WORKING GROUP ON RESILIENCE AND MARINE ECOSYSTEM SERVICES (WGRMES; outputs from 2023 meeting)

VOLUME 7 | ISSUE 27

ICES SCIENTIFIC REPORTS

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 7 | Issue 27

WORKING GROUP ON RESILIENCE AND MARINE ECOSYSTEM SERVICES (WGRMES; outputs from 2023 meeting)

Recommended format for purpose of citation:

ICES. 2025. Working Group on Resilience and Marine Ecosystem Services (WGRMES; outputs from 2023 meeting).
ICES Scientific Reports. 7:27. 22 pp. https://doi.org/10.17895/ices.pub.28389368

Editors

Andrea Belgrano • Yajie Liu • Pablo Pita

Authors

Gillian Ainsworth • Milena Arias Schreiber • Andrews Barnaby • Andrea Belgrano • Edna Cabacinha Sophia Kochalski • Natali Lazzari • Yajie Liu • Tiziana Luisetti • Carlos Montero • Arantza Murillas Pablo Pita • Cristina Pita • Sandra Ramos • Marajia Reichers • Francesca Rossi • Katina Roumbedakis Anna Ruiz • Jose Sanabria • Sebastian Villasante

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i Executive summary

The Working Group on Resilience and Marine Ecosystem Services (WGRMES) is focused on promoting scientific cooperation for the maintenance of ecosystem services and social-ecological systems, ensuring the welfare of both present and future generations. WGRMES has been promoting and conducting assessments of marine ecosystem services (MES), evaluating changes in marine ecosystems through values and/indicators through specific valuation tools. These values can be used for integrated assessments, fisheries management and trade-offs analysis. WGRMES work is linked to the following ICES Science Plan priorities areas: Ecosystem science; Impacts of human activities; Conservation and management science; Sea and Society. WGRMES assists the scientific community, stakeholders, and Member States to understand how policies, plans and programs affect multiple ecosystem services and different management objectives by guiding a selection of the best alternatives.

The key activities of WGRMES during this ToRs cycle have advanced our understanding of quantifying the resilience of marine ecosystems and fisheries. This progress has been achieved through the development and refinement of the methodologies to account for different aspects of resilience, including: 1) indicator-based climate change assessments on marine fisheries; 2) identification of tipping points and regime shift and; 3) management and policy-related pathways for resilience in marine ecosystems and fishery.

WGRMES has also highlighted the importance of Marine Protected Areas (MPAs) in providing Marine Ecosystem Services (MES) to improve human health, well-being and equity (Vil-lasante et al., 2023). This effort is In conjunction with the ICES Working Group on Marine Protected Areas and other Spatial Conservation Measures (WGMPAS); and by providing information on the multidimensional valuation of Marine Ecosystem Services (MES) as a contribution to the ICES Working Group on Economica (WGECON), (Murillas-Maza et al., 2023). WGRMES has also developed an Ocean's Benefit to People (OBP) framework aiming to link the IPBES Nature's Contribution to People (NCP) conceptual framework with the blue economy, equity and the UN SDGs, promoting EBM approach for ocean sustainability and ocean governance/equity. WGRMES members have chaired and contributed to the ICES Workshop on ASsessing CAPacity to supply Ecosystem Services (WKASCAPES), advocating for the inclusion of information of MES in the ICES advice on Ecosystem Overview. WGRMES future works aims to continue to document resilience of MES; to review and document multidimensional valuation of MES; to document and analyse transformative changes in marine social-ecological services; to evaluate and document MES across different ecosystems, ECOregions and case studies in Europe and beyond; and to actively support the initiatives with the ICES Human Dimension Steering Group (HUDISG).

ii Expert group information

Expert group name	Working Group on Resilience and Marine Ecosystem Services (WGRMES)
Expert group cycle	Multiannual fixed term
Year cycle started	2021
Reporting year in cycle	3/3
Chair(s)	Andrea Belgrano, Sweden
	Yajie Liu, Norway
	Pablo Pita, Spain
Meeting venue(s) and dates	23-26 November 2021, online meeting (17 participants)
	21-25 November 2022, Copenhagen, Denmark (15 participants)
	13-15 September 2023, Bilbao, Spain (9 participants)

1 To document resilience of marine ecosystem services by using case studies in Europe at different scales (local, regional, national)

Resilience and Fisheries

1.1 Introduction

The work in progress covers two main aspects related to resilience:

a) advances in the methodologies currently available or being developed to account for different aspects of resilience, including indicator-based climate change assessments on marine fisheries; tipping points and regime shifts;
b) the identification of management and policy-related pathways that will account for resilience in marine ecosystems and fishery.

This work was presented at the ICES ASC 2022, Theme Session C: Operationalizing resilience for climate change impacts (Co-sponsored by PICES), that WGRMES organized in collaboration with the following conveners: Andrea Belgrano (Sweden), Keith Criddle (USA), Karen Hunter (Canada), Mitsutaku Makino (Japan), Luc Doyen (France), Iñigo Martinez (ICES), Julie Kellner (ICES)

The following manuscript (to be submitted) highlighted the application of the Resilience Heuristic (Grafton et al. 2019) to a specific case study on the European hake fishery:

Realizing tipping points: understanding causes and consequences of regime shifts in the European hake fishery

Authors: Sanabria-Fernandez, J.A.; Lazzari, N.; Belgrano, A.; Villasante, S.

