WORKING GROUP ON RESILIENCE AND MARINE ECOSYSTEM SERVICES (WGRMES; outputs from 2020 meeting)

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ICES International Council for the Exploration of the Sea
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Contents

i Executive summary

The Working Group on Resilience and Marine Ecosystem Services (WGRMES) aims to improve scientific understanding and capacity to design data collection networks and methodologies in order to analyze the ecological, economic, social, and institutional dimensions of marine ecosystem services.

The group made progress in relation to five objectives: (a) testing a resilience framework to operationalize resilience for policy makers; (b) analyze approaches and methods to capture multidimensional monetary and non-monetary values of ecosystem services; (c) investigating the role of natural, social and manufactured capital for the co-production of marine ecosystem services; (d) examine tipping points and social transformations of marine social-ecological systems; and (e) investigate the role of Marine Protected Areas in their contribution to the human dimension and well-being of coastal communities.

WGRMES integrated the three Rs (resistance, recovery and robustness) into a heuristic for resilience management that the group applies in multiple management contexts to offer practical, systematic guidance about how to realize resilience. In the context of multidimensional valuation of marine ecosystem services, we show that cultural (non-material) well-being dimensions support the notion of people valuing non-human nature relationally. Although ecosystem services frameworks have depicted mainly the benefit flows that humans receive from nature, our research results suggest a bidirectional human-nature relationship. The notion of relational values about nature challenges the pervasive dichotomy between instrumental (nature's utility) and intrinsic values (nature's inherent worth) that has been guiding environmental ethics and biodiversity conservation. We also provide scientific advances in the understanding of the role of social media in capturing the importance of cultural ecosystem services. The use of Graph Theory on social media data is a promising approach to identify emergent properties of the complex physical and cognitive interactions that occur between humans and nature, in particular to show the benefits of blue natural areas for human health.

The challenge of inclusion of human dimensions of the oceans in the Integrated Ecosystem Assessments (IEAs) provides an opportunity to create synergies between the current research by the ICES and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). WGRMES developed a new Ocean's Benefits to People (OBP) framework that embraces the blue economy, equity, the UN Sustainable Development Goals (SDGs) and supports the Ecosystem-Based Management (EBM) for the oceans. Within the framework we link drivers, enabling conditions, human activities (e.g., aquaculture, fisheries, tourism, etc.) to pressures and states by including the need to empirically test the IEAs to ocean benefits, including intrinsic, relational instrumental values of ecosystem services and the local traditional knowledge perspective. We also show that sustainability transformations need to consider who, where and how profound changes in the structures, processes, rules, and norms of ocean governance are currently underway to foster desirable pathways.

Future work aims to: develop multidimensional analysis of marine ecosystem services (IPBES, 2019), including material and non-material benefits from ecosystem services (nature contributions to people); identify thresholds and tipping points of marine social-ecological services; further research on sustainable and equitable distribution of ocean benefits.

ii Expert group information

Expert group name	Working Group on Resilience and Marine Ecosystem Services (WGRMES)
Expert group cycle	Multiannual
Year cycle started	2018
Reporting year in cycle	3/3
Chair(s)	Sebastian Villasante, Spain
	Andrea Belgrano, Sweden
Meeting venue(s) and dates	19–20 November 2018, Vigo, Spain (15 participants)
	5–6 September 2019, Gothenburg, Sweden (11 participants)
	24–27 November 2020, online meeting (19 participants)

1 Undertake a literature search to assess the current data available to document the resilience of marine ecosystem services (ToR A)

Resilience Heuristic

Introduction

A new Resilience Heuristic has been developed by members of the WGRMES by operationalizing resilience in social-ecological systems called "Operationalizing Resilience: Resistance, Recovery Time and Robustness for Decision-making". The Resilience Heuristic address the current lack of operationalization of resilience by: (1) reviewing how resilience is conceptualized and measured; (2) developing a Resilience Heuristic for resilience management of social-ecological systems; (3) contextualizing this Heuristic with an illustration in relation to marine fisheries; and (4) applying this Heuristic in wild capture fisheries (Grafton *et al.* 2019).

Our proposed Resilience Heuristic encompasses seven questions or steps in relation to a marine social-ecological system (and its boundaries) under consideration:

1. What is the object (system, system component, or interaction) whose resilience is being managed?
2. For whom (stakeholders) is resilience being managed?
3. What are the metrics of system performance for the identified stakeholders?
4. What are the viability (or safety) goals of the identified stakeholders (and associated metrics) for key system variables that allow a system to retain its identity?
5. What adverse events might threaten these viability goals?
6. How are the Three R's measured in relation to system performance and in response to adverse events?
7. What are expected net benefits, currently and over time and space, of resilience management actions?

Results

The following aspects have been highlighted: (i) the measurement of three distinct, but related, characteristics of social-ecological resilience and (ii) a Resilience Heuristic that includes seven questions linked to complementary management steps, provide practical, operational guidance to those who care about, and wish to manage for, system performance in an uncertain world. Graphically, the new Resilience Heuristic is shown in Figure 1A.

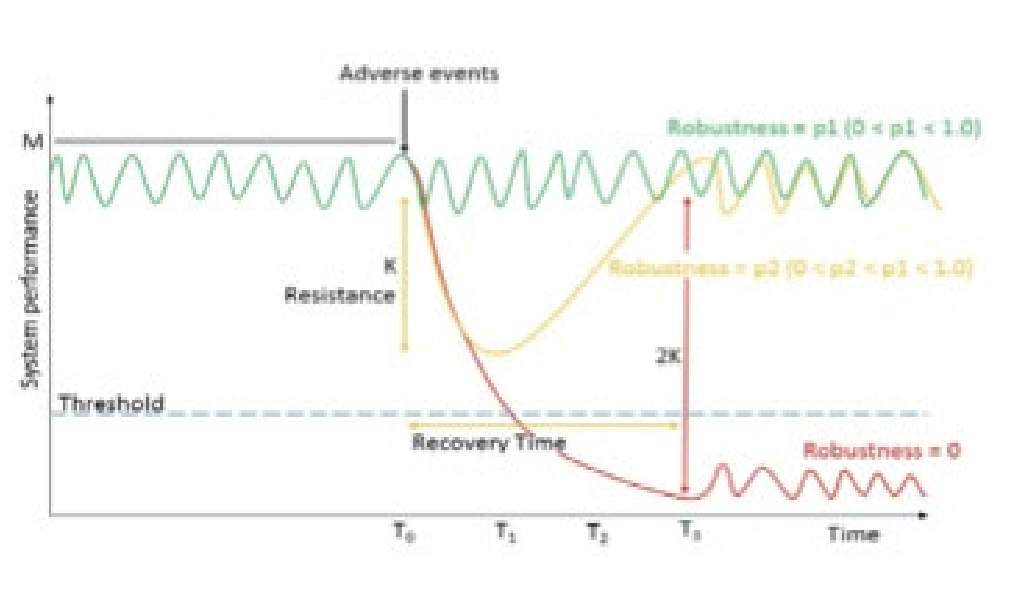

Figure 1A. Heuristic for operationalizing resilience.

We illustrated the Three R's in Figure 1A and specify dimensionless (normalized) units (from 0 to 1.0) for resistance and recovery time (robustness is measured as a probability). For consistency across the Three R's, a higher value of our dimensionless measure of recovery time represents greater social-ecological resilience:

- Resistance – a system's ability to actively change while retaining its identity or to passively withstand a decline in system performance following one or more adverse events.
- Recovery Time – a measure of the time it takes for a system to recover or to achieve a desired level of functionality or system performance following one or more adverse events; and
- Robustness - the probability of a system to stay functional, maintain its identity and not cross an undesirable (and possibly irreversible) threshold following one or more adverse events.

