strata level match those at the larger spatial scales?
- (iii) Is there spatial coherence across strata and indicators?



Bioregion Scale



Shelf Scale



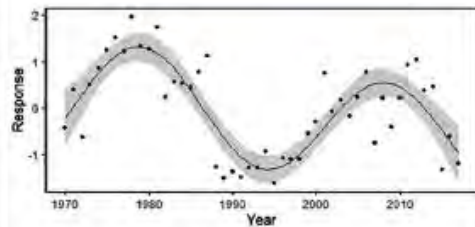
NAFO Scale



Strata Scale

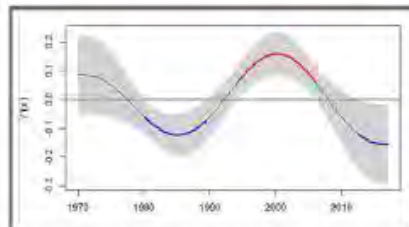


1. Regression



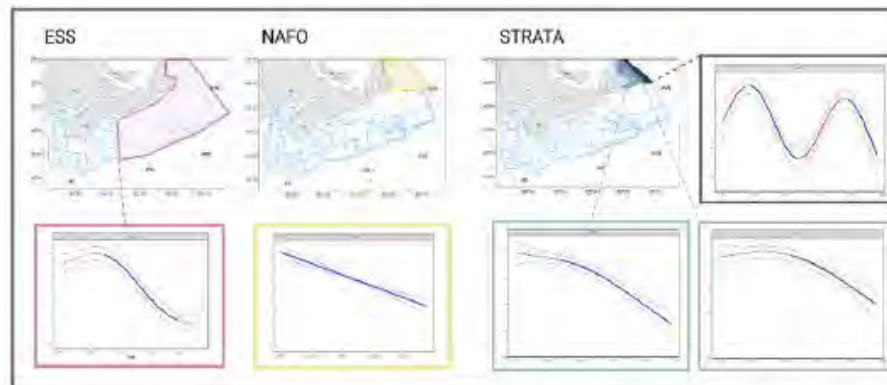
Model each indicator per spatial unit as a function of time using GAM. Check model residuals and summary statistics (e.g., r^2 , p -value, EDF). Evaluate for evidence of significant autocorrelation.

2. First Derivative



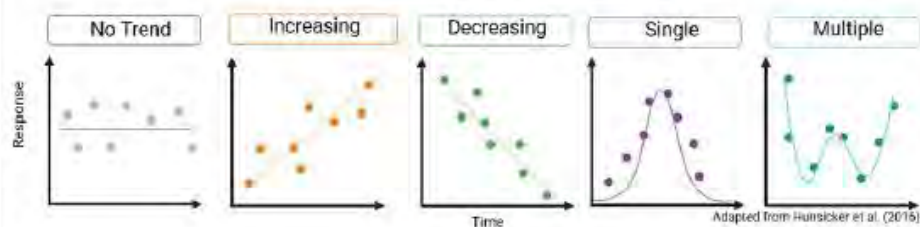
Evaluate local increases (red) or decreases (blue) in trend to facilitate peak identification.

5. Trend Comparisons

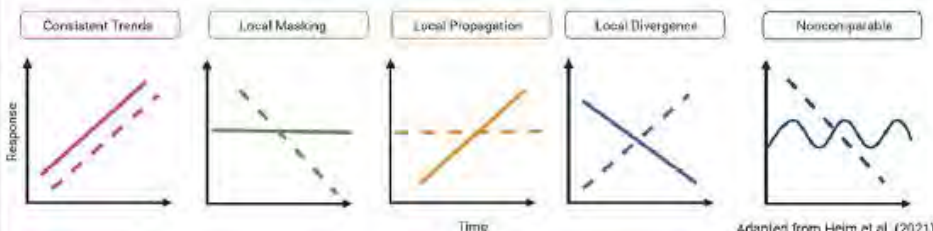


Visually compare trends and model outputs for each indicator across spatial scales and quantitatively evaluate temporal synchrony.

3. Functional Forms

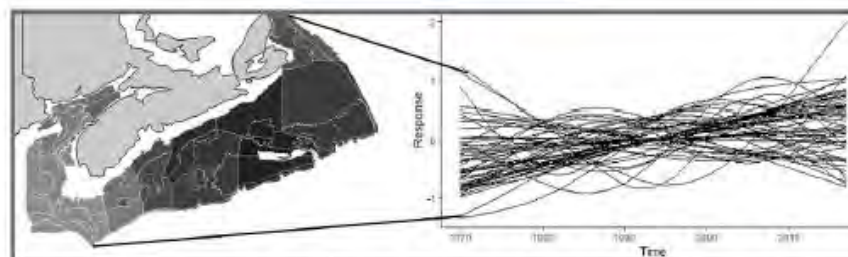


4. Scale Dependence



Evaluate local (dashed lines) and regional (solid lines) temporal trends for evidence of scale dependence

6. Coherence

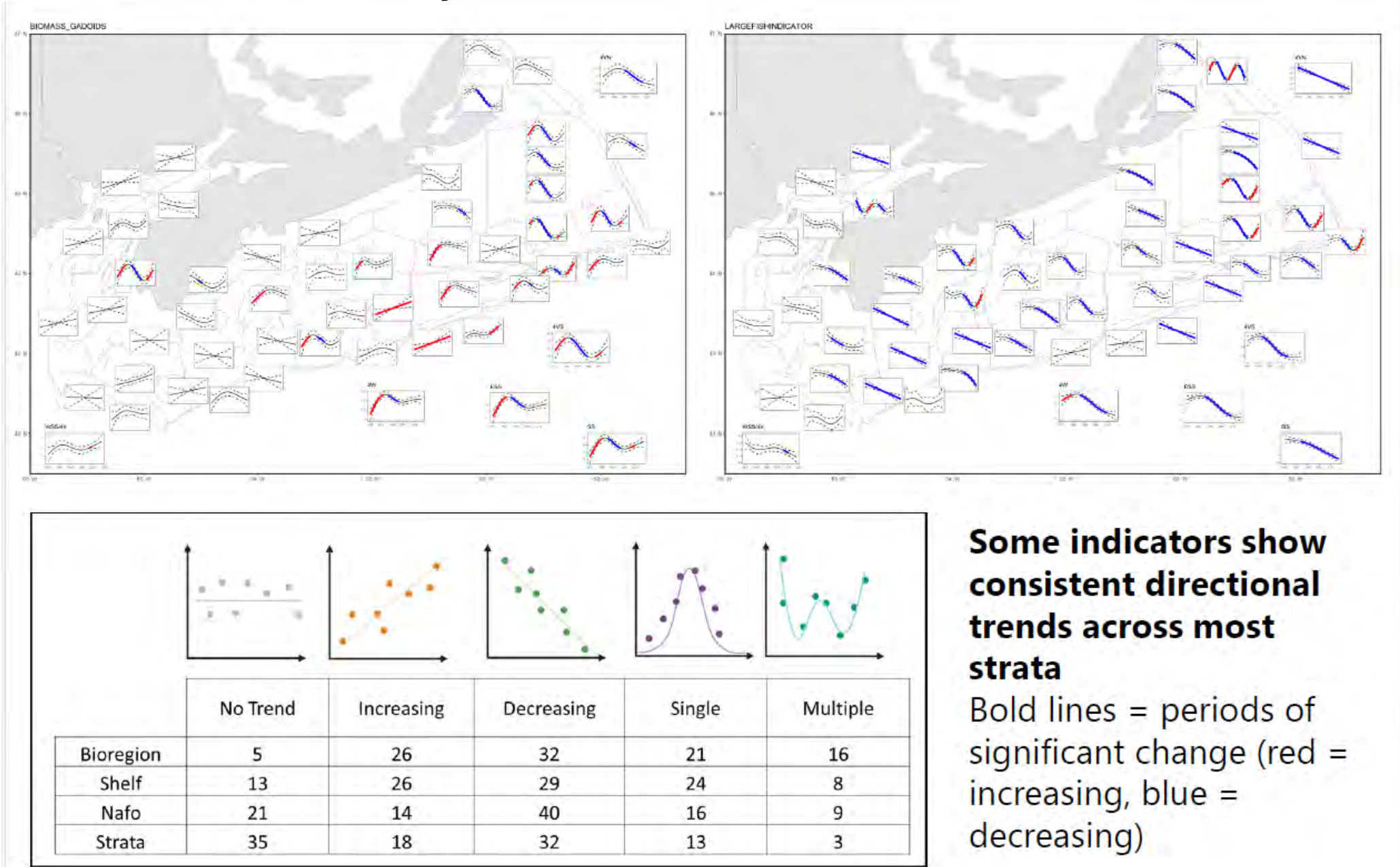


Extract time series for each spatial unit (e.g., 48 strata trends)



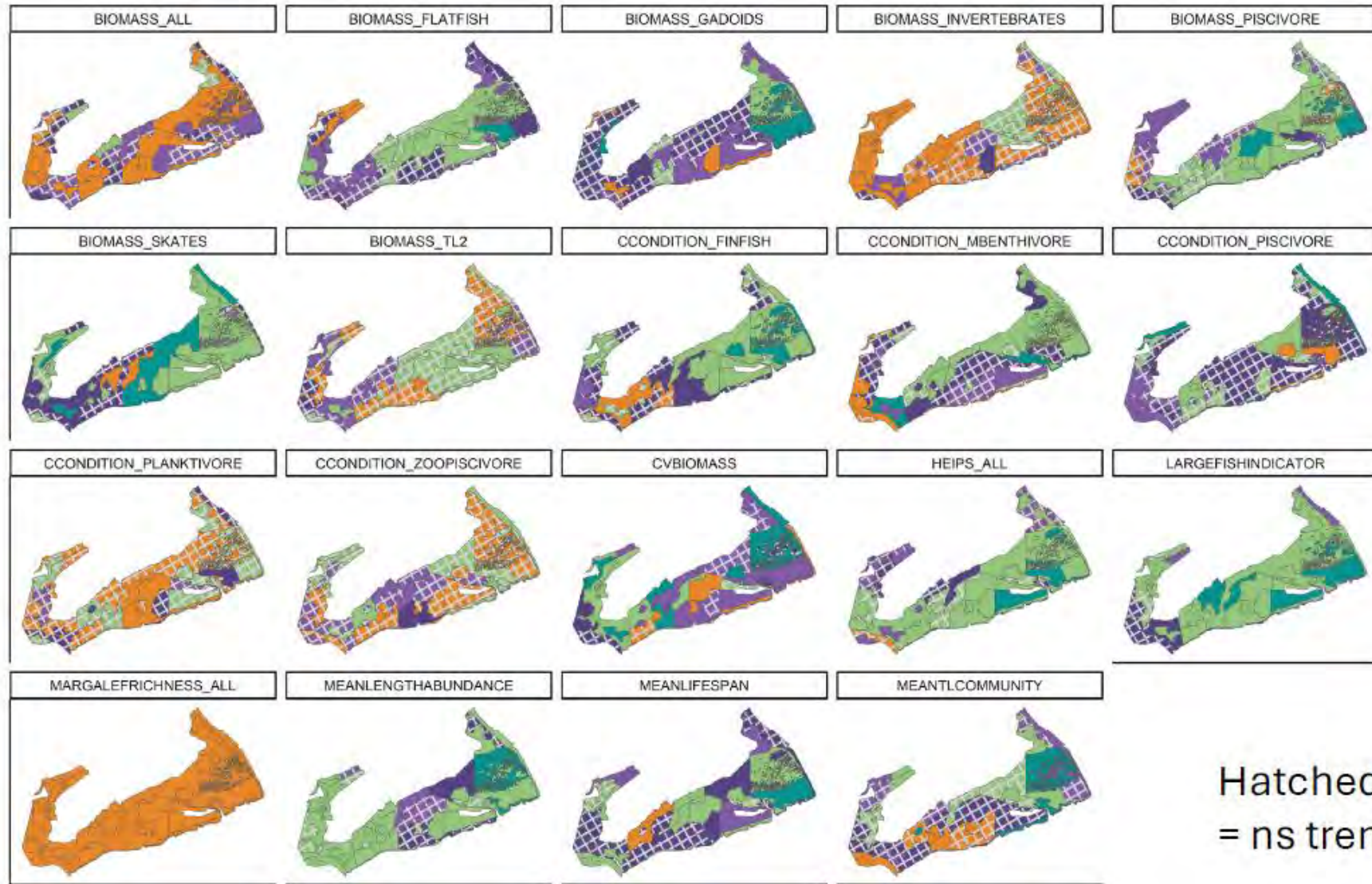
Conduct pairwise comparisons between each time-series using DTW to cluster similar series together to evaluate coherence across strata.

Spatial coherence of ecosystem indicators across the Scotian Shelf, Canada



Mapped centroid shapes show spatial structure with varying patterns across indicators

No single spatial pattern characterizes all indicators



Hatched areas
= ns trends

Centroid ■ decreasing ■ increasing ■ single-min ■ single-max ■ multiple-max-min

Q1: Detection Works

- Current survey design detects significant trends at the strata level; however, R^2 improves with aggregation

Q2: Scale Mismatch is Real

- Strata show simpler dynamics than aggregated spatial scales with shelf-wide trends may not be representative of local conditions

Q3: Coherence is Selective and Spatial Structure Exists

- Synchrony varies by indicator with biomass indicators showing more coherent trends than community metrics
- DTW shows distinct spatial groupings with variable patterns across indicators

Scale Matters

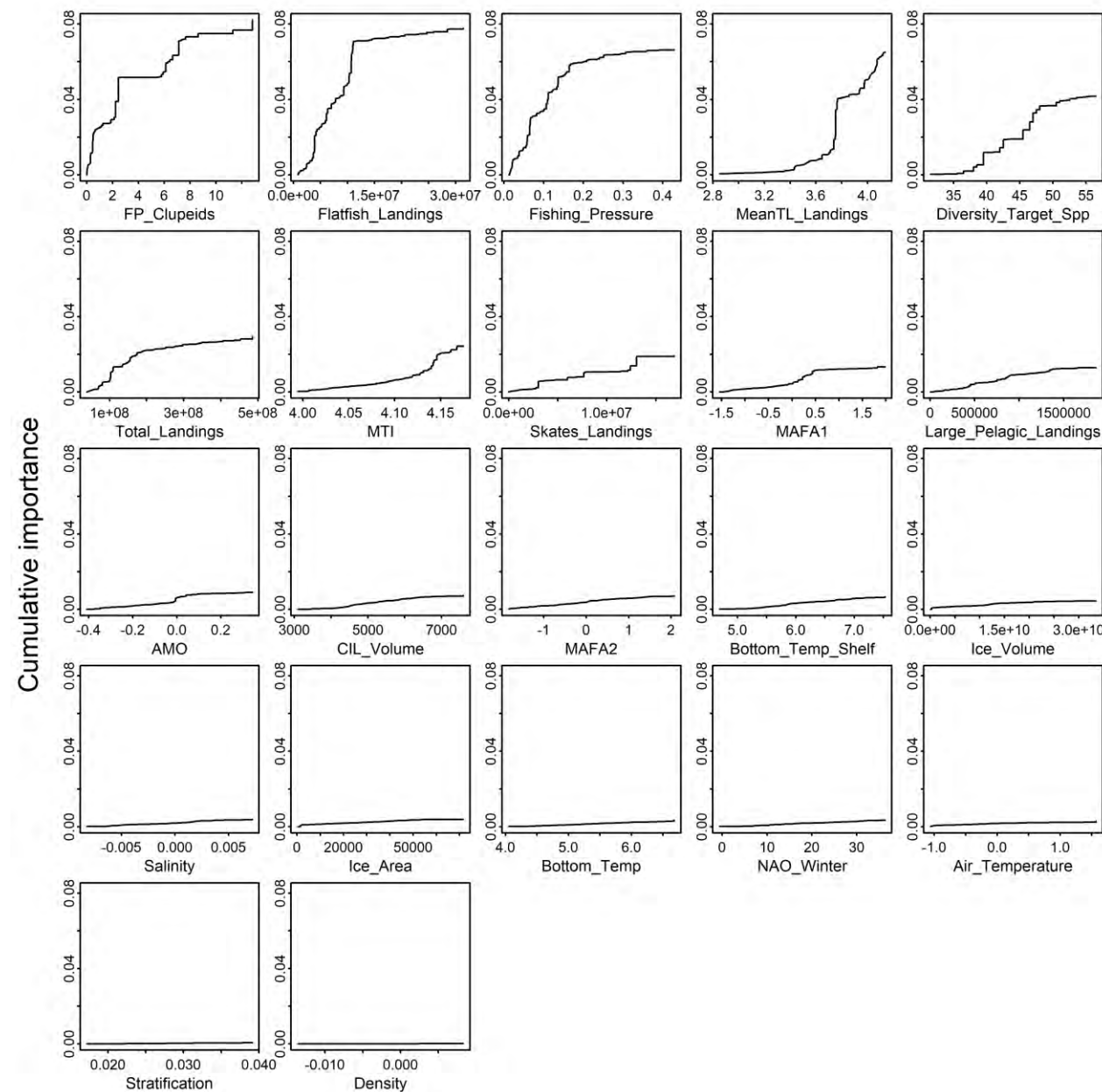
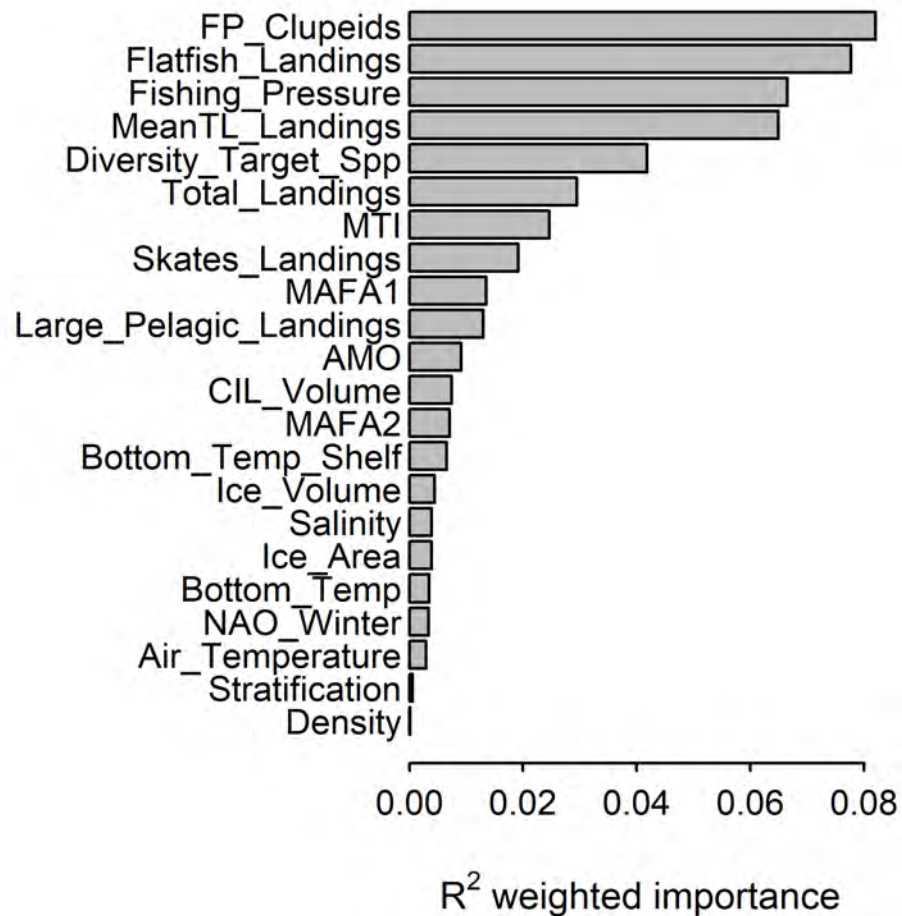
- Assessment scale should match the management scale.
- Different indicators require different scale considerations.

Danielle Dempsey and Jamie Tam

EXPLORATION OF INDICATORS, PRESSURES AND THRESHOLDS – ON-GOING

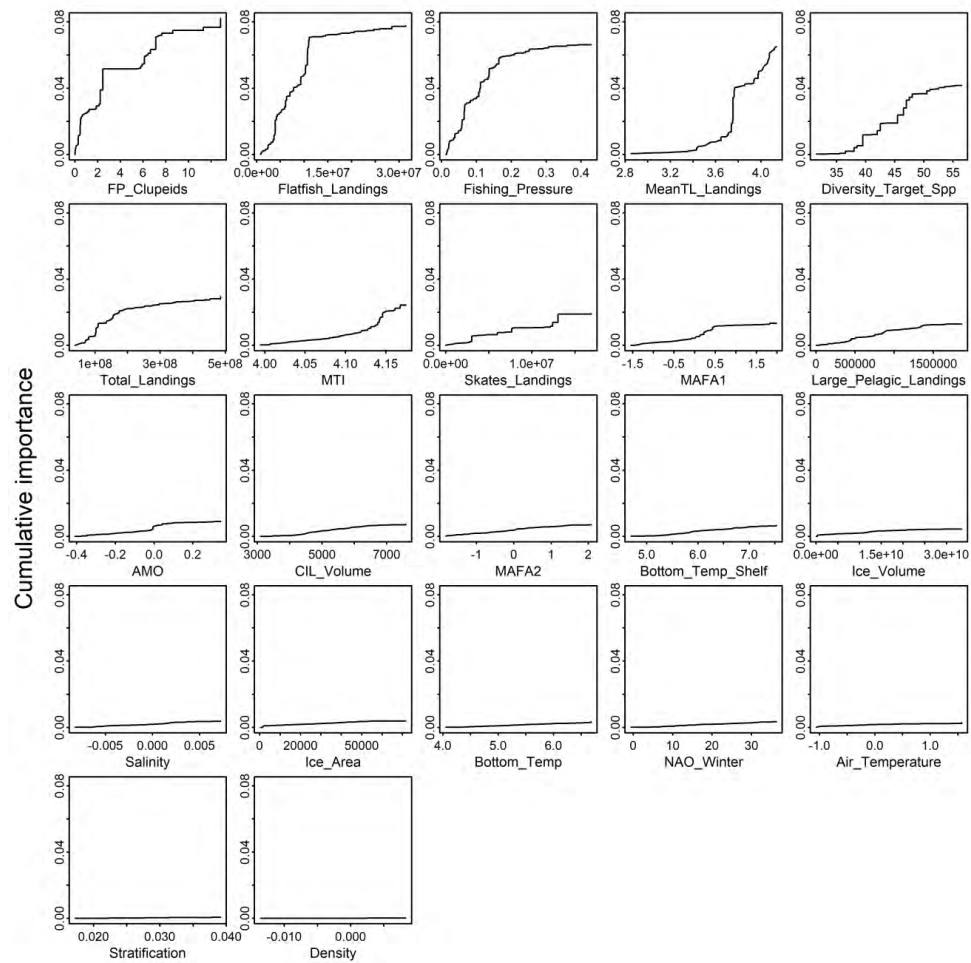
Ecological Indicators	Physical Environmental Indicators	Biological Environmental Indicators	Fishing Pressure Indicators
Heips_ALL	Air_Temperature	Chlorophyll_100m	DiversityTargetSpp_ALL
MeanTLCommunity	AMO	C_finmarchicus	MeanTL.Landings
BIOMASS_ZOOPISCIVORE	CIL_Volume	Pseudocalanus	MTI
MeanLengthABUNDANCE	Density	Copepods	Fishing Pressure
CCondition_FINFISH	Ice_Area	Non_copepods	landings_ALL
CCondition_LBENTHIVORE	Ice_Volume	Zooplankton_Biomass	landings_FLATFISH.L
CCondition_MBENTHIVORE	NAO_Winter	Diatoms	landings_LARGE_PELAGIC.L
CCondition_PISCIVORE	Salinity	Dinoflagellates	landings_SKATES.L
CCondition_ZOOPISCIVORE	SST	Ciliates	
CVBiomass	Stratification	Flagellates	
MeanLifespan	Bottom_Temp	Larvacea	
BIOMASS_ALL	Bottom_Temp_Shelf	Euphausiacea	
IVILandings	Warm_Offshore	Gastropoda	
BIOMASS_SKATES	Warm_Shelf	Chaetognatha	
BIOMASS_FLATFISH	Nitrate_0_50	Polychaeta	
BIOMASS_GADOIDS	Silicate_0_50	Ostracoda	
BIOMASS_PISCIVORE	Phosphate_0_50	Bivalvia	
Large Fish Indicator	Nitrate_50_150	Echinodermata	
	Silicate_50_150	Cirripedia	
	Phosphate_50_150	Amphipoda	
		Arctic_Calanus	
		Bloom_Start	
		Bloom_Duration	
		Bloom_Amplitude	
		Bloom_Magnitude	

Gradient Forest Results for the ESS

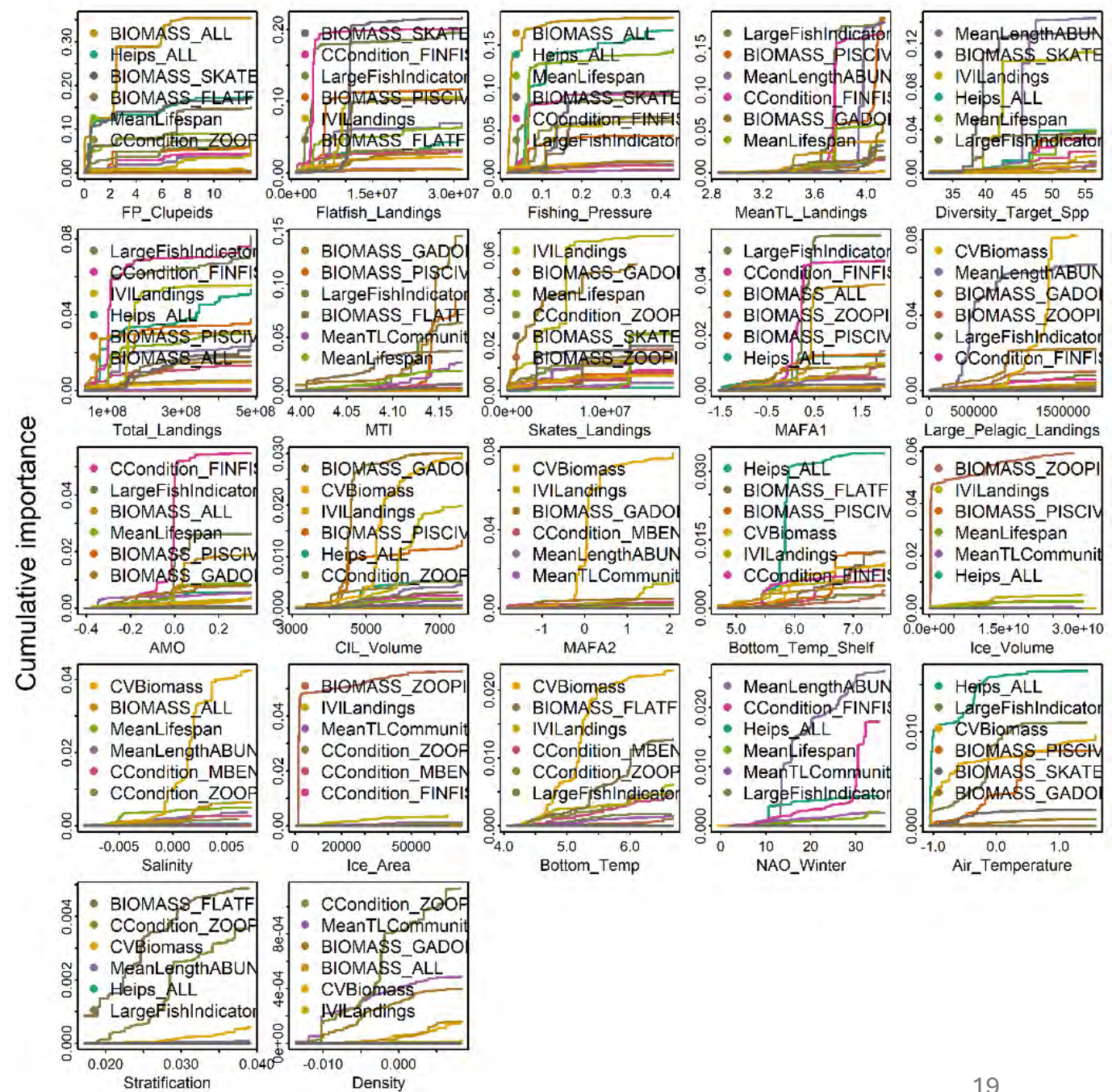


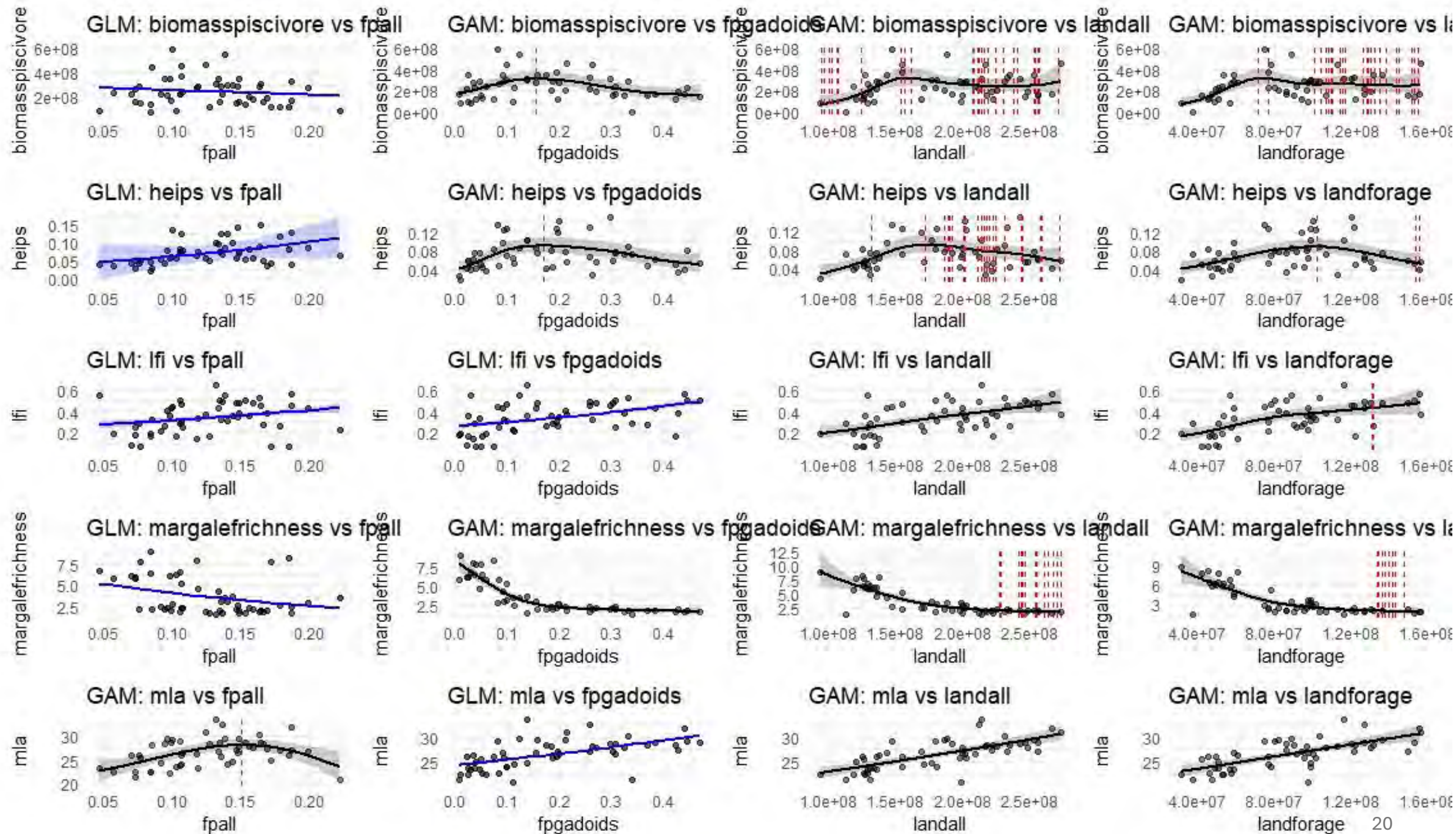
DRAFT WORK – NOT FOR DISTRIBUTION

More detailed results



DRAFT WORK – NOT FOR DISTRIBUTION





Jamie Tam and the Maritimes EBFM WG

ECOSYSTEM SUMMARY REPORTS FOR FISHERIES

Ecosystem Summary Reports

2025 Ecosystem Summary Report for NAFO 4X

Maritimes EBFM WG

2026-02-03

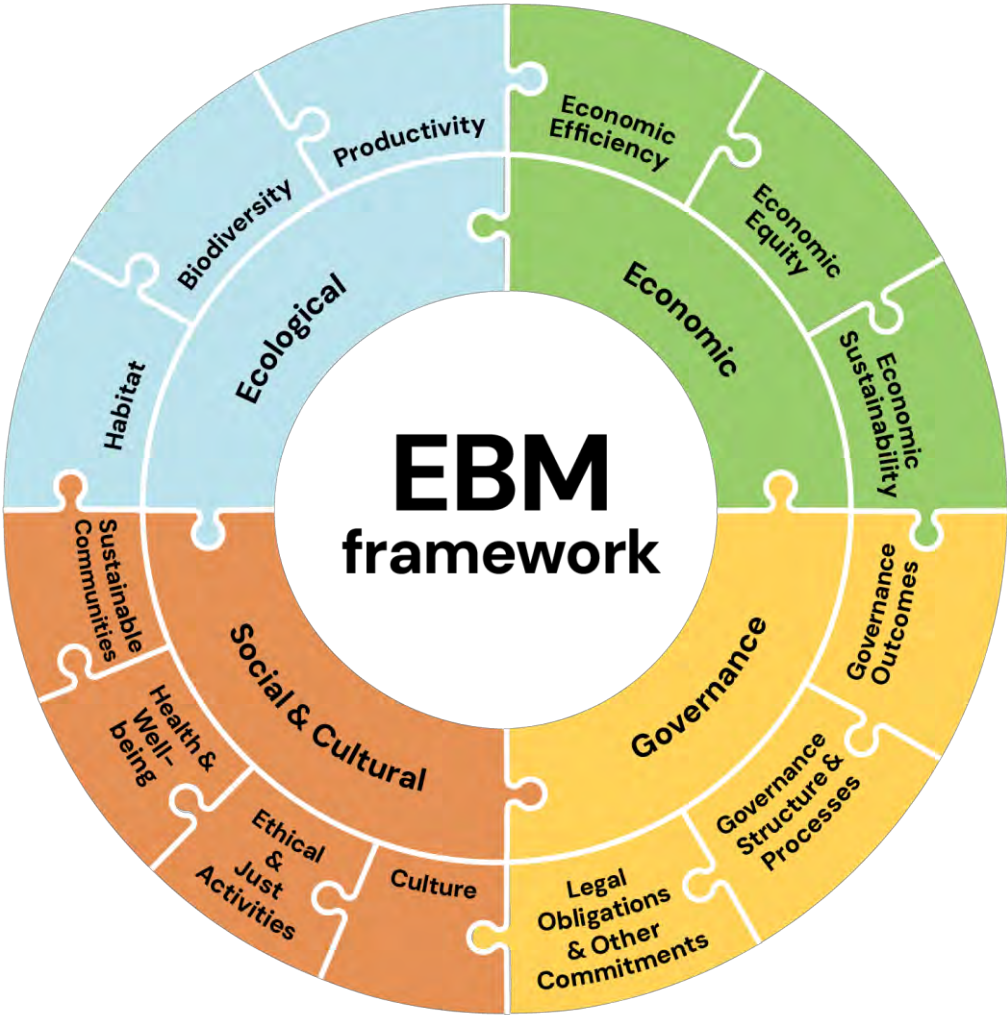
Contents

Introduction	2
Overview	2
Ecosystem Objectives	3
A. Pressures and Stressors	4
Climate and oceanography	4
Longer-term climate change	12
B. Ecological	13
Commercial Fishery	13
Habitat	16
Productivity	17
Biodiversity	21
Non-Target Species	23
C. Economic	23
Commercial Fishery	23
D. Social-Cultural	24
E. Governance	24
References	24



Dr. Jamie Tam

Maritimes EBFM WG



The large fish biomass has been replaced by smaller fish and invertebrates. Species evenness has decreased, also indicating fewer, dominant species. Fish biomass is generally below long-term mean over the latest 5 years of data, although landings and fishing pressure have generally decreased in NAFO 4X over time.

Pillar	Management Component	Ecosystem Objective	Indicators
A. Pressures and stressors	Climate and Oceanography	Monitor key signals within the environment and ecosystem	NAO, SST anomaly, Bottom Temp anomaly, SST, Bottom Temp, Stratification, Salinity, Ocean Acidification
A. Pressures and stressors	Longer-term Climate Change	Effective action and adaptation on climate change is taken	Future projection model outputs
B. Ecological	Commercial Fishery	Maintain fishing pressure consistent with the ecosystem's ability to recover	Fishing pressure, Commercial landings
B. Ecological	Habitat	Habitat and habitat features are conserved, protected, maintained, and restored	Depth <100 fathoms
B. Ecological	Productivity	Do not cause unacceptable reduction to productivity	Nitrate, Chlorophyll, Bloom statistics, <i>C.finmarchicus</i> , Zooplankton biomass
B. Ecological	Productivity	Ecosystem structure and functioning is promoted and conserved	Large Fish Indicator, predator index
B. Ecological	Biodiversity	Biodiversity is conserved, maintained, and restored to preserve the structure and natural resilience of aquatic ecosystems	Shannon Diversity Index, Margalef Richness, Heips Evenness, Guild-level biomass
B. Ecological	Non-Target species	Unintended or incidental mortality for all species is controlled	NA for this report
C. Economic	Commercial Fishery	Aquatic resources are managed to foster long term, viable, prosperous and sustainable livelihoods for all users	Landings values

Nested structure
repeated
throughout the
document

Clear links to
source material &
methods

Concise text

A. Pressures and Stressors

Climate and oceanography

The management area is strongly influenced by natural variability of the climate system (e.g., North Atlantic Oscillation) and, therefore, long-term monitoring is needed to determine how anthropogenic climate change is affecting ocean temperatures.

Changes in climate can directly and indirectly impact stock status by affecting the distribution, seasonal timing, physiology, migration and spawning of marine species.

North Atlantic Oscillation Index

[Hebert et al. 2024](#) (see Section 2.1)

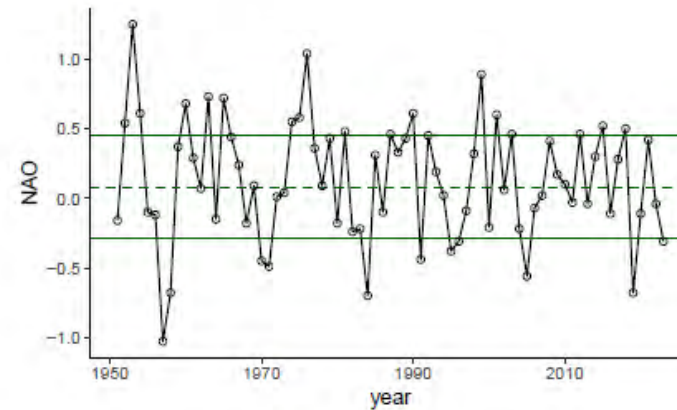


Figure 2: The North Atlantic Oscillation (NAO) index, defined as the winter (December, January, February, March) 500 mb pressure Principal Component Analysis which is representative of the difference between the Icelandic low and Azores high. Climatological mean is shown as the dashed line, solid lines are $\pm$ standard deviation (SD).

- In 2023, the winter (December–March) North Atlantic Oscillation (NAO) index was below the 1991 – 2020 mean, -0.31 (-0.84 SD). A high NAO index corresponds to an intensification of the pressure difference between the Icelandic Low and the Azores High. Strong northwest winds, cold air and sea temperatures, and heavy ice in the Labrador Sea and on the NL shelf areas, are usually associated with a high positive NAO index ([Colbourne et al. 1994](#); [Drinkwater 1996](#)). The opposite response (warm, salty conditions) occurs during years with a negative NAO index ([Petrie 2007](#)).
- The NAO has been shown to strongly affect bottom temperature distributions throughout the region from the Labrador Shelf to the Gulf of Maine ([Petrie 2007](#)). The response is bimodal, the product of direct and advective effects, with positive (negative) NAO generally corresponding to colder- (warmer-) than-normal bottom temperatures over the Labrador-Newfoundland Shelf, the Gulf of St. Lawrence, and the Eastern Scotian Shelf, and warmer- (colder-) than-normal conditions on the Central and Western Scotian Shelf and in the Gulf of Maine.

Reproducible plot



marea: Curated Ecosystem Data for the Maritimes Region

lifecycle experimental R-CMD-check passing codecov 15% DOI 10.5281/zenodo.15706086

`marea` provides curated data sets to support an Ecosystem Approach to Fisheries Management (EAFM) in Canada's Maritimes Region. It offers standardized, analysis-ready time series of oceanographic, environmental, and biological data crucial for research and stock assessment.



Philosophy

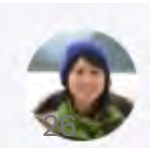
1. **A Single, Simple Data Structure:** All time series data in `marea` are stored in simple and robust `lea` class objects. This provides a consistent, predictable format, whether you are working with temperature, survey indices, or commercial catch.
2. **User-Controlled Plotting:** We provide a basic, clean plot for every dataset. From there, **you are in control**. Because our plots are standard `ggplot2` objects, you can easily customize them, add new layers, and create the exact visualization you need for your analysis or report.

- ❖ Clear data pipelines
- ❖ Very transparent
 - Metadata
 - Quality data
- ❖ Public (github)

[MarEcosystemApproaches · GitHub](#)

How Are Ecosystem Summary Reports Helpful?