1.2 Background and objectives

Resilience is an essential property of natural systems, allowing them to recover after perturbations and maintaining marine ecosystem services. However, resilience can diminish as a system approaches an abrupt and sudden shift, also known as a tipping point. When such a shift occurs in a prominent fishery, its consequences affect not only ecological systems but also socio-economic aspects. Fisheries stock collapses and regime shifts in marine ecosystems have become increasingly common in global fisheries. Management strategies that identify and incorporate tipping points into fisheries policies have been proven to be more effective in achieving policy goals than strategies that do not consider these potential tipping points.

European hake (*Merluccius merluccius*) is among the top ten commercially consumed species in the European Union, primarily caught by Spanish fleets dominating catches in the southern European stock (ICES divisions VIIIc and IXa). Historical fluctuations in landings have had a significant impact on European fishing fleets, leading to social-ecological instabilities. Understanding the causes and consequences of these abrupt shifts is crucial to prevent the undesirable collapse of the social-ecological system associated with the European hake fishery. This study aims to investigate the resilience of the European hake fishery by identifying its tipping points, their causes, and their consequences.

1.3 Methods

Based on the time-series decomposition of the total biomass of European hake landed in all European countries from 1950 to 2018, we identified its tipping points using tree models fitted through binary recursive partitioning. Tipping points were selected based on the higher deviance in the total biomass landed, where deviance was calculated using a threshold in the explanatory variable, i.e. years.

Subsequently, we delved into the examination of management drivers that could have significantly contributed to the shifts in the fishery over time. This focus on management factors is particularly relevant as they have direct implications for policy and regulatory interventions, which, if identified and addressed, could lead to more effective and targeted measures for the sustainable management of the European hake fishery. Finally, we examined the correlations between the European hake fishery and the decomposed time-series of the total biomass of the five global hake fisheries: *Merluccius bilinearis*, *M. capensis*, *M. hubbsi*, *M. senegalensis*, and *M. polli*, aiming to determine the consequences of the European hake fishery tipping points on the remaining hake fisheries. In doing so, we identified the tipping points of those hake fisheries that presented a high correlation with the European hake fishery and stablished whereas there were clear cause-consequence relationships between them.

1.4 Results

The European hake biomass landed showed a declining trend over the study period (Figure 1.1). Our results identified four tipping points for this species: in 1975, 1982, 1987, and 1996. All tipping points were followed by a drastic reduction in the total biomass landed.

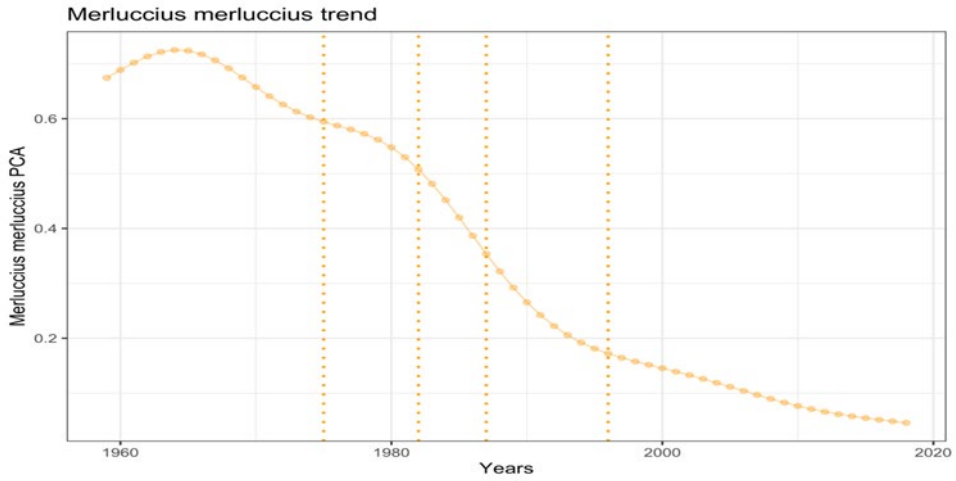

Figure 1.1 European hake (*Merluccius merluccius*) biomass landed (y--axis) over the years (x-axis). The four dashed lines represent the tipping points identified in the fishery (Sanabria-Fernandez, et al. 2024 to be submitted)

Regarding correlation analysis, our results revealed strong correlations between some of the hake fisheries. The European hake fishery, focus of our study, only showed a strong and negative correlation with the Argentinian hake fishery (*M. hubbsi*; r2 = -0.86; Figure 1.2).