Building on the insights of Carpenter *et al.* (2001), Helfgott (2018) highlights that social-ecological resilience needs to be operationalized by identifying: (i) for whom (those affected by adverse events and management actions); (ii) of what (aspects of system performance of interest, including system boundaries); (iii) to what (adverse events that affect system performance); and (iv) over what time frame (short versus long-run, time to recover, etc.). Figure 1A highlights possible policy implications of the Three R's for resilience management. System performance is measured on the vertical axis while the horizontal axis is time. System performance varies over time, within some desirable, viable or acceptable range, prior to T0 when a pulse or one-off adverse event occurs, but we observe that adversity may also include on-going and long-term influences (presses) on system performance. The threshold in Figure 1A represents a single and static critical transition point beyond which the system may move to an irreversible state where previous levels of system performance (defined by M) cannot be restored. Thresholds may not always exist; but, when they do, they may be exogenous or endogenous such as the requirement that profits always be positive, as determined by stakeholders or decision-makers.

Figure 1A includes three possible scenarios after T0. Scenario one is represented by the green trajectory where no adverse event is assumed to occur and, thus, there is no observable impact on system performance. In this case, social-ecological resilience is characterized by:

- a. Resistance, such that there is no observable decline in system performance,
- b. Recovery Time, system performance remains at M, and
- c. Robustness, is the probability $0 < p1 < 1.0$ of not crossing the threshold, and is unchanged.

We integrate the Three R's into a Heuristic for resilience management that we apply in multiple management contexts to offer practical, systematic guidance about how to realize resilience. Resilience measurement requires an empirically and statistically valid causal inference following adverse event(s) that is operationalized through statistical approaches of system performance (of what and over what time period) such as difference-in-differences, matching and propensity scoring, and Bayesian methods. This requires understanding about the adverse event(s) (to what) that might arise from the randomness or the unpredictable behaviour of systems, individuals or from imperfect knowledge, as well who are the persons of interest (for whom); (Grafton *et al.*, 2019).

2 Assess approaches available for pluralistic valuation of marine ecosystem services (ToR B)

Valuation of Marine Ecosystem Services

Introduction

WGRMES has been reviewing existing projects and data collection exercises which provide information about natural capital accounting (NCA) and marine ecosystem services (e.g., Joint Research Centre, MAES reports). Establishing a sound method for NCA, with a strong focus on ecosystems and their services, is a key objective of the 7th EAP and of the EU Biodiversity Strategy to 2020. WGRMES has been reviewing scientific literature to document and assess the role of monetary and non-monetary (socio-cultural and traditional knowledge) valuation of marine ES for decision-makers to provide a pluralistic valuation of ES in connection with IPBES recommendations. By using several case studies from small-scale fisheries, industrial fisheries and the IMTA system in EU countries (Norway, Portugal, Spain, Sweden).

Results

In Portugal, we developed a participatory mapping of marine ES in the "Parque Natural do Litoral Norte", a marine protected area (MPA) in the municipality of Esposende, Portugal, where there are zones with different levels of protection and restriction to human use (Figure 1). In addition to providing biodiversity conservation, the park is also an important supplier of ecosystem services. Ecosystem services represent the contributions of nature to human well-being. They are therefore fundamental for providing benefits that people obtain from nature, be they social, cultural, or economic. The ecosystem services provided by the habitats and species that exist in the Litoral Norte MPA are manifold. Habitats and species of the MPA are sources of food for human consumption, such as fish, bivalves, or crustaceans. Dunes and rocky reefs provide coastal protection safeguarding houses and agricultural fields from sea level rise. Estuaries and beaches are places with high landscapes and symbolic values to people. Essentially, protecting biodiversity and its ecosystem services is protecting human well-being (Garcia Rodrigues *et al.* 2021).

To shed light on the relationships between non-material NCP and human well-being, we explored the role of Litoral Norte MPA—a multiple-use MPA—in supporting cultural dimensions of subjective well-being. To this end, we ask the following research questions:

- What cultural dimensions of subjective well-being underlie the non-material connections between people and Litoral Norte MPA sites?
- How do people's socio-economic characteristics and environmental behaviour affect cultural dimensions of subjective well-being?
- What insights of subjective well-being assessments can be drawn for MPA practice and policy?

To measure subjective well-being, we relied on the same 15 indicator statements used by Bryce *et al.* (2016). Based on our literature review about the theoretical constructs behind the indicator statements, we believe these statements are broad enough to encompass similar aspects in different geographies. In this sense, we applied them in our research in Litoral Norte MPA in northern Portugal to study the relationships between non-material NCP and subjective human well-

being. We added one indicator statement reflecting 'solitude' because positive experiences of solitude in nature suggest that being alone in nature contributes to peace, tranquillity, self-reflection, and a sense of freedom.

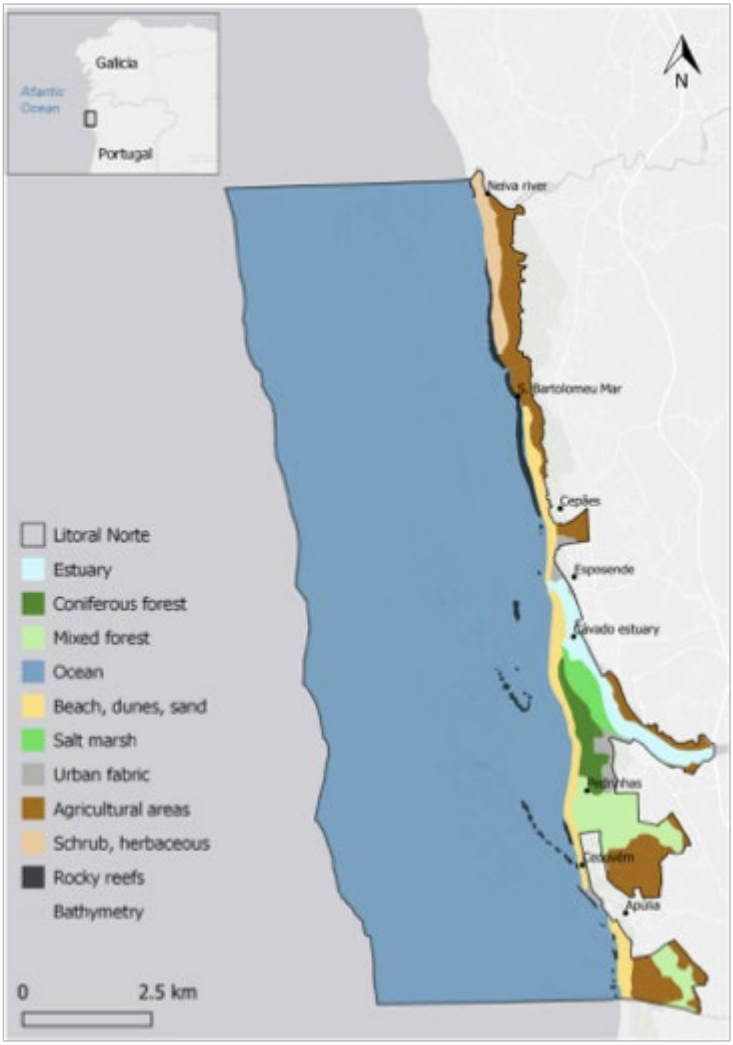

Fig. 1 Location of Litoral Norte Marine Protected Area. Map shows the main land-use types in the coastal fringe of the MPA

Figure 1. Location of the Litoral Norte Marine Protected Area. Map shows the main land-use types in the coastal fringe of the MPA.