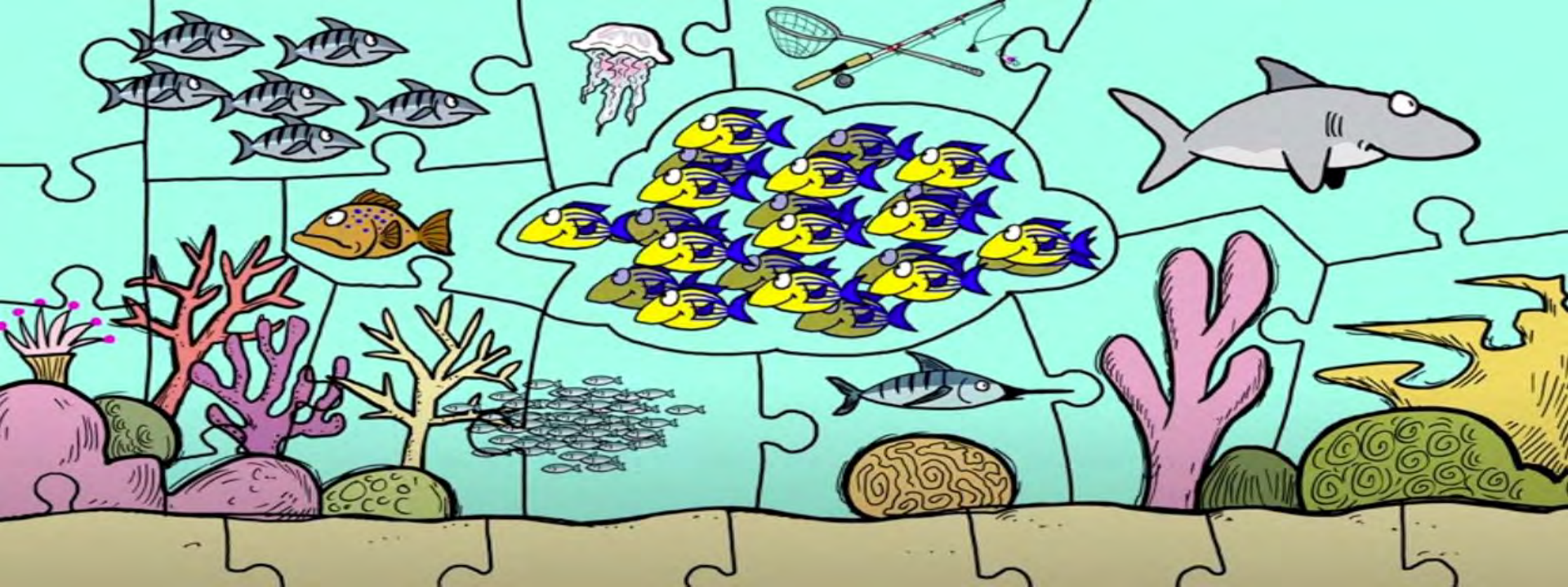
- Developing ecosystem data pipelines that facilitate research (R Package and github)
- Integrates ecosystem context and provides indicators for fisheries assessments (e.g. improving assessment models, secondary indicators).
- Included in Canada's National standardized reporting for fisheries assessments (i.e. Fisheries Science Advisory Reports). Science support documents for decision-making.
- A platform to support evidence-based decision making (e.g. applying risk-based approaches, Integrated Ecosystem Assessment)
- Makes the development of an ecosystem summary less daunting
- Easily identify barriers
- Builds integrative research communities (e.g. multidisciplinary, transdisciplinary)
- Builds logical, long-lasting workflows that can be used by others



Some Parting Thoughts....

- How will the indicators be used?
- Scale Matters – spatial and temporal
- Behaviour and Response -
- Multiple pressures – may not be able to distinguish between different pressures
- Be careful what you wish for!
- Simple is better?

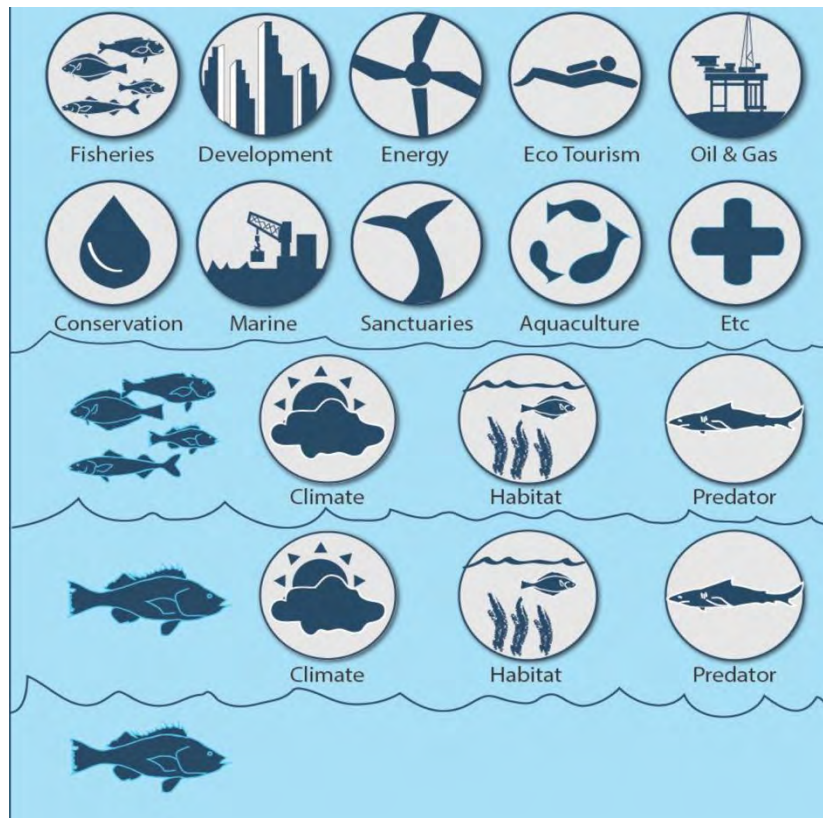
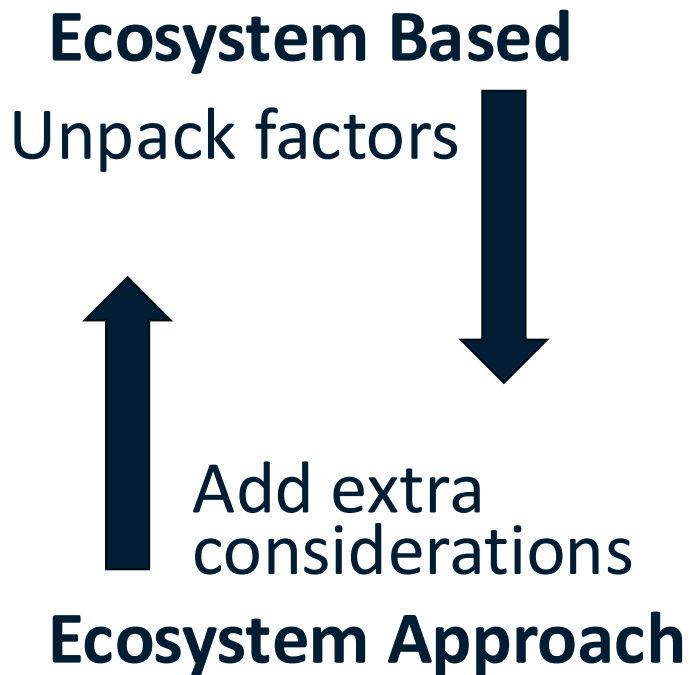




EAFM, EBFM in other jurisdictions

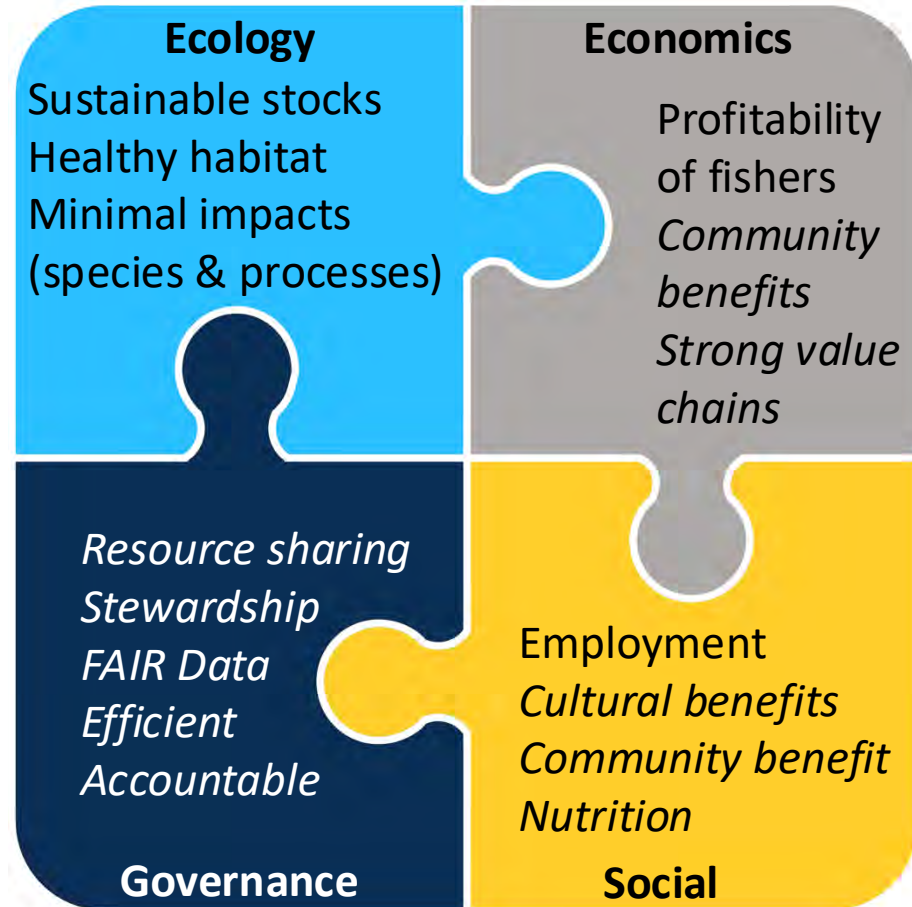
Annex 6

Beth Fulton



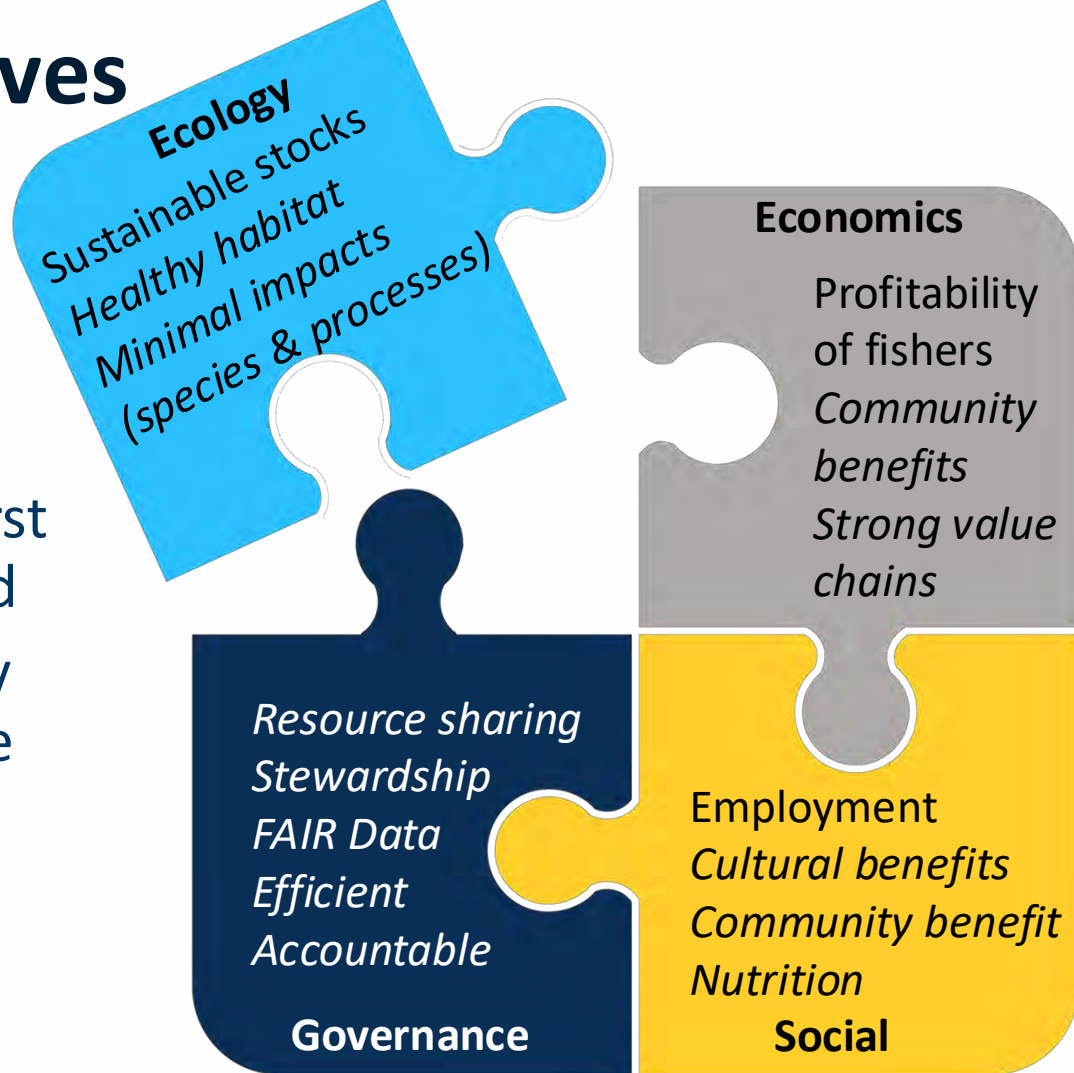
CSIRO Objectives

- International & national policy (and laws) cover natural and human dimensions in intent



CSIRO Objectives

- Ecology has dominated
 - background of first scientists engaged
 - path dependency of processes since



CSIRO Focus of disciplines

Short term/Tactical

- Sustainable stocks
- *Economic return*
- *Employment*
- *Food*

Long term/Strategic

- Sustainable stocks
- Healthy predators and prey
- Intact habitats
- Economic health
- Employment
- Cultural needs
- Food supply

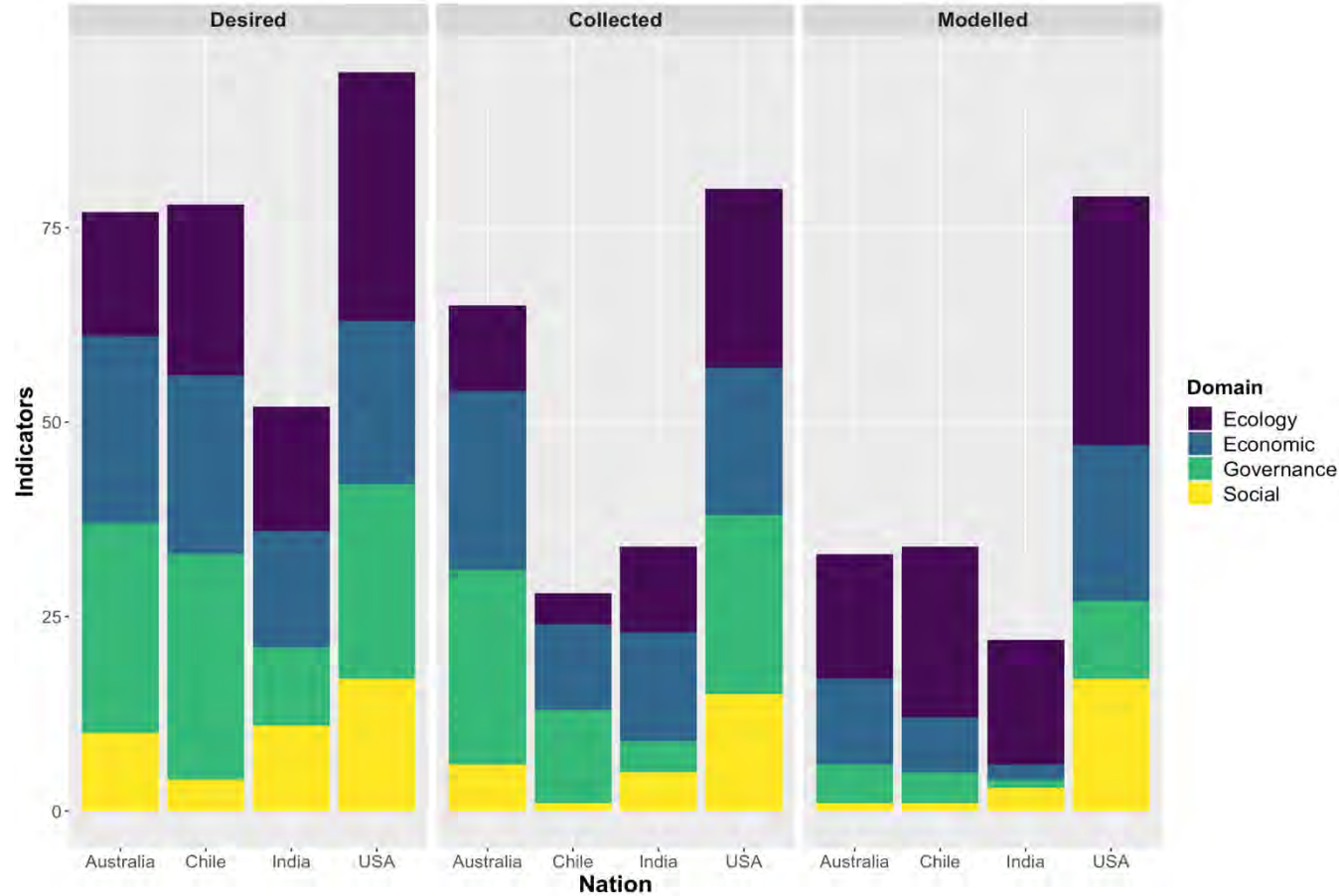


CSIRO What Managers Care About

- Survey of managers (multiple countries):
 - catch (amount & composition)
 - fleets (size and composition)
 - Effort
 - CPUE
 - value & costs
 - biomass
 - fishing mortality
 - impacts (habitat, other species)
 - compliance
 - access & *dependence*
 - *nutrition*
- 100s of proposed indicators managers care about <10%
- Context dependent priorities (within & across dimensions)

CSIRO What Is Collected

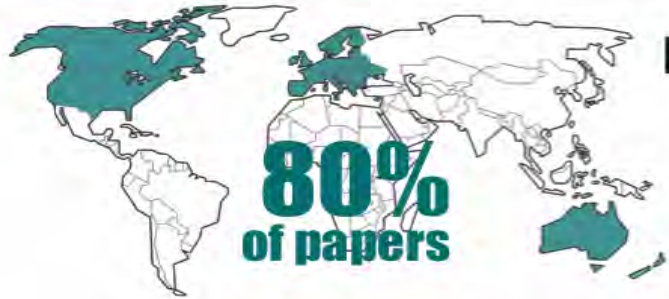
- Collect 25-90% of desired info
- Model even less
- Especially want more social and governance attention than science supplies (data and models)



CSIRO Indicators – Human Dimensions

134 Papers

Indicators **57** Objectives **60**



Objectives and indicators not linked

181 Indicators

Mainly to do with:

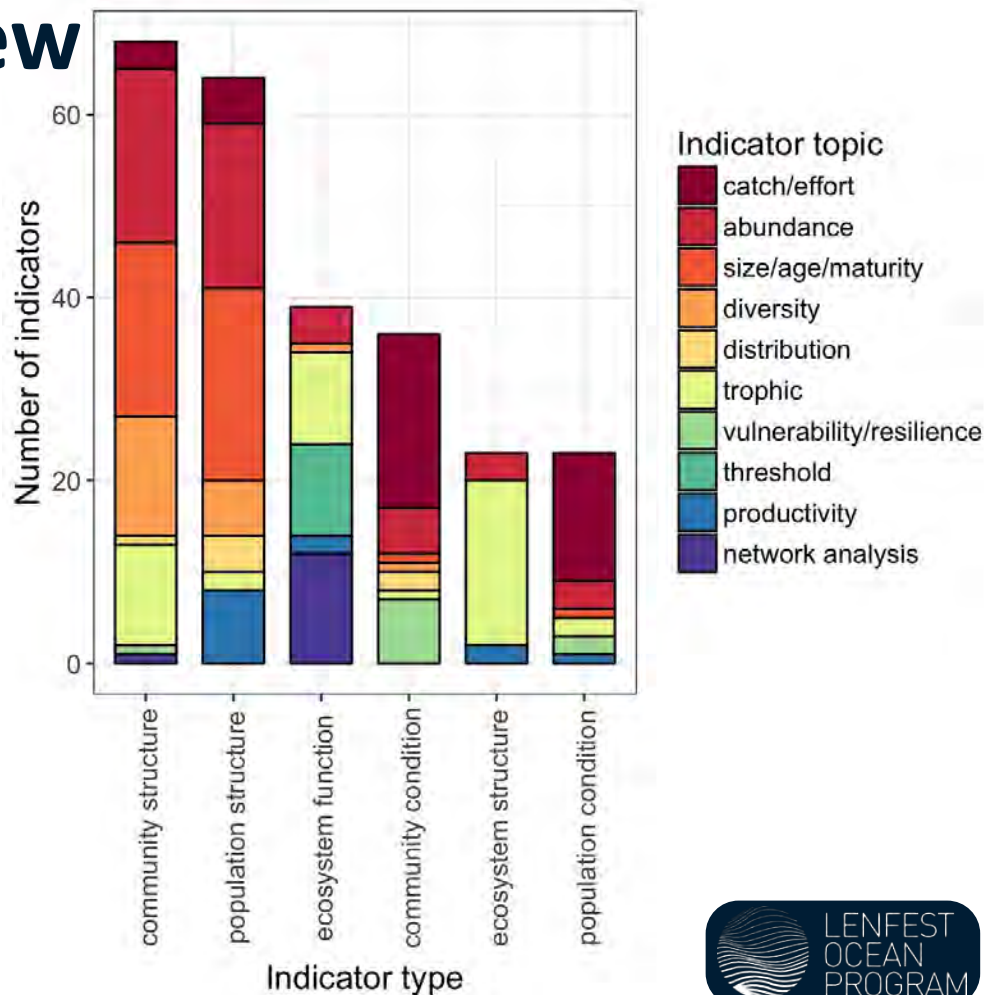


Economic indicators dominate

Governance indicators get least attention

CSIRO Indicator Review

- Few common indicator types per topic:
 - **population & community structure:** indicators = abundance, size/age/maturity and diversity
 - **population & community condition:** indicators = catch/effort
 - **ecosystem function:** indicators = trophic, threshold & network analysis
 - **ecosystem structure:** indicators = trophic, biomass ratios



Options to support EBFM

DATA

METHOD

USE

Catch and ocean colour

Simple indices of catch vs primary production (Link & Watson 2019)

Upper bound on catch

Catch composition

Catch composition through time

Understand change

Catch composition and food web information

Cumulative biomass vs TL

Find ecosystem reshaping

“Green band”

Gao resilience

Hub species

Ecosystem Traits Index

Guide management priorities; check on pressure & system state



CSIRO Fishery Ecosystem Plan



- Goals
- Strategic objectives
- Operational objectives
- Indicators
- **Reference points**
- Track performance
- Increasing use of ecosystem models for operational advice

THE STRUCTURE AND PROCESS OF FISHERY ECOSYSTEM PLANS





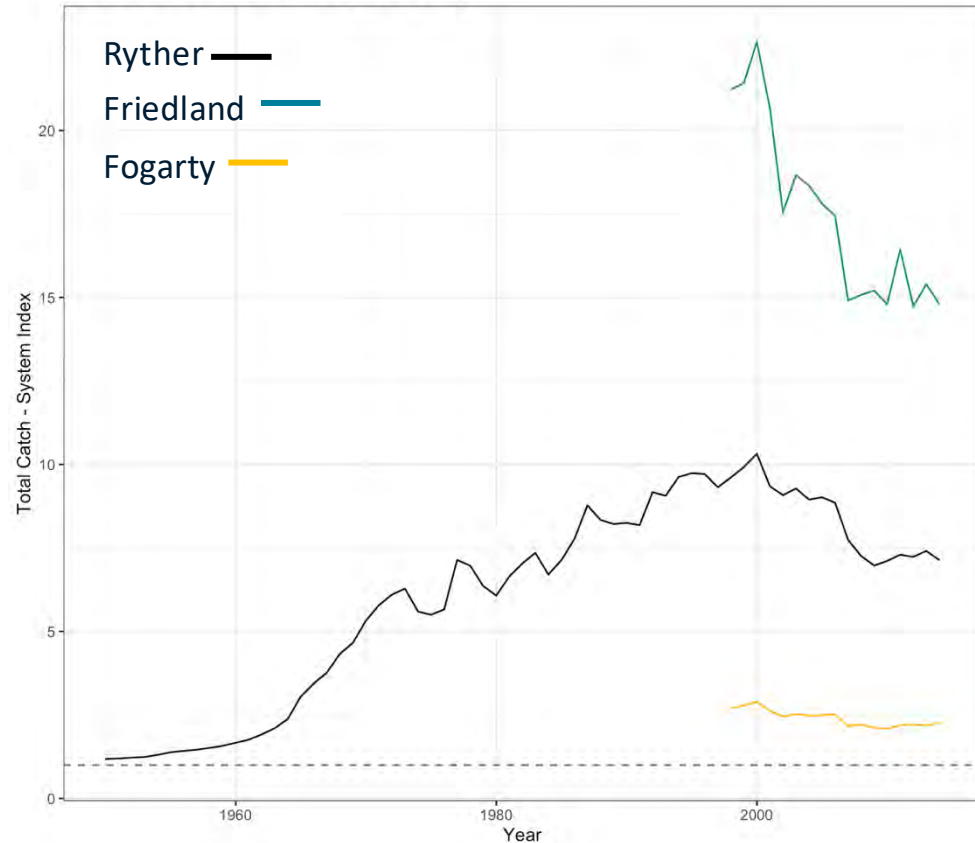
- “Acceptable” total catch levels vs primary production

Tot catch $< 1\text{t km}^{-2}\text{ yr}^{-1}$ (Ryther index)

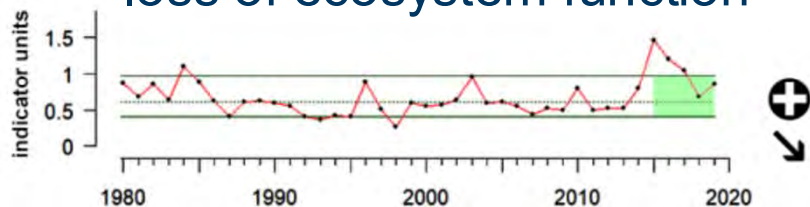
Tot Catch / Tot PP $< 1\text{‰}$ (Fogarty, Friedman indices)

- Ryther (Catch per area)
- Fogarty (Catch / primary production)
- Friedman (Catch / Chlorophyll)

Total Catch Gulf of Thailand (1950-2015)



- When pressure on the ecosystem leads to depletion, restructuring, loss of ecosystem function



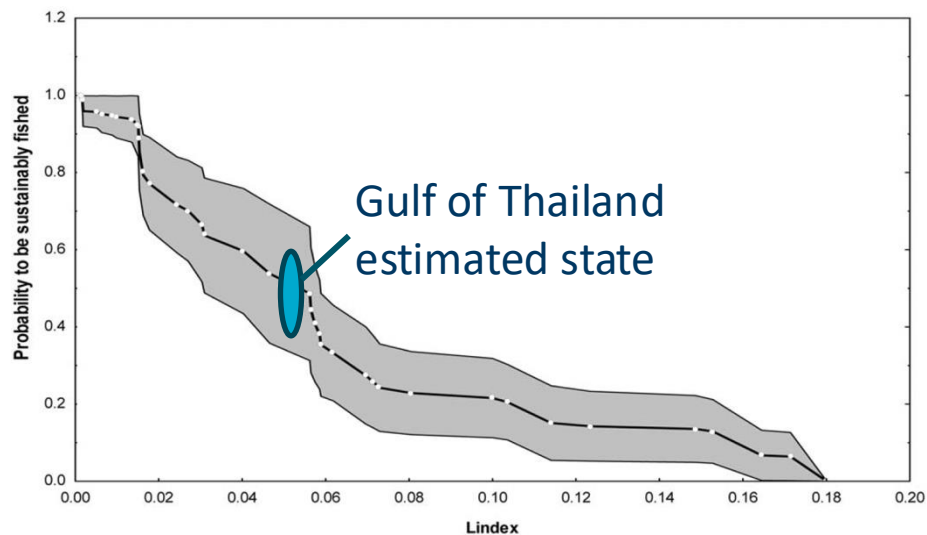
-- median indicator value — 90th (upper line) and 10th (lower line) percentile values

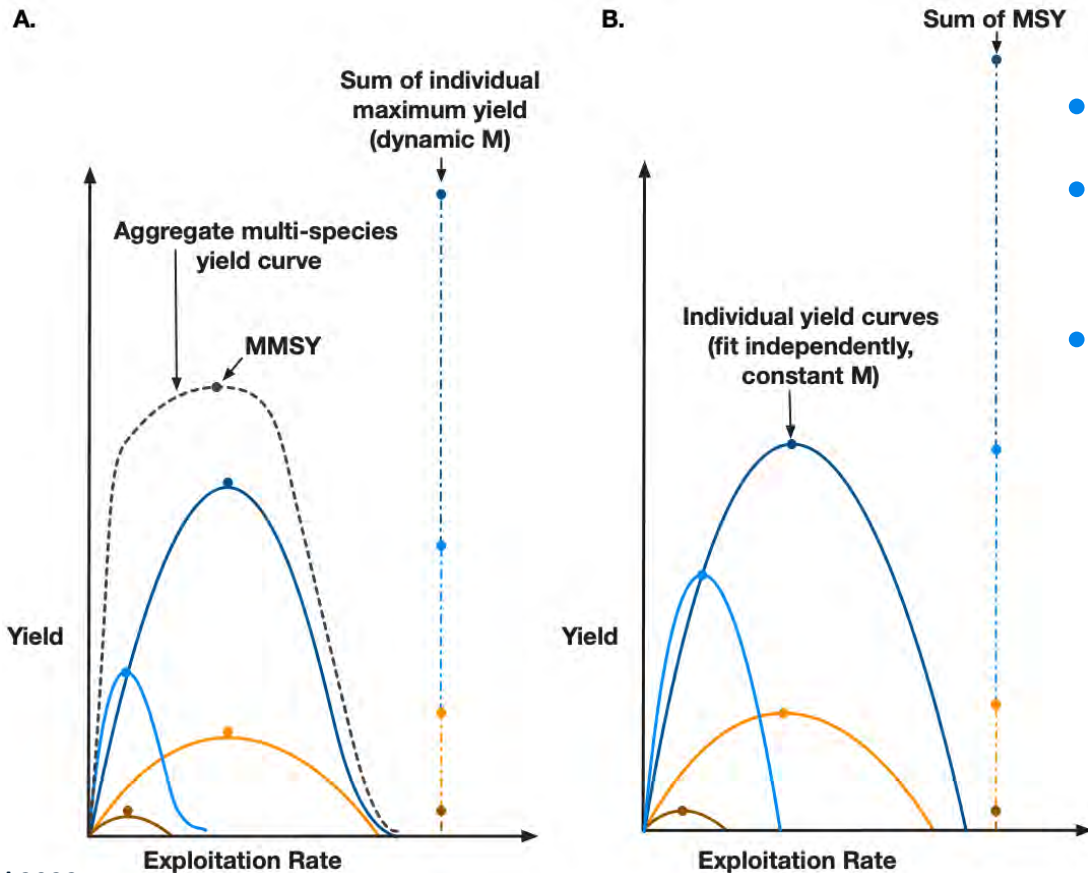
evaluation period

recent trend analysis

- | | | | |
|--|--|--|---------------------------|
| | above 90 th percentile | | slope greater than 1 S.D. |
| | between 10 th and 90 th percentile | | no trend |
| | below 10 th percentile | | slope less than 1 S.D. |

- Often uses ecosystem model based calculation and testing

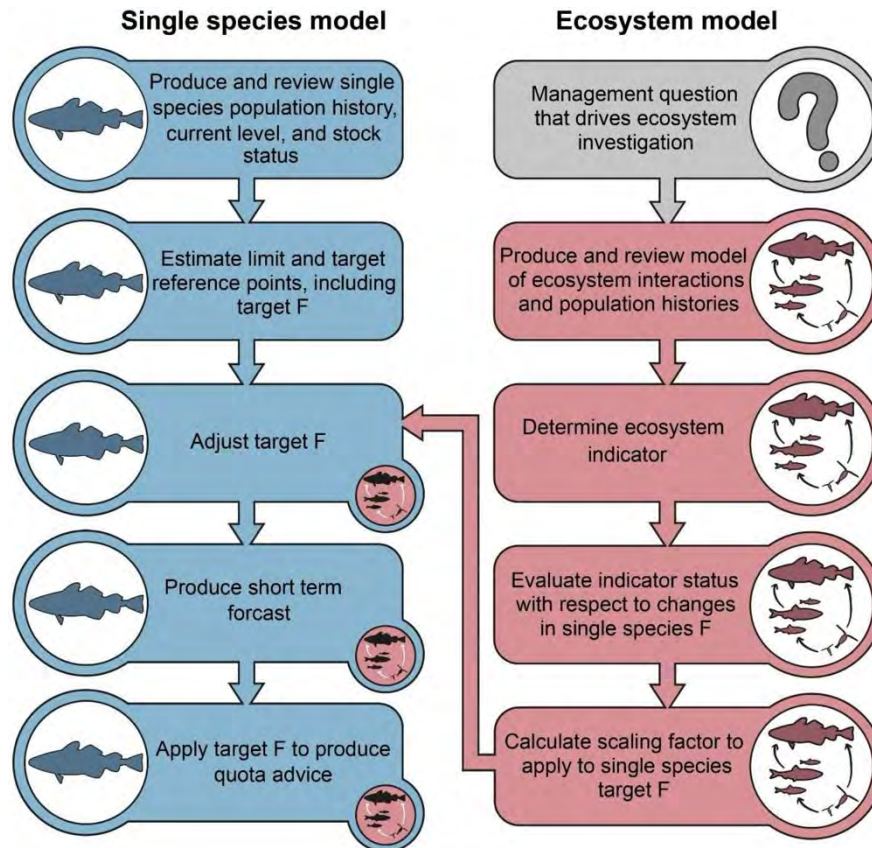




- North Pacific
- Total catch cap (now) set based on MMSY
- When $\text{sum}(\text{quota}) > \text{MMSY}$ then decide which species to catch less of to ensure $\text{sum}(\text{catch}) \leq \text{MMSY}$



- Use ecosystem or multispecies models to “double check” single species results
- e.g. Feco (reset target F based on ecosystem interactions)
- Modify assessment parameters based on multi-species model/data



CSIRO Ecosystem As Context

- Ecosystem context informs production estimates & reference points
- Ecosystem indicators guide whether things “on track”
- Risk table so systematic way of presenting context (and adjusting decisions accordingly)

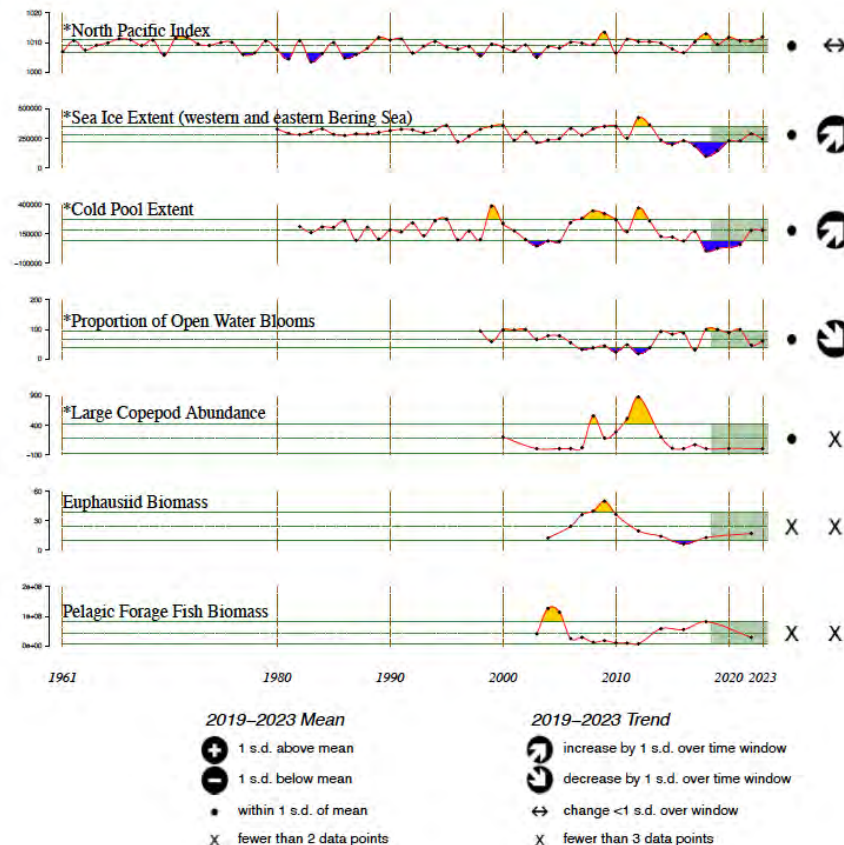


- Assessment
 - Bias, Model fits, Estimation uncertainty
- Population & Community
 - Stock or Recruitment changes, Biomass trends
- Environment & Ecosystem
 - Productivity, Fish condition, Phenology, Habitat, Blooms
- Fishery performance:
 - CPUE trend vs biomass trend
 - Changes in grounds, composition, closures

CSIRO Report Cards

- US status reporting
- Uses available information
 - 250 pg report
 - 2 pg report card
 - Easy read summary
- Informal context setting for decision making

Eastern Bering Sea 2023 Report Card





- Transparent, consistent and rigorous use of ALL information into decision making using risk tables
- Assessment report for each target species must rate:

Table 1. Risk classification table for assessment, population dynamics, and environmental/ecosystem considerations.

	Assessment-related considerations	Population dynamics considerations	Environmental/ecosystem considerations
Level 1: Normal	Typical to moderately increased uncertainty; minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns.
Level 2: Substantially increased concerns	Substantially increased assessment uncertainty or unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing an adverse signals but the pattern is not consistent across all indicators.
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level, and/or b) up or down trophic levels (i.e., predators and prey of stock)
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented. More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock. Potential for cascading effects on other ecosystem components.



2023 Eastern Bering Sea Ecosystem Status Report:

IN BRIEF

Current Conditions

The eastern Bering Sea has experienced multi-year periods of warm or cold conditions of varying durations since 2000. The recent warm stanza (2014–2021) was unprecedented in magnitude and duration with the near-absence of sea ice during two winters (2017/18 and 2018/19). The following summers (2018 and 2019) had dramatically reduced cold pool extent (areas of cold bottom waters).

Groundfish and crab stocks shifted their distribution in response to changes in sea ice and cold pool extent. Some stocks experienced increased recruitment during the warm stanza: sablefish, Togiak herring, and Bristol Bay sockeye salmon. Conversely, some stocks experienced declines: snow crab and Bristol Bay red king crab, and multiple Western Alaska salmon runs.

Since 2021 conditions have cooled. Ocean temperatures and cold pool extent were near historical average in 2023, though the cold pool was significantly smaller than the large extents that were common prior to 2010. More broadly, the North Pacific is also undergoing a transition from three consecutive years of La Niña conditions to predicted El Niño conditions by early 2024. Marine life, like zooplankton and fish, have lagged in their expected response to these cooler conditions. Ecologically, the eastern Bering Sea remained in a transitional state in 2023.



NOAA
FISHERIES

Alaska Fisheries
Science Center

Ecosystem Impacts

The southeastern and northern Bering Sea (divided at 60°N) have different oceanographic and zoogeographic characteristics. An assessment of the ecosystem response to the recent transitional state (since 2021) and current 2023 status in the ecoregions is provided.

Southeastern Bering Sea

Winter 2022/2023 was on the warmer side while summer 2023 was cooler. Sea-ice advance in the winter was delayed due to warmer conditions, but spring ice melt-out occurred near the historical date. **Sea ice** did eventually reach as far south as St. Paul Island in 2023, providing a source of freshwater as ice melted at the ice edge, reversing a trend of **increasing salinity** during the recent warm stanza.

Chlorophyll-a, the base of the food chain, has generally been decreasing and 2023 was among the lowest levels across the shelf. Meanwhile, **coccolithophore blooms** (generally not considered a positive sign of ecosystem productivity) have been more prominent since 2017 with 2023 being the largest bloom. In spring 2023, a moderate amount of **small copepods** were available, but **large copepods and euphausiids** were scarce. In fall, the moderate abundance of small copepods continued, and the abundance of large copepods and euphausiids remained low, but increased from south to north. The abundance of **jellyfish** – potential competitors for zooplankton prey – was average in 2023, representing no significant change in competitive pressure.

The effects of water temperature and prey availability are evident in the indicators of pelagic fish condition, which were mixed in 2023. **Age-0 pollock**, the numerically dominant forage fish, as well as juvenile and adult pollock showed continued declines in fish condition in 2023. Togiak herring and Bristol Bay sockeye salmon biomass remained high. Seabird reproductive success was mixed with birds on St. George Island having higher success than birds on St. Paul Island.