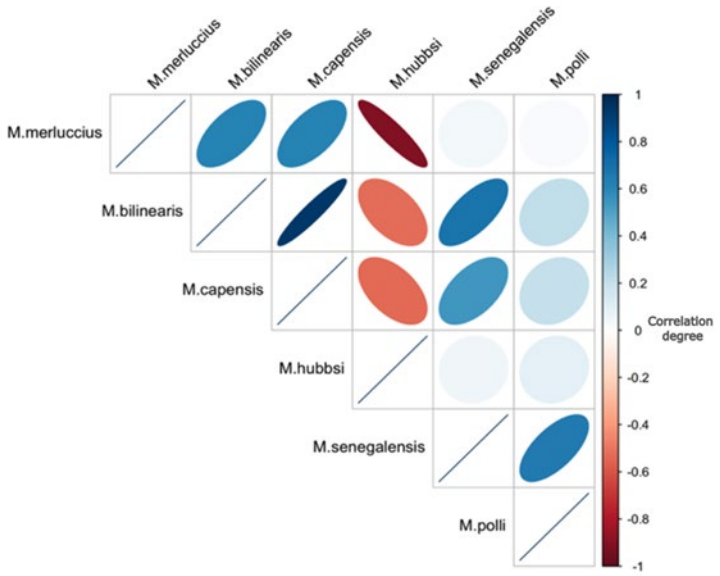

Figure 1.2 Correlation plot showing the correlation between six fisheries of hake species, (Sanabria-Fernandez, et al. 2024 to be submitted).

Due to this negative correlation found between these two species, we explored the cause-consequence relationships of the tipping points found in the European hake and the Argentinian hake fisheries. To do so, we identified the tipping points in the Argentinian hake fishery over the study period. We unveiled five tipping points: in 1970, 1980, 1992, 1997, and 2006. The first four tipping points were followed by an upward trend in the fishery, whereas the last one was followed by a downward trend, indicating a significant reduction in the *M. hubbsi* fishery to date (Figure 1.3).

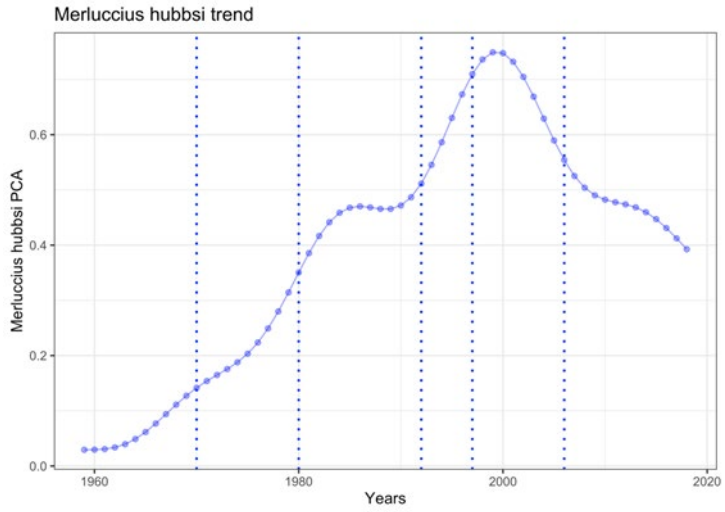

Figure 1.3 Argentinian hake (*Merluccius hubbsi*) biomass landed (y-axis) over the years (x-axis). The five dashed lines represent the tipping points identified in the fishery, (Sanabria-Fernandez, et al. 2024 to be submitted).

1.5 Discussion

We found that fishing restrictions associated with the expansion of the European Community were the primary drivers of the tipping points in European hake fishery, at least for the first three tipping points, i.e. 1975, 1982, and 1987. As we mentioned before, Spain dominated the European hake catches in the southern European stock (Pastor, 1986). In 1976, Spain started negotiations to get into the European Economic Community (EEC). In the 80's the Spanish fishing sector represented 0.8% of the gross domestic product, the fish annual consumption in Spain doubled the consumption in the rest of the EEC, and Spain employed 45% of the fishers in the EEC. Because of this, the adhesion of Spain to the EEC threatened the delicate balance of the common fisheries policy by tightening these negotiations. Finally, negotiations came to an end in 1985, two years before the tipping point. The adhesion of Spain to the EEC implied the acceptance of very restrictive measures, such as the limitation of 150 Spanish vessels fishing simultaneously; the geographical restriction of the catches to four ICES areas; or the assignation of specific quotas (Pastor, 1986). One of the species under strict regulation was the European hake, letting Spain with a quota of 30%, approximately 18,000 annual tons. Therefore, the adhesion of Spain to the EEC arises as the main reason for the first three tipping points in the European hake fishery.

Our results also suggest that the tipping points occurring in the Argentinian hake fishery from the years leading up to Spain's adhesion to the European Community until 1992 are closely related to the European hake tipping points, showing a possible catches compensation between both fisheries. For instance, the first shift that significantly increased the Argentinian hake fishery occurred in 1970, coinciding with a significant increase in investment in the construction of freezer vessels and the boom of a new business structure called joint ventures (Giddings, 1980). These joint ventures are collaborative agreements or strategic alliances between companies, to carry out specific commercial activities, such as fishing in third country waters. Between 1970 and 1980, there were a fast increase in the number of European (mainly Spanish) joint ventures with Argentinian companies for fishing Argentinian hake (Giddings, 1980; Figure 1.4). The

tipping point in 1980, matched with the period of starting the negotiations between Spain and the EEC. These negotiations implied numerous restrictions for the Spanish European hake fishery, which tried to maintain the hake supplies in Europe fishing Argentinian hake.