We conducted 453 face-to-face structured interviews between October and December of 2018 in Esposende—the Portuguese municipality where Litoral Norte MPA is located. We used two sampling strategies: one for residents of the municipality, and other for non-residents (hereafter, visitors). Visitors are the people who visit the Litoral Norte area mainly for cultural or recreational purposes. Since we knew the number and distribution of residents in the municipality, we applied a stratified random sampling per municipality parish (351 interviews, 95% confidence interval, ± 5% margin of error).

For visitors, we only had estimates of the annual number of MPA visits. That is why we applied a convenience random sampling in places known to be frequently visited by non-residents (102 interviews, 95% confidence interval, ± 10% margin error). In both sampling groups, we chose to interview people over 18 years old. We pre-tested interview questions before implementing the survey to assess the suitability of the survey design.

To measure the cultural dimensions of well-being supported by the MPA, we asked survey respondents to report their degree of agreement with a set of indicator statements (Table 1). Survey respondents had to choose an option from a 5-point Likert scale for each indicator statement. The scale ranged from 'strongly disagree' to 'strongly agree'. Indicator statements were intended to represent cultural well-being constructs relevant for users of the marine environment. The constructs we used reflect a 'eudaimonic' conception of well-being. Constructs were selected based on human well-being frameworks and on previous studies about the relationship between people and nature. To measure subjective well-being, we relied on the same 15 indicator statements used by Bryce *et al.* (2016).

Based on our literature review about the theoretical constructs behind the indicator statements, we believe these statements are broad enough to encompass similar aspects in different geographies. In this sense, we applied them in our research in Litoral Norte MPA in northern Portugal to study the relationships between non-material NCP and subjective human well-being. We added one indicator statement reflecting 'solitude' because positive experiences of solitude in nature suggest that being alone in nature contributes to peace, tranquillity, self-reflection, and a sense of freedom. We pre-tested interview questions—including all indicator statements—before implementing the survey, to assess its suitability. Our preliminary results suggested that interviewees recognised the various non-material NCP represented in the survey, and hence we considered them valid for our study of Litoral Norte MPA.

Table 1. Indicator statements used in the survey to assess non-material NCP from sites of Litoral Norte MPA. Adapted from Bryce *et al.* (2016).

Table 1 Indicator statements used in the survey to assess non-material NCP from sites of Litoral Norte MPA (adapted from Bryce et al. 2016)

Indicator statement	Theoretical constructs
Visiting this site clears my head	Reflection and sense of wholeness
I gain perspective on life during my visits to this site	Reflection and sense of wholeness
Visiting this site makes me feel more connected to nature	Reflection and sense of wholeness; connection to nature
At this site I feel part of something that is greater than myself	Reflection and sense of wholeness; spiritual value
This site feels almost like a part of me	Place identity and continuity with the past
I feel a sense of belonging in this site	Place identity and continuity with the past
I've had a lot of memorable experiences in this site	Place identity and continuity with the past; transformative values
I miss this site when I have been away from it for a long time	Place identity and continuity with the past
Visiting this site has made me learn more about nature	Knowledge about nature
I have made or strengthened bonds with others through visiting this site	Social bonds
I feel like I can contribute to taking care of this site	Participation
I have felt touched by the beauty of this site	Aesthetics
This site inspires me	Inspiration
Visiting this site leaves me feeling healthier	Health
Visiting this site gives me a sense of freedom	Freedom
I can be alone and appreciate solitude when I visit this site	Solitude value

Reported levels of well-being derived from marine and coastal sites varied significantly according to some socio-economic characteristics of interviewees (Figure 2). We found significant differences in composite scores of the four factors. Composite scores of engagement with nature & health, sense of place, solitude in nature, and spirituality, varied depending on interviewees' place of residence (that is, resident of the municipality of Esposende vs. visitor; and rural vs. urban), level of formal education, household size, gender, and number of years living in the municipality of Esposende.

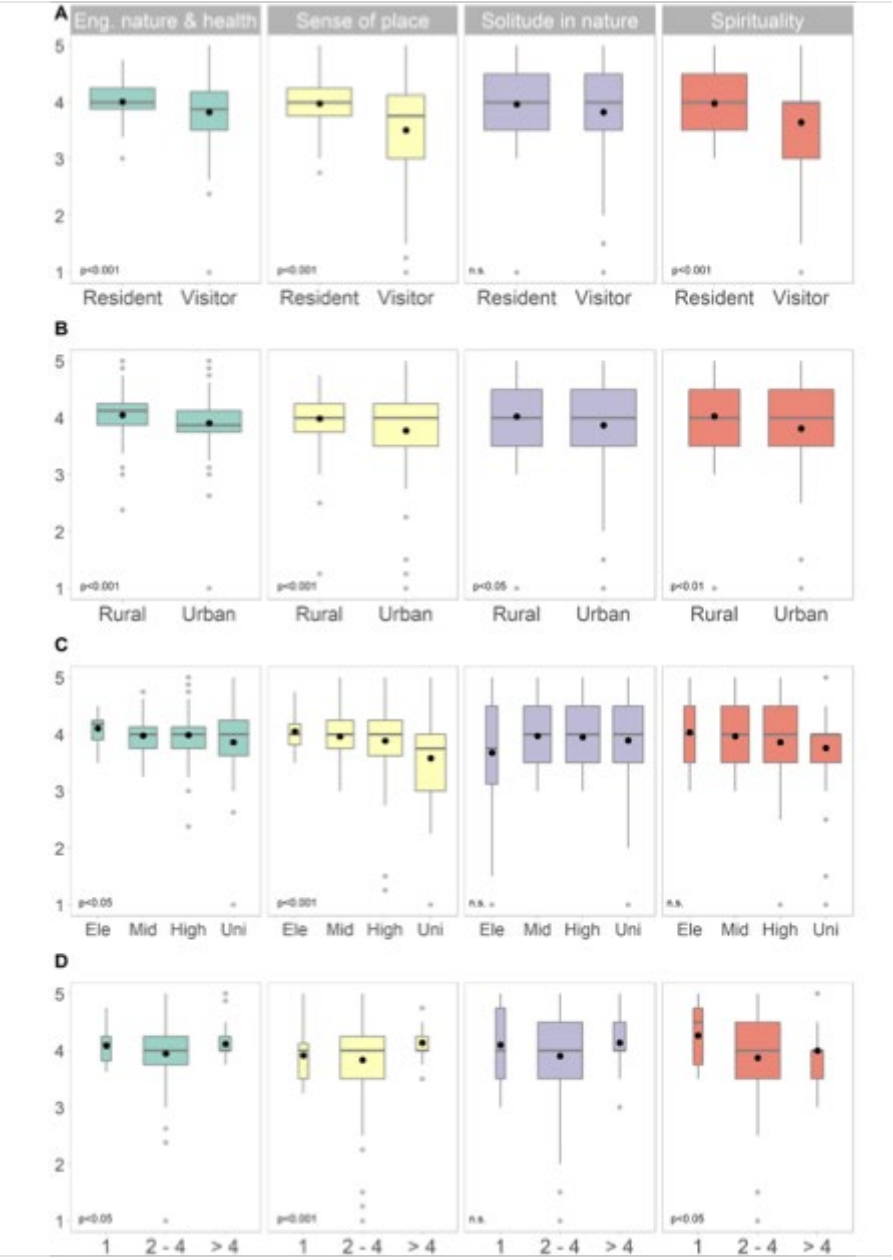

Figure 2. Composite scores of cultural dimensions of subjective well- being by socio-economic characteristics. Cultural dimensions are engagement with nature & health, sense of place, solitude in nature, and spirituality. Socio-economic variables include: A if is a resident or visitor of the municipality of Esposende; B if lives in a rural or urban setting; C formal education level; D household size. Only vari- ables with more than one significantly different dimension are shown. Boxes range from the first (25th percentile) to the third (75th percen- tile) quartiles, and whiskers extend to the highest value that is within 1.5 times the first and third inter-quartile range. Data beyond the end of whiskers are outliers (grey dots). Median score is indicated by the horizontal line in the boxes. Black dots represent the mean score. Box widths are proportional to the square-roots of the number of obser- vations in the groups. Non-statistically significant results are represented by 'n.s'.