The benthic habitat showed mixed responses following the recent warm stanza. There were continued declines in habitat disturbance by fishing gear. The biomass of some epifauna (e.g., anemones and sea whips) increased in 2022 and 2023 yet sponges have shown a steady decline since 2015. **Sea stars and brittle stars** continued to have high abundance and biomass while several **crab stocks** showed declines in 2023. Flatfish, like yellowfin sole and flathead sole, that feed on benthic infauna have continued to decrease in abundance, suggesting potential prey limitations. In fact, fish condition declined from 2022 to 2023 for **several flatfish species**: arrowtooth flounder, northern rock sole, yellowfin sole, flathead sole, and Alaska plaice.

Northern Bering Sea

Ecosystem-wide impacts of the loss of sea ice have been observed in the northern Bering Sea (NBS). Northward shifts in the distribution of groundfish species and concerns about the food web dynamics and carrying capacity have existed since 2018. However, since 2021, the NBS ecosystem has also been transitioning to more average conditions. Sea surface temperatures have cooled. Marine life has experienced lower metabolic stress.

Chlorophyll-a has been decreasing over the northern shelf, and 2023 was among the lowest levels. In fall, small copepods were present and increased in abundance from south to north. Hot spots of large copepods and **euphausiids** were observed around St. Lawrence Island. The abundance of **jellyfish** increased over the NBS shelf.

Integrated indicators of the pelagic environment were mixed for the NBS in 2023. Adult pollock condition was the highest observed during the bottom trawl survey since 2017, yet juvenile pollock condition has decreased since 2021. Observations from St. Lawrence Island indicated that seabirds, like **crested auklets**, did well in 2023. Western Alaska **salmon** runs have experienced precipitous declines in recent years. This is largely attributed to ecosystem conditions experienced in both the freshwater and marine residency phases. However, slight increases were observed in juvenile Chinook and chum salmon indices in 2023.

Fewer metrics of benthic habitat condition are currently available for the NBS. Those available for 2023 were mixed, but largely showed declines. Trends in anemones show low biomass in 2023. Sponges are more variable and biomass was moderate in 2023. Indirect measures of benthic productivity show continued low biomass of eelpouts in 2023 and continued declining trend in poachers since 2017. The condition of **yellowfin sole** decreased to its lowest level and Alaska plaice condition remained just below the time series average in 2023.

The prevalence of **harmful algal blooms** (HABs) in marine food webs of the NBS are important indicators of ecosystem health and of potential threats to wildlife and human health. Recent oceanographic changes have made conditions more favorable for HAB species. Dedicated research has documented HABs in the Bering Strait and this trend will continue to be monitored.

What do the indicators tell us this year?



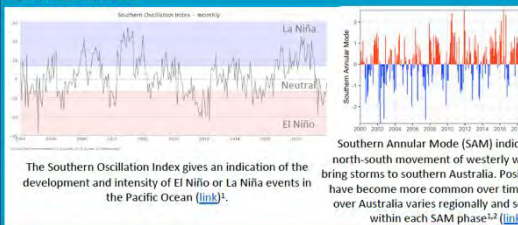
CSIRO Assessment Supporting Information

- Report cards (current vs historical; projections)
- Plankton trends
- Stock exposures > preferred temperatures
- System level indicators
- Analogous years
- Pre-caution warnings
- Data collection priorities

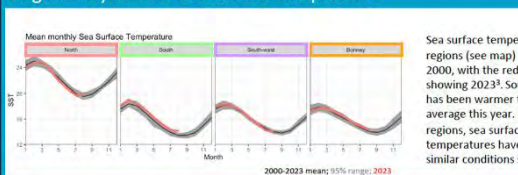
Climate & Ecosystem Status Report Southern & Eastern Scalefish & Shark Fishery November 2023

Historical Period

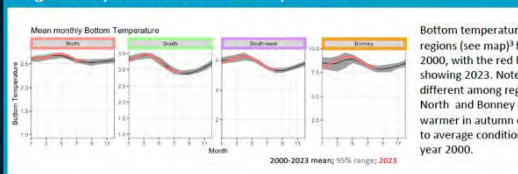
Climate Drivers



Regional Dynamics: Sea Surface Temperature



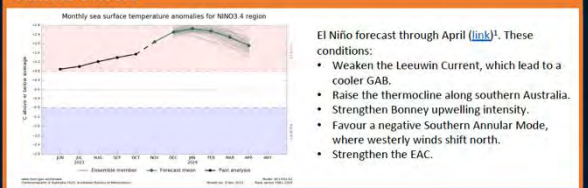
Regional Dynamics: Bottom Temperature



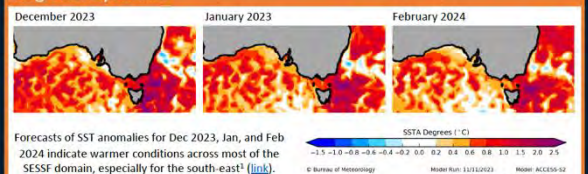
Climate & Ecosystem Status Report Southern & Eastern Scalefish & Shark Fishery November 2023

Future Outlook for 2023-2024

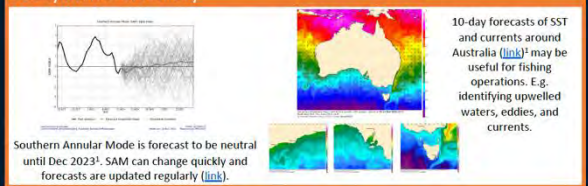
Climate Drivers



Regional Dynamics



Ecosystem and Fishery



Sources: BOM¹ NOAA² CMEMS³ IMOS⁴ CSIRO⁵

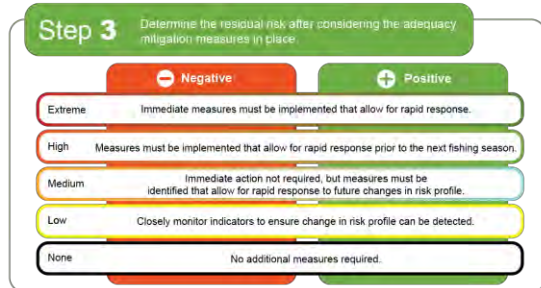
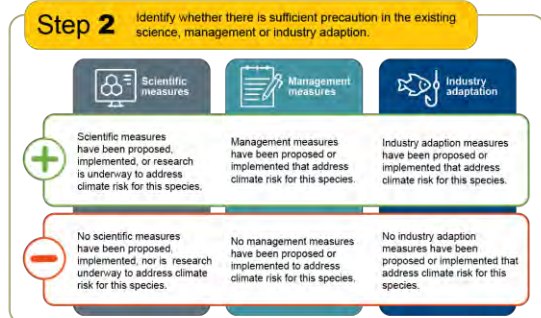
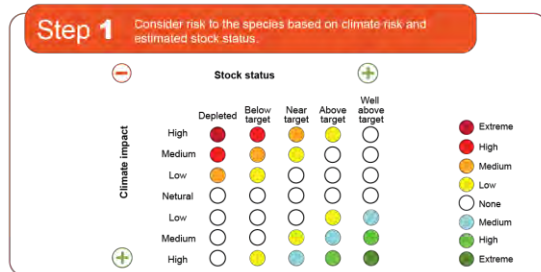
Management Example: AFMA Climate Risk Framework

Step 1 Consider risk to the species based on climate risk and estimated stock status.

Step 2 Identify whether there is sufficient precaution in the existing science, management or industry adaption.

Step 3 Determine the residual risk after considering the adequacy mitigation measures in place.

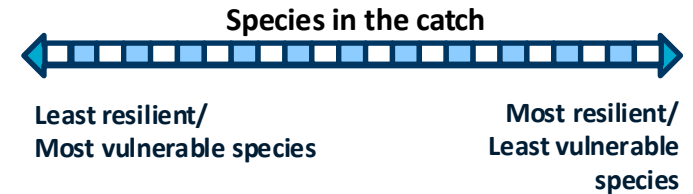
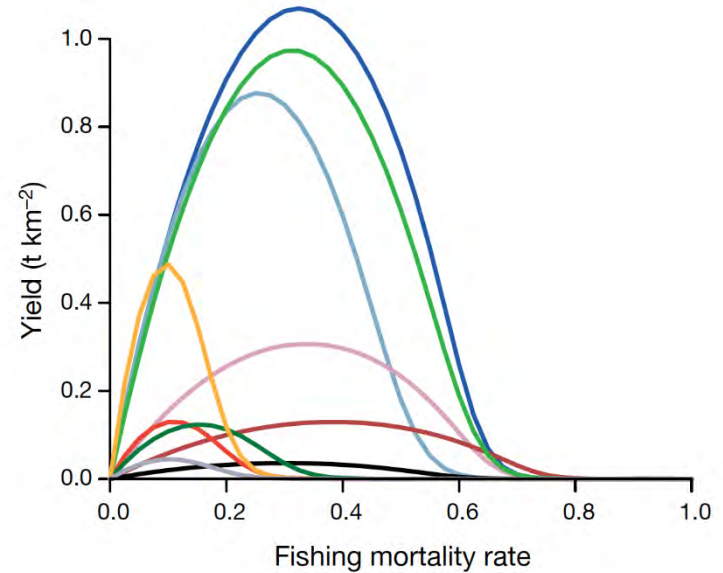
Step 4 Provide advice to the AFMA Commission on any additional measures required to respond to climate risk.



CSIRO Multi-Species Harvest Strategy



- Ecosystem context informs production estimates & reference points
- Ecosystem indicators guide whether things “on track”
- Check proposed fishing levels (e.g. vs green band)
- Tier assessments, companion species
- Indicator species-based harvest strategy



CSIRO Indicator Species – Respect Structure



- Use “management determining” species (3-4 per class of species)

Least resilient/ Most vulnerable species

- Likely overfished
- Monitor to ensure not excessively depleted
- Additional protection measures needed
- **TARGET:** None
- **LIMIT:** Avoid overfishing
($B > B_{LIM}$)

Target species in the catch

- Optimise yield
- Management, monitoring & stock assessment focused on these species
- **TARGET:** $B > B_{MSY}$ (e.g. B_{MEY})
- **LIMIT:** Avoid overfishing
($B > B_{LIM}$)

Most resilient/ Least vulnerable species

- Likely underfished
- Monitor to confirm expected stock status
- May have opportunity for increased pressure
- **TARGET:** $B > B_{MSY}$ (e.g. B_{MEY})
- **LIMIT:** Avoid overfishing
($B > B_{LIM}$)

Hub species

- Ecologically Significant
- Monitor to confirm expected stock status
- Take care not to deplete
- **TARGET:** $B \gg B_{MSY}$
- **LIMIT:** Avoid overfishing
($B \gg B_{LIM}$)

Pros and Cons

METHODS:

Qualitative

Quantitative



Use available data

Fast

Fewer resources / costs

High uncertainty

Needs precautionary buffers

Only some data types
needed

Moderate costs and time

Strong assumptions

Intermediate uncertainty

Buffers required
(especially for some
endangered species)

Need specific data

Slower

High resources / costs

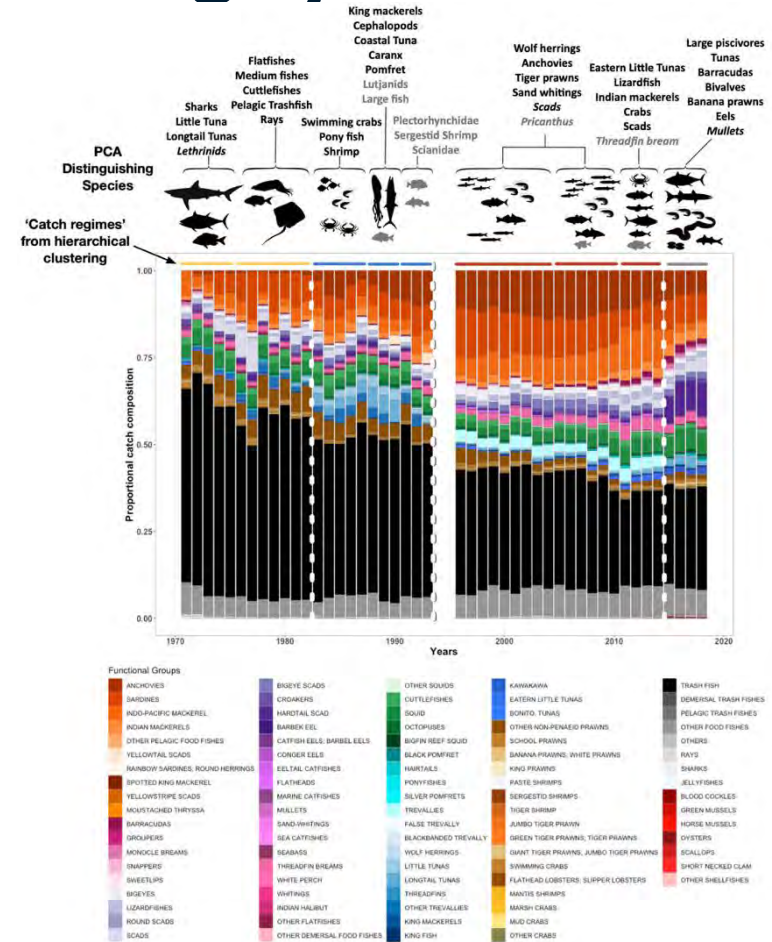
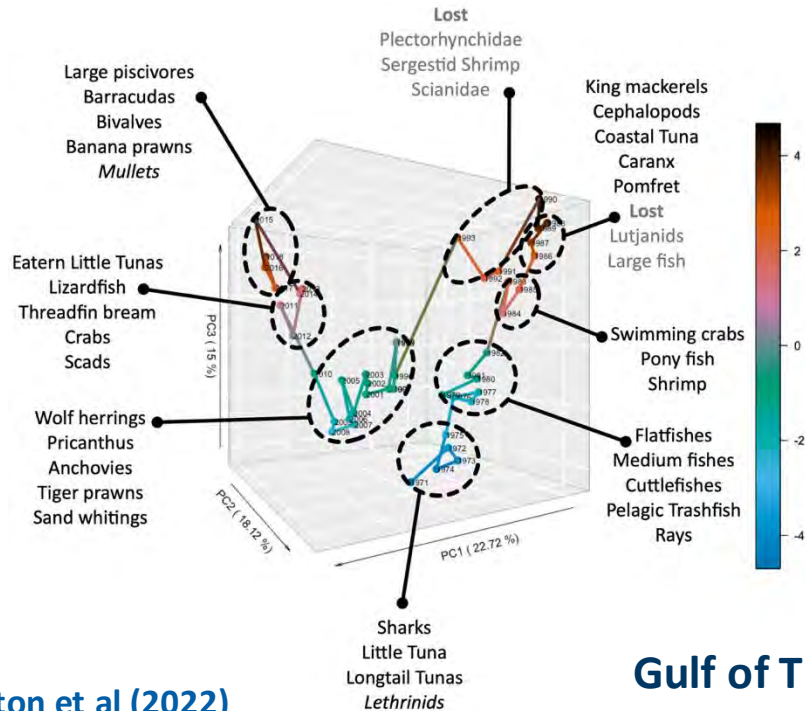
Lower uncertainty

Less buffers required

- Best if explicitly linked to indicators and targets & use risk framework

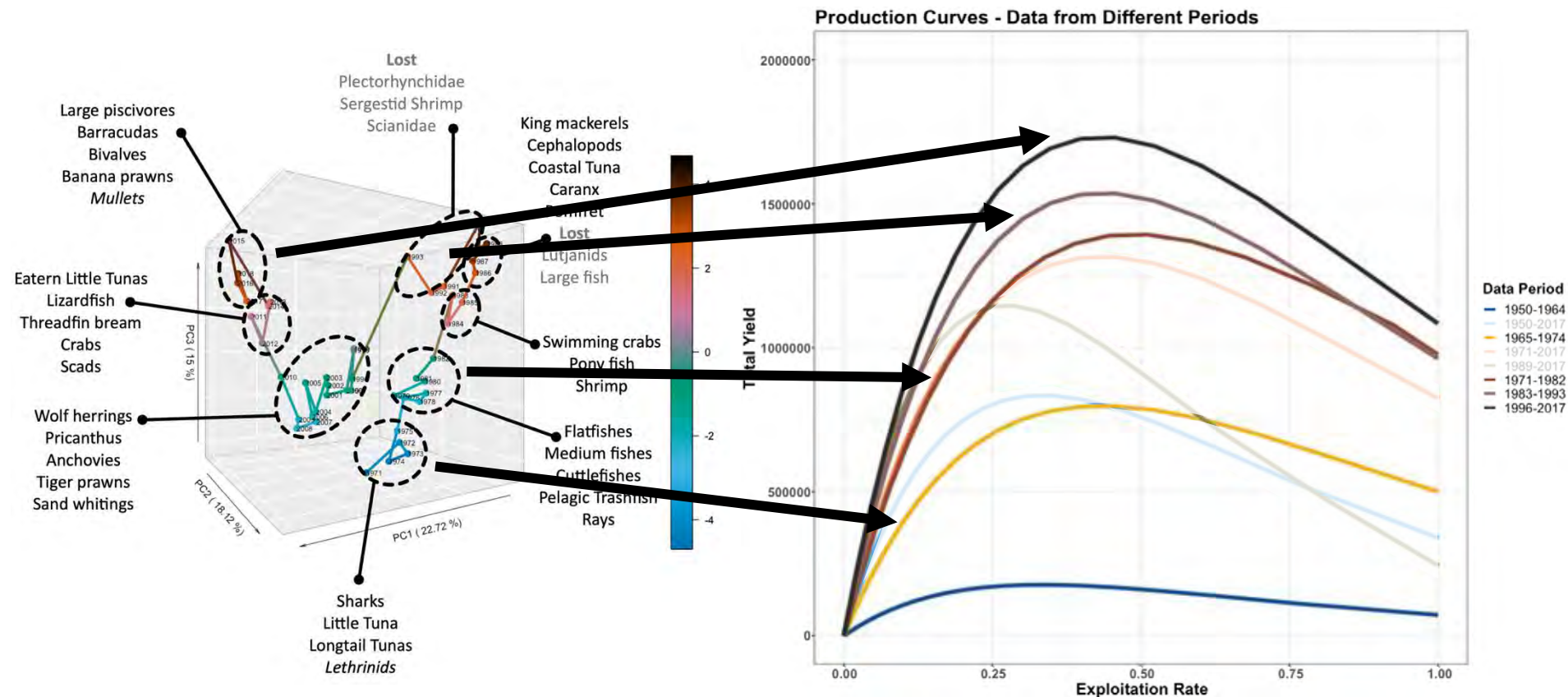
CSIRO Thailand: understanding system

- Provide system understanding of change (drivers & transitions)
- PCA on survey or catch composition

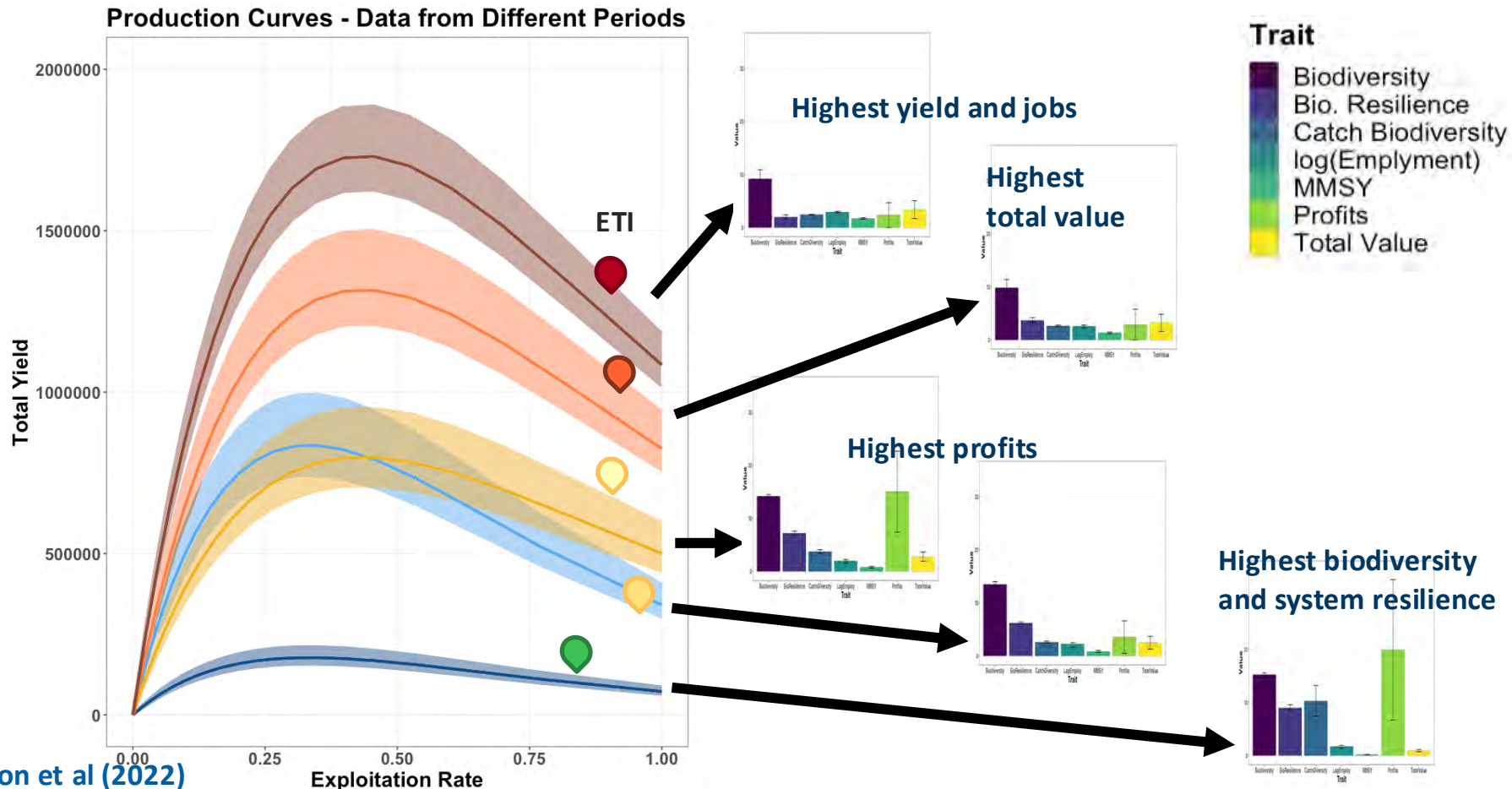


Gulf of Thailand

CSIRO Trade-offs between system states

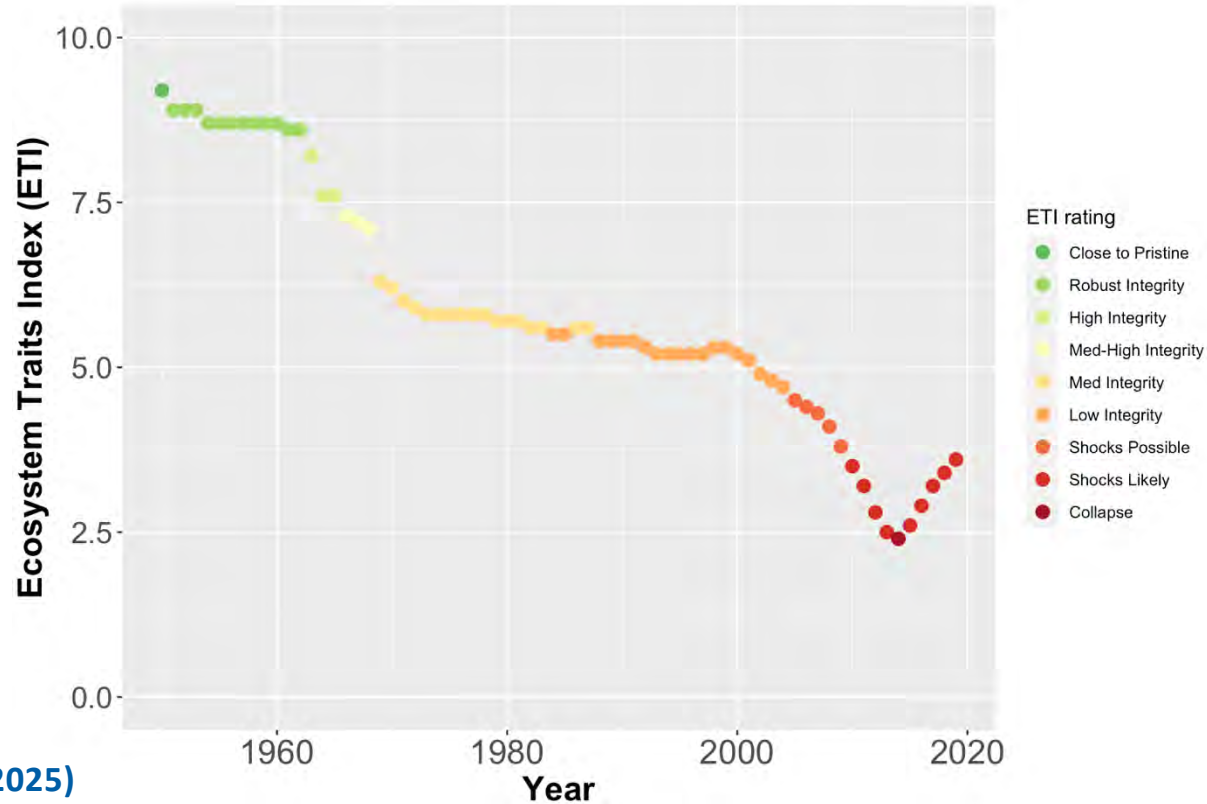


CSIRO Trade-offs between system states



CSIRO Ecosystem Traits Index

- Responsive through time (and can be used in forecast mode)

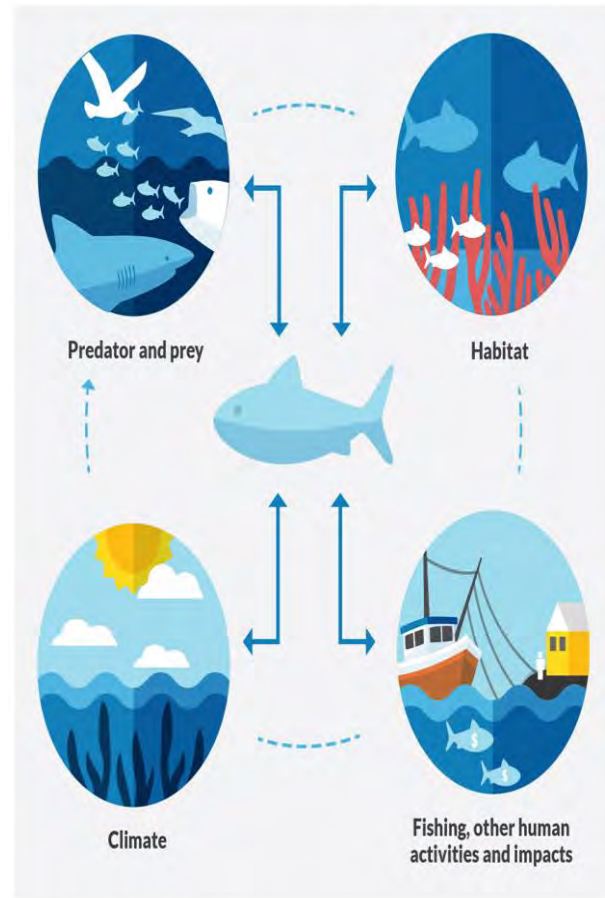


CSIRO Thailand: starting harvest strategy

- Proto single-multi-species & EAFM harvest strategy designed

INDICATOR TYPES	PERFORMANCE MEASURE	RESPONSE	COMBINED RULES
Multispecies groups			
BIOMASS ESTIMATE (multispp) and FMMSY - aggregate production model	$B > \text{target}$ → Not overfished $\text{Limit} < B < \text{target}$ → Not overfished $B < \text{limit}$ → Overfished	Not overfished & No overfishing → No change required (increase in effort may be possible) Not overfished & Overfishing → 5% reduction in effort	Effort state (and change) after Multispecies rules
	$F_{\text{current}} > F_{\text{MMSY}}$ → Overfishing occurring $\text{Current} < F_{\text{MMSY}}$ → Not overfishing	Overfished & Not overfishing → 20% reduction in effort Overfished & Overfishing → 50% reduction in effort	
EMMSY	$\text{Effort} > \text{EMMSY}$ $\text{Effort} < \text{EMMSY}$	Excessive effort → Reduce effort back to EMMSY Effort acceptable for this criteria → No additional change required	
Indicator species			
Individual single species BIOMASS ESTIMATE - single species production model - length based assessment	$x\% \text{ species} > \text{target}$ → 20% increase in effort $\text{All species} > \text{Limit}$ → No change $1-5 \text{ species} < \text{Limit}$ → Further 5% decrease in effort $5-10 \text{ species} < \text{Limit}$ → Further 10% decrease in effort $> 10 \text{ species} < \text{Limit}$ → Further 20% decrease in effort		Any further reduction in effort Potentially additional spatial and gear management changes
	These criteria could be applied - Spatially (if area specific)	If spatial and species < limit criteria met then - close the relevant area (will need to have a rule for how long or what criteria must be met to re-open the area) - OR set spatial incentives (which must be negotiated with fishers before the harvest strategy is finalised), for example: $1-5 \text{ species} < \text{Limit}$ → 5 day penalty per day fished in that region $5-10 \text{ species} < \text{Limit}$ → 10 day penalty per day fished in that region $> 10 \text{ species} < \text{Limit}$ → 20 day penalty per day fished in that region	
	- Or gear specific	Change gear so avoid targeting of relevant species	
Ecosystem			
Respond to ALL that apply			
A. Productivity Can also use catch/area, which has the same numerical values as target and limit reference points	$\text{Catch} / \text{Chl} < 1$ → No change $1 < \text{Catch} / \text{Chl} < 3$ → 20% further decrease in effort $\text{Catch} / \text{Chl} > 3$ → 50% further decrease in effort		

- Governments undertake EAFM (EBM may be desire but building off existing legislation)
- Most commonly a combination of monitoring, reports, (informal) links to decision making, spatial and temporal closures
- Most effective when risk-based framework used (so can account for uncertainty in clear and rigorous way)
- More and more use of ecosystem models for operational information
- No one solution – all have benefits and costs and system specific





Thank you

CSIRO Environment

Beth Fulton

Domain Lead Integrated Ocean Stewardship

+61 2 9123 4567

beth.fulton@csiro.au

csiro.au

Australia's National Science Agency

CSIRO

The ICES Framework for Ecosystem- Informed Science and Advice

*Eider Andonegi (AZTI)
(Eirini Glyki, Marie-Julie Roux)*

ICES – an overview

A global
scientific
community

5000

scientists from
nearly **60** countries

1500

active experts
annually

160

working groups
and workshops



Geographic
scope



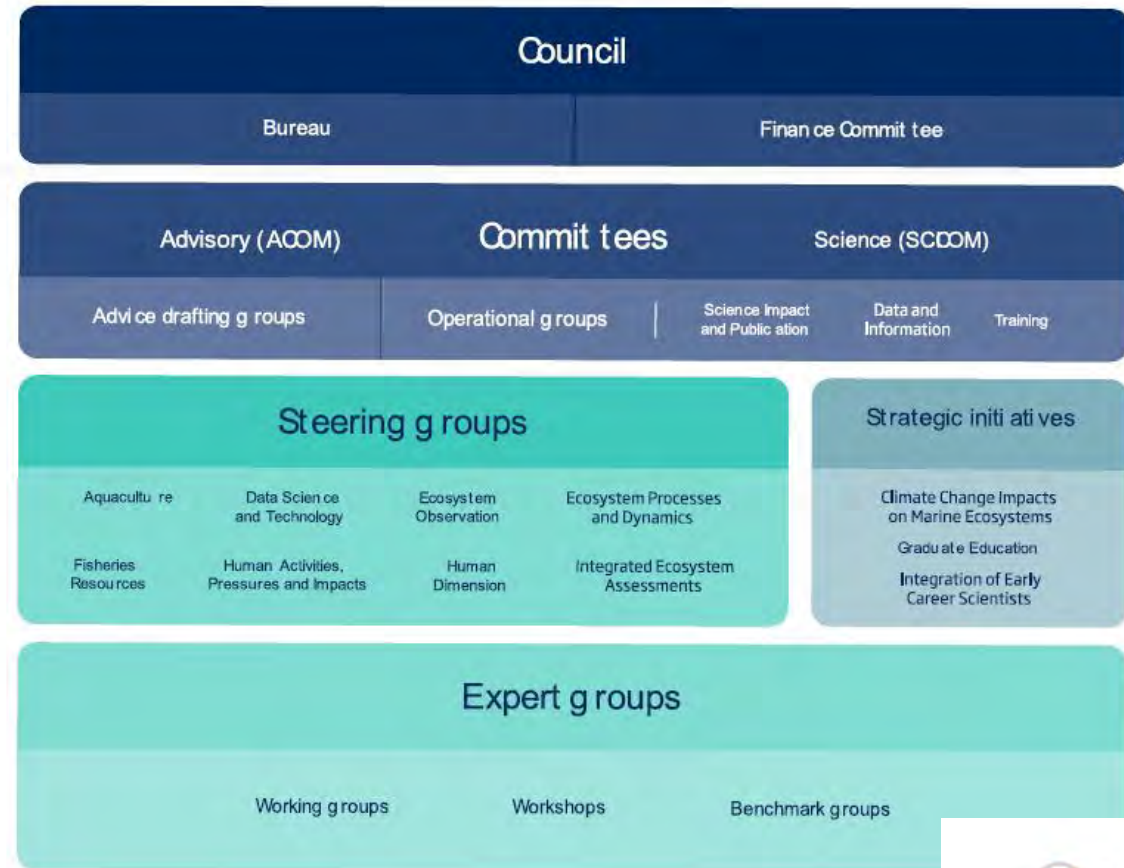
20

member
countries



Strategic
partnerships
globally

ICES organizational structure



Secretariat



ICES advice

...by employing the knowledge of ICES to effectively meet the societal needs for impartial evidence, and to generate state-of-the-art advice on meeting conservation, management and sustainability goals.

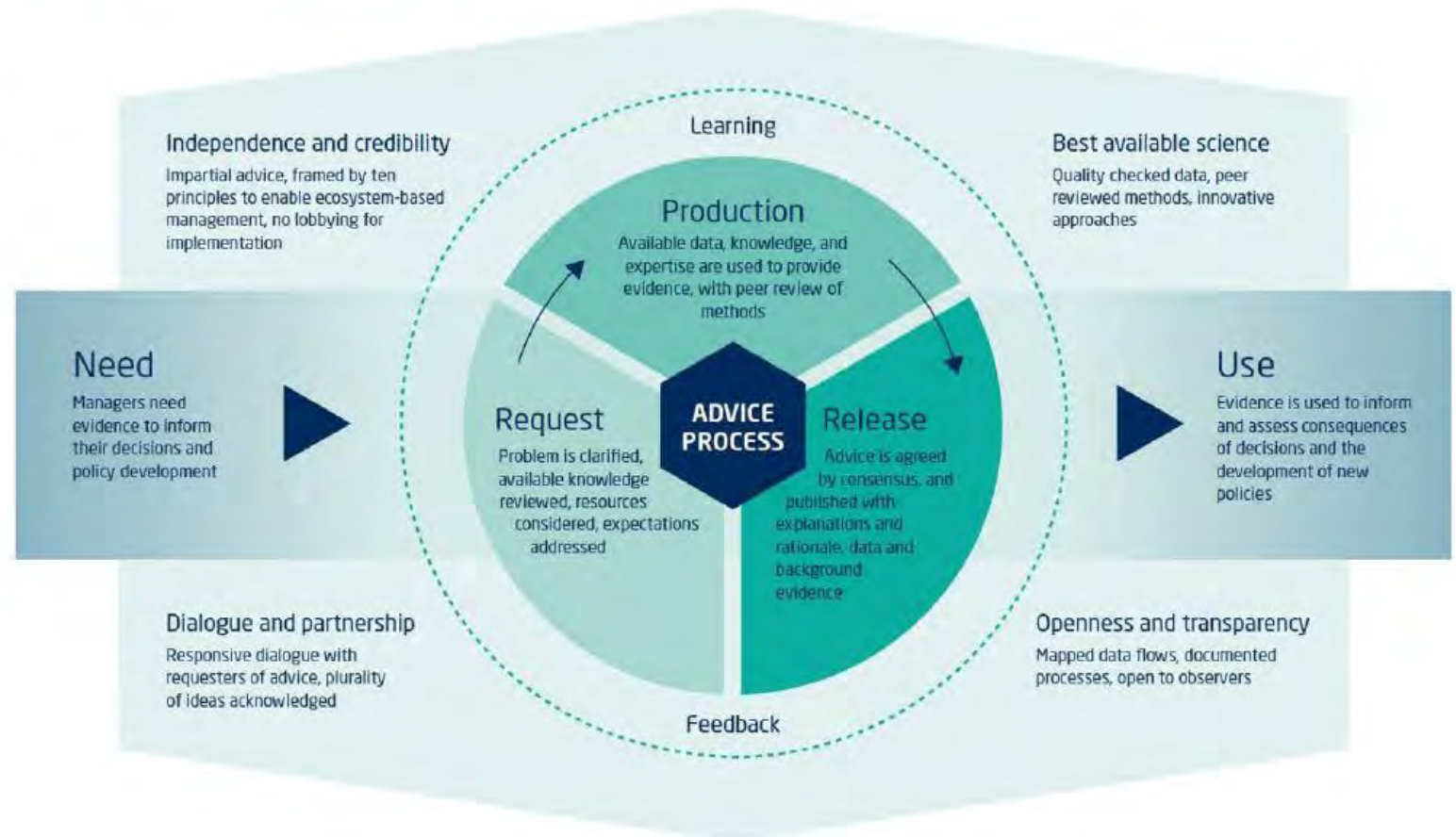
ICES Advice Recipients

ICES provides advice to international organizations and its Member States



ICES Advisory Framework

Document openly,
transparency across the
entire process



Advice Principles



Stakeholder Engagement Strategy



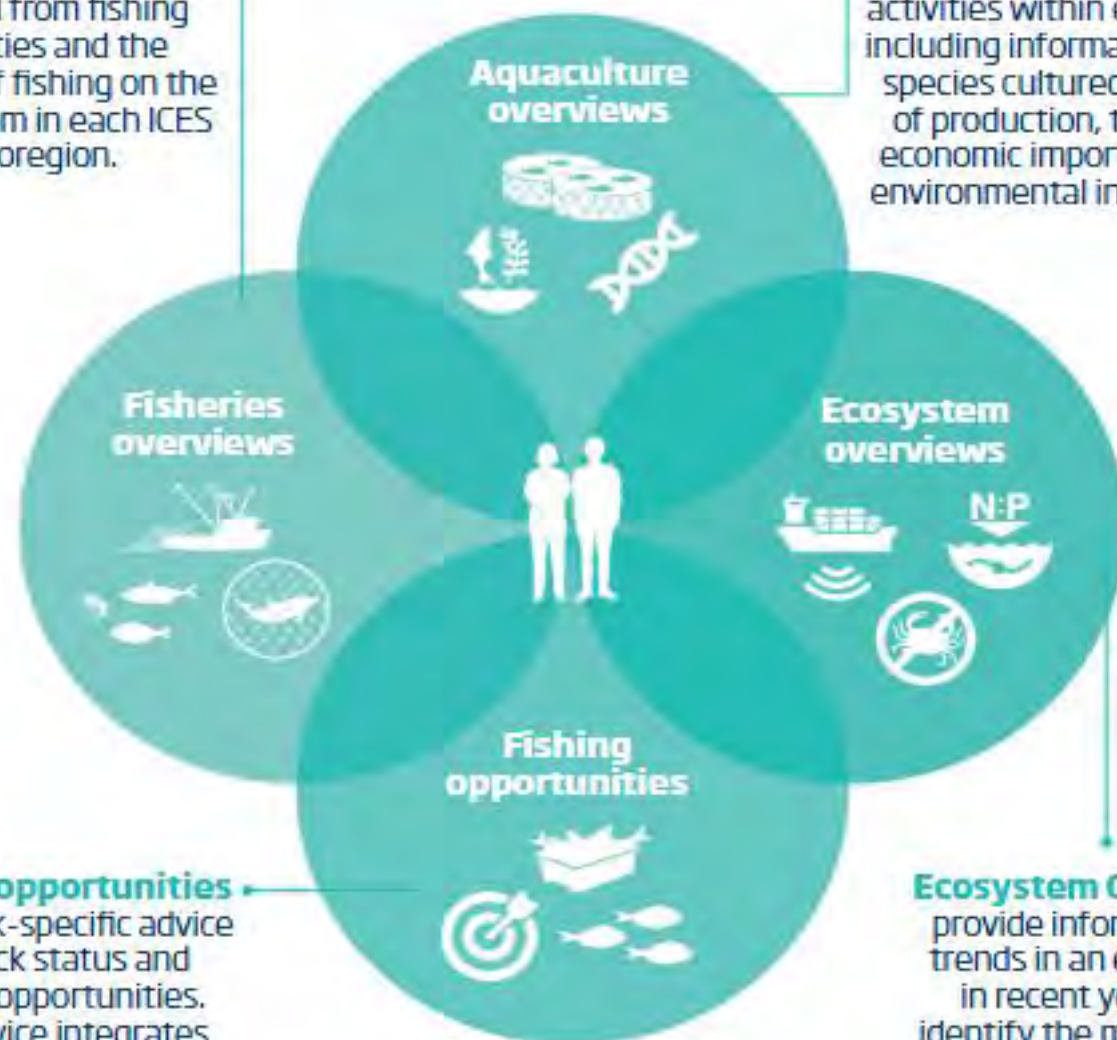
Guidelines on request formulation



Advice for decision-making

Fisheries Overviews summarize the services derived from fishing activities and the effects of fishing on the ecosystem in each ICES ecoregion.