The third tipping point in the Argentinian hake fishery occurred in 1992, significantly increasing the fishery once more, coinciding with the implementation of new regulatory measures by the European Community, aimed at reducing the European hake fishery again (Figure 1.4).

The fourth significant shift in the Argentinian hake fishery took place in 1997, reaching historic highs in landings. This coincide with the moment when the Argentinian hake crisis is declared led by a constant exceeds in the Argentinian hake catches above the maximum recommended. It seems that this may have been motivated by the continuous decline of the European hake catches, stressed after the tipping point occurred a year earlier, in 1996 (Figure 1.4). The causes behind this tipping point in the European hake fishery are currently uncertain, and thus, the ToR a team continues to work to shed light on the factors that contributed to it. In 2006, the last tipping point occurred in the Argentinian hake fishery. Contrary to the previous shifts, this tipping point resulted in a significant decline of the fishery, which continues up to date. Fishing restrictions aiming to recover the Argentinian hake stocks and difficulties in this recovery seem to be the reasons of this decline. Since both the Argentinian and European hake fisheries are currently declining, we are now investigating, if there is another hake fishery that is supplying the European hake demand.

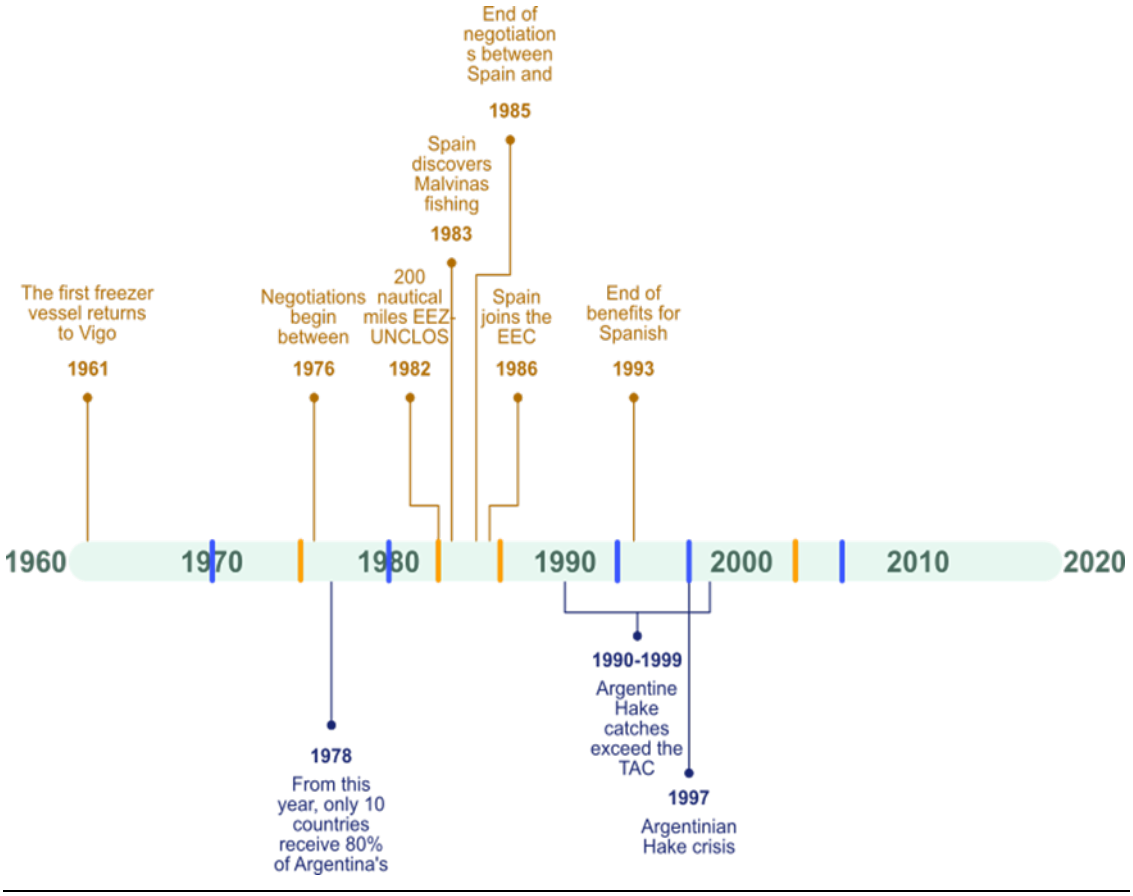

Figure 1.4 Timeline of the study, where the tipping points in the Argentine hake fishery are marked in orange, and those in the European hake fishery are marked in blue. The upper panel includes key events and potential causes that may have led to the tipping points in the Argentine hake fishery, while the lower panel pertains to the European hake, (Sanabria-Fernandez, et al. 2024 to be submitted).

1.6 Next steps

- To verify the relationship found between the European hake and the Argentinian hake, we will collect temporal data on the consumption per person, exports, and imports.
- Discover which species or species of hake are currently the focus of industrial fishing pressure.