Residents of Esposende rated higher than visitors the non-material NCP associated with engagement with nature & health ($W = 887966$, $df = 1$, $p < 0.001$), sense of place ($W = 247672$, $df = 1$, $p < 0.001$), and spirituality ($W = 247672$, $df = 1$, $p < 0.001$) (Figure 2A). Compared with urban interviewees, those living in a rural setting reported higher benefits from the four cultural dimensions of well-being (Figure 2B): engagement with nature & health ($W = 1104309$, $df = 1$, $p < 0.001$), sense of place ($W = 283403$, $df = 1$, $p < 0.001$), solitude in nature ($W = 69548$, $df = 1$, $p < 0.05$), and spirituality ($W = 59037$, $df = 1$, $p < 0.01$).

We also found significant differences in reported well-being according to the level of formal education (Figure 2C; S4). Those who had lower levels of formal education tended to report higher levels of non-material NCP provided by interactions with the marine environment. Comparing with interviewees with a university degree, those who attended high school reported significantly higher levels of benefits about engagement with nature & health ($Z = 2.53$, $df = 3$, $p.adj < 0.05$), and sense of place ($Z = 4.33$, $df = 3$, $p.adj < 0.001$). Similarly, comparing with university graduates, those who had an elementary or middle level of formal education reported higher levels of benefits about sense of place ($Z = 3.31$, $df = 3$, $p.adj < 0.01$; $Z = 4.63$, $df = 3$, $p.adj < 0.001$; respectively).

We found significant differences in interviewees' self-assessed levels of non-material NCP according to reported environmental behaviour (Figure 3). Variables of environmental behaviour with significant differences include the type of interactions between people and marine and coastal sites (that is, cognitive, physical, or both); interviewees' visit frequency to local beach and sea; amount of perceived benefits to human well-being provided by local marine and coastal sites; whether the interviewee had visited a protected area over the past year; and whether the interviewee read environmentally themed books/magazines.

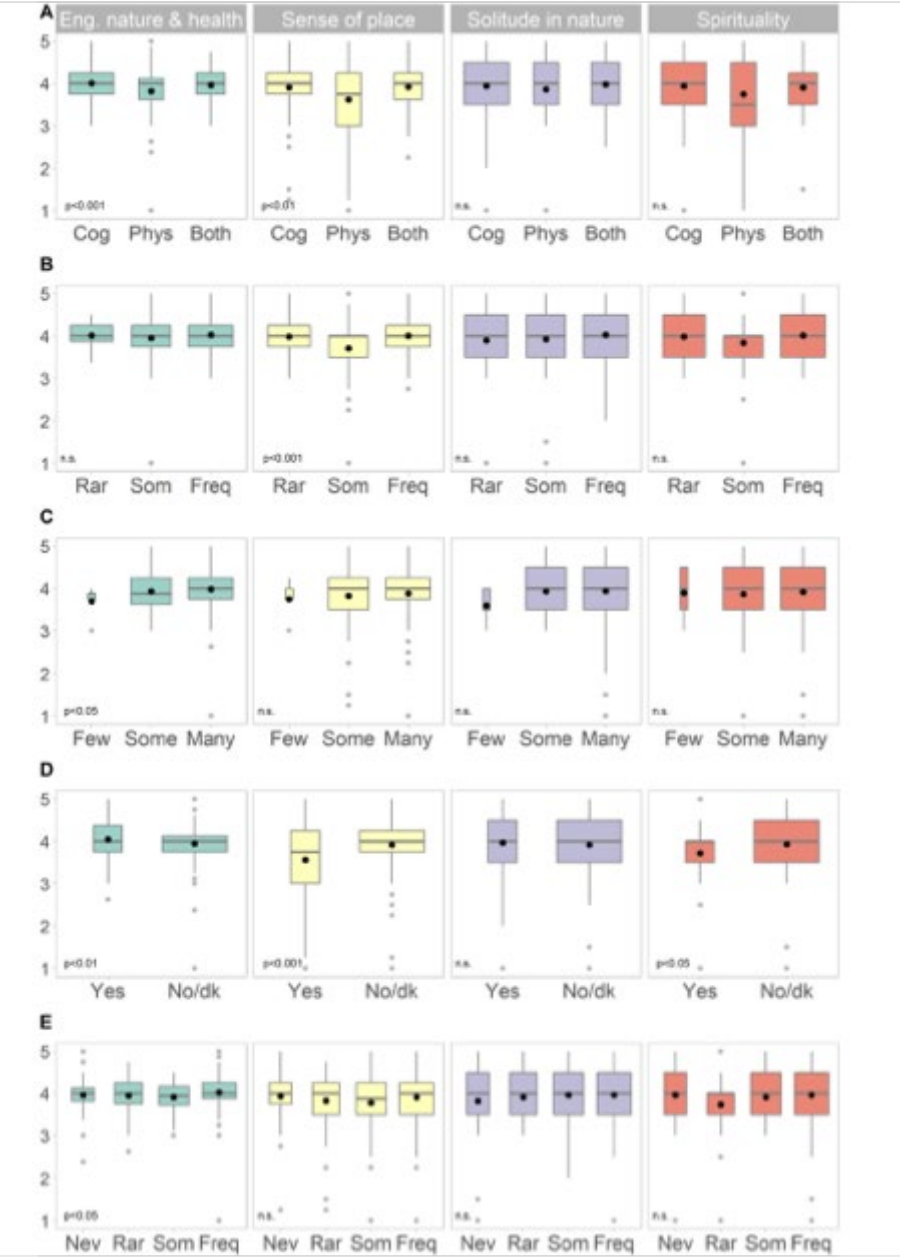

Figure 3. Composite scores of cultural dimensions of subjective well- being by reported environmental behaviour. Cultural dimensions are engagement with nature & health, sense of place, solitude in nature, and spirituality. Reported environmental behaviour variables include: A type of interaction with MPA sites (cognitive, physical, both); B visit frequency to sea/beach (rarely, sometimes, frequently); C amount of perceived benefits provided by sea/beach; D if visited a protected are over the past year (yes, no/don't know); E if reads environmentally themed books/magazines (never, rarely, sometimes, frequently). Boxes range from the first (25th percentile) to the third (75th percentile) quartiles, and whiskers extend to the highest value that is within 1.5 times the first and third inter-quartile range. Data beyond the end of whiskers are outliers (grey dots). Median score is indicated by the horizontal line in the boxes. Black dots represent the mean score. Box widths are proportional to the square-roots of the number of observations in the groups. Non-statistically significant results are represented by 'n.s'.