Aquaculture Overviews summarize aquaculture activities within ecoregions, including information on the species cultured, the level of production, the socio-economic importance, and environmental interactions.



Fishing opportunities give stock-specific advice on stock status and fishing opportunities. This advice integrates the precautionary approach, with the objective of achieving maximum sustainable yield (MSY).

Ecosystem Overviews provide information on trends in an ecosystem in recent years and identify the main human pressures, explaining how these pressures affect key ecosystem components.

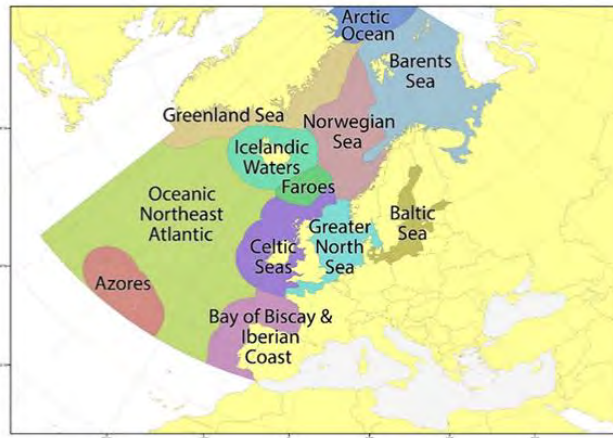
ICES Framework for Climate Informed EBM Advice

Key properties:

- **Align** terminology, concepts, scenarios with IPCC
- **Risk-based framework**, embrace **uncertainty**
- Use **scenario building** at diverse levels:
understanding assumptions/trade-offs/risk of
inaction
- **Plurality of knowledge**, participation mechanisms
→ build capacity **beyond** traditional
competencies
- Delivery through spatial visualization; **FAIR** data
principles

ICES Ecoregions

ICES uses ecoregions as the spatial units to synthesize the evidence for the ecosystem approach

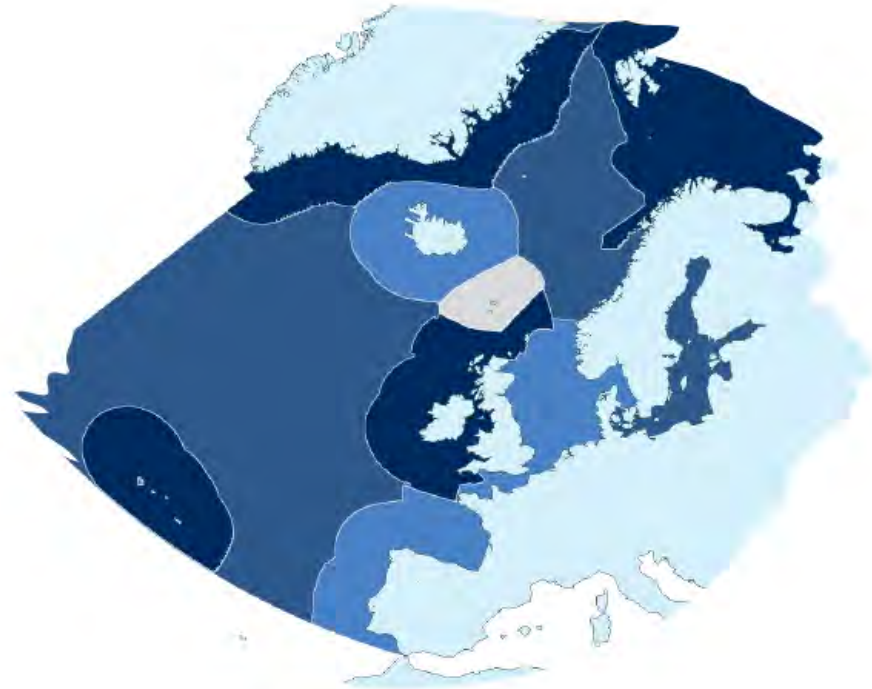


<https://www.youtube.com/watch?v=J6YxywEmRp4>

Definition and Rational of ICES Ecoregions

ICES EBM Advice - Ecosystem Overviews

- Key mechanism for ICES to provide the evidence base for EBM
- Regional scale
- Annual updates
- 5-year cycle revision: new assessment



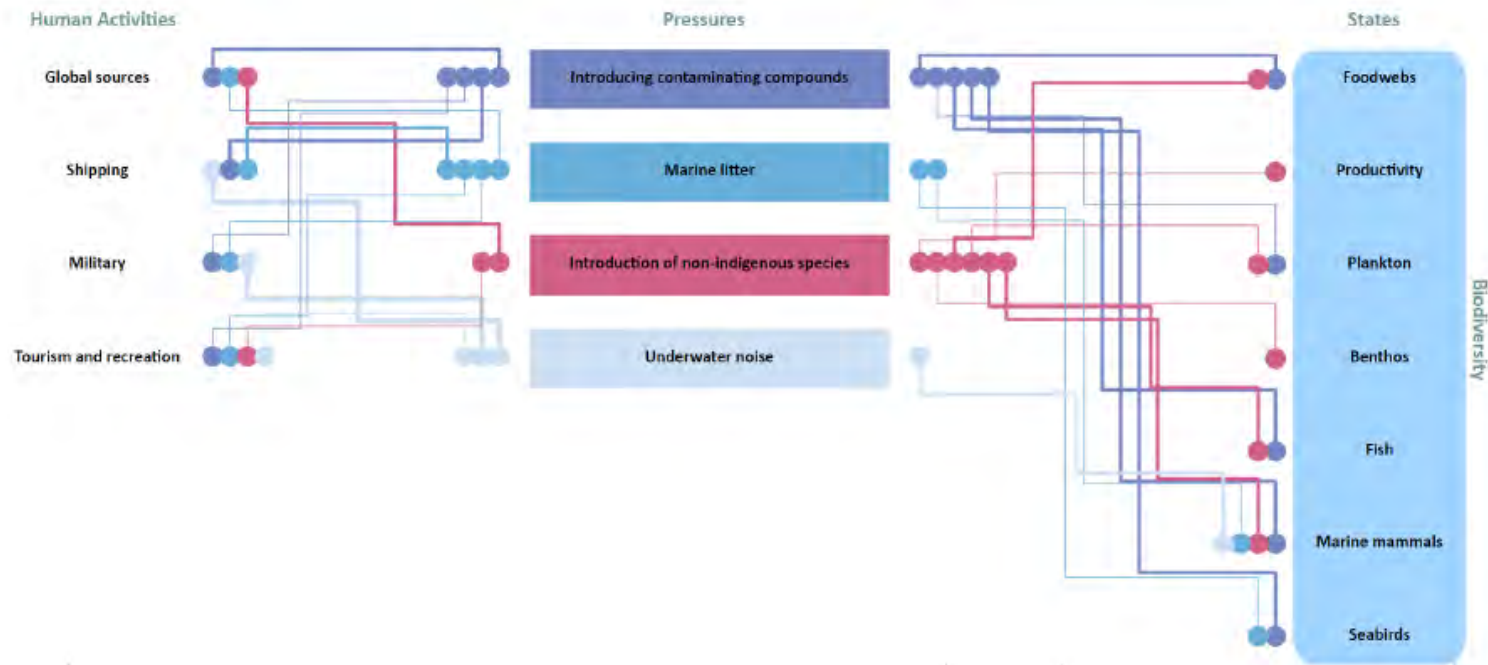
ICES Ecosystem Overviews - Content

- EBM key signals within the environment and the ecosystem
- Ecoregion description
- Identify the main human activities and resulting top pressures → how are key ecosystem states impacted?
- Social and economic considerations; climate change impacts
- Trends in the ecosystem



Ecosystem Overviews: Activities-Pressures-Impacts diagram

EBM tools: risk assessment / indicators



6.1 Bay of Biscay and the Iberian Coast ecoregion – Ecosystem Overview

Table of contents

Bay of Biscay and the Iberian Coast ecoregion – Ecosystem Overview	1
Ecoregion description	1
Key signals within the environment and the ecosystem	2
Pressures	3
Climate change impacts.....	8
State of the ecosystem	10
Sources and acknowledgements	14
Sources and references	15
Annex A	20

Ecoregion description

The Bay of Biscay and the Iberian Coast ecoregion covers the southwestern shelf seas and adjacent deeper eastern Atlantic Ocean waters of the EU. The oceanography in this ecoregion is characterized by marked seasonal mixing and stratification of water masses typical of temperate seas. This general pattern is modified over the shelf by wind-driven upwelling, river outflow, and tidal-related processes, increasing the productivity of the system with large variation across the region. Habitats further offshore are shaped by the influence of Atlantic waters in the Bay of Biscay and western Iberia.

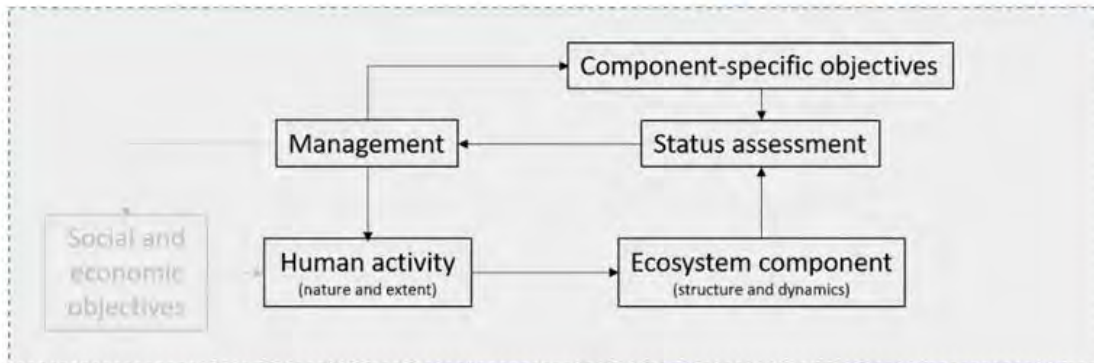
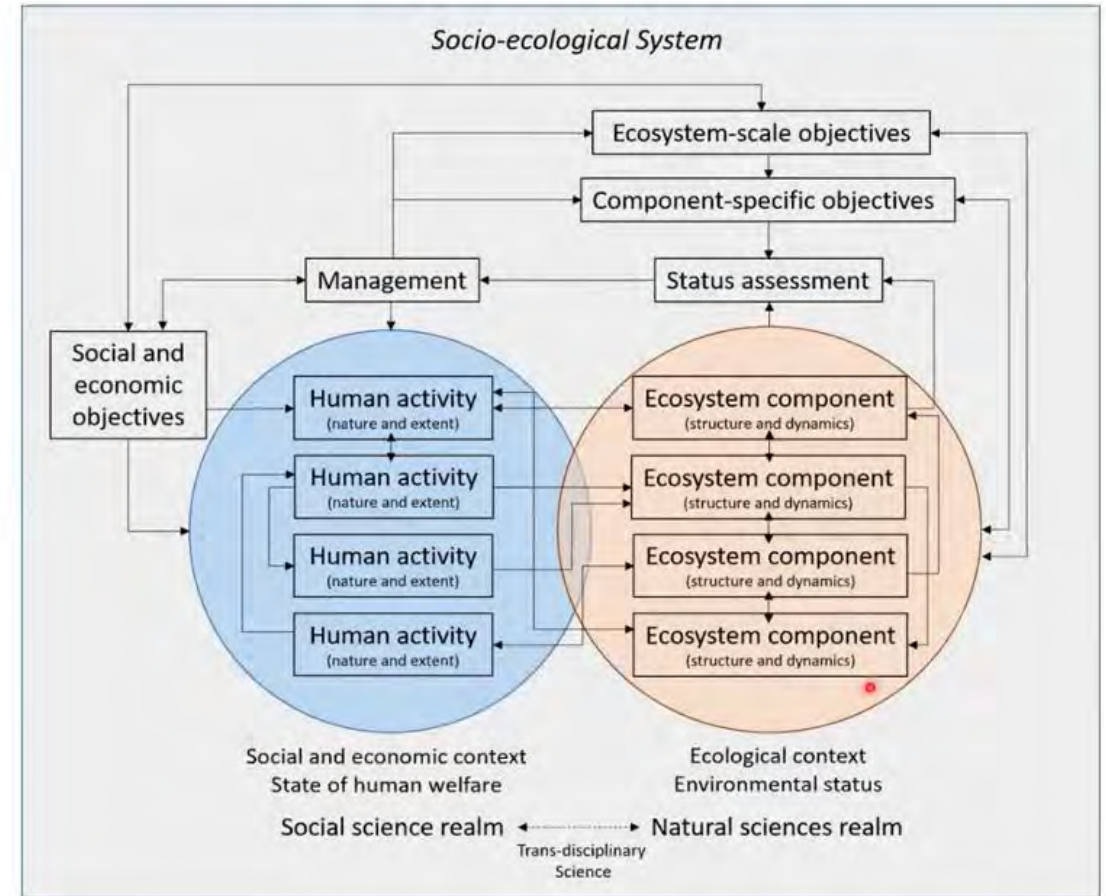
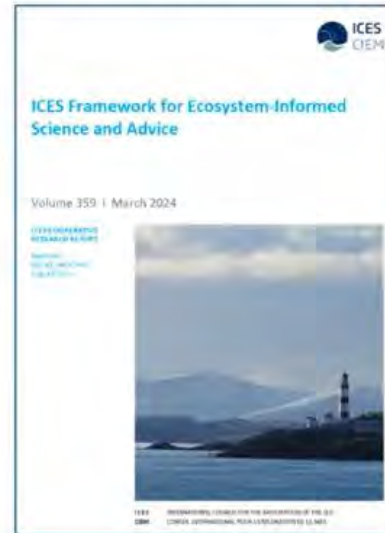
The ecoregion includes waters from Brittany to the Gulf of Cadiz; four key areas constitute the ecoregion (Figure 1):

- the **Bay of Biscay**, characterized by a wide shelf extending west of France. Upwelling events occur in summer, off southern Brittany, and low-salinity water lenses are associated with the river outflows of the Landes coastline;
- the **Cantabrian Sea** (northern Iberian shelf) characterized by a narrow shelf with intermittent summer upwelling

ICES Framework for Ecosystem-Informed Science and Advice (FEISA)

To guide knowledge development in support of EBM and its practical implementation into ICES advice

To evaluate and guide incremental progress from conventional to ecosystem-informed science and advice

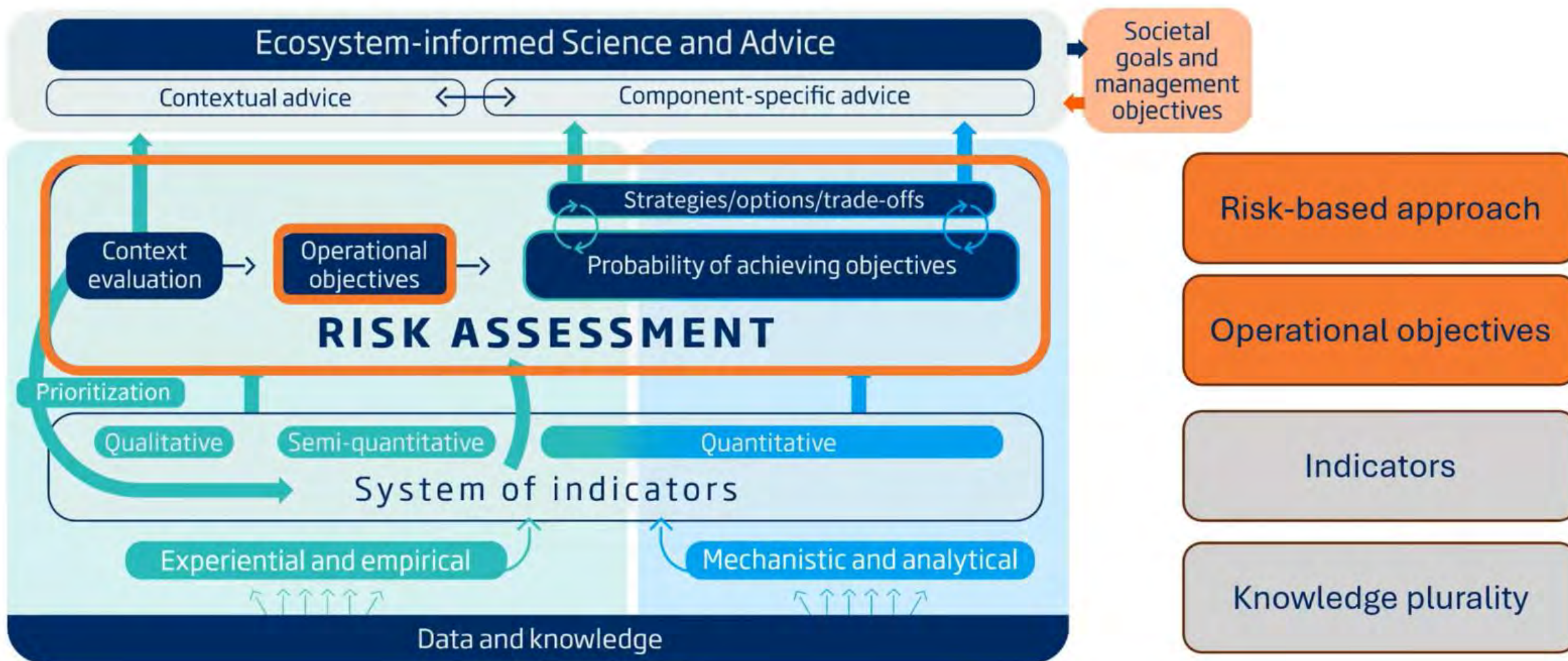


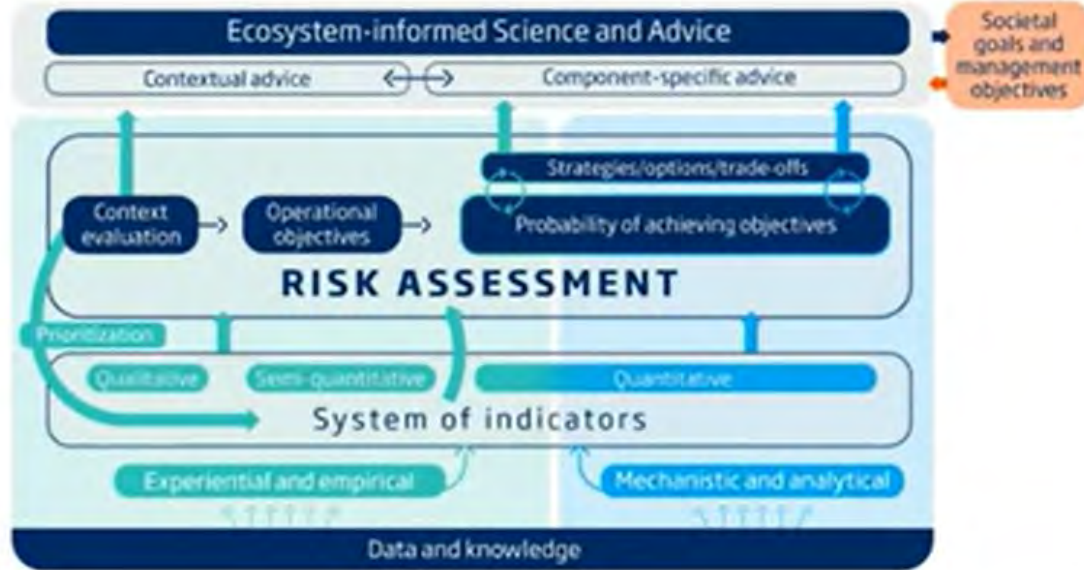
From conventional science and advice... ...to ecosystem-informed science and advice

ICES Framework for Ecosystem-Informed Science and Advice (FEISA)

ICES Framework for Ecosystem-Informed Science and Advice (FEISA) combines a system of indicators for knowledge development and integration as relevant to stated management objectives (i.e. consolidation of the evidence base in support of EBM) and a risk-based approach for operationalizing indicators into advice (implementation of the evidence-base for EBM into advice products

FEISA architecture – main components

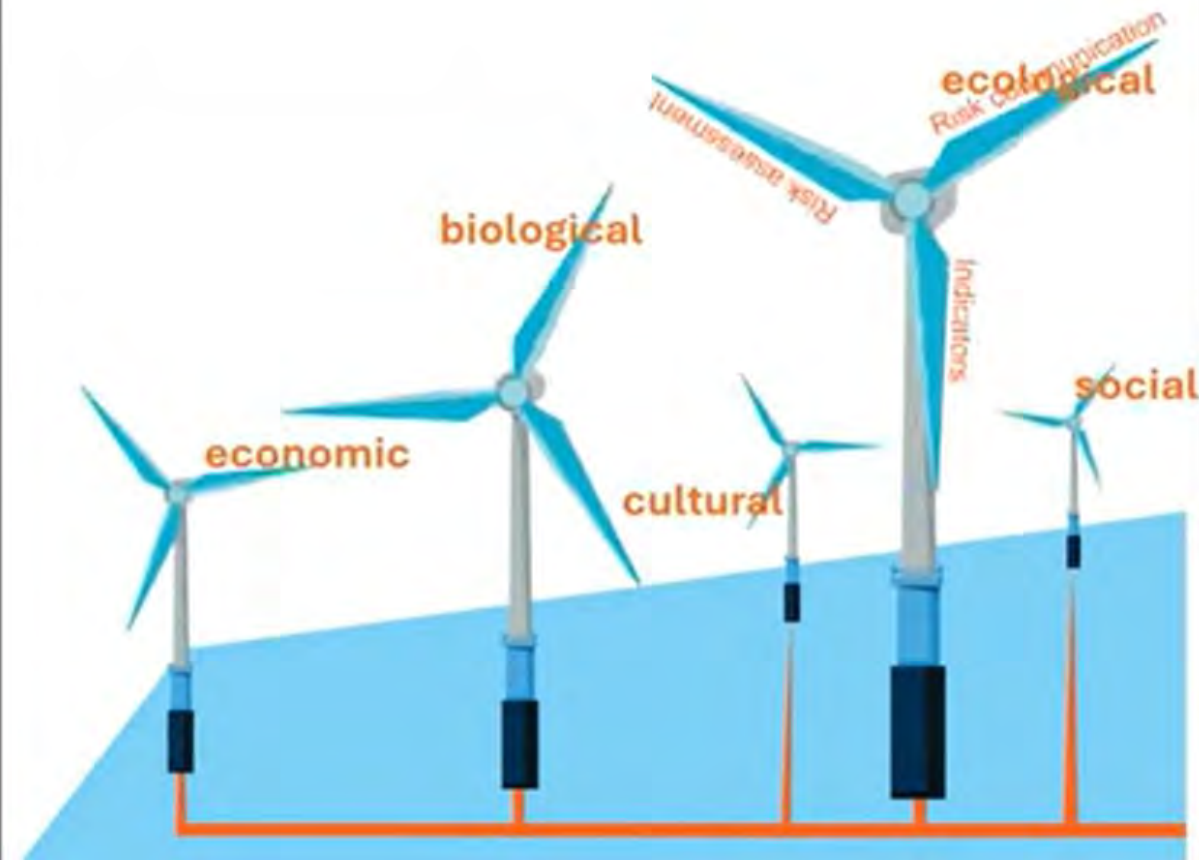




1. **Knowledge plurality** as a basis for ecosystem-informed advice
2. Ecosystem-informed science has a role in guiding the identification of **operational objectives**
3. Ecosystem-informed advice formulation involves routine exploration of alternative hypotheses, scenarios and pathways for ecosystem effects (**scenario-based approach**)
4. Ecosystem considerations will affect the level of risk associated with the advice (**risk assessment**)
5. Risk is the currency for effectively and consistently communicating potential, demonstrated or projected consequences of alternative management options and ecosystem effects in advice (**risk communication**)

FEISA implementation

Five actionable principles



European Eel advice on fishing opportunities and conservation

	Current Advice	Future Directions
Operational objectives	✓ Empirical recruitment level (R_{lim}) below which serious biological harm is expected	Propose measurable objectives for eel habitat
Indicators	✓ Empirical recruitment index (Quantitative)	
	✓ Qualitative information on non-fisheries anthropogenic impacts	Specify indicators for non-fisheries anthropogenic factors and relevant habitat properties
Risk Assessment	✗	Prioritize risk factors for management action and knowledge development
Risk-based scenarios	✗	Evaluate probability of achieving R_{lim} under different habitat restoration measures
Risk Communication	✗ Implicit (conservation aspects)	Communicate priority risks and risk equivalent options for achieving R_{lim} in advice

Evaluating progress



ICES Advice on fishing opportunities and conservation
Ecoregions in the Northeast Atlantic
Published 01 November 2023
Version 2: 02 November 2023



European eel (*Anguilla anguilla*) throughout its natural range

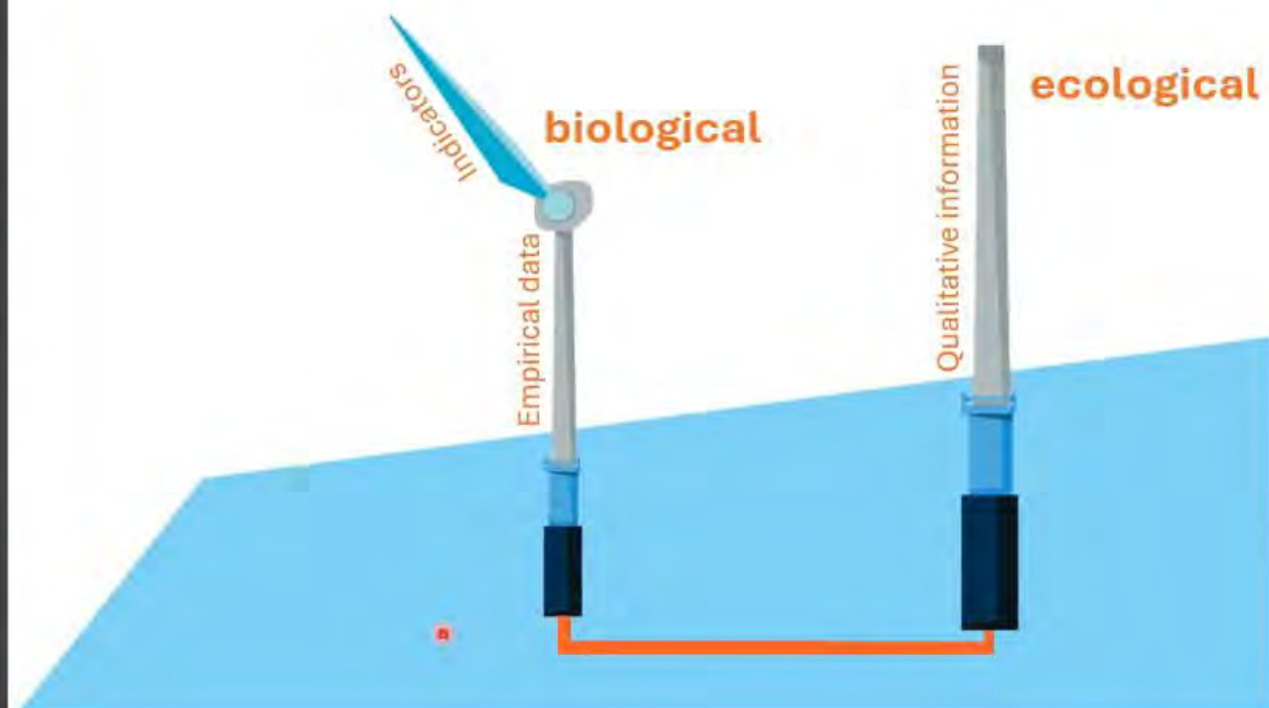
ICES advice on fishing opportunities

ICES advises that when the precautionary approach is applied, there should be zero catches in all habitats in 2024. This applies to both recreational and commercial catches and includes catches of glass eels for restocking and aquaculture.

ICES advice on conservation aspects

Based on ecosystem-based management considerations, ICES advises that:

- all non-fisheries related anthropogenic mortalities should be zero.
- the quantity and quality of eel habitats should be restored; this includes restoring connectivity and the physical, chemical, and biological properties of the habitats.



Eastern Baltic cod advice on fishing opportunities, catch and effort

	Current Advice	Future Directions
Operational objectives	✓ Analytical biological objectives (B_{lim} , B_{pa})	Investigate achievable socioeconomic and ecological objectives
Indicators	✓ Analytical (SSB, F, M, R) and empirical (size structure, length at maturity, condition) biological indicators	Specify relevant ecological and socioeconomic indicators
	✓ Qualitative ecological information (prey availability, parasitism, and habitat/O2 degradation)	
Risk Assessment	✓ biological risk assessed relative to B_{lim}	Identify priority ecological and socioeconomic risks
Risk-based scenarios	✓ Catch options with biological risk relative to B_{lim}	Explore strategies to mitigate socioeconomic and ecological risks
Risk Communication		Communicate potential trade-offs

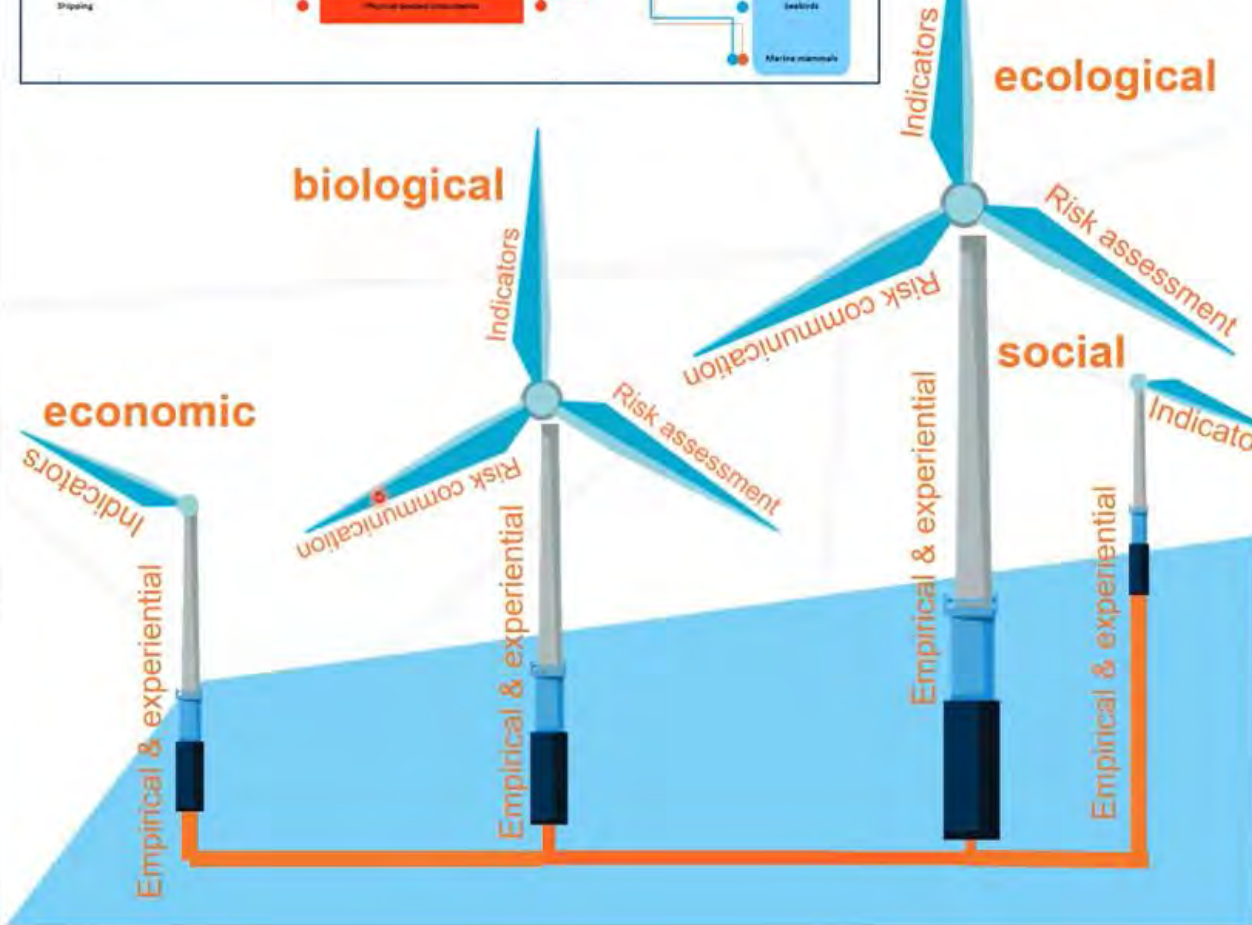
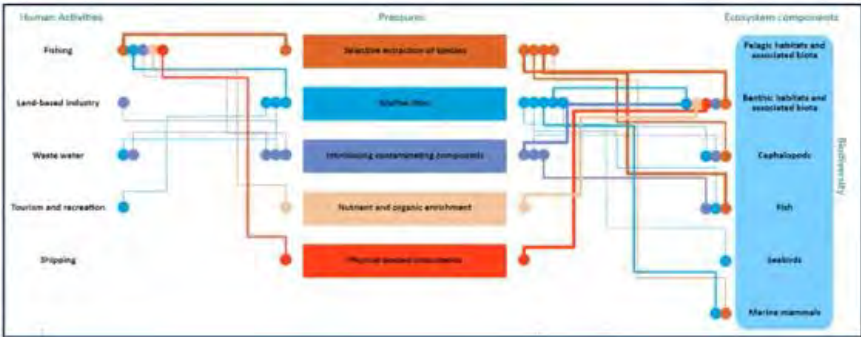
Evaluating progress



ICES Ecosystem Overviews

	Current Advice	Future Directions
Operational objectives	x	Investigate and identify achievable biological and ecological objectives
Indicators	✓ Empirical biological, ecological, climate, human activity and in some cases economic and social indicators	Expand to include social, economic, cultural, governance and ecosystem services indicators
Risk Assessment	✓ Contextual risk assessment for biological and ecological components	Evaluate social and economic risks
Risk-based scenarios	x	Identify management strategies and trade-offs relative to objectives
Risk Communication	✓ Explicit in some regions but only for biological and ecological components	Communicate priority risks and potential trade-offs

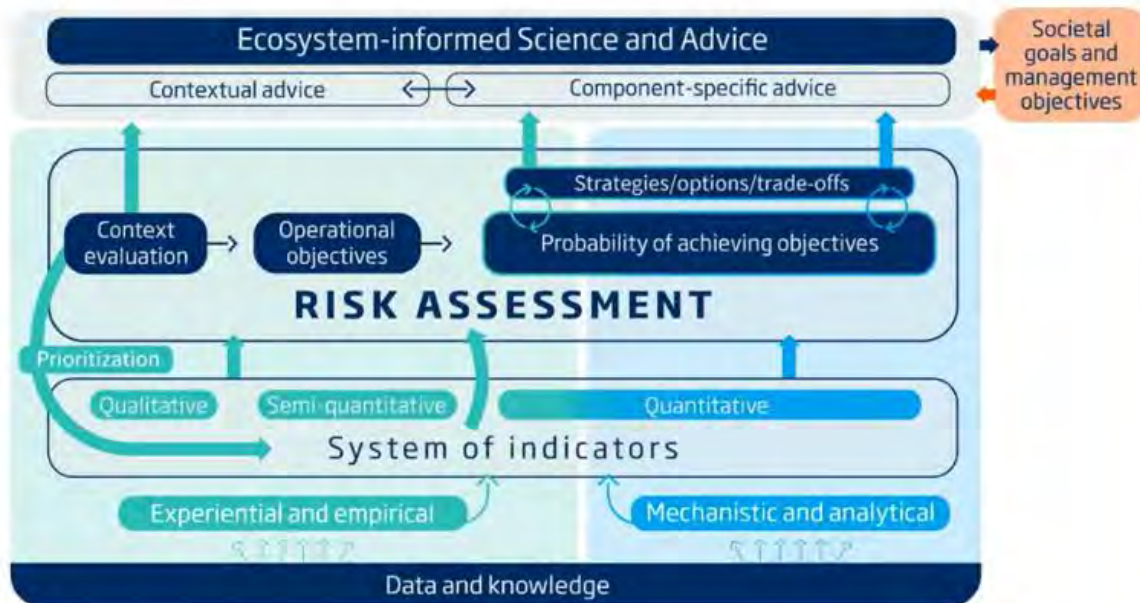
Evaluating progress



Conclusions (1 of 2)

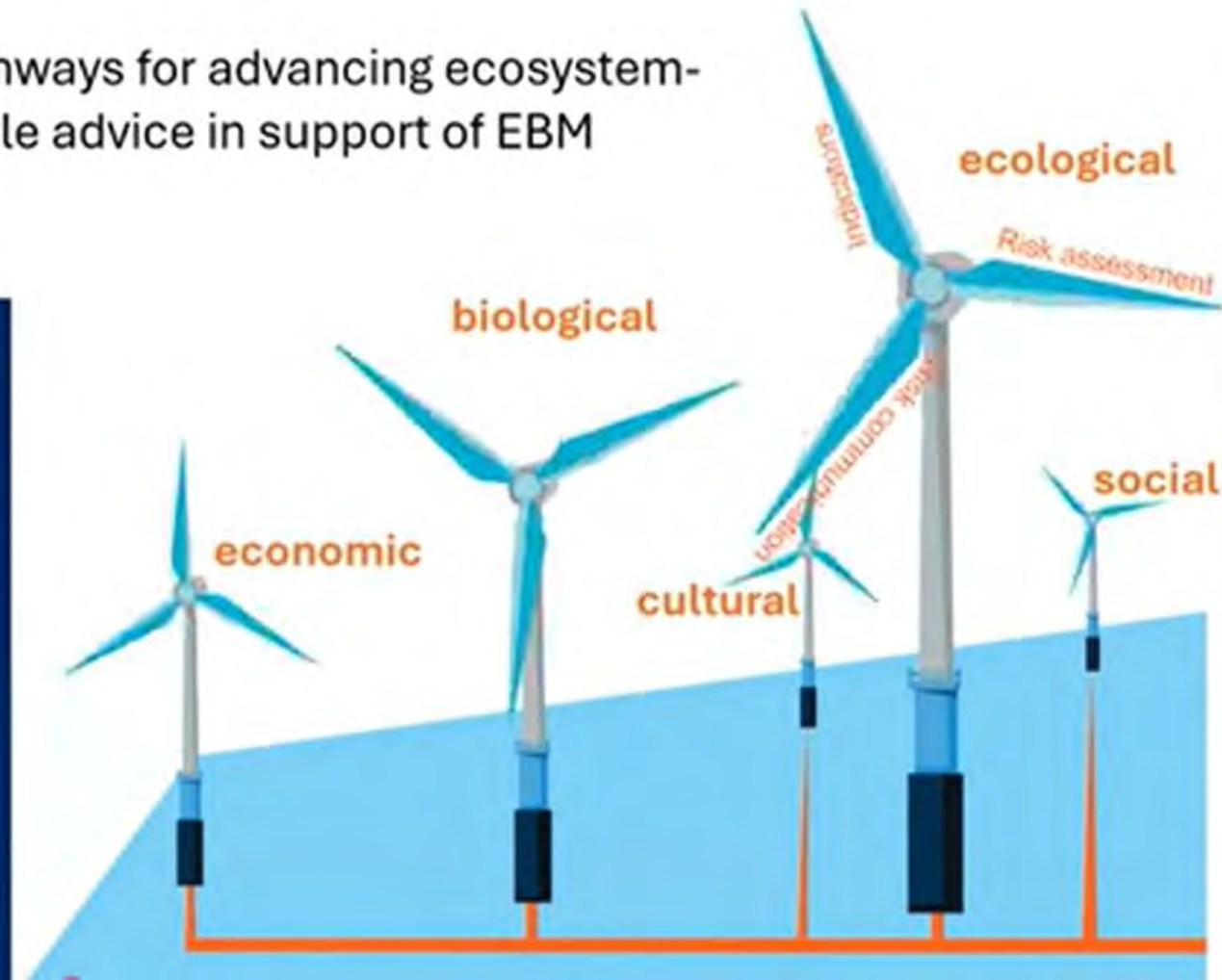
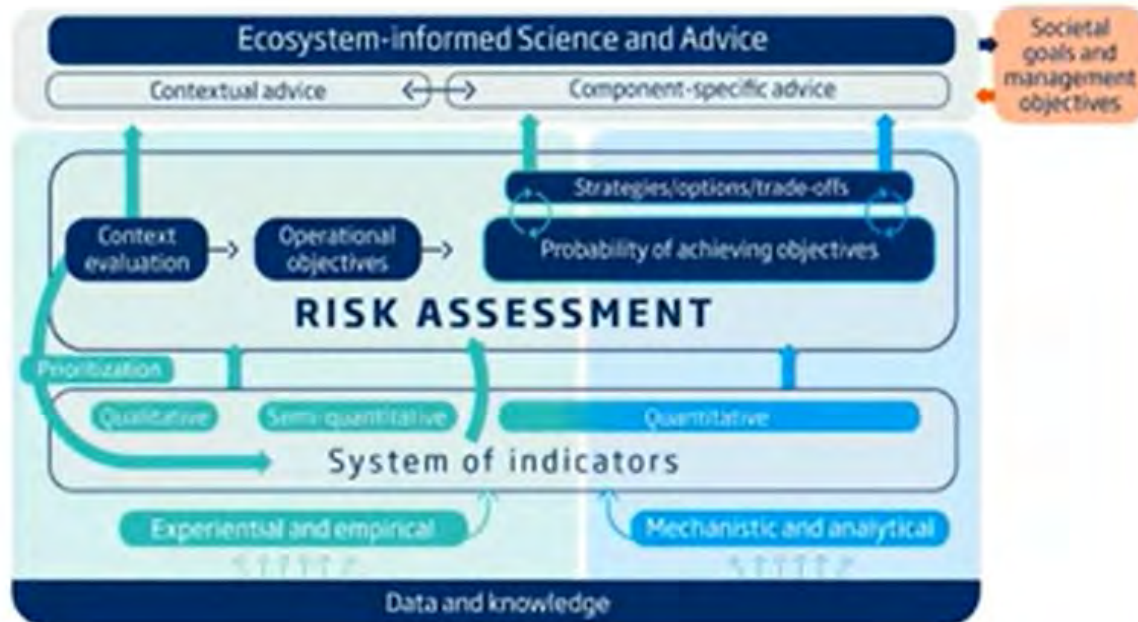
FEISA proposes a risk-based approach for mobilizing different types of data and knowledge in science and advice aimed at :

- **prioritizing** human activities and ecosystem components for management actions
- **evaluating** the **effectiveness of management actions** for achieving EBM objectives



Conclusions (2 of 2)

- FEISA is applicable and relevant to all human activity sectors and aspects of socioecological systems
- FEISA can be applied to identify priorities and pathways for advancing ecosystem-informed science and its translation into actionable advice in support of EBM



CURRENT PRACTICE

- **Indicator development** mainly focused on biological and ecosystem-component-specific indicators with primarily empirical and/or analytical indicator developments.
- There is a realistic expectation from science that management **objectives will be defined, clarified, and prioritized by management**. However, this is not always the case. There is a similar expectation from managers for science to guide the identification of operational objectives in support of EBM. While objectives are often implied, they are becoming increasingly explicit in national legislations and international agreements (Stephenson et al., 2021).