2 To review and document multidimensional valuation of marine ecosystem service

WGRMES has continued the work in progress addressing this aspect based on previous analysis (ICES 2021), using information about the natural capital accounting (NCA) and marine ecosystem services (e.g. Joint Research Centre, MAES reports).

Work emerging from ICES WGECON (Thebaud *et al.* 2023) identified two knowledge gaps that are relevant to Tor B, regarding fisheries sustainability and valuation of ecosystem services. More specifically, Tor B will contribute to answering the following questions posed by Thebaud *et al*. 2023:

- What are the economic specificities of different fishing fleets, and how can these best be incorporated in the evaluation of trade-offs associated with the management of their activities?
- How can changes in MES associated with fisheries and their impacts on marine ecosystems be included in the science supporting ecosystem-based fisheries management?

The WGRMES agreed to produce a review paper on the role and integration of MES into fisheries management. The paper will also provide a practical guide on how to integrate MES into management. The results of this literature review is linked to the process of producing Ecosystem Overviews, and therefore could contribute to the work developed in the Workshop on ASsessing CAPacity to supply Ecosystem Services (WKASKAPES) organized in 2022, and the Working Group on Cumulative Effects Assessment Approaches in Management (WGCEAM) on ecosystem services and foodwebs.

To help policy-makers, the review paper will include some examples of success and/or failures. The main objectives of the review paper are:

- Provide an analysis/assessment on the integration (or lack of) of MES in fisheries management based on the results of the literature review. This will provide information on how MES have been considered in or integrated into fisheries management (e.g. which MES have been considered, how they've been considered/integrated, what methodologies have been used, etc. It will also highlight those MES that have not been taken into account, highlighting knowledge gaps and identifying research needs;
- The systematic literature review will highlight gaps regarding the consideration and/or integration of MES into fisheries management (both MES stemming from fisheries such as provisioning or cultural services; and MES supporting fisheries development, that is, supporting services);
- A set of tools will be provided to assess the different MES related to fisheries;
- Finally, an analytical framework will be designed on how to best incorporate MES into fisheries and what methods to use in the different cases.
- The work in progress related to ToR B has provided new knowledge regarding the multidimensional valuation of marine ecosystem services, and in particular highlighted the importance of the cultural (non-material) well-being dimensions related to the relational values that ecosystem services provides in the human-nature relationship (Villasante et al., 2023). It has also provided new information on the many challenges regarding the inclusion of the human dimensions from an IEAs perspective. In particular, WGRMES has developed an Ocean's Benefit to People (OBP) framework that try to link the IPBES Nature's Contribution to People (NCP) conceptual framework with the blue economy,

equity and the UN SDGs toward and EBM approach for ocean sustainability and ocean governance (Belgrano and Villasante, 2020).

This work is also based on the results from the H2020 GENIALG project (https://genialgproject.eu), where WGRMES members have extended the co-production matrix globally by developing three tasks:

- an inventory of co-production examples in marine social-ecological systems,
- an international expert consultation, and c) the development of a local interviews program in key selected case studies (France, Portugal and the United Kingdom).

3 To document and analyse transformative changes of marine social-ecological systems towards ocean equity

3.1 Introduction

The ongoing work has contributed to (a) linking MPAs with their roles in providing eco-system services, enhancing human well-being, and promoting equity (Villasante et al., 2023), and (b) offering a perspective on ecosystem indicators to assess the effectiveness of marine nature-based solutions on society and biodiversity under climate change (Murillas-Maza et al., 2023). The WGRMES continues to develop innovative methods for capturing the im-portance of MES using Graph Theory and network visualization (ICES, 2021; de Juan et al., 2021). The work in progress also highlighted the importance of considering co-production mechanizms of marine ecosystem services, in particular by describing and capturing the interactions between people and the eco-systems in relation to the provision of ecosystem ser-vices (Outeiro et al. 2017).

3.2 Results

Linking MPAs with their roles in providing eco-system services, enhancing human well-being, and promoting equity

We demonstrated how natural processes and components in MPAs are valued by different groups and how addressing these values can maximize effectiveness while avoiding negative socio-economic impacts, such as social conflicts or inequitable benefit distribution. We recommend that the creation and management of MPAs involve collecting and integrating interdisciplinary data to develop pluralistic valuation methods and foster social equity by involving local stakeholders. To enhance decision-making processes, it is crucial to use interdisciplinary evaluation data and engage local stakeholders in MPA management.

Using a case study of the Os Miñarzos MPA in Spain, we evaluated the role of this MPA concerning fishing interests. The analysis (Figures 3.1, 3.2) highlighted the importance of engaging the local fishing community, including small-scale fishers, artisanal fishers, and shellfish harvesters. This engagement has proven key to establishing sustainable management practices for the MPA, facilitating positive transformative changes toward sustainability and enhancing human well-being in the coastal community (Villasante et al., 2021).