The four cultural well-being dimensions that emerged from factor analysis support the notion of people valuing non-human nature relationally. Although ecosystem services frameworks have depicted mainly the benefit flows that humans receive from nature, this study's results suggest

a bidirectional human-nature relationship. The notion of relational values about nature challenges the pervasive dichotomy between instrumental (nature's utility) and intrinsic values (nature's inherent worth) that has been guiding environmental ethics and biodiversity conservation. Relational values broaden the outlook of environmental valuation enabling more pluralistic assessments of values. Broadening environmental valuation assessments by including relational values can provide stronger arguments to conserve or further protect areas that are important beyond their intrinsic or instrumental worth, such as Litoral Norte MPA. These arguments can help extend protection to those unprotected areas with deep human-nature connections that combine high relational and ecological values.

However, top-down designation and management of MPAs, as is the case in Litoral Norte, deserves careful attention. MPAs can be sources of social injustice when social dynamics are neglected. MPAs are often established near coastal communities whose well-being depends on locally provided resources. After designation, MPAs can enhance or decrease resource provision by restricting or allowing human activities (Pascual *et al.*, 2016). For example, MPAs can entail trade-offs such as opportunities for tourism instead of fishing. MPAs can also give rise to synergies such as maintenance of habitats and species, and harvestable fish through 'spill-over'.

The WGRMES has been also working on the development of innovative methods to capture the importance of cultural ecosystem services. In Ospina-Alvarez *et al.* (2021) we recently developed a global study to measure cultural ecosystem services in several iconic areas of the world. The use of Graph Theory on social media data is a promising approach to identify emergent properties of the complex physical and cognitive interactions that occur between humans and nature. To test the effectiveness of this approach at global scales, Instagram posts from fourteen natural areas were selected to analyse the emergent discourse around these areas. The fourteen areas, known to provide key recreational, educational and heritage values, were investigated with different centrality metrics to test the ability of Graph Theory to identify variability in ecosystem social perceptions and use (Figure 4).

Instagram data (i.e., hashtags associated with photos) was analysed with network centrality measures to characterise properties of the connections between words posted by social media users. With this approach, the emergent properties of networks of hashtags were explored to characterise visitors' preferences (e.g., cultural heritage or nature appreciation), activities (e.g., diving or hiking), preferred habitats and species (e.g., forest, beach, penguins), and feelings (e.g., happiness or place identity). Network analysis on Instagram hashtags allowed delineating the users' discourse around a natural area, which provides crucial information for effective management of popular natural spaces for people.

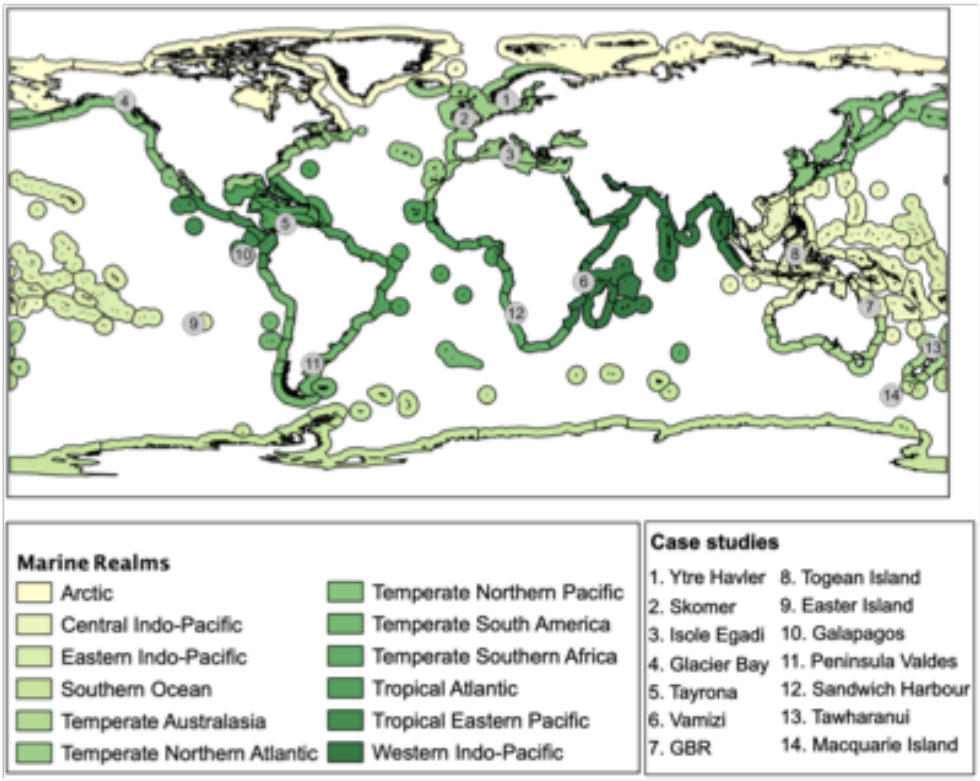

Figure 1. The 14 case studies selected across the twelve marine realms proposed by Spalding et al.[32].

Figure 4. The 14 case studies selected for the use of Graph Theory and marine cultural ecosystem services.

Results indicated that network graphs captured information on distinct types of ecosystem services, for example, those based on wildlife and nature, heritage, or beach tourism. In areas such as Galapagos, central hashtags were nature, wildlife, photography, travel and adventure, evidencing a preference for wildlife and nature-based tourism. In this area, betweenness evidenced the connections between the most frequent hashtags group with other peripheric hashtags and provided a complete picture on the discourse of Galapagos' visitors (Figure 5). As such, nature and wildlife-based travel and photography is related with natural science concepts like evolution and endemism, and specific biotic and abiotic components like crabs and waves, altogether related with positive feelings (e.g. happiness). Other areas emerging for their wildlife and nature were Skomer nature reserve, characterised by the hashtags birds (including the species Puffin), nature and wildlife photography; and Península Valdés, characterized by many locality names and by fauna, with the frequently posted hashtags' wildlife, whales and nature funnelling most connections to other less frequent hashtags (e.g., wind, hiking, relax) and providing a full picture of the social perception on nature recreation activities, iconic fauna and positive feelings.