CURRENT PRACTICE

- **Scenario-based approaches** are currently ubiquitous in ICES advice but are rarely used to investigate ecosystem (or climate change) effects on the advice or consequences in relation to ecological, economic, social/cultural, or governance objectives. Scenario assumptions and outcomes are also not consistently nor systematically communicated.
- Despite risk and risk assessment being used in a range of contexts, there remain **very different understandings of risk in the ICES community** (e.g. risk as a prioritization tool in qualitative space vs. risk as a probability of achieving objectives in MSE). This is sometimes seen as an obstacle when in reality these approaches can be used to harmonize progress (e.g. via a common currency such as risk).

PRIORITIES FOR MOVING FORWARD

- Strengthen and broaden the scientific (including experiential and qualitative) basis for **indicator development** as related to existing or candidate EBM objectives.
- Broaden the scope of **stakeholder engagement** in ICES science and advisory process and reappraise how ICES engages with the scientific community, managers, and society.
- Enhance efforts to **develop measurable social, cultural, economics, human wellbeing, and climate-change indicators** as related to existing or candidate EBM objectives.
- Develop **tools and/or methodologies for translating perceptions of resource users and communities into measurable indicators** (e.g. social acceptability).

PRIORITIES FOR MOVING FORWARD

- **Strengthen dialogue and collaborations** with partners/advice requesters and the social science community to inform the development of clear and meaningful operational objectives aligned with management objectives and societal goals.
- Map interim, incrementally **achievable operational objectives** in line with both management expectations and the available evidence (e.g. roadmap for PETS bycatch advice (ICES, 2022d).
 - Identify, propose, and implement in advice meaningful and **ecosystem-informed operational objectives** for well-developed indicators
- **Advance socio-ecological science** to underpin the distinction between good vs. degraded, good vs. resilient, and degraded vs. compromised, etc.

PRIORITIES FOR MOVING FORWARD

- Continue developing **risk assessment methodologies** for full-spectrum scenario comparisons and integrating complementary contextual (prioritization) and objective-based (probability estimation) risk assessments for operationalizing different data and knowledge types in recurring and developing advice.
- **Advance socio-ecological science** to investigate interactions between socio-economics and bioecological objectives and explore “viable pathways” and trade-offs.
- Develop **guidelines for the evaluation and effective communication** of the consequences and benefits of alternative management options, trade-offs, and ecosystem effects in advice (Δ Risk).
 - Promote the proposal of **new ideas across the community** (e.g. via “pipeline” processes) to strengthen ecosystem-informed advice.

WKFoodWeb 2024



Eider Andonegi
AZTI, Spain



Jacob Bentley
Natural England, UK



Maciej T. Tomczak
SLU-Aqua, Sweden



Marian Torres
IEO, Spain



ICES
CIEM

Science for sustainable seas



Terms of Reference



ToR a

Food web indicators

Streamline existing examples, knowledge, experience, and recommendations on food web, trophic level and other ecological indicators from across the ICES network (e.g., from IEA groups, WGECON, WKFOOWI, WKASCAPES) and beyond (e.g. MSFD, OSPAR, HELCOM, UKMS, etc.)



ToR c

Food web modelling

Prepare a roadmap, including risks and opportunities, for the systematic and transparent use of food web models to support ICES advice with information on trade-offs.



ToR b

Information to advice

Identify priority areas where food web information/indicators could enhance existing advice and align with the ICES EBM framework (including advancing the Feco approach).



ToR d

Ecosystem Overviews

Develop a pipeline proposal to strengthen the 'food web' component of ICES ecosystem advice (ICES Ecosystem Overviews) that can be applied in a consistent way across ICES ecoregions and preferentially on the short-term timescale.



Mechanisms

Ecological Reference Points
 F_{eco}
Available food index
Multi-species reference points
Management Strategy Evaluation

Methods

Integrated Trend Analysis
eDNA

Models

StrathE2E
Ecopath with Ecosim
Ecospace Stock assessment models
Atlantis
Ensemble modelling
Linear Inverse Modelling

ICES

IEASG
Catch Advice
WKASCAPES
WGSAM
WKFISHCARBON
ICES FEISA
Ecosystem Overview
ICES

Indicators

Feeding guilds
Ecological Network Analysis
Food web state indicators
Topology-based indicators
GES indicators
OSPAR Indicators

Policy

UKMS
CFP
UK Fisheries Act
MSFD



Roadmap



Clear recommendations to ICES for the future use of food web information and direction of WKFoodWeb.

How can we best support the existing ICES structure to deliver ecosystem-based advice where and when needed?

WGFOODWEB *(from 2027 onwards)*



Indicators of ecosystem structure and function – development and some applications



Beth Fulton
CSIRO
Australia

March 2026
Noumea, New Caledonia

Keith Sainsbury
University of Tasmania
Australia

Annex 8



Indicators of ecosystem structure and function

Outline

Why tackle this issue?

Ecosystem assessments in 5 different countries and ecosystems

- not tuna RFMOs but most have significant coastal tuna catches

Developed four indicators for ecosystem structure and function

Application in some fishery assessments



Why tackle “indicators of ecosystem structure and function”?

Many of the international and national management instruments require maintenance of ecosystem structure and function

There are many ways to measure ecosystem structure and function

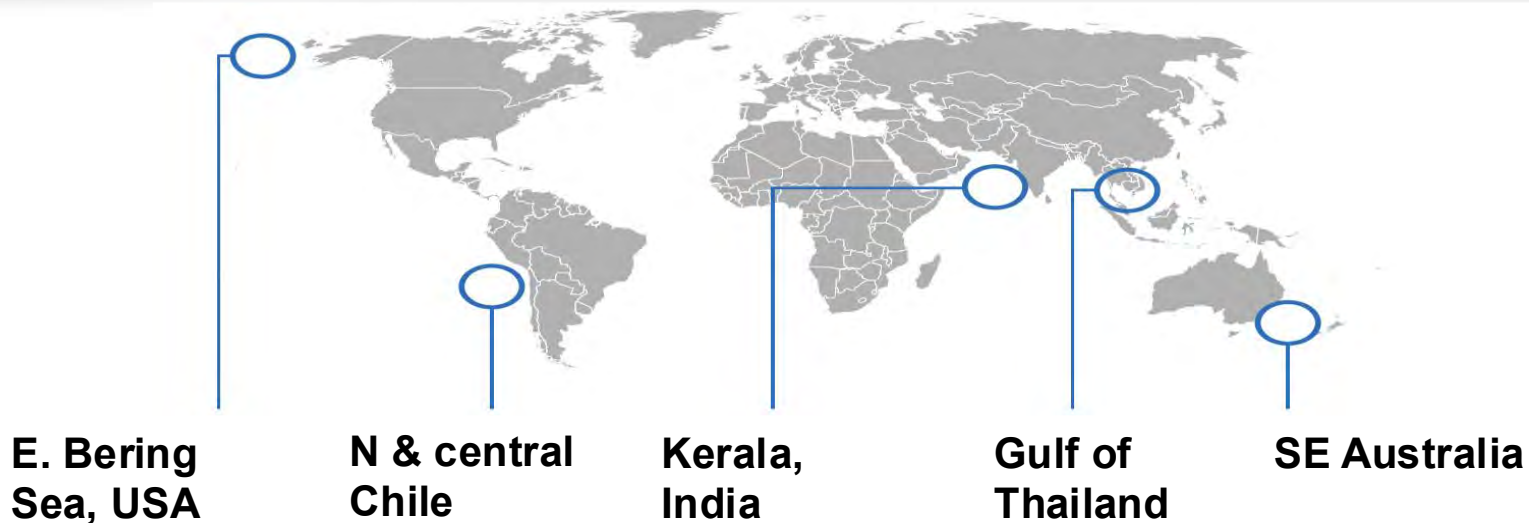
- biodiversity, various ratios (e.g. size, trophic level) etc
 - they describe some issues but not the whole ecosystem
- not easy to use in fishery management decisions
 - e.g. few thresholds

Four new ecosystem indicators developed in 5 countries

- these indicators are model-based
- several empirical indicators also calculated



Assessment and management in five fisheries



Each fishery has different:

- ecosystem and fishery complexity
- objectives (i.e. ecological, economic, social)
- available information
- institutional and management arrangements

For each fishery directly engaged with policy, management and science



The methods and indicators in these assessments

Overall fishery analysis for each fishery

- Broad ecosystem production bounds (e.g. area, primary production, Ryther index, Fogarty index)
- Statistical description (e.g. species composition, gears, fishery management, heat map, cluster analysis)
- Calculate empirical indicators
- Assessment models (e.g. for species, species groups and total catch)
- Ecosystem trophic models (e.g. Ecopath with Ecosim, EwE)
 - 4 new model-based indicators of ecosystem structure and function



Indicators for ecosystem structure and function

Four ecosystem indicators

Topology	- ecosystem structure & key food-web connecting species
Resilience	- capacity to function when perturbed
Food-web distortion	- effects of fishing on food-web
Ecosystem Traits Index (ETI)	- integrates the above 3 indicators

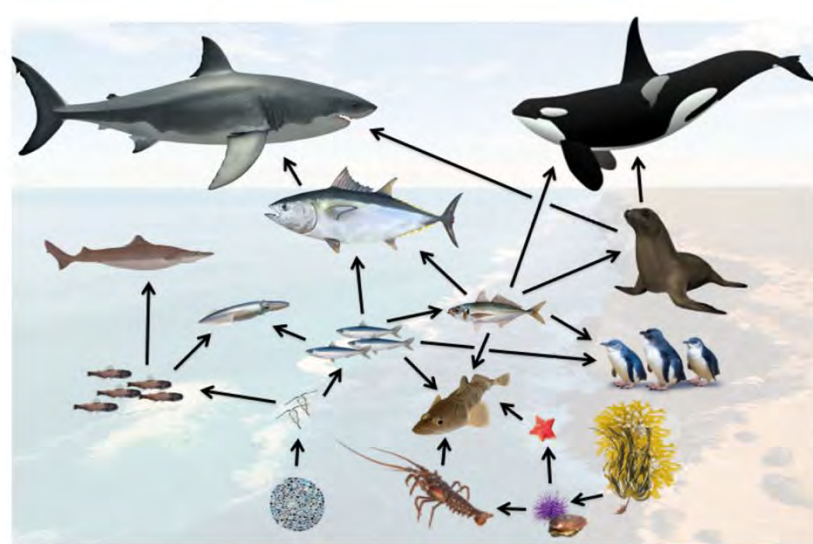
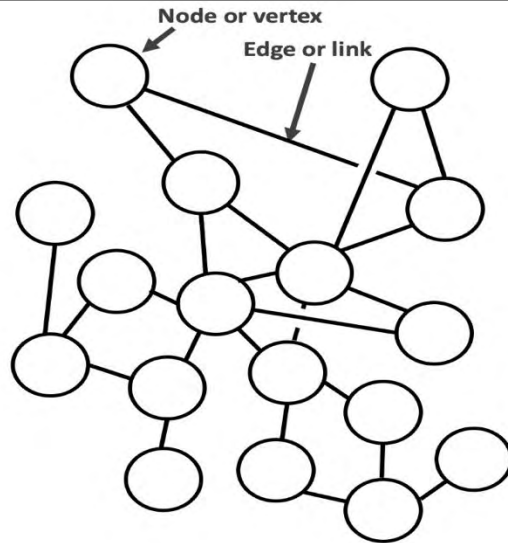
These indicators can be used

- individually
- combined
- spatially
- at a single time or as a time series
- in future projections (e.g. fishery management, climate change, Management Strategy Evaluation, etc)



Ecosystem topography

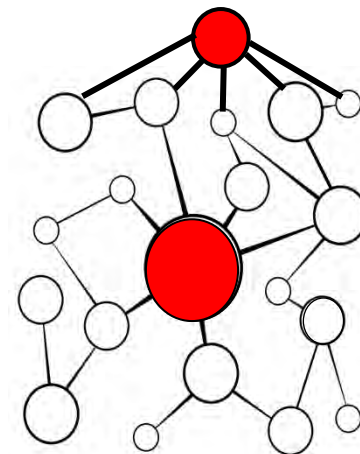
- structure & key network connecting species



Use Criticality Analysis from engineering to identify:

- highly connected species (often predators)
- species supporting food-web structure (often key prey)

➤ Identify Ecologically Critical or “Hub species”



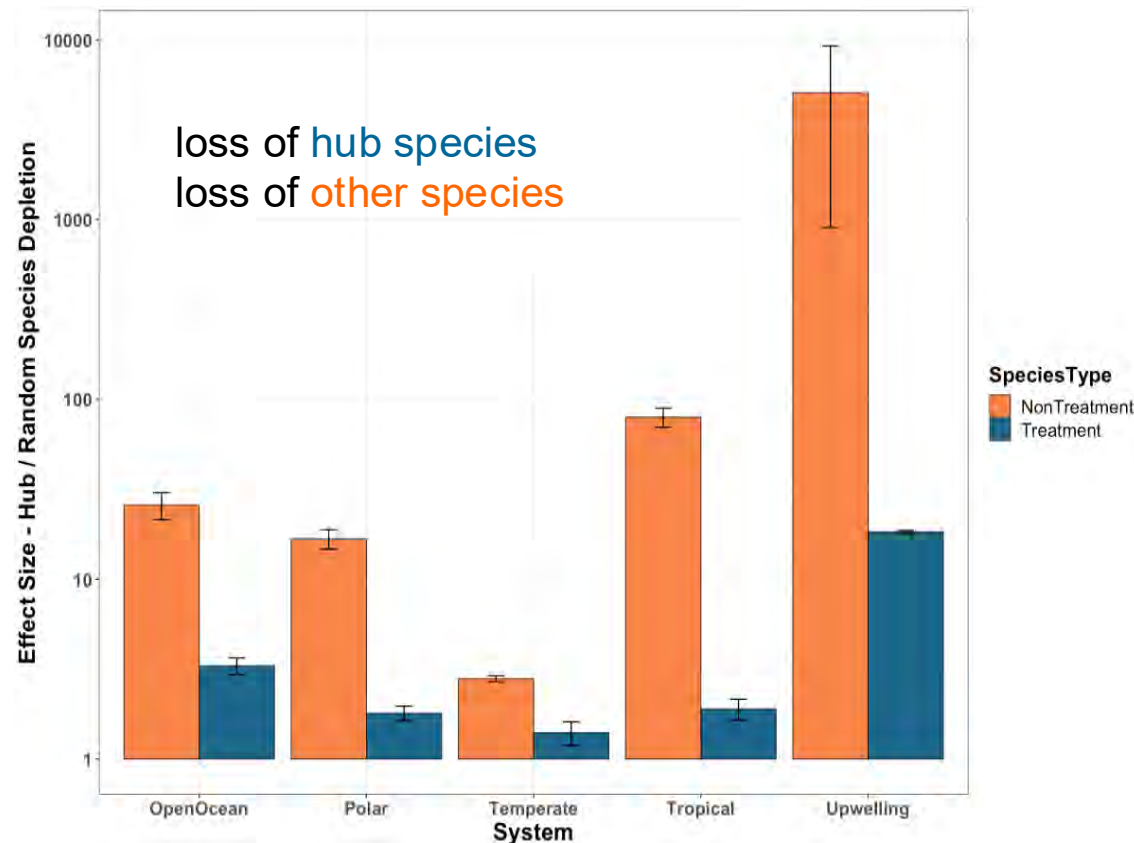


Ecosystem topography

- Hub species

- Loss of hub species has a bigger effect on ecosystem than loss of other species
- Hub species are stable over long time periods
- Hub species should have conservative reference points to protect them

Ecosystem reduction from loss of hub species vs loss of other species





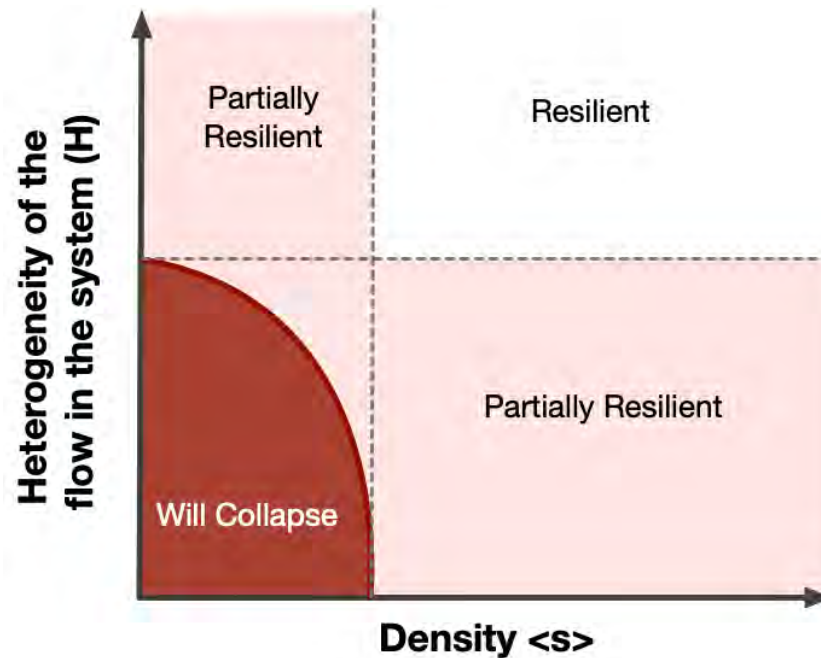
Ecosystem resilience

- capacity to function when perturbed

Network flows and structure determine resilience

Heterogeneity of flow

The variance across species of the number of food-web links, each weighted by its strength



Density of connections

The ratio of the actual direct links between species compared to the maximum if all species were connected

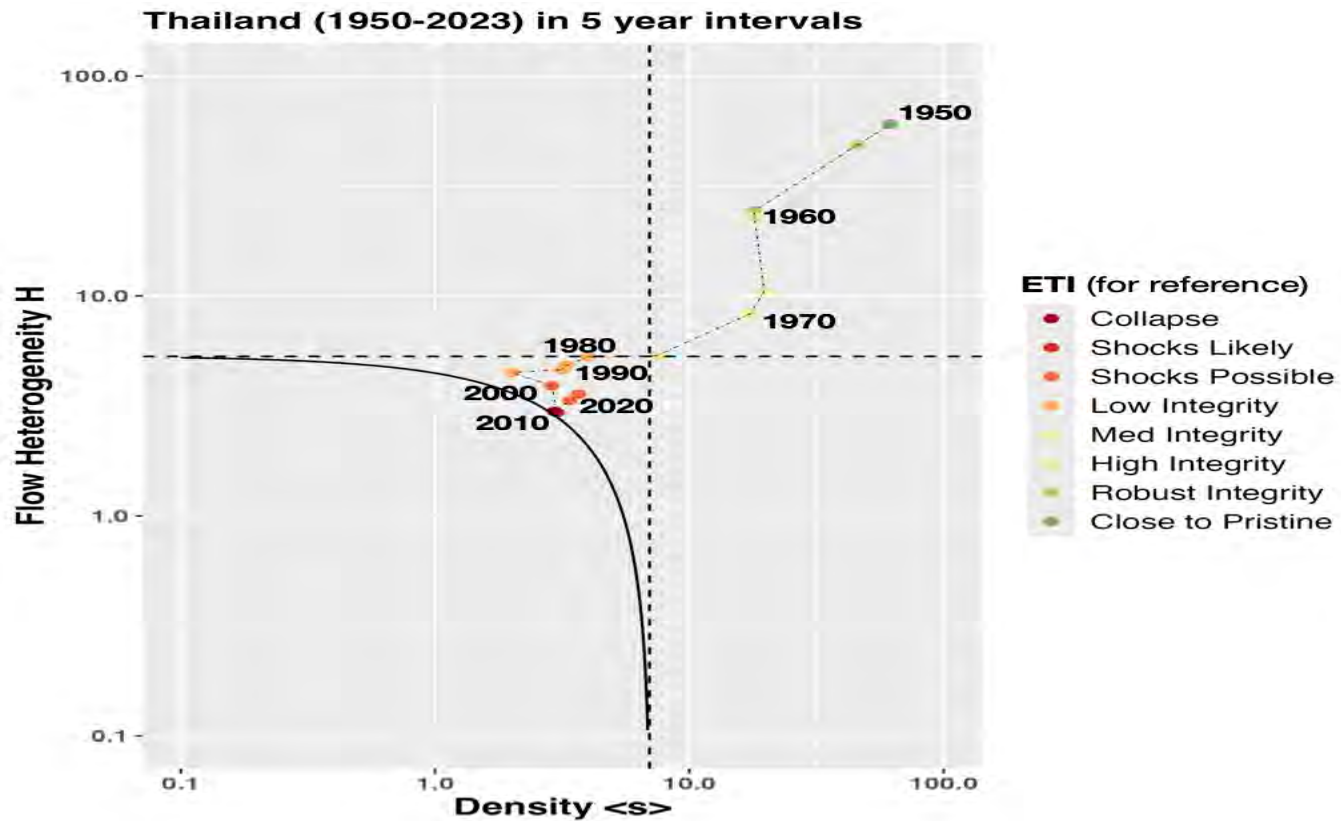
Note: 'collapse' means major ecosystem change



Ecosystem resilience

- capacity to function when perturbed

Resilience for the Gulf of Thailand (GoT) fishery



Fishing has reduced resilience in GoT

- but some improvement after effort reductions starting 2015



Food-web distortion

- effect of fishing on ecosystem food-webs

Targeting and fishing selectivity varies greatly between species, fisheries and through time

- species can have total mortalities that are not in the same ratios as in the unfished ecosystem

Aim is to :

- achieve ratios of mortality similar to the unfished ecosystem
- avoid overfishing
 - catch no more than half of production

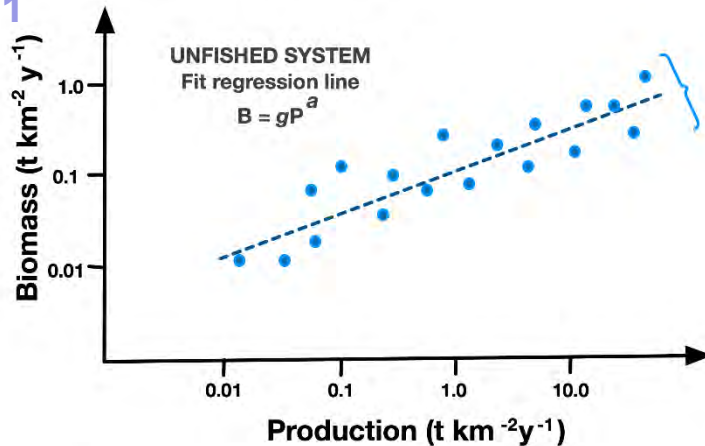
➤ This gives the 'Green Band' for species and groups of species



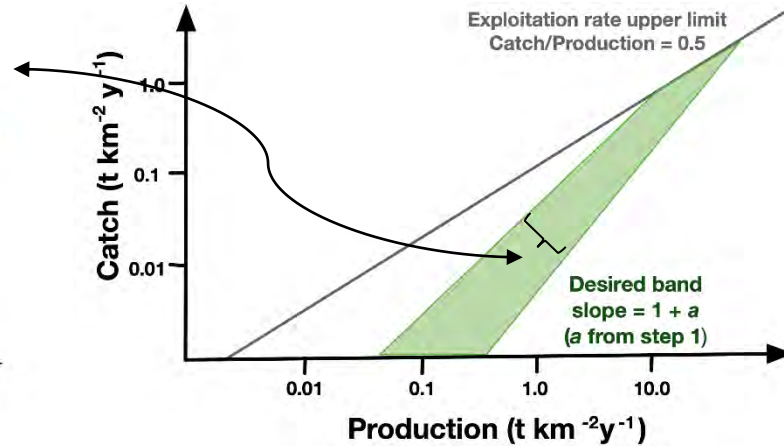
Food-web distortion

- Calculating the Green Band

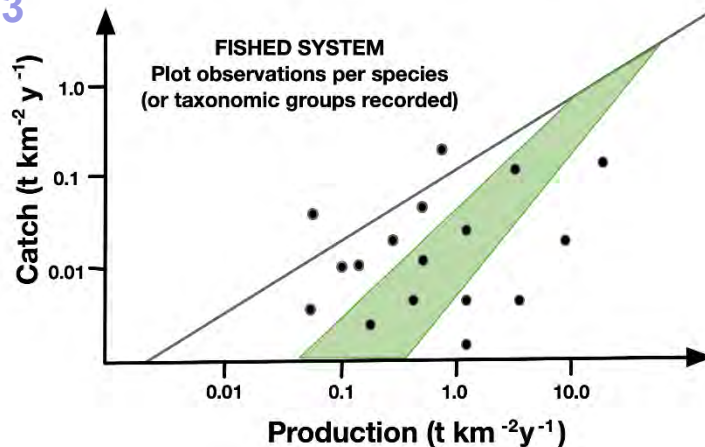
STEP 1



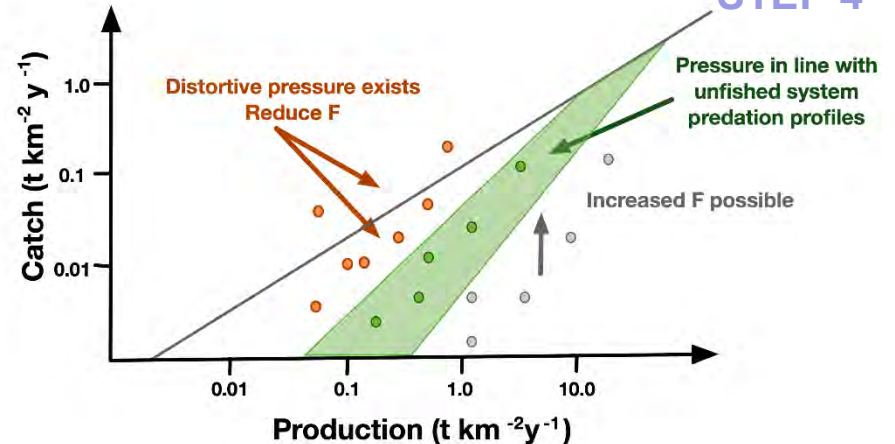
STEP 2



STEP 3



STEP 4



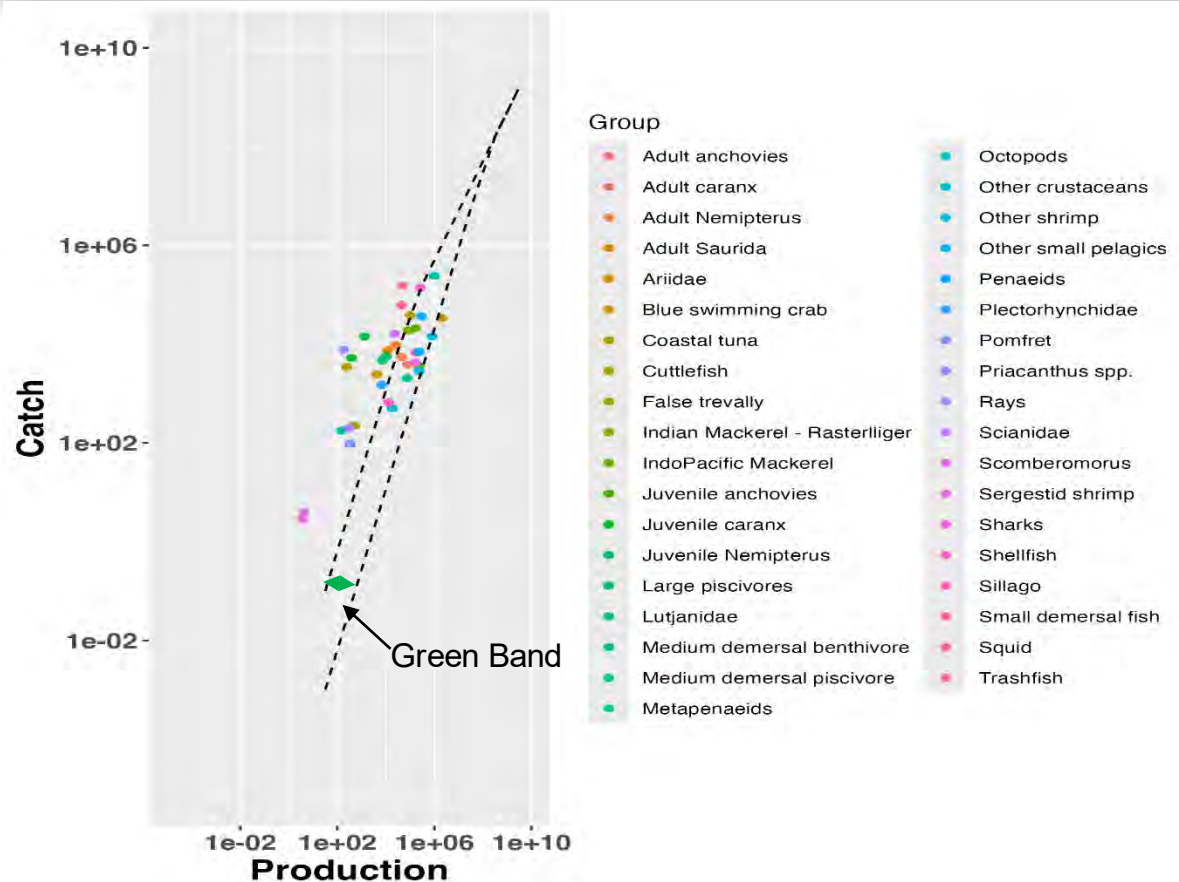
Plot catch-production for the species or species groups

Interpret how catches should change to have all groups in the Green Band



Food-web distortion

- applying the Green Band for GoT Thailand



~56% under distortive pressure (above Green Band)

~38% within Green Band

~5% below Green Band

- Identified species that should have increased or decreased catch
- These can be considered in management decision making



Ecosystem Traits Index (ETI)

- integrating the 3 ecosystem indicators

Topology



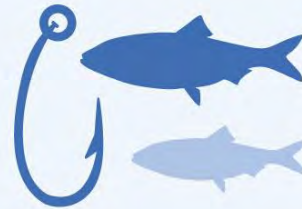
+

Resiliency



+

Distortive pressure



ETI



ETI =

$$\text{ecosystem resiliency} * \left\{ \begin{array}{l} \text{Species type} \\ \text{(target, byproduct,} \\ \text{bycatch, habitat,} \\ \text{vulnerable,} \\ \text{robust, hub)} \end{array} \right\} * \text{Index of} \left\{ \begin{array}{l} \text{Green Band} \\ \text{biomass depletion} \end{array} \right\}$$

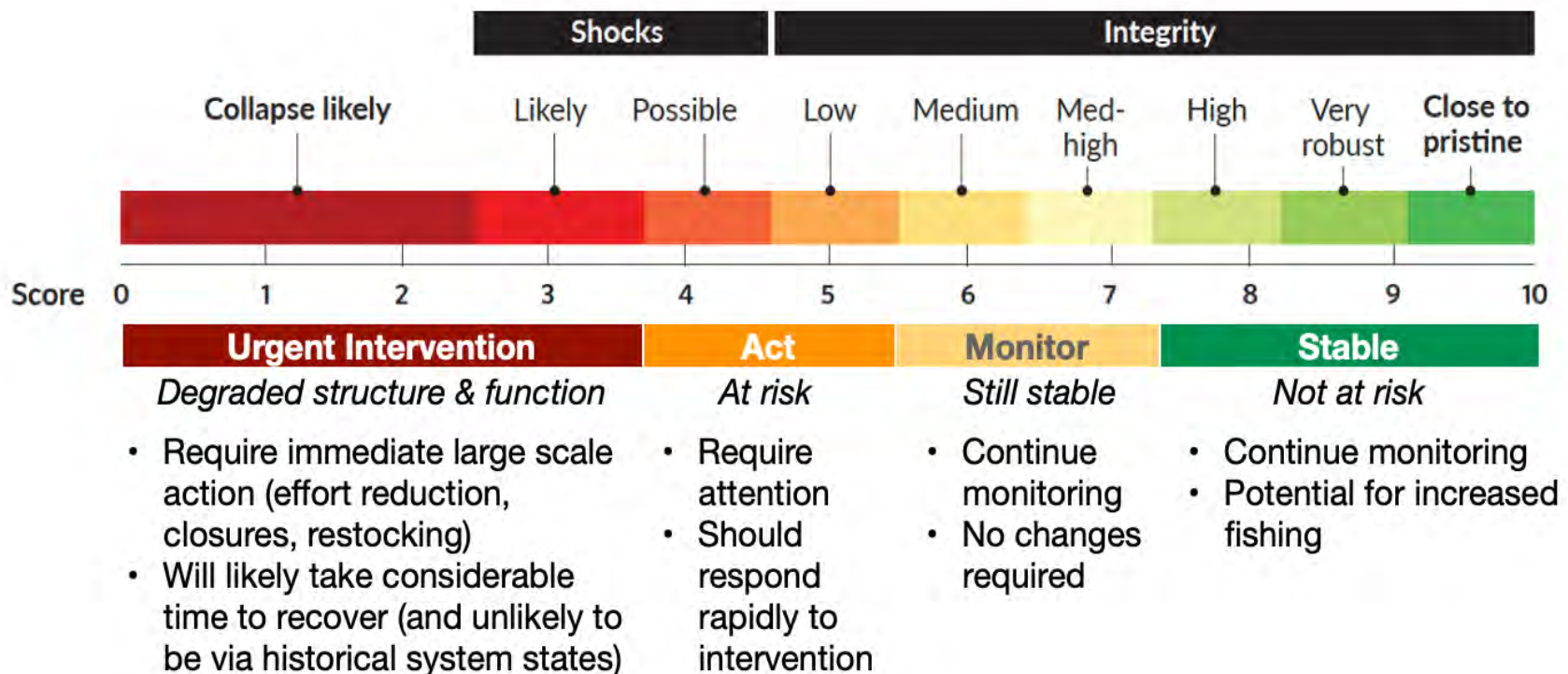
Gives an overall ETI score

- ETI scores 0-10
- ecosystem interpretation
- fishery management interpretation



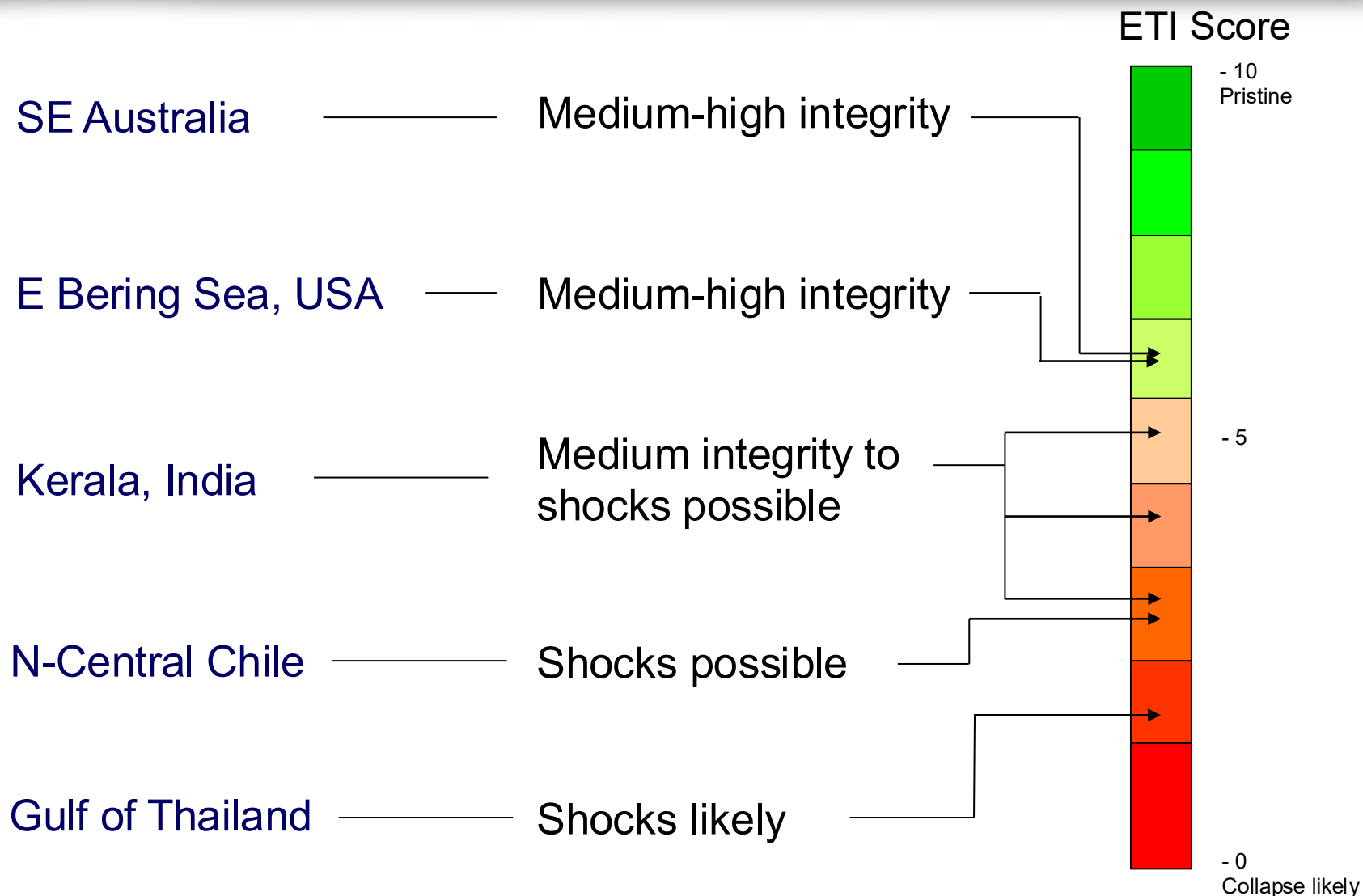
Ecosystem Traits Index (ETI)

- ETI scores and interpretation





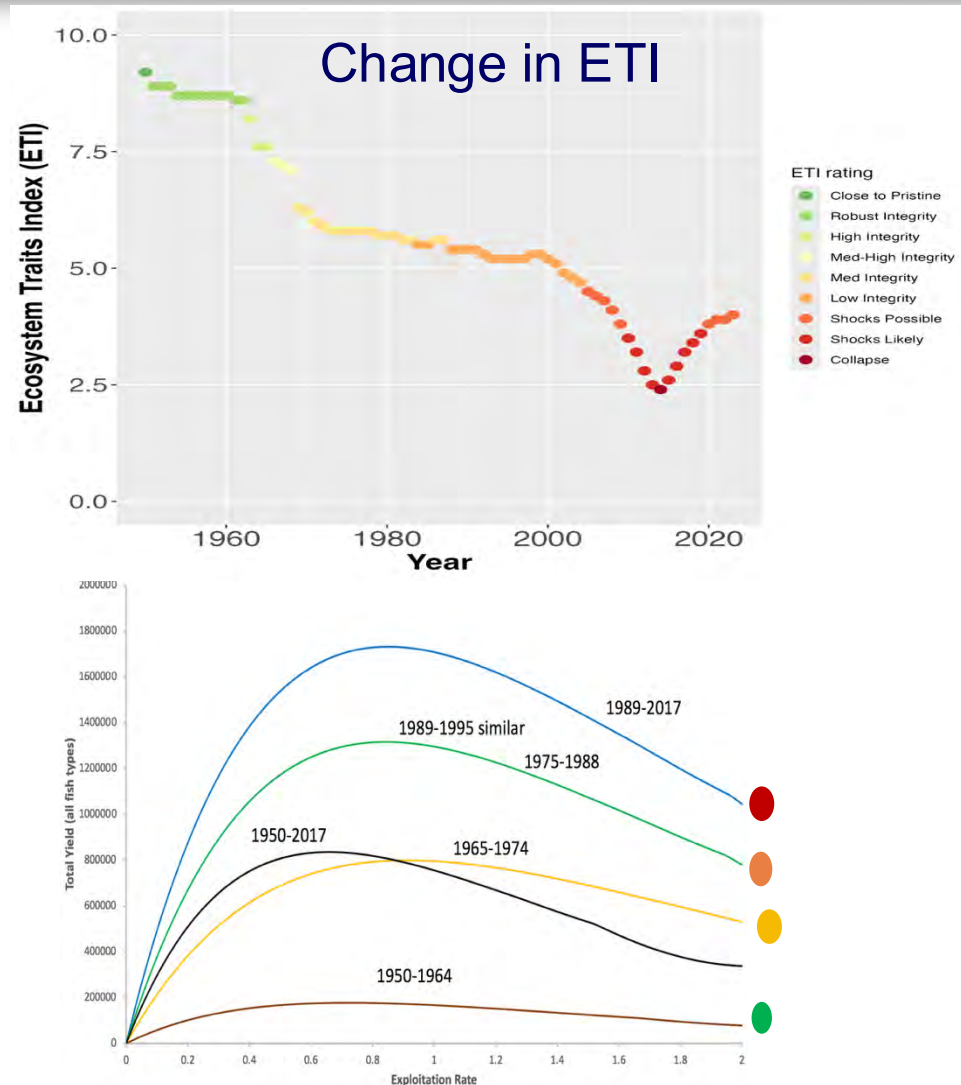
What did the Ecosystem Traits Index (ETI) show for the 5 assessed fisheries?