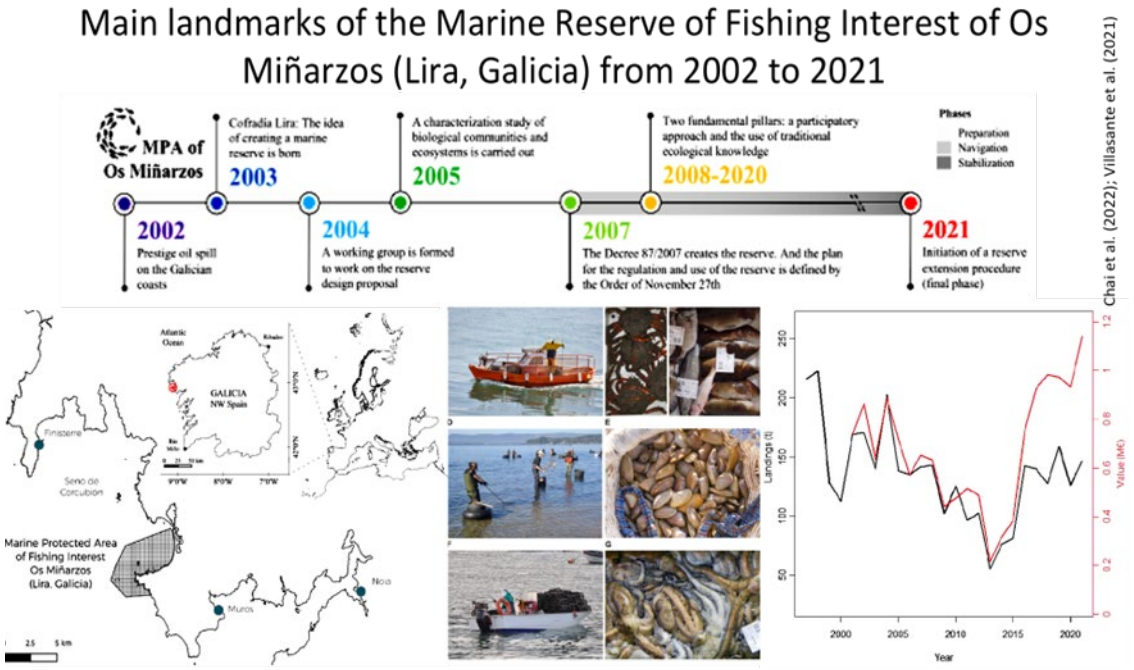

Figure 3.1 Timeline of the transformative changes in the MPA Os Miñarzos (Spain), (modified from Villasante et al 2021.