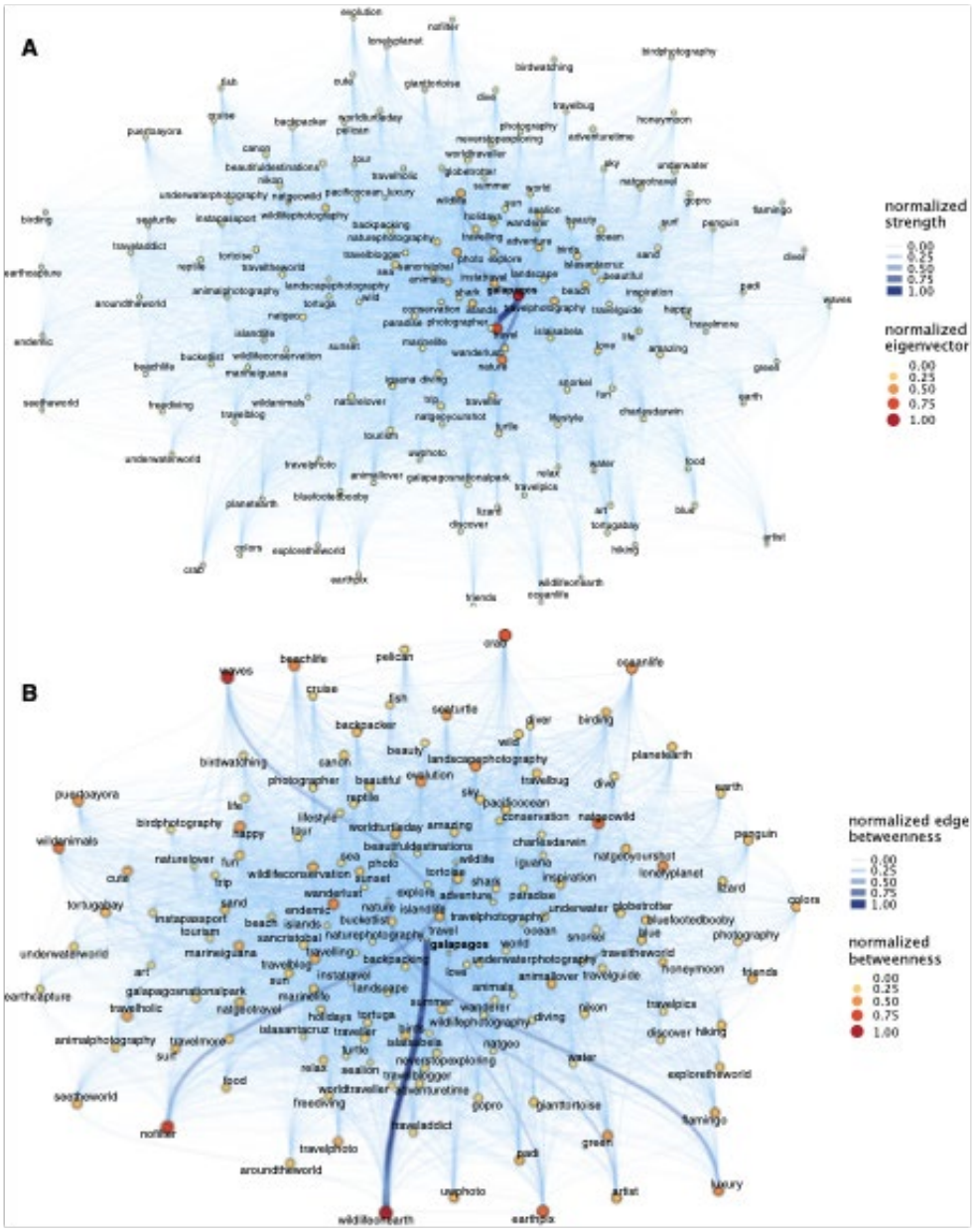

Figure 5. Example of network graphs in Galapagos case study. In plot (A) node size represents the Eigenvector centrality and edges represent normalized strength (weighted degree). In plot (B) node size represents normalized Betweenness centrality and edges represent normalized Edge betweenness.

A group of areas were appreciated by their underwater ecosystems. For Great Barrier Reef, popular hashtags were related with the coral reef: ocean, diving, underwater photography, travel, nature, coral and reef; whereas betweenness highlighted a set of hashtags related with conservation: science, sustainability, save the reef, 4 ocean (Figure 6) and evidenced the presence of a conservationist discourse in the social media. In Toguean Island net- work, the frequent hashtags beach, wonderful and charming are connected to peripheral hashtags related with the sea (e.g., sea life, diving), while in Vamizi, popular hashtags were related with high-income tourism, private island, travel, luxury travel, and were connected to less frequent hashtags linked to the sea, including recreational fisheries. These last two examples illustrate differences in the benefits, and beneficiaries, provided by two popular tourist destinations.

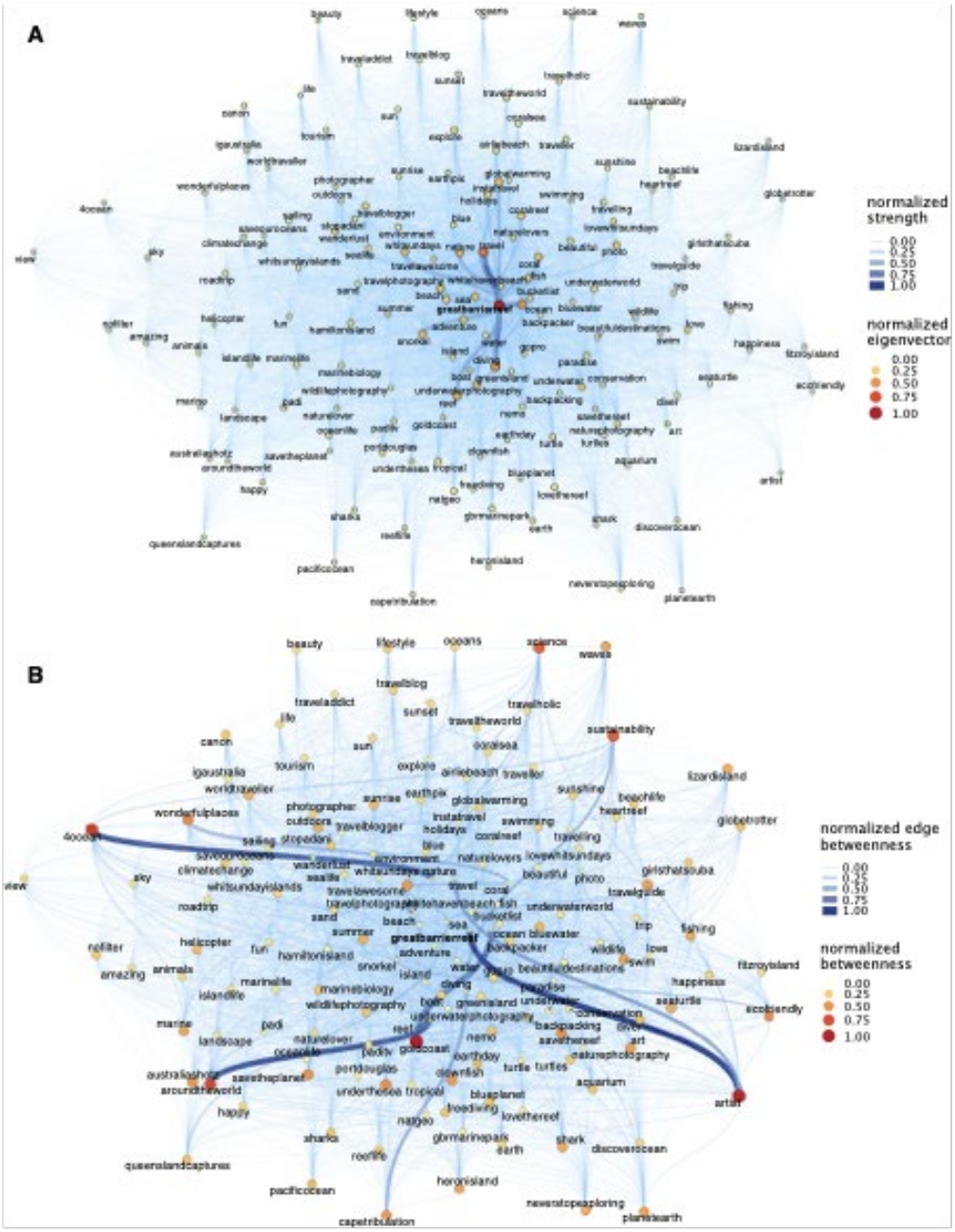

Figure 6. Example of network graphs in the Great Barrier Reef case study. In plot (A) node size represents the Eigenvector centrality and edges represent normalized strength (weighted degree). In plot (B) node size represents normalized Betweenness centrality and edges represent normalized Edge betweenness.

The merged network highlighted several hashtags that act as bridges between communities of hashtags (Figure 5). Nature, travel, photography and travel photography are key to structure the global network. However, several low eigenvector hashtags connect smaller groups: sunset and island connect the subgroups from Easter Island, Isole Egadi and Vamizi.