ETI for GoT Thailand

- Catch increased but the ecosystem became more fragile
 - ETI green to red dots
- GoT fishing effort decreased in 2017
- But what is the desired fishery?

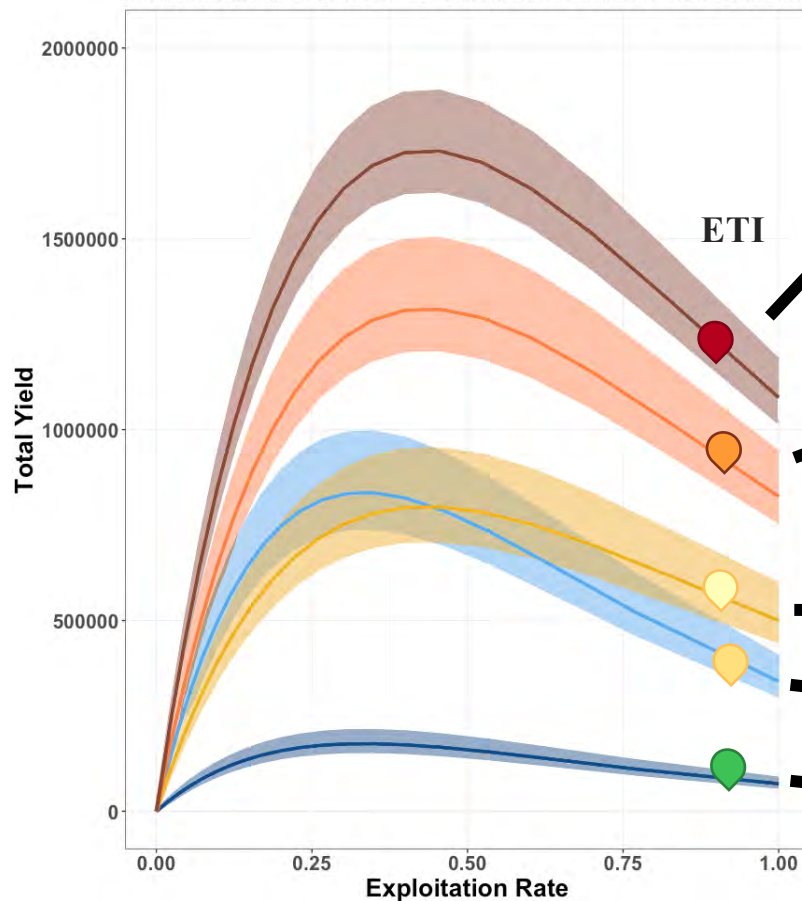




Trade-offs between ecosystems for GoT Thailand

What fishery is desired?

Production Curves - Data from Different Periods



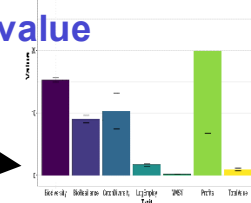
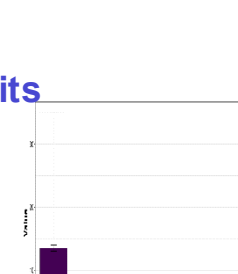
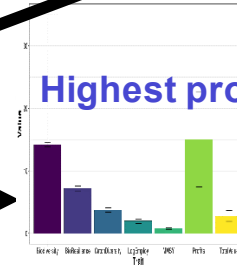
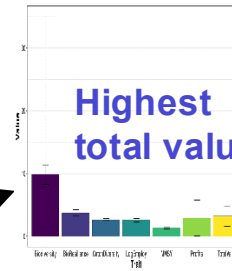
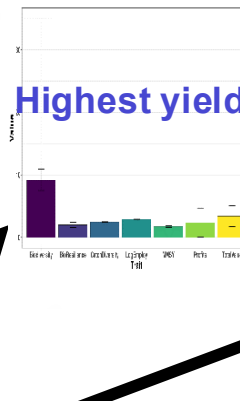
Highest yield and jobs

Highest total value

Highest profits

- Highest biodiversity and system resilience
- low catch and total value

Trait

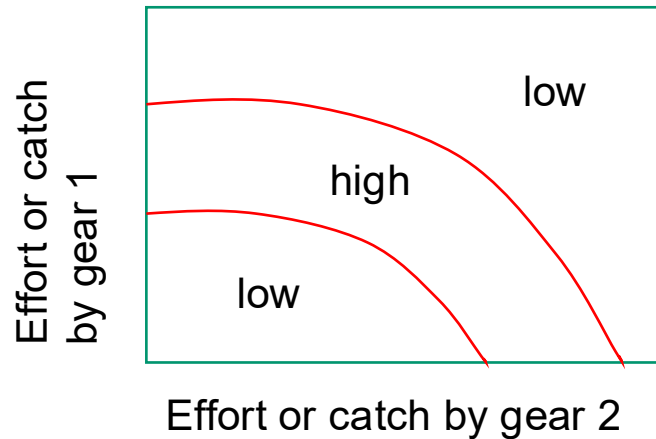




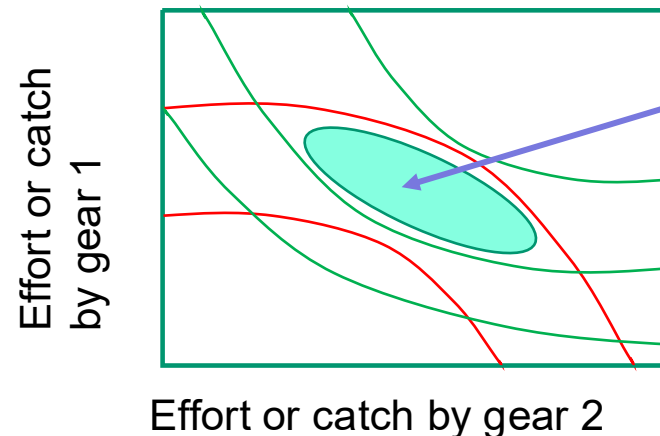
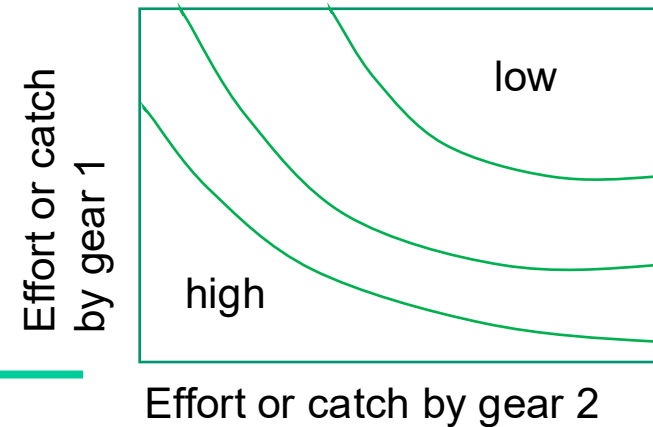
Using ecosystem indicators in decisions

- combine fishery benefits with ecosystem index

Human fishery benefits from two gears



Ecosystem index from two gears



“Acceptable” zone

- fishery benefits plus ecosystem status
- ecosystem indicators can be reference points



Ability to perform fishery ecosystem assessments

The 4 ecosystem indicators could be calculated for all five fisheries

Data limitation was an issue but not a limiting issue for any fishery

Further applications

- an EAFM review for NEAFC
- follow-up implementation projects in Thailand and Indonesia
- now considering applications in tRFMOs

Thank You



References

Executive summary of Lenfest project

Moving from A to B - Guidelines for Practical Ecosystem-Based Fishery Management. www.lenfestocean.org/-/media/assets/extranets/lenfest/ebfm_es_march2024.pdf

Papers on fishing ecosystem indicators

Fulton, E.A. and K.J. Sainsbury (2025) The Ecosystem Traits Index is proposed as a composite index of ecosystem robustness for use in marine resource management. *Nature Sustainability* 15: 32281.

<https://doi.org/10.1038/s41598-025-15322-z> and www.nature.com/articles/s41598-025-15322-z

Fulton, E.A., K. Sainsbury, C. Bulman, C. Novaglio, J. Porobic, D. Hayes, E.I. van Putten, L.X.C. Dutra, L. Thomas, W. Norris, C. Pert, A. Willock, S.C. Montenegro, L. Garay-Narvaez, S. Hernández Concha, A. Hernández Saso, K.S. Mohamed, T.V. Sathianandan, S. Kuriakose, E. Varghese, T.M. Najmudeen, S. Vasudevan, M. Anish, S.S. Salim, I. Mandro, S. Zador, I. Ortiz, A. Whitehouse, K. Aydin, W. Tweit, D. Evans (2025) "The Green Band": Using Production and Catch to Judge Distortive Pressure on an Ecosystem. *BioRxiv* doi: <https://doi.org/10.1101/2025.06.09.658403> Note: this is citable but is not a peer reviewed publication. A formal publication is currently in review.

Fulton, E.A. and K.J. Sainsbury (2024) Food web structure, the hub index and identifying species of ecological significance. *Ecological Indicators* 166. <https://doi.org/10.1016/j.ecolind.2024.112378>

Fulton, E.A., K. Sainsbury, P. Noranartragoon, D. Leadbitter, D. J. Staples, J. Porobic, Y. Ye, R. Phoonsawat and N. Kulanujaree (2022) Shifting baselines and deciding on the desirable form of multispecies maximum sustainable yield. *ICES Journal of Marine Science* 79: 2138-2154. <https://doi.org/10.1093/icesjms/fsac150>

Report on ecosystem approaches to fisheries for ICES

ICES (2024) Expert report on scoping ecosystem approaches to fisheries management to assist NEAFC request to ICES. *ICES Scientific Reports*. 06:76. 73 pp. <https://doi.org/10.17895/ices.pub.27051049>

Authors: Mark Dickey-Collas; Beth Fulton; Andrew Kenny; Keith Sainsbury

Annex 9



Ecosystem Models for ETI calculation

Beth Fulton

CSIRO Ecosystem Model Suite

Using easily measurable proxy to predict what care about

Using physiological tolerance to track likely locations etc

Using observed patterns to create a short cut method of summarising dynamics

Most common approach = who eats who

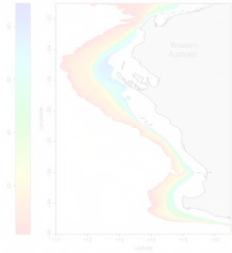
Use a mosaic of methods (whatever works best for each bit)

Probability of A becoming B used to predict change ('impact chains')

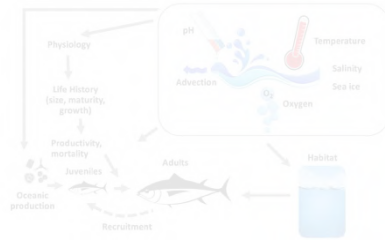
Picking out just the most important bits (where most data is)

CSIRO Eligible ecosystem models

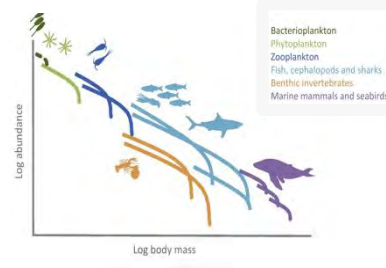
Statistical
distributions



Species
distributions



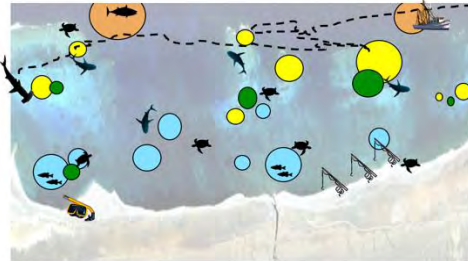
Size & Trait
based



Trophic



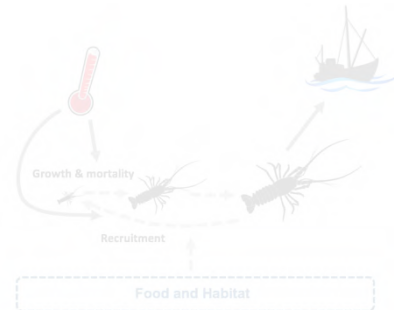
Agent based
& hybrid models



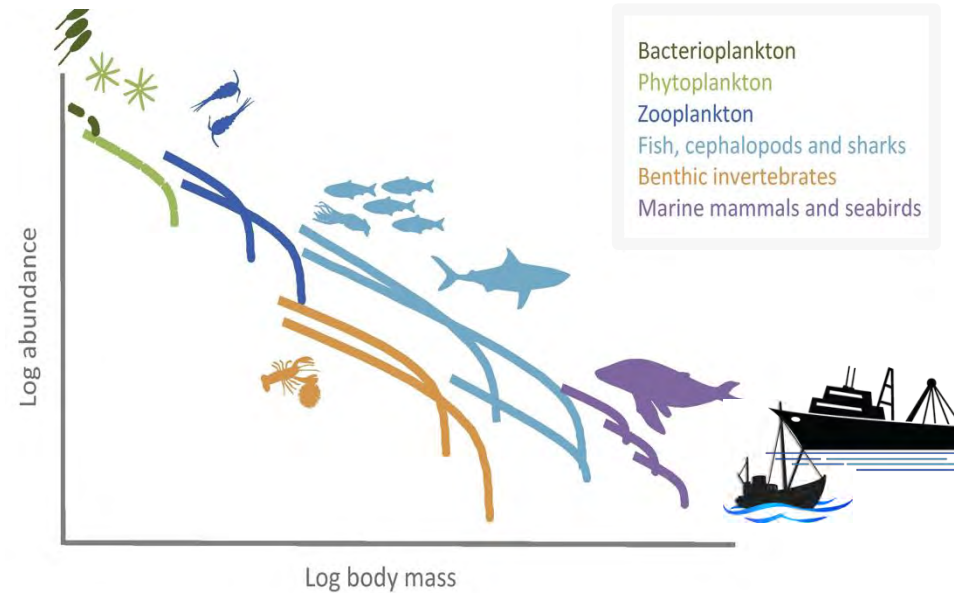
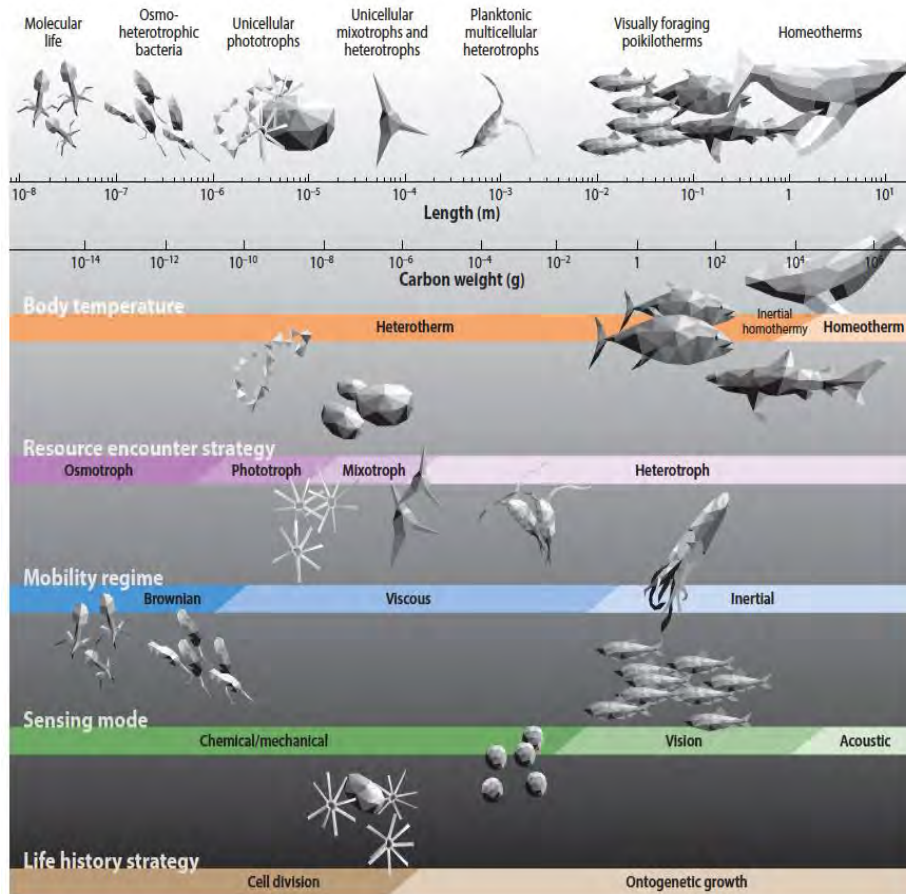
Bayesian
networks



Intermediate
Complexity

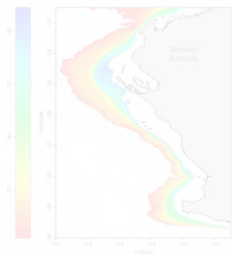


Trait & Size based models

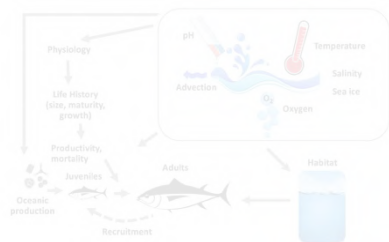


CSIRO Eligible ecosystem models

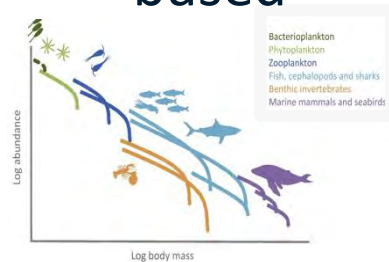
Statistical
distributions



Species
distributions



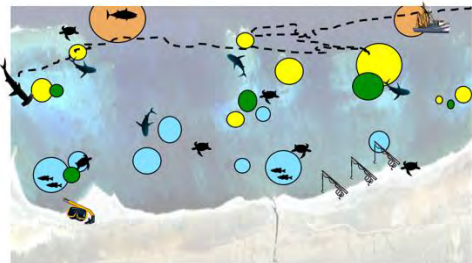
Size & Trait
based



Trophic



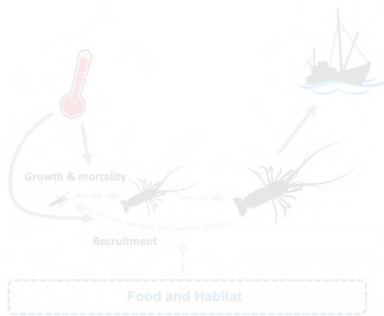
Agent based
& hybrid models



Bayesian
networks

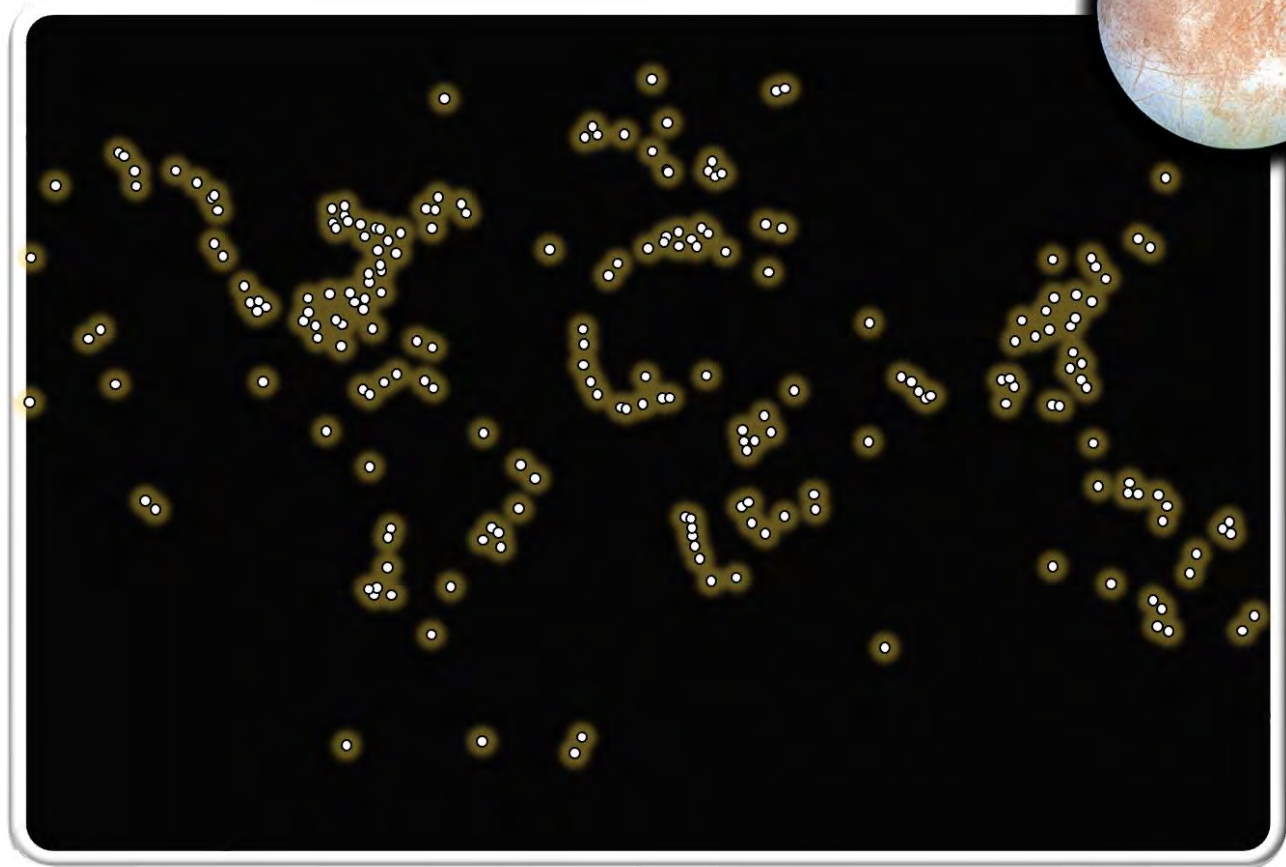


Intermediate
Complexity



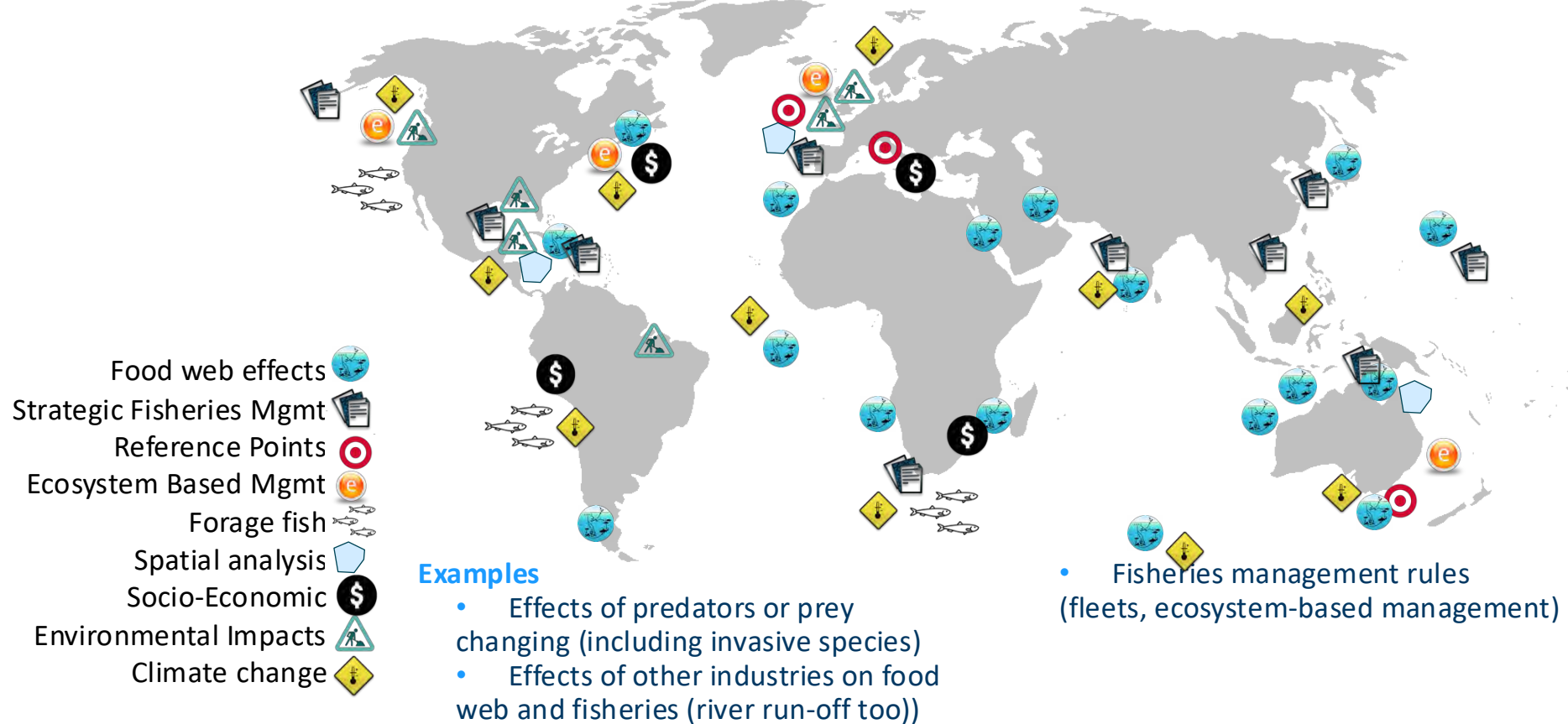
CSIRO Why Ecopath with Ecosim?

- Widely used
- 7000+ users
(151+ countries)
- 1000+ models
(500 in ecobase)
- >7500 pubs
- 52000+ citations
- Easy and faster
to use



CSIRO EwE current status

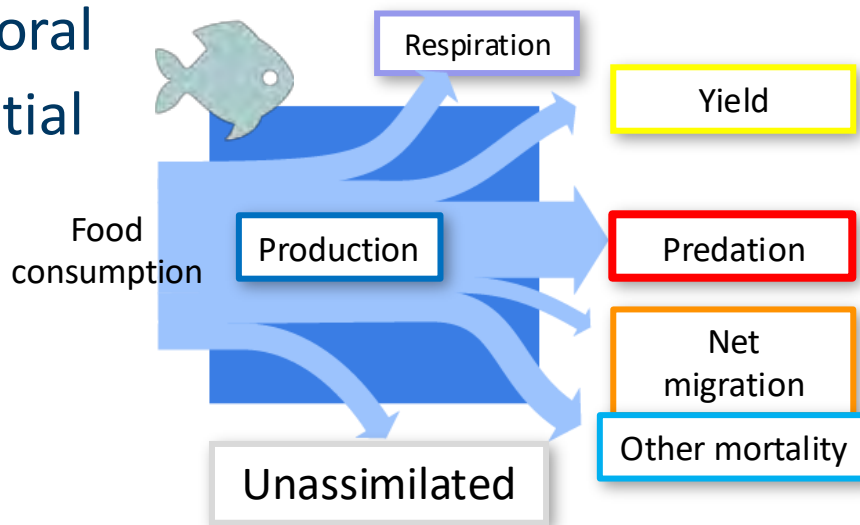
- Used for system understanding and management questions



CSIRO EwE current status



- Basic concepts still hold (Ecopath as basis of all else)
- Ecosim = temporal
- Ecospace = spatial



B_i	Biomass
P_i/B_i	Production
Q_i/B_i	Specific consumption
DC_{ij}	Fraction of prey i in diet of predator j
$B_i A_i$	Biomass accumulation
EE_i	Production used in the system
$1-EE_i$	Unexplained mortality

$$1. \left(\frac{Q}{B} \right)_i \cdot B_i = \left(\frac{P}{B} \right)_i \cdot B_i + R_i + UN_i$$

$$2. \left(\frac{P}{B} \right)_i \cdot B_i = \sum_{Pred_j=1}^n \left(\frac{Q}{B} \right)_j \cdot B_j \cdot DC_{ij} + E_i + Y_i + BA_i + \left(\frac{P}{B} \right)_i \cdot B_i \cdot (1 - EE_i)$$

CSIRO EwE data dependency

B	P	Q	EE	P/Q
✓	✓	✓	✗	✗
✓	✓	✗	✗	✓
✓	✗	✗	✓	✓
✗	✓	✓	✓	✗

Most common

- Diet composition, catch composition

CSIRO EwE data requirements

- Groups
 - alive or dead
 - producer or consumer
 - multi-stanza
- Biomasses
- Diets (and consumption rates)
- Total mortality (production)
- Fisheries data (time series for fitting and driving model)
- Other = specific circumstances, not a first pass inclusion
 - climate and primary production time series (driving model)



CSIRO Model construction considerations

- Spatial
- Temporal
- Processes details
 - physical, chemical, ecological, anthropogenic
- Currencies
- Trophic components (taxonomic resolution)
- Human industries
- Boundary conditions (and forcing)
- Sub-structure

**Complexity trade-offs
across these dimensions**



CSIRO Model construction principles

- Only as much as needed (critical dynamics)
 - Detail needed or just the response/effect?
- Uncertainty means try multiple options (ensemble)
- Feedbacks critical (multiple stable states)

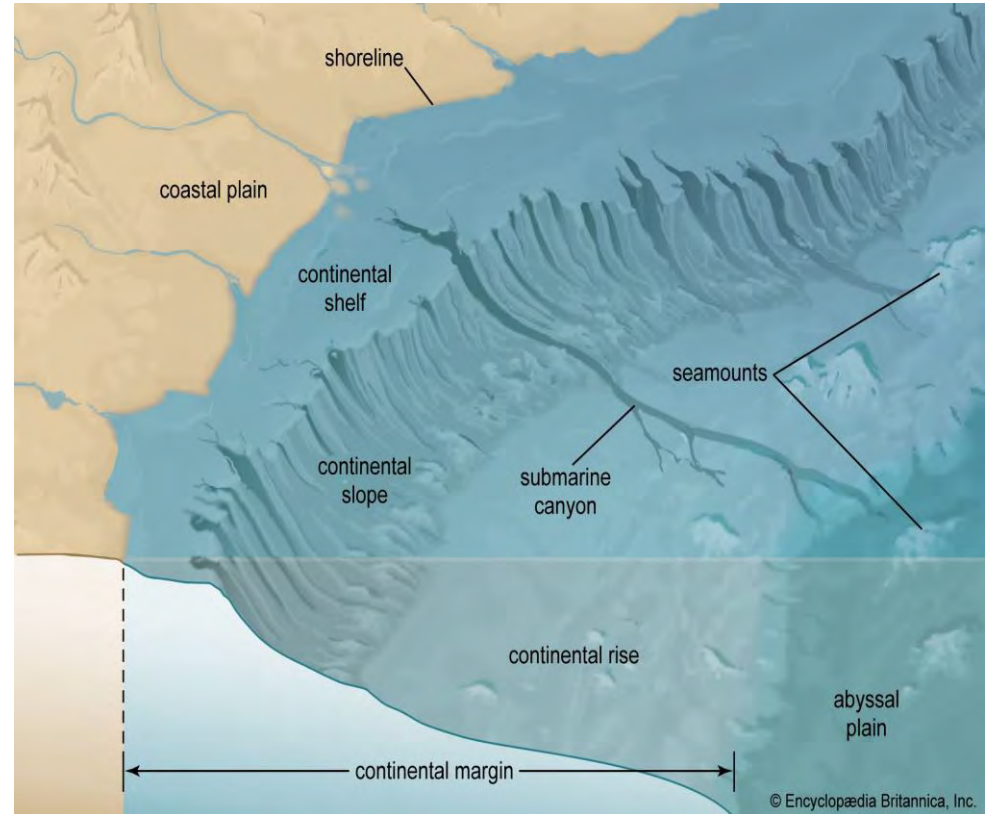
Attack problems at appropriate scales,
with appropriate theories and methods.
A universal scale is NOT useful

Rudolph Marcus



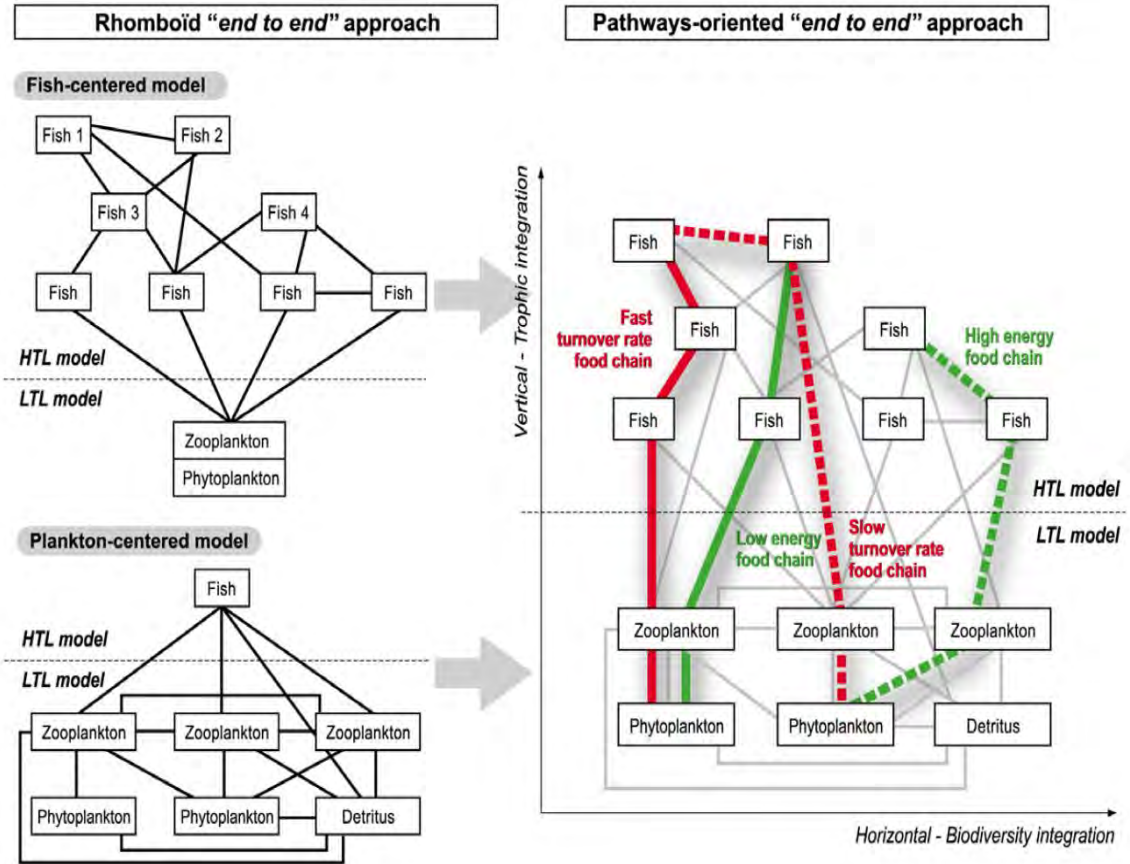
CSIRO Characteristics of good model

- Build implicit spatial structure from the start (vertical and horizontal)
- Points of physical influence (primary producers, habitats, individual responses)
- Biophysical habitats (demersal systems)



CSIRO Characteristics of good model

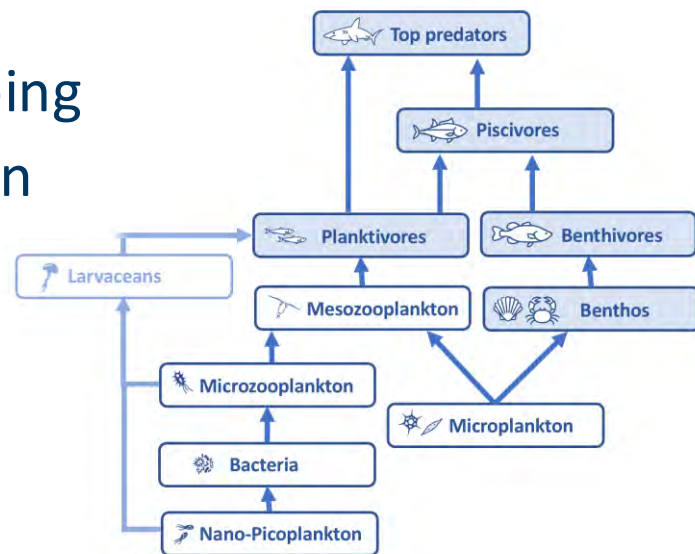
- Food web (ensure multiple pathways)



CSIRO Characteristics of good model

- Food web (ensure multiple pathways)
 - key species (target, ETP) + functional groups
 - reasonably balanced resolution across web
 - major change in behaviour/pathway with age or size then include stanzas
 - web structure: sensible ecological grouping
 - Avoid extremes: ideally 20-80 “groups” in model = reasonable for “end to end”
 - ▶ less = misleading
 - ▶ more = overwhelming

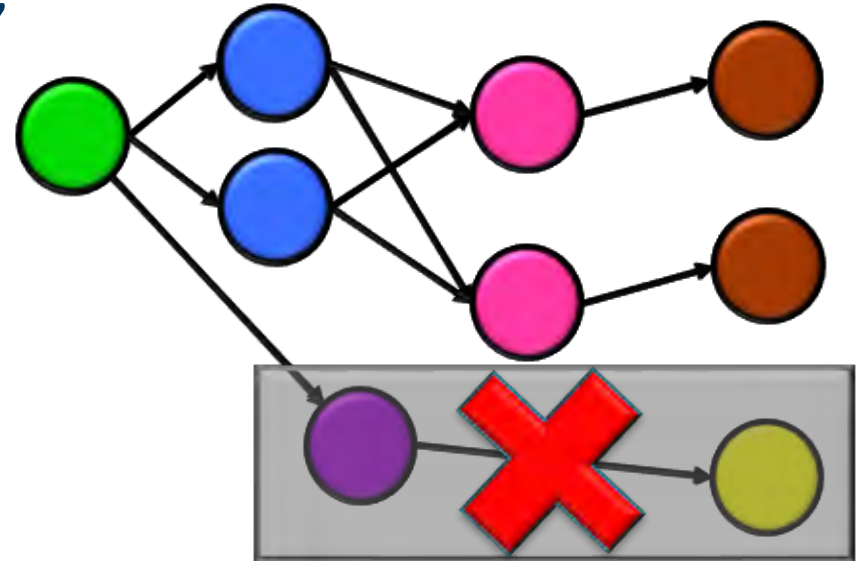
NB: MICE models are simpler intentionally



CSIRO Building a sensible food web

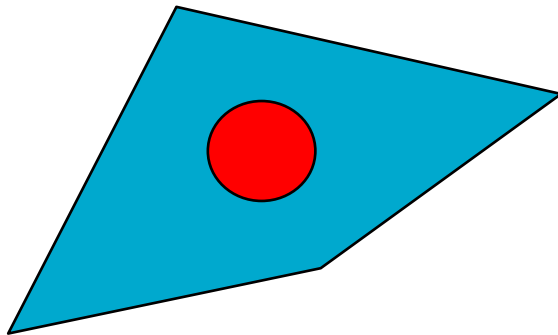


- Don't over lump/split species in model
 - can use feeding, age and size to decide group definitions
- Ecological principles for aggregation
 - Functional groups defined by size, ontogeny, habitat use, prey, predators, distribution, non-trophic interactions
 - don't group if rates $>3x$ different
 - omissions permissible (better than over aggregating)

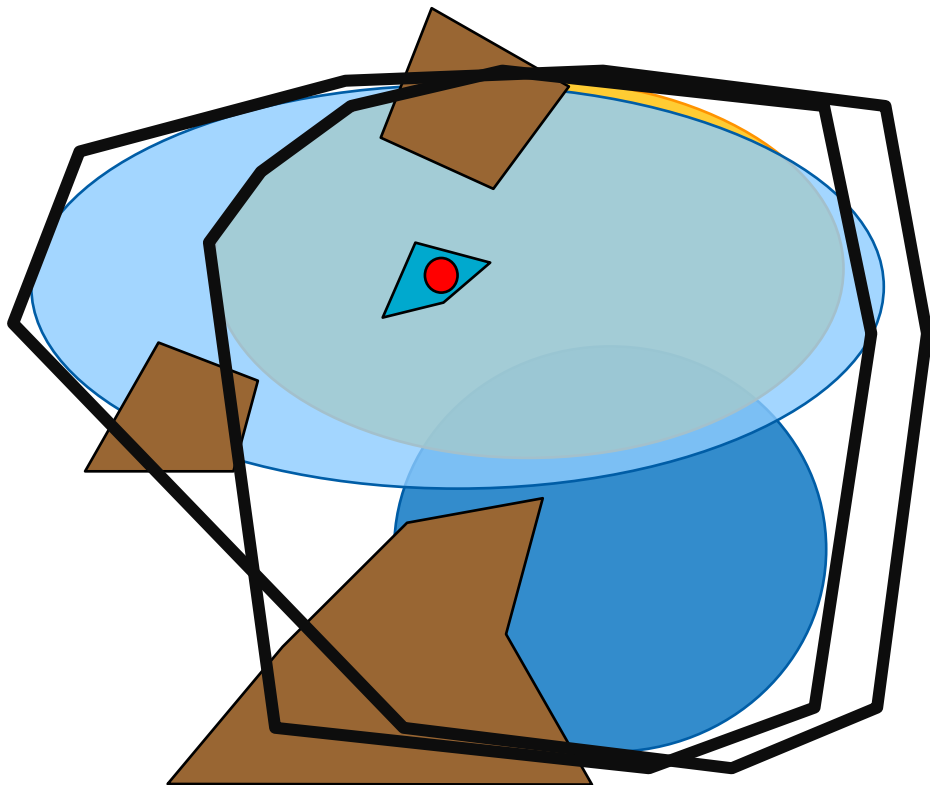


CSIRO Geographic scope

- What is the core area of interest?
 - do the species range? Expand domain?