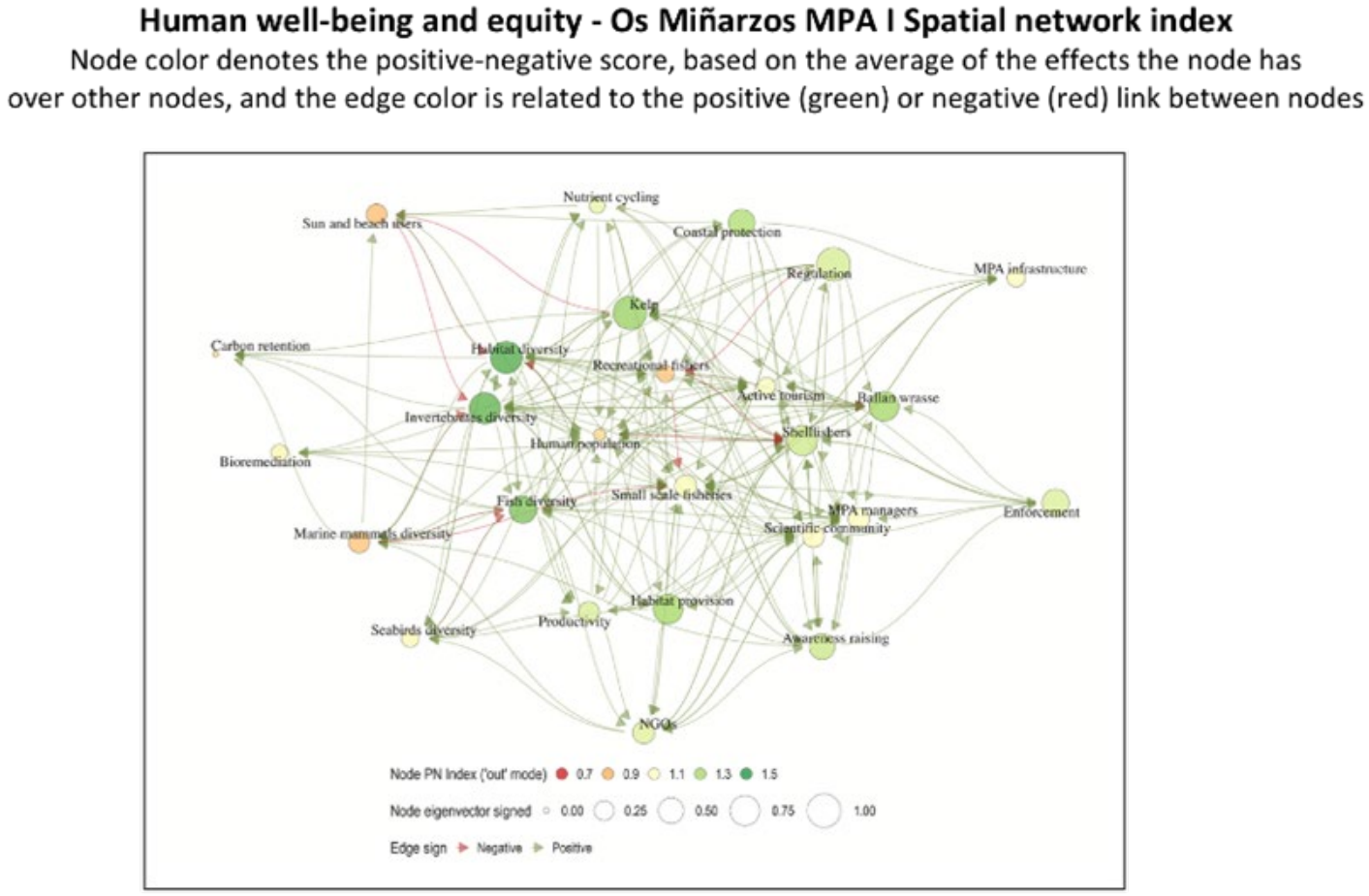

Figure 3.2 Spatial network index linking human well-being and equity in the MPA Os Miñarzos (Spain), modified from de Juan et al 2021.

Offering a perspective on ecosystem indicators to assess the effectiveness of marine nature-based solutions on society and biodiversity under climate change

A literature review (Murillas-Maza et al., 2023) identified 155 multidisciplinary indicators, with biodiversity and environmental indicators representing 34% and 23%, respectively. Socio-economic indicators considering climate change were scarce, mainly addressing carbon footprint valuation. Empirically verified with 27 European storylines, the indicators showed high coverage for biodiversity, environmental, and climate change aspects (91%), moderate coverage for economic aspects (71%), and lower coverage for social aspects (31%). Harvest, pressure, and habitat indicators were prominently used in assessing ecosystem services for marine and coastal ecosystems. The study identified 14 substantial gaps or weaknesses, emphasizing the need for a more balanced use of quantitative indicators across dimensions and key groups to effectively guide the implementation of nature-based solutions and nature-inclusive habitats.

The work in progress in relation to ToR C, is based on WGRMES work on sustainability transformations (Villasante et al. 2021), and mapping of ecosystem services to MPAs (Belgrano et al. 2020), providing a novel and timing analysis of the transformative changes of small-scale-fisheries SSF in Galicia (NW Spain), pointing out the importance of the establishment of the Marine Protected Area of fishing interest Os Miñarzos, through a co-creation process with multistakeholder's engagements to consolidate the transformative changes needed toward sustainability. The analysis based on the Graph Theory, provided a promising approach to identify and quantify the complex interactions and emergent properties underlying the human-nature relationship in particular in the benefits that MPAs provide for human well-being and human health.

4 Science highlights

The following publications have been produced and contributed to the work of WGRMES during this ToRs cycle:

- Mangano, M. C. et al. (*2022*). The Aquaculture Supply Chain in the time of COVD-19 pandemic: vulnerability, resilience, solutions and priorities at the global scale. *Environmental Science and Policy 127: 98 - 110*.
- Murillas-Maza, A, Stefanie Broszeit, Sarai Pouso, Juan Bueno-Pardo, Ana Ruiz-Frau, Jorge Terrados, Susanna Jernberg, Ane Iriondo, Marina Dolbeth, Stelios Katsanevakis, Paul J. Somerfield, Jose A. Fernandes-Salvador, Ecosystem indicators to measure the effectiveness of marine nature-based solutions on society and biodiversity under climate change, Nature-Based Solutions, 2023, 100085,ISSN2772-4115,https://doi.org/10.1016/j.nbsj.2023.100085. https://www.sciencedirect.com/science/article/pii/S277241152300037X
- Villasante, S., et al. (2023). The Role of Marine Protected Areas in Providing Ecosystem Services to Improve Human Health and Wellbeing. In: Oceans and Human Health: Opportunities and Risks (Fleming, L. E., et al, eds.) Elsevier, pp. 23-37.
- Pita, C., et al. 2024. The global impacts of COVID-19 on small-scale fisheries. Submitted to the Special Issue in Marine Policy focused on the impact of COVID-19 on SSF.

5 Future work: To document and analyse transformative changes of marine social-ecological systems towards ocean equity

WGRMES future work will focus on assessing marine ecosystem services or changes in marine ecosystems through ecosystem services assessment for values and/or indicators using specific valuation tools and case studies. Particularly relevant will be the implementation and/or transference of common tools and indicators across large ECOregions. These values or indicators can be used for integrated assessments and fisheries management or implementing trade-off analyses. This work will be carried out as part of the new ToR cycle (2024-2026) in collaboration with WGECON, or others if relevant.