From the hashtag, travel photography diverges from a branch that connects 7 areas through adventure; a small group of hashtags deriving from this node represent Sandwich harbour and Vamizi, connected through Africa. The hashtag ocean, connected to adventure, relates the Great Barrier Reef with Tawharanui, and to wanderlust (a German expression for the desire to explore the world) that connects Península Valdés, Skomer and Macquairie Island. These three areas and Tayrona are also connected through the central hashtag travel photography, and Skomer and

Macquairie Island through wildlife photography. The hashtag adventure is also connected to a group of hashtags from Galapagos that also derive from the high eigenvector hashtag nature.

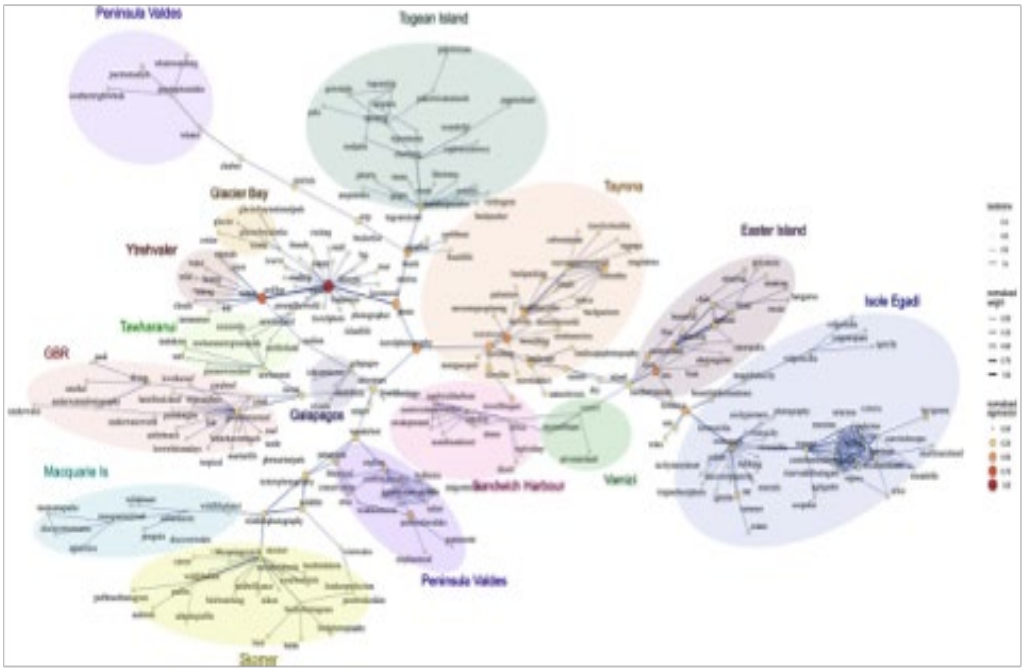

Figure 7. Global network graph including the fourteen case studies where the node size represents the Eigenvector centrality. The coloured clusters arrange the case studies to facilitate the visual identification of areas connected in the network.

The hashtag nature is key to include the fragile sub-network Ytrehvaler, and also derives from another high eigen- vector hashtag, travel, that in turn, connects to the small sub-network from Glacier bay. Photo, a central hashtag related with travel, connects to paradise, that is key to integrate Toguean Island, a few hashtags from Tayrona related with the Caribbean and beach, and a group of hashtags from Peninsula Valdez related with whale watching. Some other small hashtags that are connected to high eigenvector hashtags but are not included in any particular area are shared by many of the areas, e.g., sun, relax, landscape photography, nature lovers, sunset, sky.

Finally, the fundamental challenge of the inclusion of the human dimension of the oceans in the Integrated Ecosystem Assessments (IEAs) provides an opportunity for a transdisciplinary approach to create synergies between the current research by the International Council for the Exploration of the Sea (ICES) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). In this regard, the Belgrano and Villasante (2020) developed an Ocean's Benefits to People (OBP) framework that embraces the blue economy, equity, the UN SDGs goals and supports an Ecosystem-Based Management (EBM) for the oceans.

Recently, the work developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) provides a novel approach for the integration of a wide range of knowledge around biodiversity, and the importance of integrating social drivers with the provision of ecosystem services. For example, Díaz *et al.* (2018) perspective on how to assess NCP suggests the need to embrace a transdisciplinary approach that takes into account diverse sources of knowledge and cultural background including ILK, necessary for improving our capacity to understand the trade-offs between conservation measures, policy and governance.

To illustrate the integration of the social sciences in IEAs, here we provide, for the first time, an example for the Bay of Biscay and Iberian Waters ecoregion (Figure 8), on how current IEAs approaches can be further developed to embrace the human dimensions of marine ecosystems by linking the NCP concept (Díaz *et al.*, 2015, 2018) for promoting synergies and transformative changes and valuing NCP toward ocean equity. The important pressures in the Bay of Biscay and Iberian coast ecoregion are the selective extraction of species, abrasion, smothering, substrate loss and nutrient and organic enrichment. These pressures are linked mainly to human activities such as fishing, aquaculture, coastal construction, land-based industry, maritime transport, agriculture, dredging and offshore structures.

We extend the central concept of IEAs, linking drivers, enabling conditions of marine social–ecological systems (SES), human activities (e.g., aquaculture, fisheries, tourism, etc.) to pressures and state by including the need to develop the IEAs concept to include specific multiple drivers and to the ocean benefits, including intrinsic, relational instrumental values of ES and the ILK perspective (Díaz *et al.*, 2019; Pascual *et al.*, 2017).

By combining the enabling conditions, the characteristics of marine SES, local and distal direct (e.g., changes in sea use, direct exploitation of organisms, climate change, pollution and invasion of alien species) and indirect (such as rapid human population growth, unsustainable production and consumption and associated technological development) drivers affecting ecosystems (IPBES, 2019), our Ocean's Benefits to People (OBP) framework allows understanding how a SES might evolve from original state to another across space and time.

3 Review the available information about the co-production of marine ecosystem services (ToR C)

Co-production of Marine Ecosystem Services

Introduction

WGRMES worked on the co-production mechanisms of marine ES. Co-production of ES has been described as interactions between people and ecological systems that result in the provision of ES. We analysed five marine harvesting systems: two small scale fisheries in Northern Portugal and three small-scale shellfisheries in Galicia. The harvesting system with the largest use of non-natural capital is intensive intertidal semi aquaculture, as it uses all the forms of non-natural capital (human, social, manufactured, financial capital). The second most important activity using non-natural capital is the extensive semi-aquaculture which needs almost the same practices as intensive semi aquaculture but at a lower intensity level, using all the forms of non-natural capital except financial capital. These scientific results have been already published in Outeiro *et al.* (2017).

Results

Based on these results, we are extending the co-production matrix globally by developing three tasks: a) an inventory of co-production examples in marine social-ecological systems, b) an international expert consultation, and c) the development of a local interviews program in key selected case studies (France, Portugal and the United Kingdom) under the H2020 GENIALG project (https://genialgproject.eu).

The inventory of co-production processes of marine ES globally is collecting case studies to better understand what experiences have been made, what lessons and conclusions have been drawn and what have been key issues for advancing collaboration/key challenges for further inclusion of the co-production of marine ES in integrated assessments of marine social-ecological systems. The inventory is going through existing documentation from international and national agencies, other authorities and research institutions that have documented information from current or finished research projects about and/or including the physical and cognitive types of co-production. We are comparing and contrasting these diverse experiences through quantitative and qualitative and scientific analytical methods, as well as through qualitative, descriptive methods. The material gathered, and the synthesis conducted, will be shared by and discussed with a range of stakeholders in a workshop format.