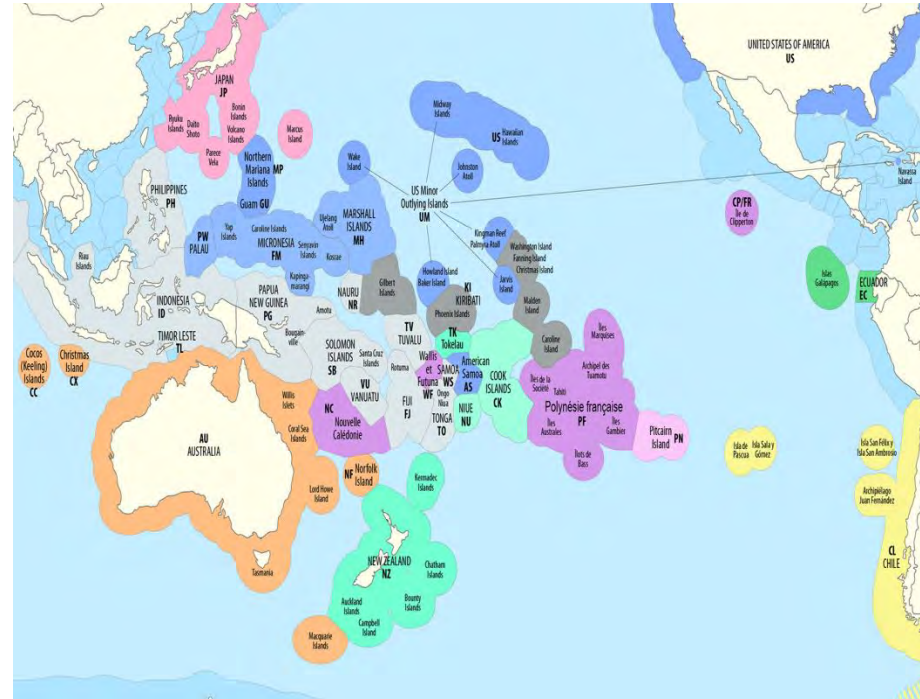
CSIRO Geographic scope



- Do the species migrate?
- Have distributions shifted through time (fish and fisheries)
- Expand domain, but have to be sensible (do you want a global model?)
- Use oceanography/bathymetry (and geopolitical boundaries) to help define bounds
- Model “tricks” (migration boxes)

CSIRO Application to pelagic ecosystems

- Multiple scales important
 - overall extent (aggregate state)
 - regional specifics (local performance)
 - ▶ national EEZs
 - ▶ ecoregions
- Are new approaches (additional steps) required?



CSIRO Use of EwE output for indicators

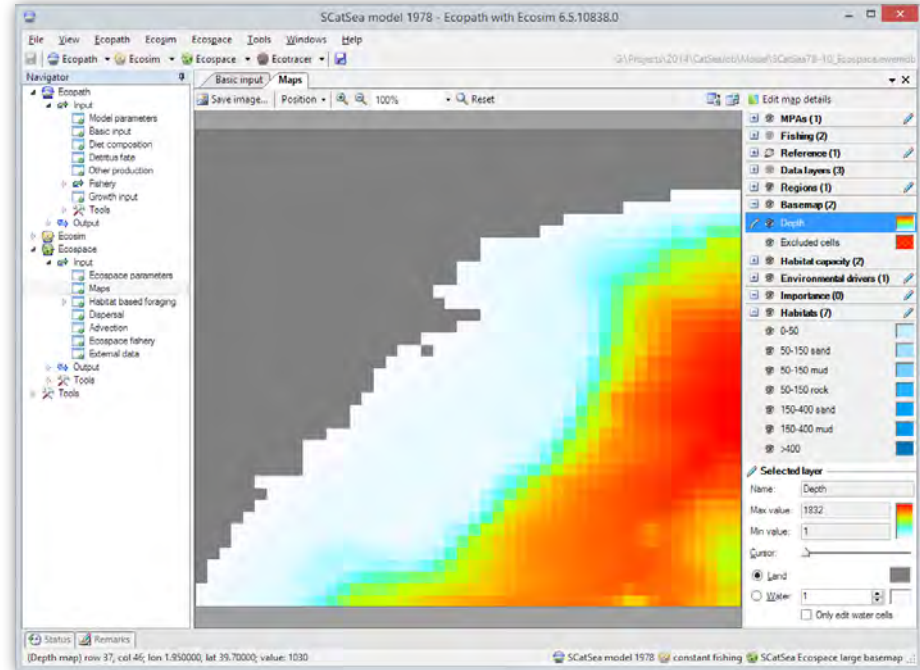
- Base output
 - biomass, mortality, consumption
 - catch, discards (value)
- Additional EwE output
 - size based (lengths and weights; mean; community)
 - trophic level (system and catch, MTI)
 - biodiversity indices (Shannon, Kempton Q)
 - primary production required
 - network indices: keystone, mixed trophic impacts
 - biomass ratios

} Used outside
EwE to calculate
indicators
(e.g. using R)



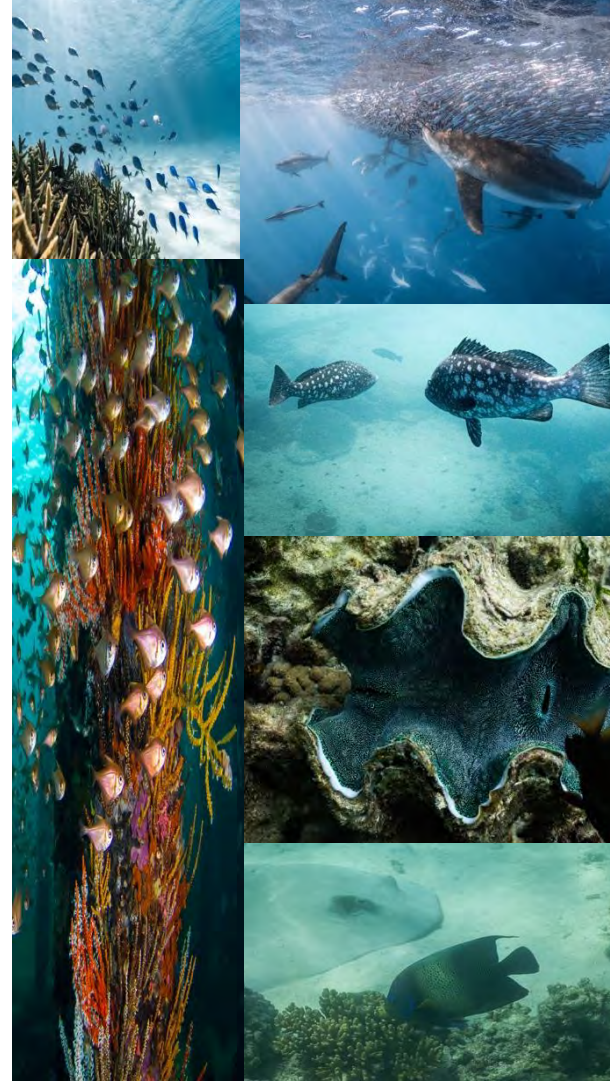
CSIRO Ecospace as an option

- Spatial data (bathymetry, advection, primary production, migration movement patterns)
- Environmental conditioning
- Fleet rules (distance-based, or calculated from historical effort)
- Harder to use (can diverge from Ecosim results)
- Can output "regional" data for calculating spatially resolved indicators



CSIRO Summary

- Take time to think about what goes into a model structurally
- Range of data can be brought together (highly resolved to ecologically informed inference)
- Try reconstructing the past, can you reproduce observed (remembered) change? Sensible responses to perturbation?
- Sensibly built model provides reliable basis for structural indicators (and inform management)





Thank you

CSIRO Environment

Beth Fulton

Domain Lead Integrated Ocean Stewardship

+61 2 9123 4567

beth.fulton@csiro.au

csiro.au

Australia's National Science Agency

CSIRO



Requirements to calculate ETI and related indicators

Beth Fulton

CSIRO What and why model?

- System understanding
- What's there
 - What's common
 - What's rare
 - Who is connected to who
 - What shapes up interactions and productivity
- How responds to pressure or management action (assess intervention options)



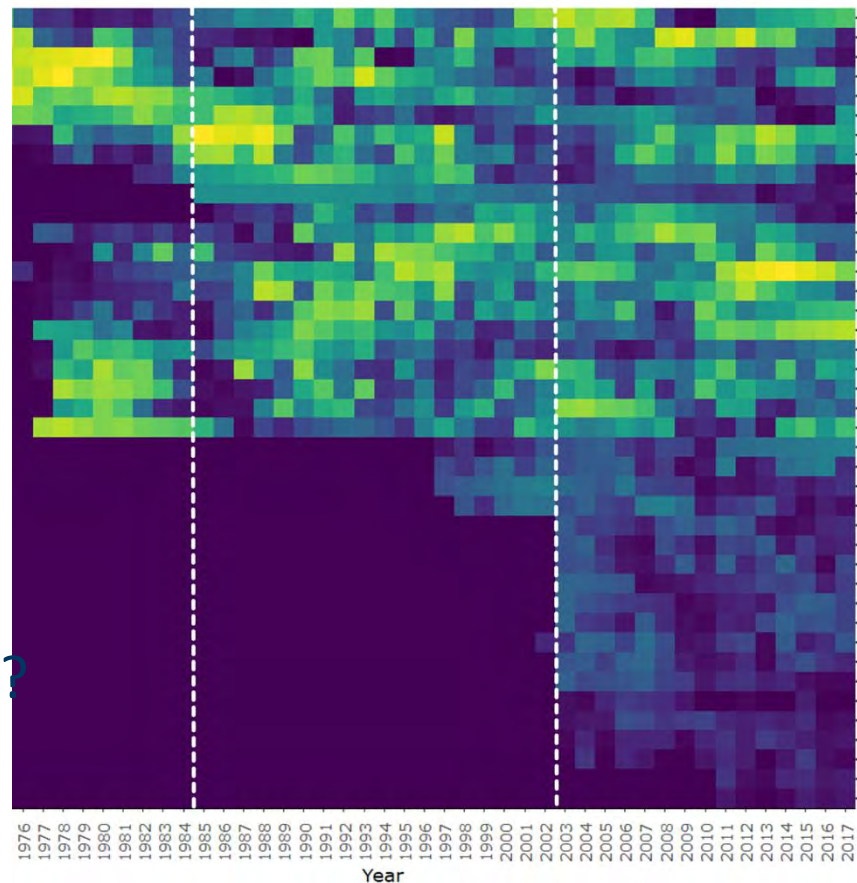
CSIRO Data requirements

- Biomass
- Catch
- Diet connections
- Habitat dependency
- Facilitation
- Climate and productivity forcing
- Snapshot at minimum, ideally through time
- Use models if missing data
 - but also for exploring future options



CSIRO Uneven data availability

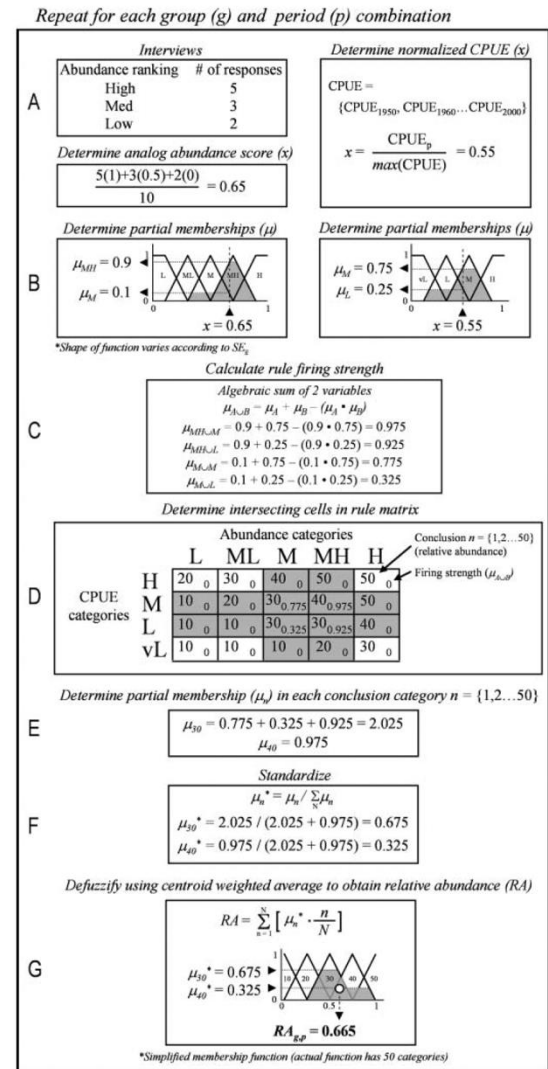
- Incrementally expanding data availability
- Hypothesis based reconstruction
 - current selectivity (and ecology) historical effort
 - begin with unfished, possible to reproduce known change?
 - what's needed to make it work?
Changed gear? Additional fisheries?
Environmental events or trends?



CSIRO Uneven data availability

- Seek out “old knowledge”
 - old reports
 - fisheries independent data sets (observers, surveys, conservation, citizen science)
 - memories/recollections (fuzzy logic possibilities)

Ainsworth (2011)



CSIRO Data Hierarchy (Pedigree)

- Data usually from where-ever you can get it!

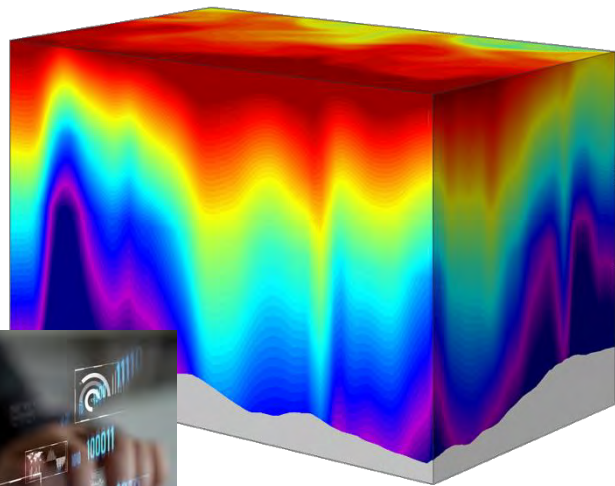
- 
- ▶ specific surveys (industry independent)
 - ▶ industry records
 - ▶ observer reports
 - ▶ local expert info
 - ▶ similar systems / species elsewhere around the nation (or world)
 - ▶ educated guesses
 - ▶ see what needed to fit



Increasing modeler
desperation

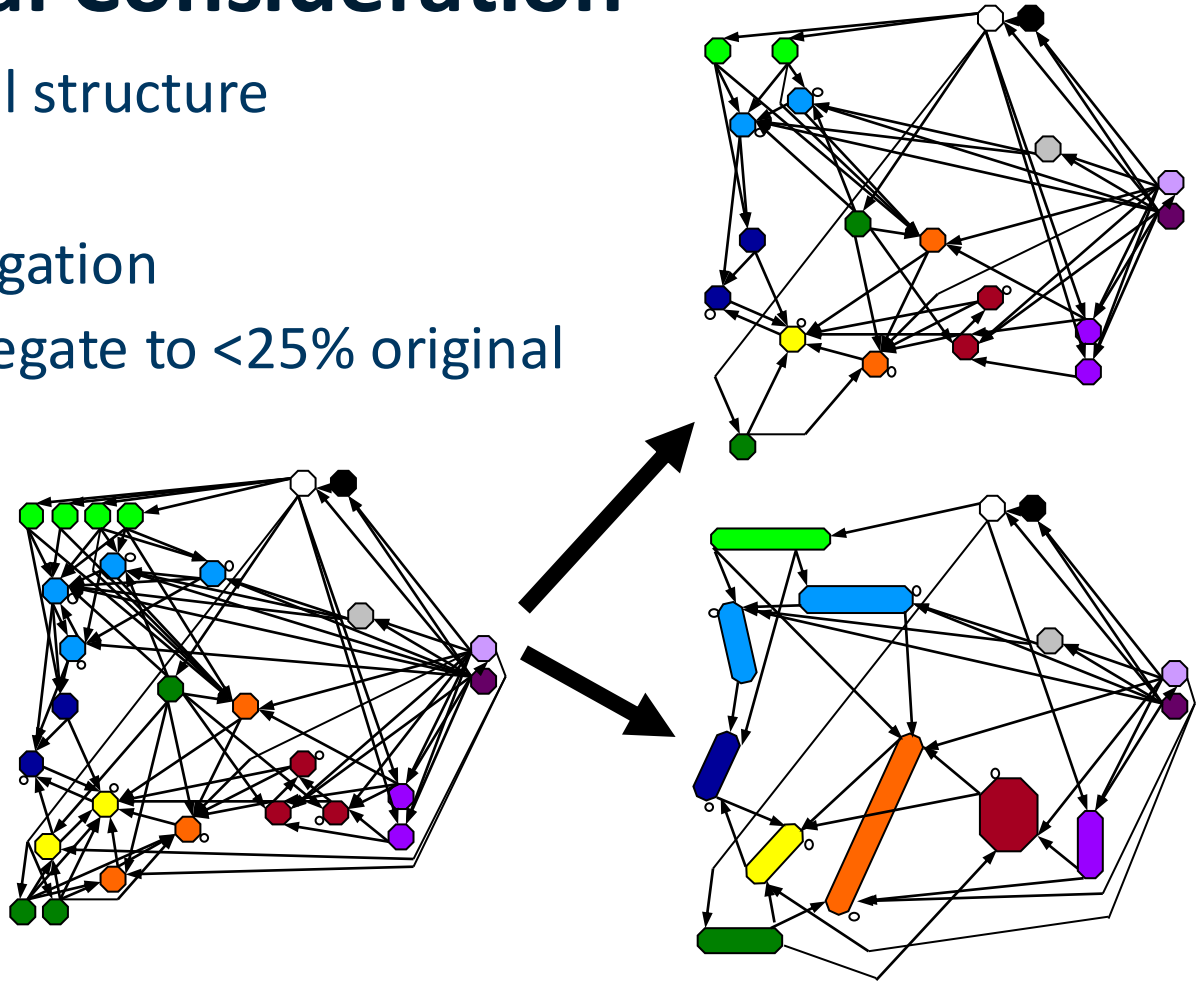
CSIRO Technical capacity needed

- Disciplines
 - ecological (and touch on oceanography, biogeochemistry)
 - modelling
 - fisheries science
 - *economics*
- Tools (e.g. R packages)



CSIRO Additional Consideration

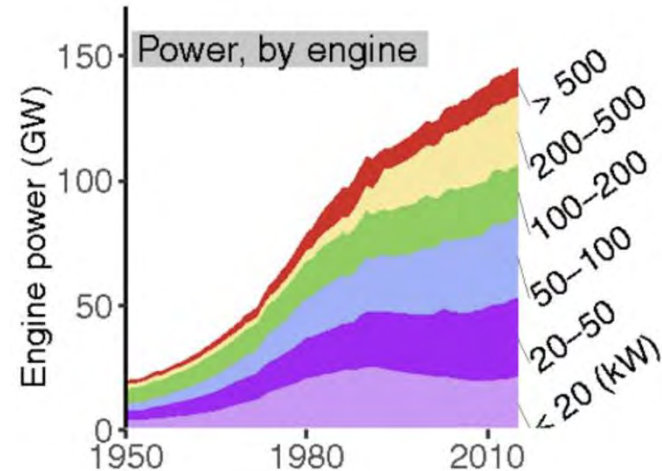
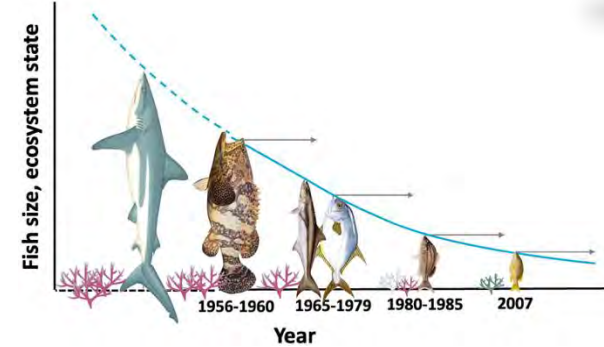
- Sensitivity tests: model structure
 - what is in/out
 - degree of diet aggregation
 - ▶ misleading if aggregate to <25% original detail
 - ▶ lump then chop
 - ▶ cannibalism <10% best
 - ▶ retain keystone species (or model performance step change)



CSIRO Additional Consideration

- Sensitivity tests
 - model structure (degree of diet aggregation)
 - has the ecosystem structure changed? Does the model allow for this or “stuck” in one form?
- Historical reconstructions
 - RFMO data
 - FishMIP (Watson database)
 - Sea Around Us

McClenachan (2009)



Rousseau et al (2019)

CSIRO Additional Consideration

- Sensitivity tests
 - model structure (degree of diet aggregation)
 - has the ecosystem structure changed? Does the model allow for this or “stuck” in one form?
 - parametric uncertainty (model fit time series dependent?... model skill and adequacy)
- Perturbation experiments (shock system, response plausible)



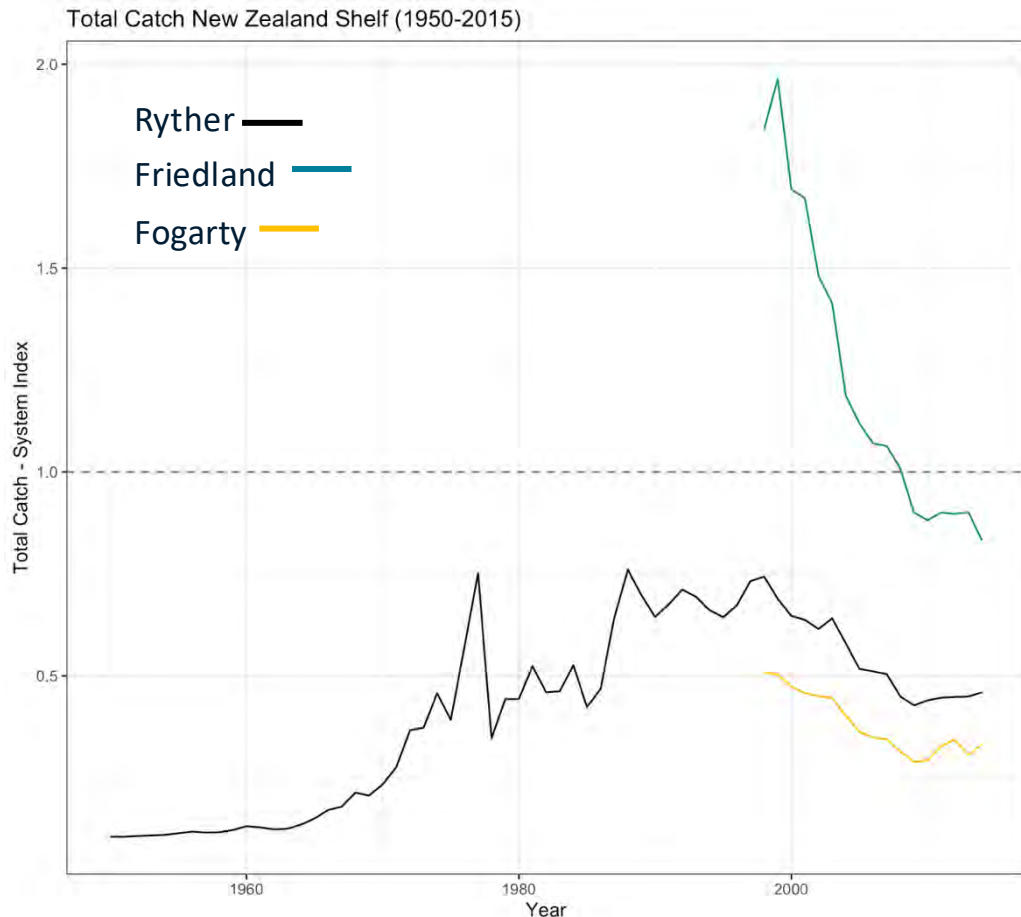
CSIRO Additional Evidence: Ecosystem Cap

- “Acceptable” total catch levels vs primary production

Tot catch < 1t km⁻² yr⁻¹ (Ryther index)

Tot Catch / Tot PP < 1 ‰ (Fogarty, Friedman indices)

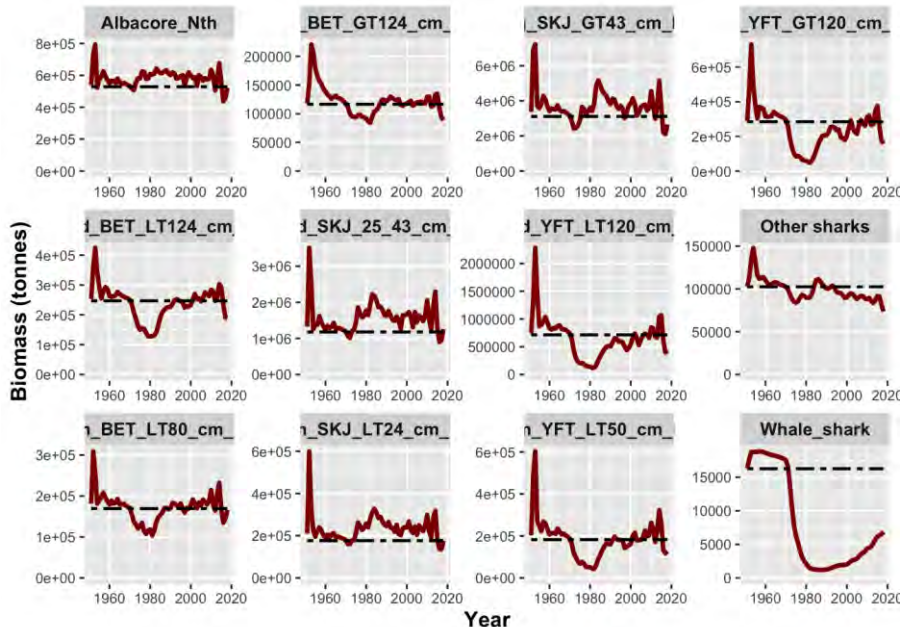
- Ryther (Catch per area)
- Fogarty (Catch / primary production)
- Friedman (Catch / Chlorophyll)



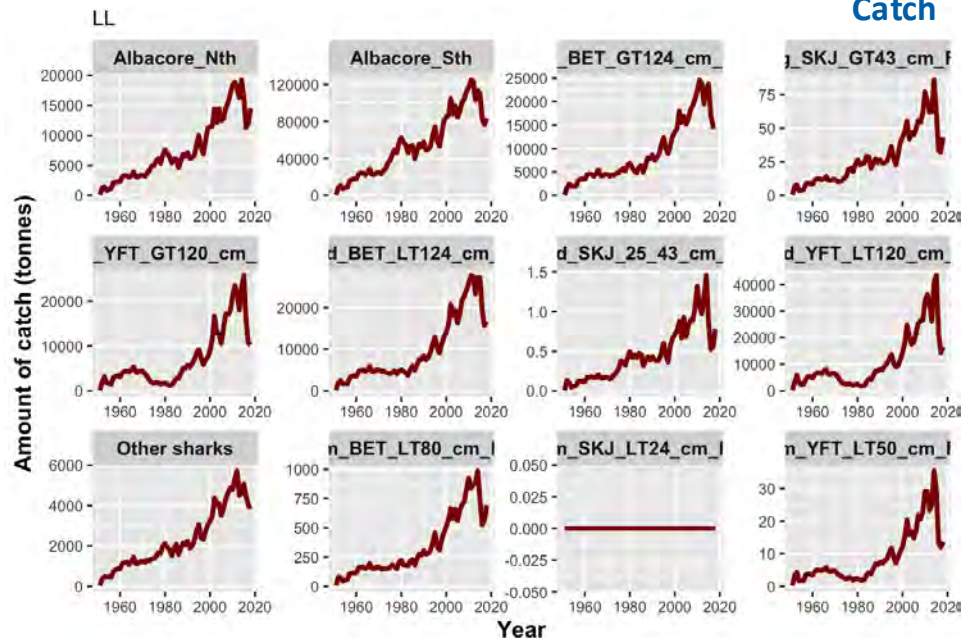
Importance of Diagnostics

- Plots (biomass, catch, composition)

Biomass



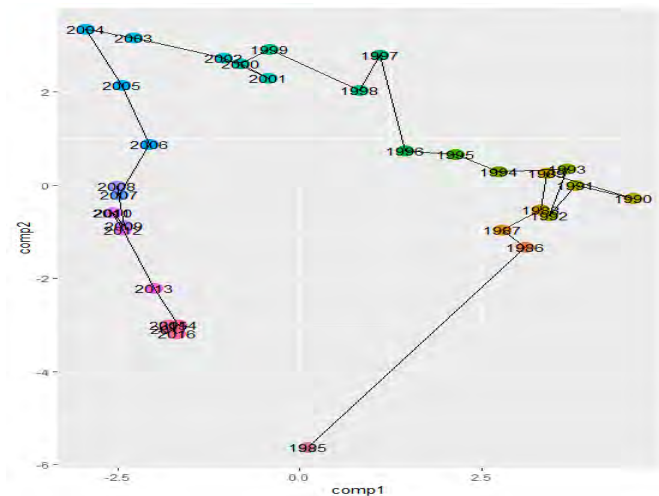
Catch



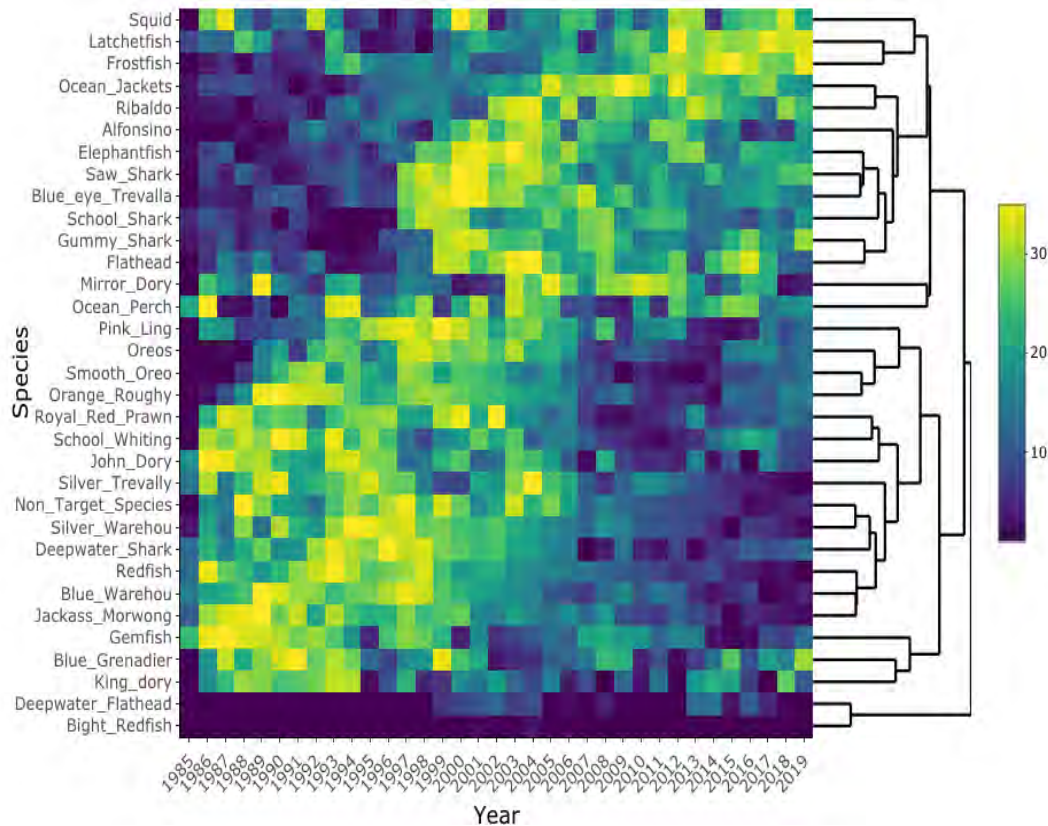
- Check its making sense (is it all there, right fleets, right timing, sharp discontinuity events real?)

CSIRO Importance of Diagnostics

- PCA on survey or catch composition
- Heatmap of contribution to catch through time
- Provide system understanding of change (drivers & transitions)



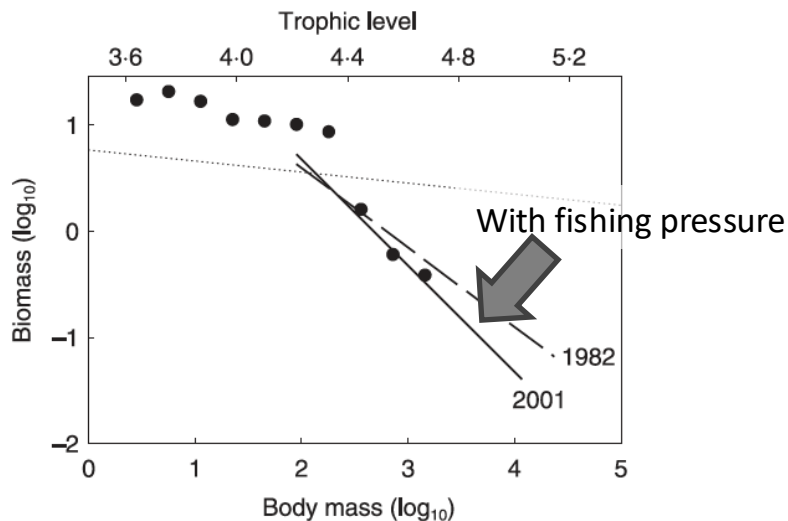
SE-Australia Heatmap of catch contribution through time (and space)



CSIRO Additional Evidence: System Indicators

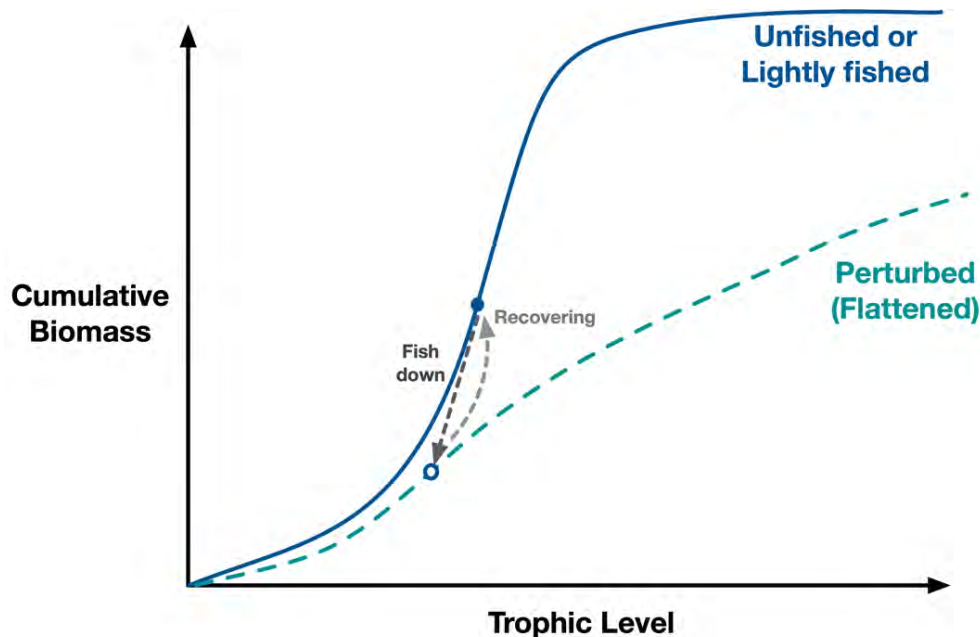
- Function hard to measure, structure easier (core of most reliable indicators)

Size based indicators



- Slope steeper and ratio of small:large (or pelagic:demersal) increases under pressure

Cumulative biomass vs TL

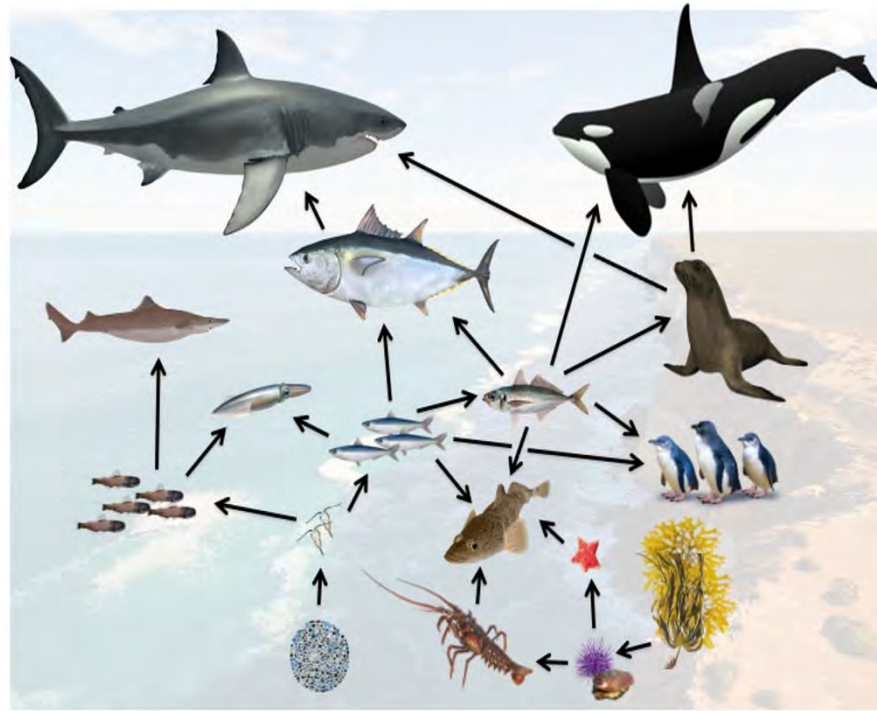
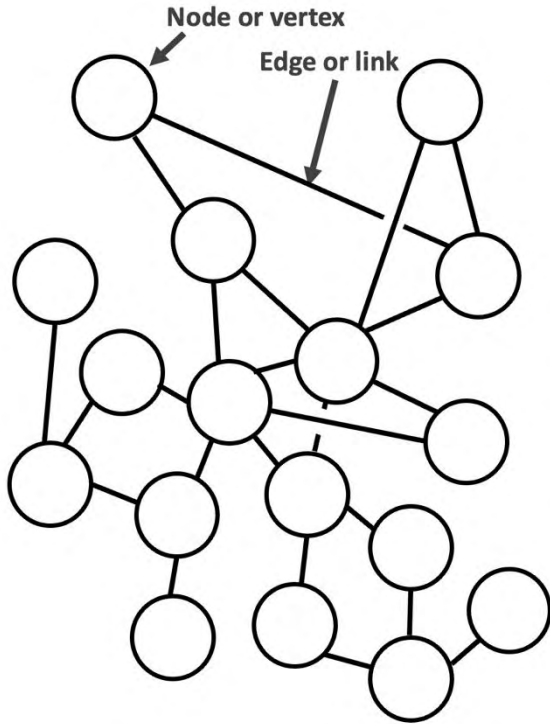


CSIRO Previously Identified Indicators

- Exploitation rate — Measure of pressure
 - Biomass ratio - piscivorous:zooplanktivorous fish
 - Biomass ratio - pelagic:demersal fish
- } Structure
- Coefficient of variation of ecosystem versus individual
- Stability
(resilience)
- Mean length (in community or catch)
 - Mean longevity (in community or catch)
 - Mean trophic level (of community, catch)
 - Proportion of large fish (LFI)
- } Structure,
productivity,
vulnerability

CSIRO Ecological Significant Species

- Use network properties of ecosystems (food webs and habitat connections) to find “hub” species



CSIRO Identifying hub species

- Consumption matrix (diet matrix another option)
- Calculate network indices
 - degree = total number of non-zero connections (in and out)
 - degree out = predation on that species
 - page rank = measure of “importance of flow” to that species (originally by Google for internet pages)
- Score (highest value of index = 1.... Lowest value = n)

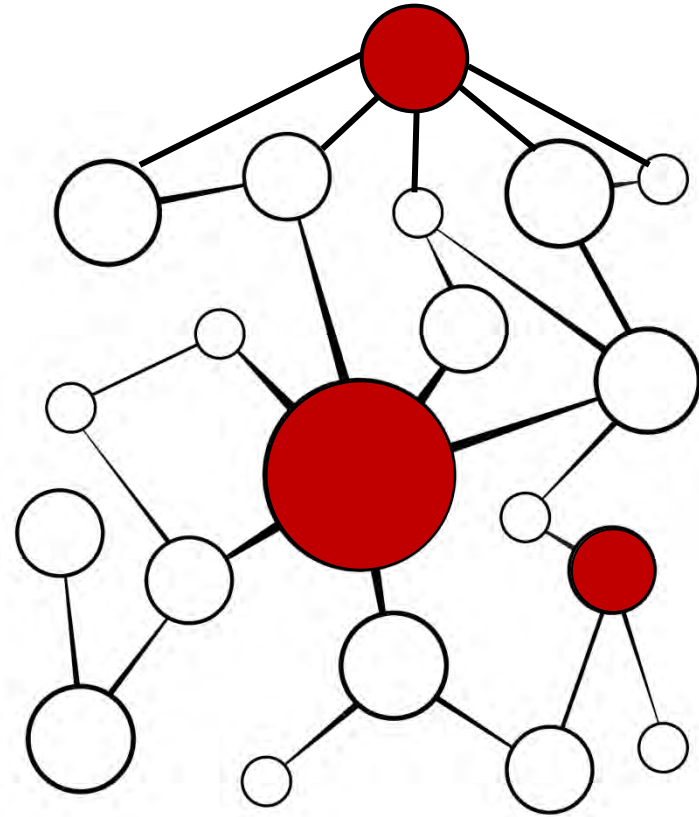
$$\text{HubIndex} = \min(R\text{degree}, R\text{degree out}, R\text{pagerank})$$