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Annex 1: List of participants

Name	Institute	Country (of institute)	E-mail
Andrea Belgrano	SLU/SIME	Sweden	andrea.belgrano@slu.se
Yajie Liu	UIT	Norway	yajie.liu@uit.no
Pablo Pita	UDC	Spain	p.pita@udc.es
Arantza Murillas	AZTI	Spain	amurillas@azti.es
Gillian Ainsworth	USC	Spain	gill.ainsworth@usc.es
Arias Schreiber Milena	UGOT	Sweden	milena.schreiber@gu.se
Barnaby Andrews	Cefas	UK	barnaby.andrews@cefas.gov.uk
Edna Cabecinha	UTAD	Portugal	edna@utad.pt
Sophia Kochalski	USC	Spain	sophia.kochalski@gmail.com
Natali Lazzari	USC	Spain	lazzari.natali@gmail.com
Lillebo Ana	UA	Portugal	lillebo@ua.pt
Tiziana Luisetti	Cefas	UK	tiziana.luisetti@cefas.co.uk
Carlos Montero	MSC	Spain	carlos.montero@msc.org
Cristina Pita	UA	Portugal	c.pita@ua.pt
Jose Sanabria	USC	Spain	jsanabriafernandez@gmail.com
Sandra Ramos	CLIMAR	Portugal	ssramos@ciimar.up.pt
Maraja Riechers	Thuenen Institute	Germany	maraja.riechers@thuenen.de
Francesca Rossi	CNRS	France	francesca.rossi@cnrs.fr
Katina Roumbedakis	USC	Spain	katina.roumbedakis@ua.pt
Sebastian Villasante	USC	Spain	sebastian.villasante@usc.es

Annex 2: Resolutions

Working Group on Resilience and marine ecosystem services (WGRMES)

2020/FT/EPDSG09 The **Working Group on Resilience and Marine Ecosystem Services** (WGRMES), chaired by Andrea Belgrano, Sweden; Yajie Liu, Norway; and Pablo Pita, Spain; will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2021	23–26 November	Online meeting	Interim e-evaluation	
Year 2022	21–25 November	ICES HQ	Interim e-evaluation	
Year 2023	13–15 September	Bilbao, Spain	Final report by November 2023	

ToR descriptors

ToR	Description	Background	Science Plan Codes	Duration	Expected Deliverables
A	To document resilience of marine ecosystem services by using case studies in Europe at different scales (local, regional, national).	Information, data and evidence on resilience and marine ecosystem services (and nature contribution to people) are scarce and not organized. Links to ICES Science Plan 1st, 2nd and 3rd thematic areas, and WGs described above.	1.3; 2.1; 2.4	3 years	-Interim report -Public online repository of data/case studies. -Special Session at ICES Conference
B	To review and document multidimensional valuation of marine ecosystem services.	Valuing marine ES is key for policy-makers. This task will be directly linked with the IPBES Global Multiple Values Assessment and the IPBES Global Nexus Assessment. Links to ICES Science Plan 1st and 2nd Thematic Areas; and WGs described above.	3.6; 6.1; 6.5	3 years	-Interim report -A review paper on multidimensional values of marine ecosystem services -Special Session at ICES Conference
C	To document and analyse transformative changes of marine social-ecological systems towards ocean equity.	Document fundamental changes (including property rights, management systems and Marine Protected Areas) which facilitate transformations of social groups. Links to ICES Science Plan	6.4; 6.5; 7.4	3 years	-Interim report -A review paper -Database with marine seeds for a good Anthropocene linking

	1st, 2nd and 3rd thematic areas, and WGs described above and below. This task will be directly linked with the IPBES Global Transformative Change Assessment, and the Strategic Initiative on the Human Dimension, and the High-Level Panel for a Sustainable Ocean Economy.	marine social-ecological information -Special Session at ICES Conference -Special Issue about Ocean Equity

Summary of the Work Plan

Year 1	Document and review of existing conceptual frameworks, methodologies and tools to analyse and operationalize resilience to monitor sustainability of marine ecosystem services
Year 2	Understand the role of tangible and intangible benefits of the oceans to human well-being from fisheries and aquaculture sectors and their associated value chains.
Year 3	Document and review transformative changes of marine social-ecological systems, including commercial and recreational fisheries, and aquaculture. Provide a better understanding on how fisheries resources, governance institutions and actors learn and respond to diverse drivers of climate change and other human-induced drivers, as well as to design policies and actions aimed at building resilience. Review what plausible pathways exist for achieving the UN 2030 SDGS and the 2050 Vision for Biodiversity.

Supporting information

Priority	Very high. The current activities of this Group will lead ICES into issues related to marine ecosystem services, integrating fisheries management and transformative changes towards ocean equity. Consequently, these activities are considered to have a very high priority.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 20–25 members and guests.
Secretariat facilities	Standard EG support.
Financial	No financial implications. The WGREMS will explore to get funds from H2020 calls and others to support and expand the activities inside and outside Europe
Linkages to ACOM and groups under ACOM	AFWG, WGRFS.
Linkages to other committees or groups	There is a close working relationship with WGBIODIV, WGECON, WGSOCIAL, WGMHM, WGMPCZM, WGSFD, WGISUR, WGMARS, WGECO and SICCME.
Linkages to other organizations	The work of this group is aligned with other global nodes of ES research such as the IPBES, Future Earth and the Ecosystem Services Partnership. The work is also in line with the Natural Capital Project

(http://www.naturalcapitalproject.org/) , ++ and numerous scientific and regulatory governmental and university's departments in ICES countries.