- Top 5% of ranks (e.g. 1-5) = hub species (elevated effect on system structure and function if lost)



CSIRO Interpreting hub species

- Applying “criticality” methods from engineering to identify critical nodes (hubs)
 - degree, degree out, page rank
 - Highly connected (often predators)
 - Species supporting the web structurally (often key prey)
 - Some are also keystone (not all)



CSIRO Hub vs Keystone species

- Hub = connectors in the system (lose them then system “fragments”)
- Keystone = has disproportionate influence on ecosystem given its biomass (e.g. eco-engineer)
- Some hub = keystone, but not 1:1 match

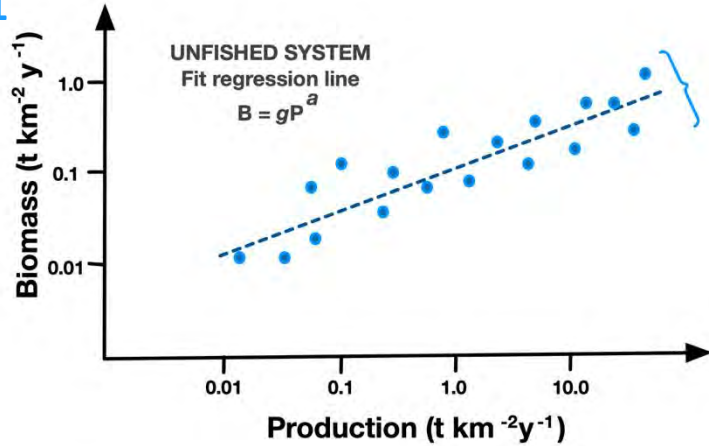


CSIRO Understanding the Green Band

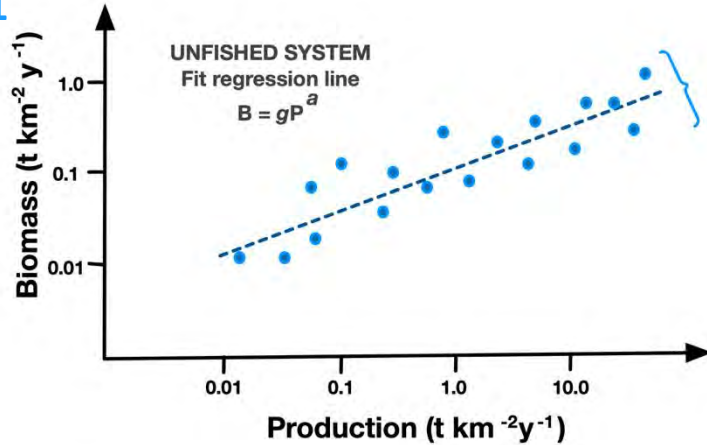
- Measure of pressure on the system
- What pressure can ecosystem structure deal with?
 - predation pressure
 - how does fishing compare to predation profile?
- If fishing putting more pressure than predation (of different pattern) can “stress weak points in web”



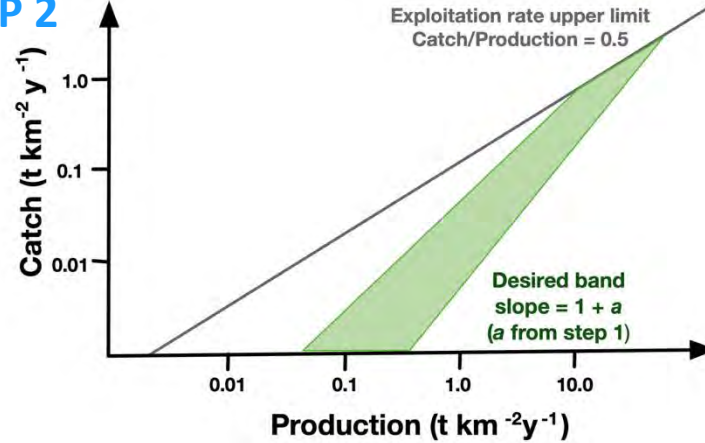
STEP 1



STEP 1

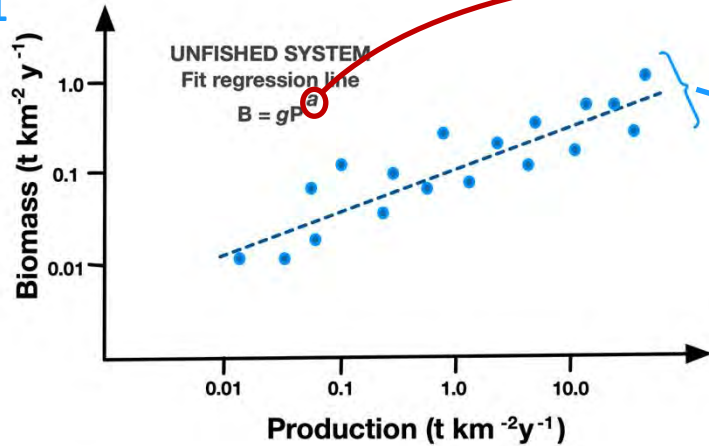


STEP 2

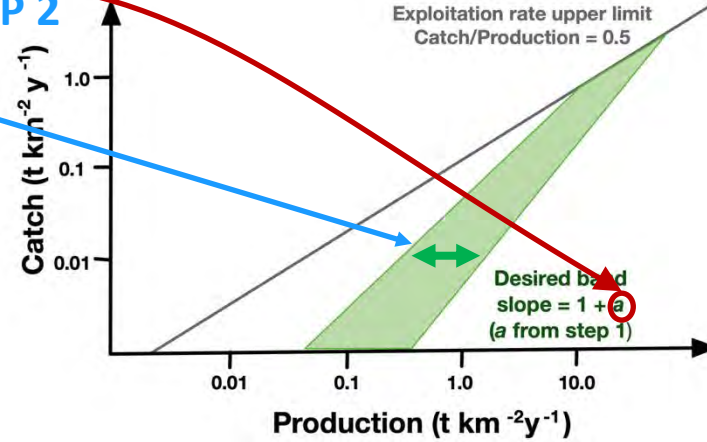


Checking for Distortive Pressure

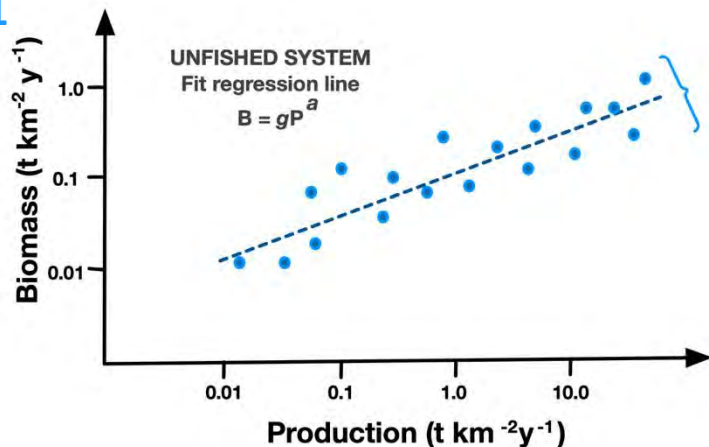
STEP 1



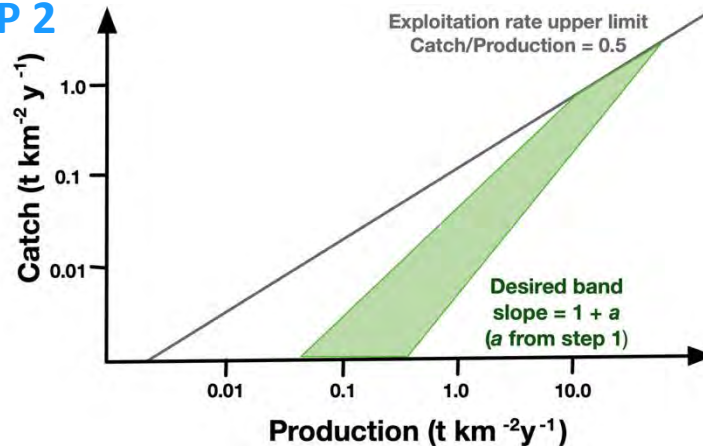
STEP 2



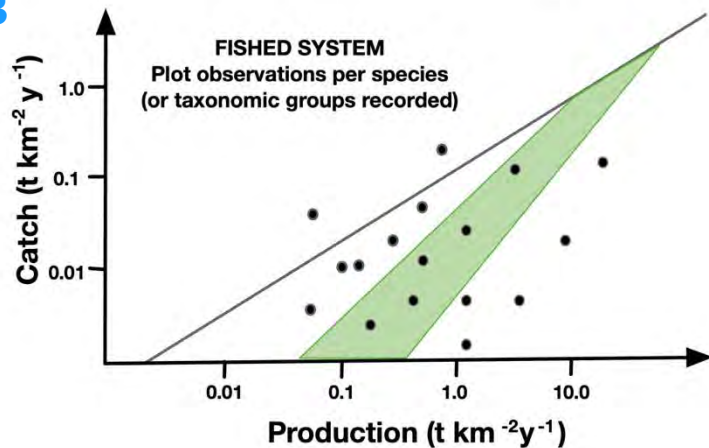
STEP 1



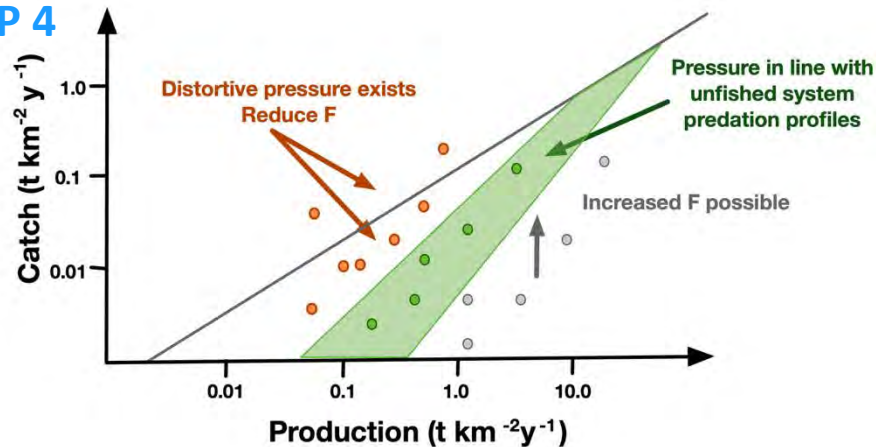
STEP 2



STEP 3

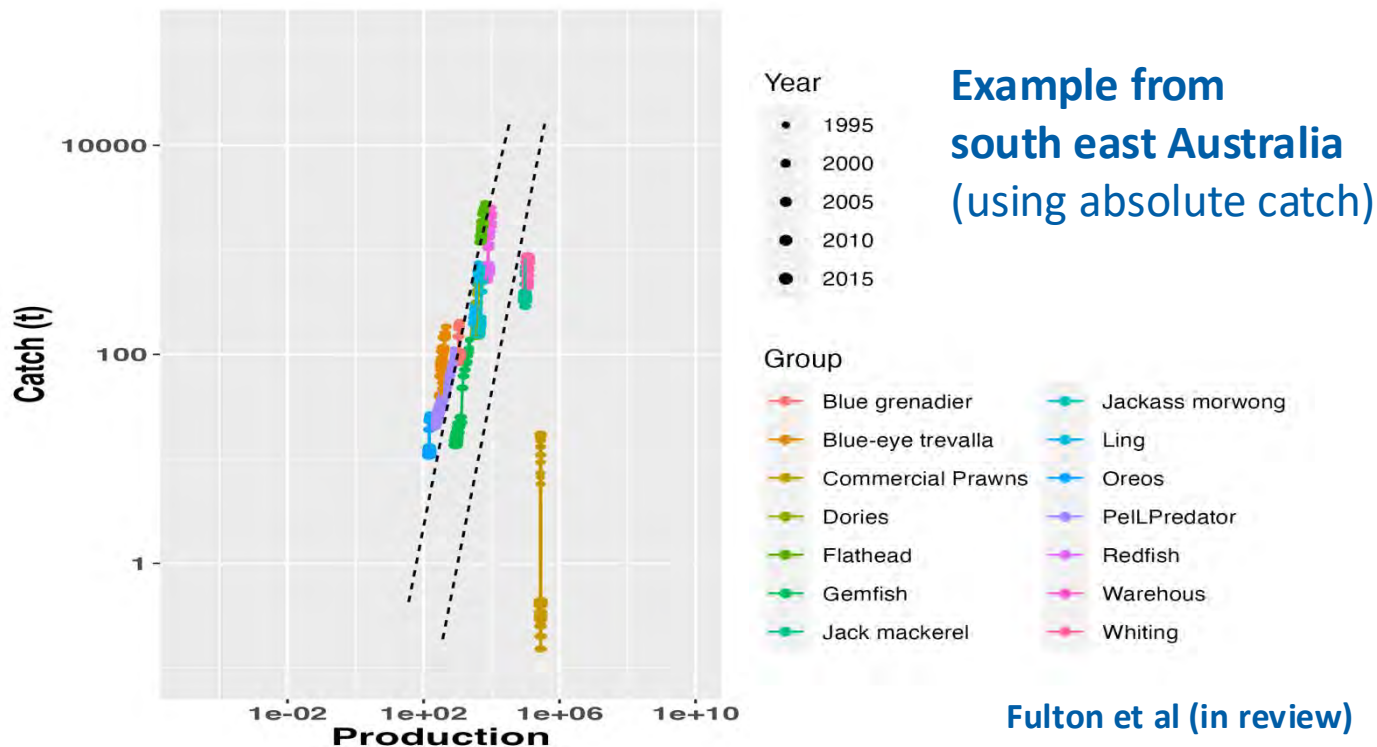


STEP 4



CSIRO Checking for Distortive Pressure

- Inform single species management on whether meeting EBFM

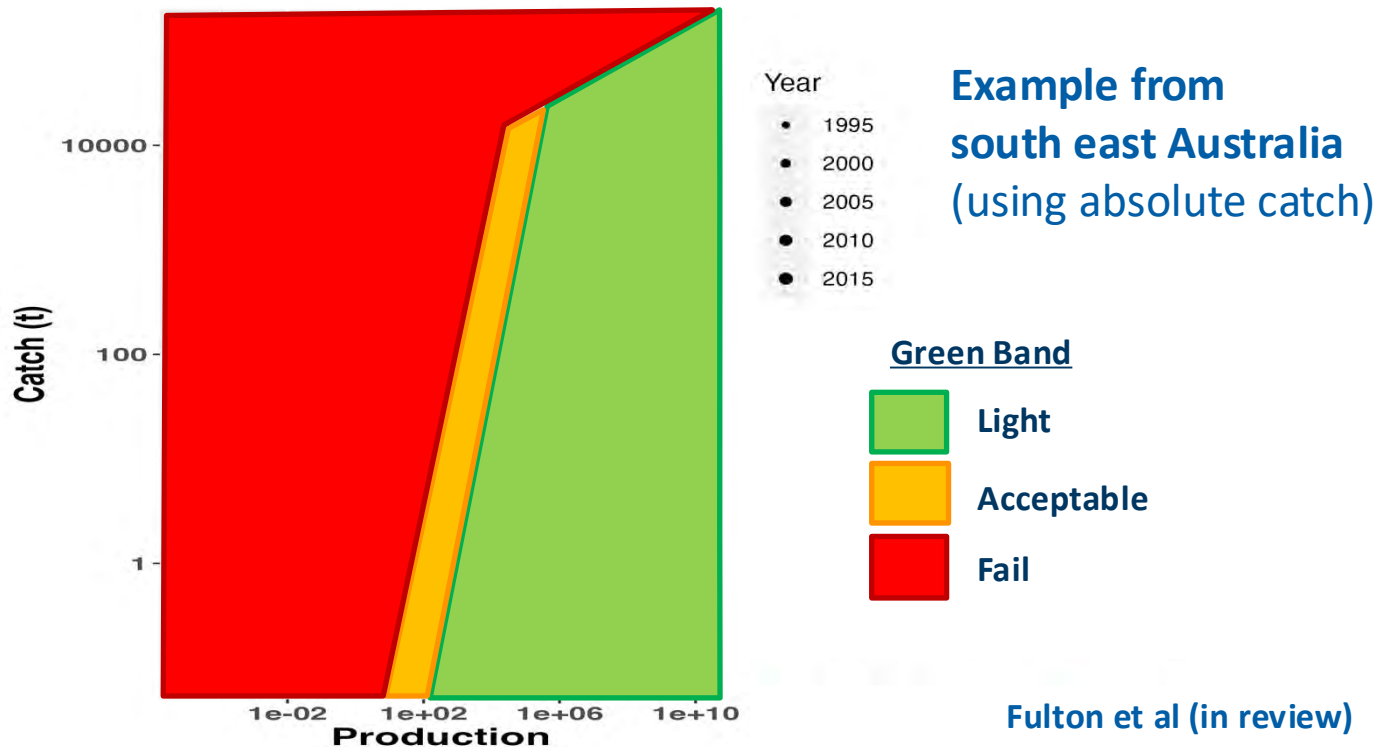


- Track through time to see response to fishing pressure, management interventions, productivity changes



CSIRO Checking for Distortive Pressure

- Inform single species management on whether meeting EBFM

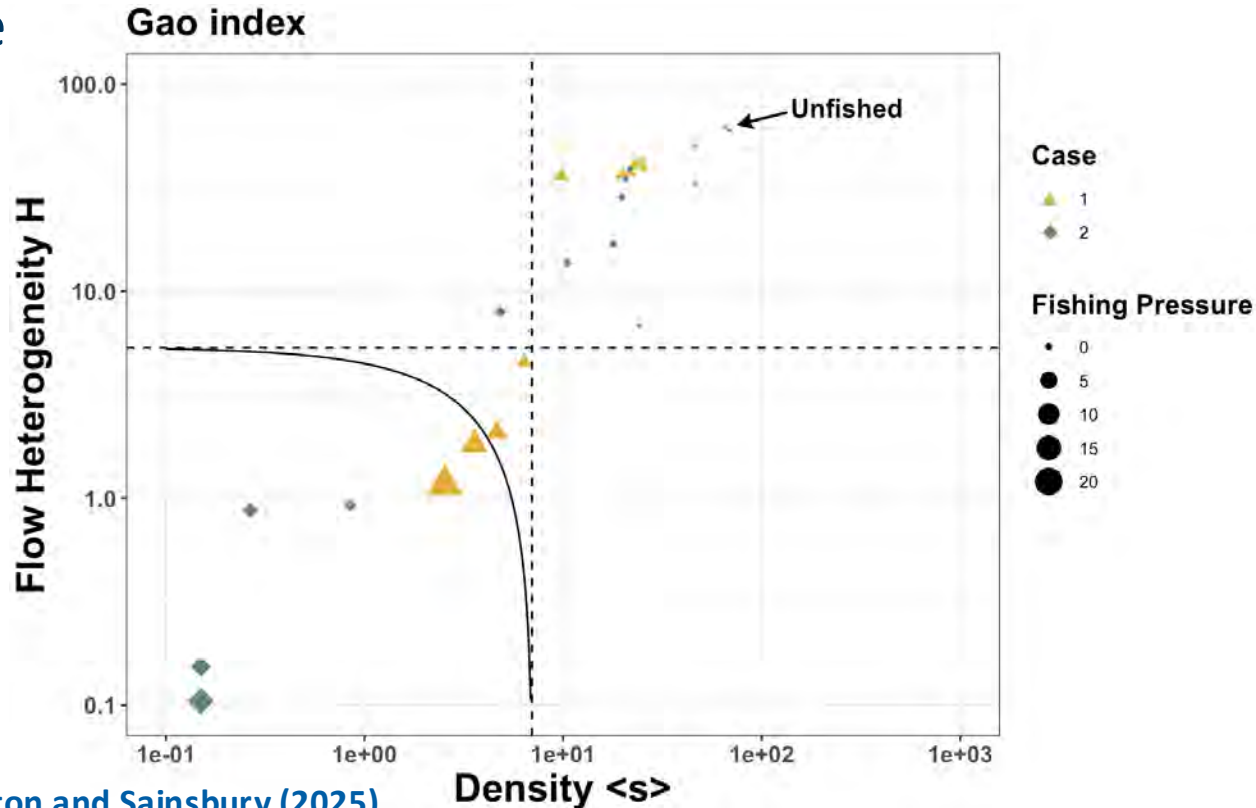


- Track through time to see response to fishing pressure, management interventions, productivity changes



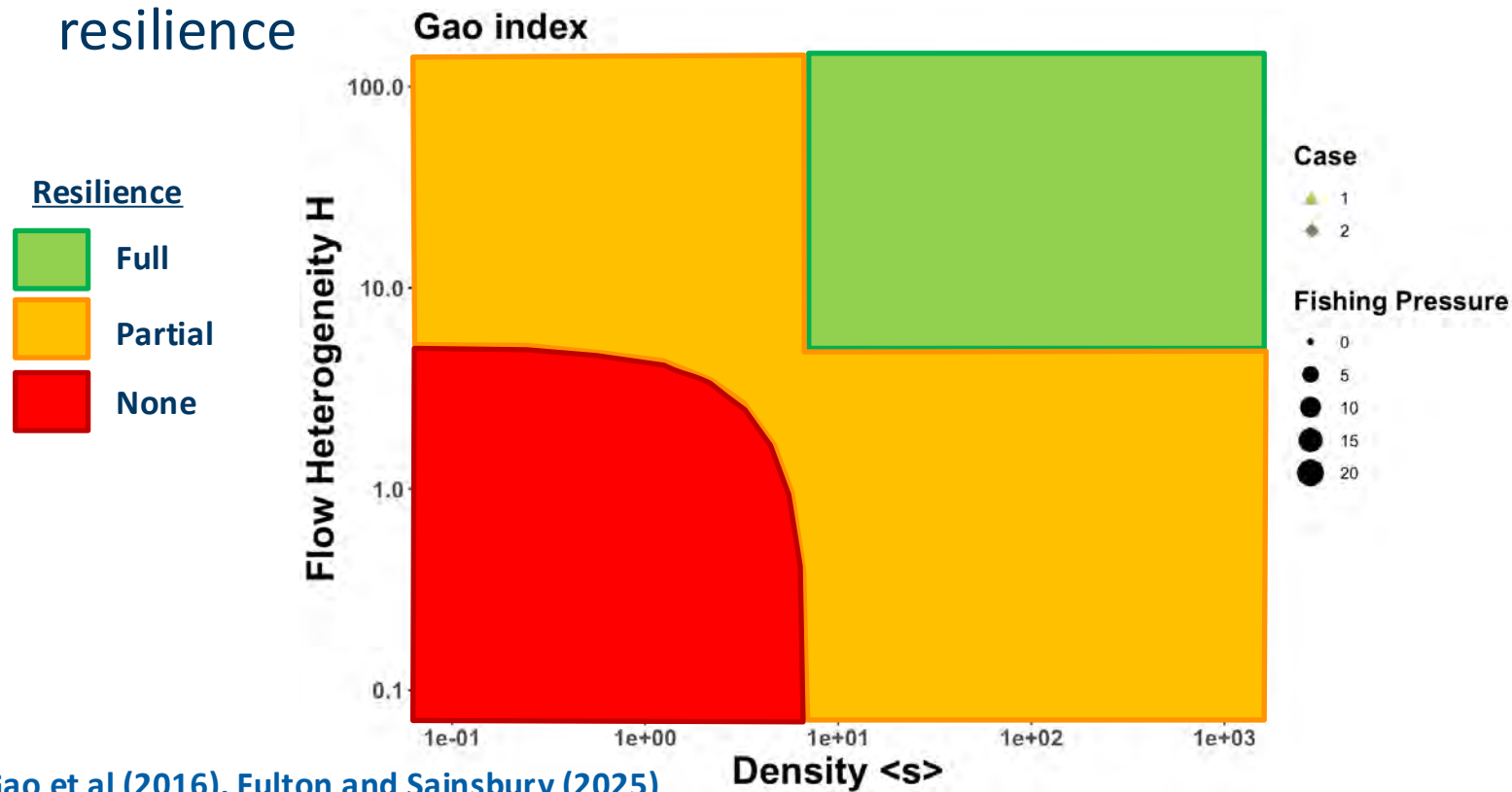
CSIRO OFFICIAL What is Gao's Index Telling Us?

- Same network structure (and flows) can inform on system resilience



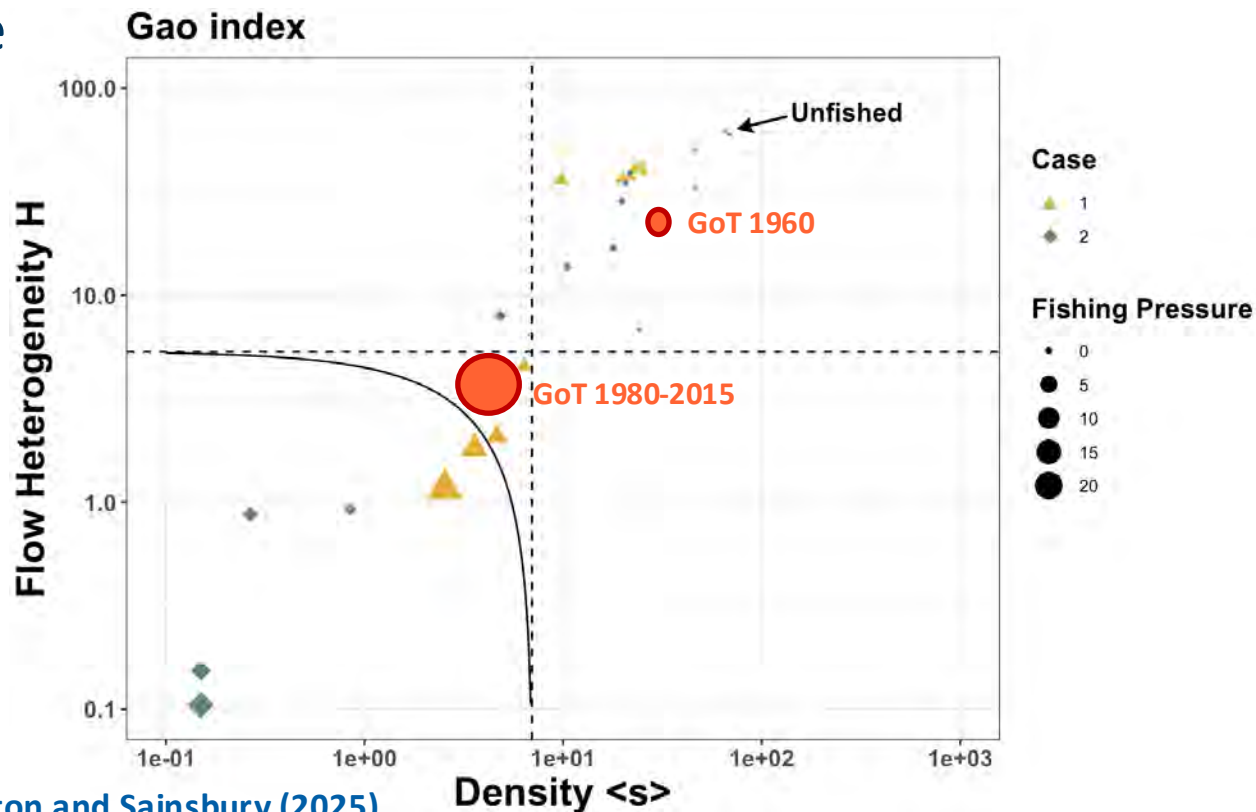
What is Gao's Index Telling Us?

- Same network structure (and flows) can inform on system resilience



CSIRO ^{OFFICIAL} Checking for System Resilience

- Same network structure (and flows) can inform on system resilience



Gao et al (2016), Fulton and Sainsbury (2025)



CSIRO Management Cue: Ecosystem Traits Index

- Possible to combine all the previous aspects to provide a system level indicator for guiding EBFM

Topology



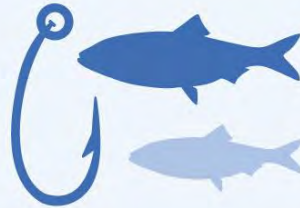
+

Resiliency

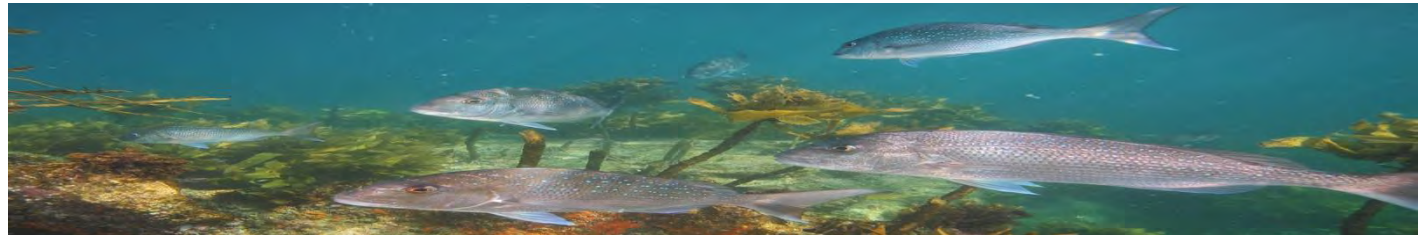


+

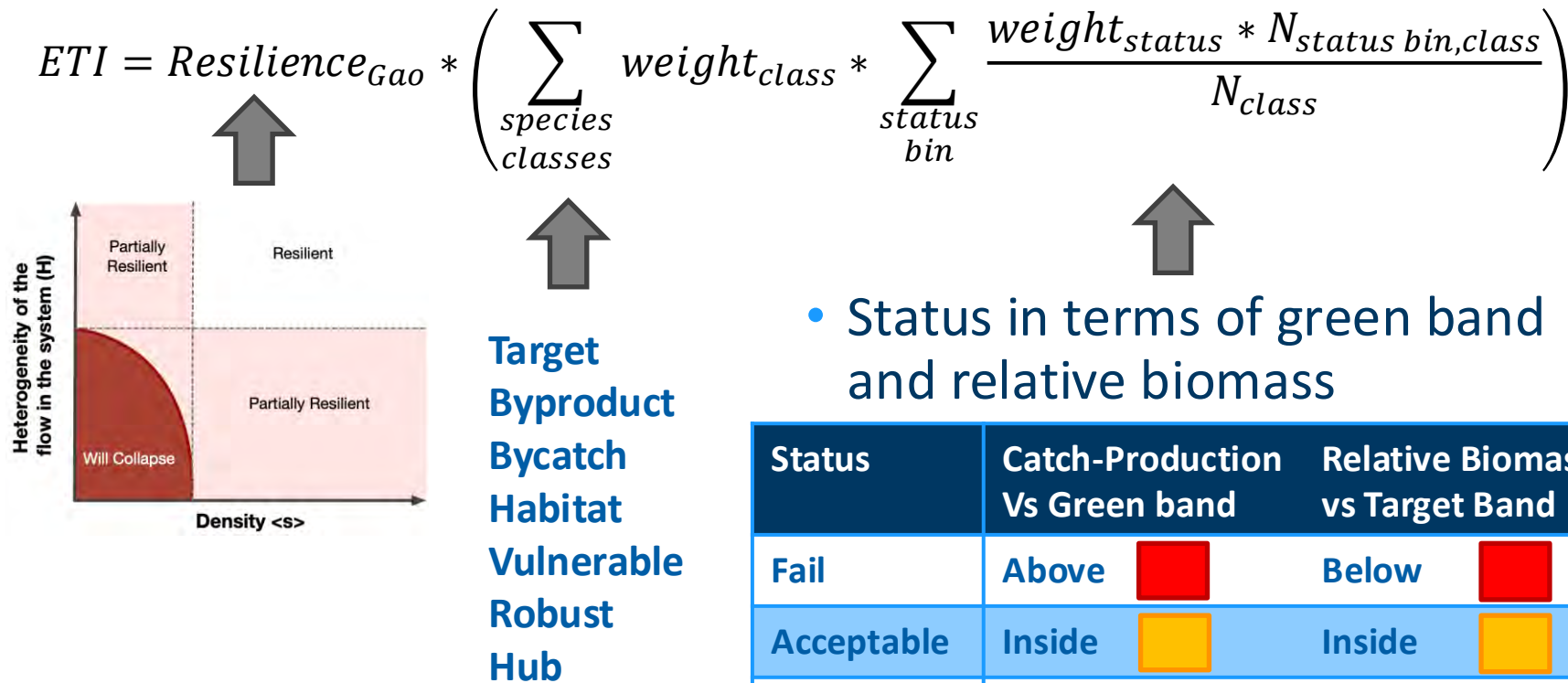
Distortive pressure



ETI



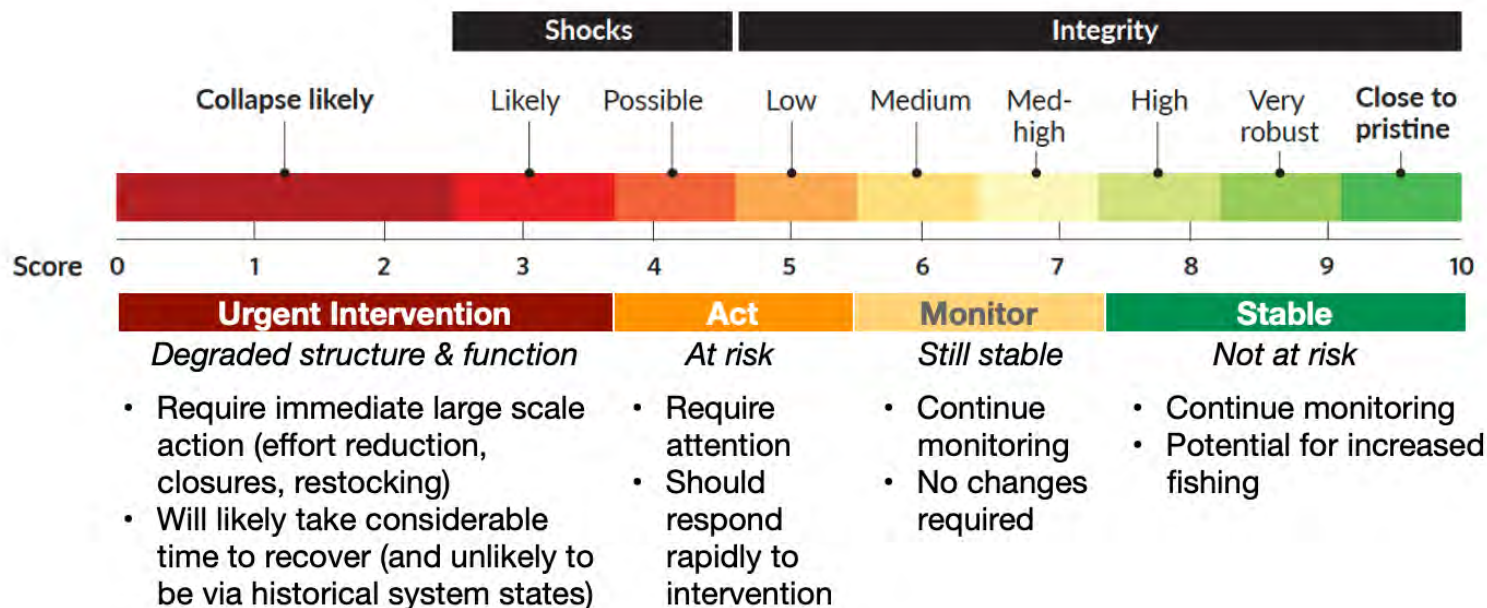
CSIRO ETI – logic of the calculation



Status	Catch-Production Vs Green band		Relative Biomass vs Target Band	
Fail	Above		Below	
Acceptable	Inside		Inside	
Light	Below		Above	

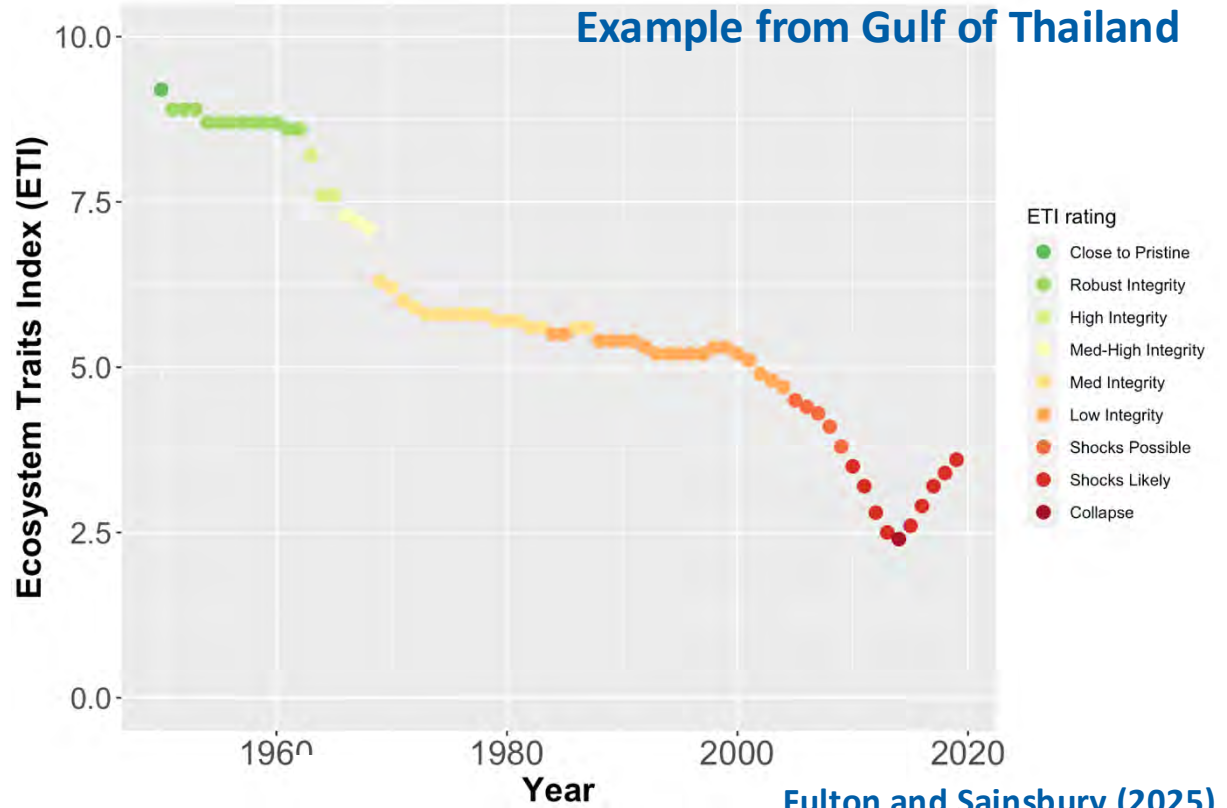
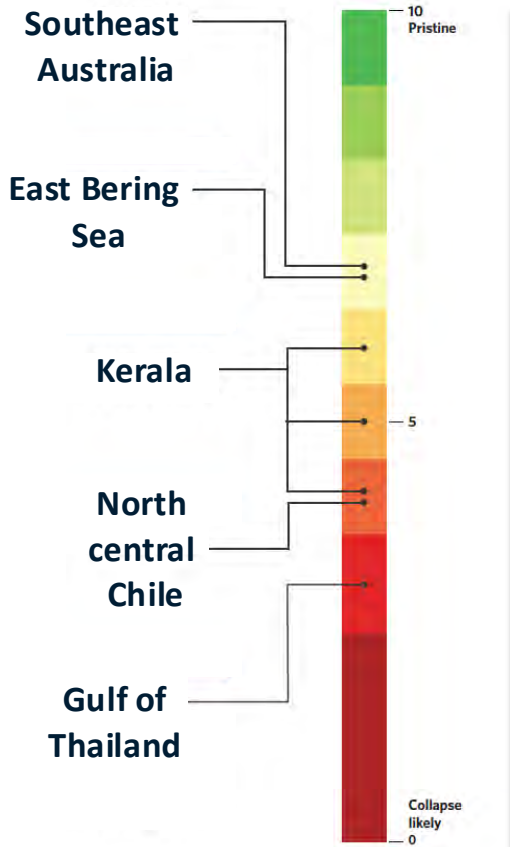
CSIRO ETI – logic of use (interpretation)

- ETI score informs on status, need for management action



CSIRO ETI comparable across systems

- Responsive across systems and through time (can be forecast)



CSIRO ETI – caution

- Reasonably robust to model structure
 - so long as the food web is ecologically sensible (the web building rules mentioned previously)
 - tested on this from complex to simplified models
- Does your model cover alternative stable states?
 - if your model is missing species (e.g. if only for recent years) then can misjudge state (ecosystem shifting baseline)



CSIRO Summary

- Sensibly built model provides reliable basis for structural indicators
- Understand the system using the diagnostics
- Structural indicators for system structural health (and by inference healthy function)
 - trying to make logic clear
 - trying to make it model agnostic
 - can inform management





Thank you

CSIRO Environment

Beth Fulton

Domain Lead Integrated Ocean Stewardship

+61 2 9123 4567

beth.fulton@csiro.au

csiro.au

Australia's National Science Agency

CSIRO



iss-foundation.org

3706 Butler Street, Suite 307
Pittsburgh, PA 15201
United States

Phone: + 1 703 226 8101
E-mail: info@iss-foundation.org