Based on the existing evidence, we are mobilizing our international scientific networks

(e.g., Future Earth, Ecosystem Services Partnership, etc.) through meetings with experts to synthesize existing knowledge associated with the co-production of marine ES in order to ensure that no key examples from the inventory are missing, and help us to extract insights and lessons from our international inventory.

We will also use the conceptual framework developed by Palomo *et al.* (2016) to conduct interviews and questionnaires with key stakeholders (e.g., fishers, enterprises, ONGs, policy makers) in Galicia (Spain) and Northern Portugal to study in depth the role of different forms of natural and non-capital in the ES delivery across a selected number of case studies. We are exploring the

co-production pathways and their effects on ES quantity and quality, associated trade-offs, resilience and social equity. Co-production analysis at local scale will help to better identify the effects of co-production on the final distribution of ES, their benefits and costs. Such distribution of the costs of co-production, and the benefits of the resulting services is a key (often implicit) policy question that affects the equity of well-being in society.

4 Examine tipping points and social transformations of marine ecosystem services (ToR D)

Transformations of Marine Ecosystem Services

Introduction

Social vulnerability is a term describing how resilient a coastal community is when confronted by external stresses or drivers on human wealth and health. These stressors can range from natural or human-caused disasters to disease outbreaks. By reducing social coastal vulnerability, we can decrease both human suffering and economic losses to economic activities. Determining which of your group's assets are most likely to be affected by a climate threat can help your group decide where and how to start. One consideration in the decision is how close each asset may be to a tipping point—a point when incremental change in a system results in a new, irreversible response. Some people refer to tipping points as critical thresholds. Looming tipping points aren't the only factor groups need to consider when deciding which assets to protect, but the potential for a large change in the system can elevate the level of concern for those assets.

We have started to develop the Social Vulnerability Index in the European Union (EU). The SVI has been created by NOAA and based on the requirements of the Data Collection Framework in the EU. We have established a regular and solid collaboration with members from the WGSOCIAL from the NOAA (Lisa Coulborn and FAO (Amber Himes-Cornell) to apply the SVI in several coastal communities in the EU, starting with the detailed analysis in France, Portugal and Spain. For example, in Galicia (NW Spain) we have already collected the following data:

- Fisheries data (1997–2019)
    - Official platform www.pescadegalicia.gal
    - Reported landings (volume and value) by auction markets ("Lonjas")
    - 295 commercial species (fishes, crustaceans, mollusks)
    - Number of fishing vessels (length, tonnage and fishing power) by port
- Social data (1997–2019)
    - Official platform www.ige.eu
    - Selection of key variables by local experts (from 123 indicators)

Some of the key indicators for which we are collecting data are listed in Table 2.

Table 2. Categories and variables used for the social vulnerability of coastal communities in Galicia (NW Spain).

Category	Variable	Definition	Data period
1. Population	N° people (female/male)	People living in coastal municipalities	1996-2017
2. Houses	N° houses residential use	Houses destined to be inhabited by one or several people	1996-2017
3. Rent household	Gross income/capita	Account balance of the secondary distribution of the income	1996-2017
4. Population studies illiterate	% population of primary, secondary and tertiary	Population of 16 years and older in family homes by type of studies	1996-2017
5. Labour force structure	(Un)employment by economic sector	(Un)employed population by the location of their work	2001-2017
6. Employment	N° employment in fisheries sector	Population of 16 years working fisheries sector	1991-2017
8. Private sector	N° companies in each economic sector	Companies by activity sector (fishing) and legal status (cooperatives ...)	1997-2017

Results

The empirical results of the SVI will help the European Commission and national governments to a) provide empirical evidence of social vulnerability of fishing communities in the European Union, b) analyse the dynamic changes in contribution of fishing activities to coastal communities c) understand how fisheries management tools can contribute to reduce social vulnerability of people, and d) understand adaptive strategies developed by coastal communities to increase resilience over time. Another progress of the ToR about tipping points and social transformations is the update of two repositories of public and global information: The Social Transformation and the "Marine and Coastal ecosystem services" Datasets. Both repositories are described in detail above.

In addition, WGRMES have been intensively working on the topic of sustainability transformations. Villasante *et al.* (2021) have recently published an innovative work documenting transformative changes of small-scale fisheries in Galicia (NW Spain). The objectives of this paper were twofold: to document the current state of the art of Galician small-scale fisheries, and to evaluate the innovations and changes that occurred between 1990 and 2020, to explore whether such changes have scaled-up as seeds of desirable transformative changes and, if not, what obstacles and/or barriers have been identified in the scientific literature. Villasante *et al.* (2021) selected two cases, the Galician shellfisheries and the Marine Protected Area of Fishing Interest Os Miñarzos, to understand when and how profound changes in small-scale fisheries took place. The authors hypothesize that obstacles for building resilience to consolidate transformative changes once triggered are the still moderate effectiveness of the fisheries management systems, the low progress of incorporation of scientific and traditional knowledge into decision-making processes and policy arenas, the lack of studies about socio-economic contribution to coastal communities and commercialization models, and the presence of persistent ecological and economic drivers hindering desirable transformative changes.

The authors searched scientific papers, PhD thesis, books, book chapters and oral presentations presented at congresses proceedings published in English, Spanish and Galician between 1990–2020 period in Scopus, Web of Science and Google Scholar by searching titles, abstracts and keywords using the following search string: "small-scale fisher*" OR "artisanal fisher*" OR "shellfisher*" AND "Galicia". Once we compiled the relevant literature to be included in the review, we extracted 22 variables and their corresponding response categories (Table 3). These variables were recorded in pre-defined categories for comparability purposes. Data variables included, among others, SSF type assessed; location, scale, dimension and type of analysis; fishery management system; type of data used; key actors in the case study; drivers affecting SSF; innovations developed toward transformative changes; actors who promoted them; obstacles for SSF sustainability.

Table 3. Data variables and corresponding categories used to collect data in the systematic literature review.

Data variables	Description
Keywords	Keywords of the scientific contribution
Language	English | Spanish | Galician
Type of the paper	Conceptual | Empirical | Review
Dimension	Environmental | Economic | Social | Governance
Type of analysis	Quantitative | Qualitative | Mapping | Other
Scale	Local | Regional | National | Global
Location	Indicate the name of the place where the study is conducted
Province	Province of the study
Multispecies SSF	1 if the study is multispecies | 0 if only one species
Commercial species	Indicate the name of the species (or group of species, e.g., cephalopods)
Type of data used	Official data | Interviews | Models | Other
Temporal data	Indicate year or time series used
Source of data used	Indicate the name of the source with link if possible
Fishery management system	TAC | Co-management | TURF | MPA | Other
Key actors involved the case study	Women | Small-scale fishers | Shellfishers on foot | Shellfishers on boat | Other
Drivers affecting SSF	Climate change | Overexploitation | Other
Obstacles to SSF sustainability	Range of constraints and challenges that arise within and between political, legal, technological, physical (e.g., infrastructure), economic/financial and other social systems and the functioning of SSF
Innovations towards transformative changes?	Yes | No
Who promoted the change?	Fishers | Administration | Scientists | NGOs | Other
Specify innovations	Certification | MPA | Other
Values of inclusiveness, justice and equity are considered?	Yes | No
What are the most important knowledge gaps for achieving the transformative changes?	Provide a brief explanation of knowledge gaps

To document transitions and desirable transformative changes of Galician SSF, we also included variables already used in the scientific literature regarding transformative changes (IPBES, 2019). However, we also attempted to capture the key role of a given type of actor who promoted new transitions or transformational changes which are usually lacking in the scientific literature. This element should be considered essential for policy makers, given that developing programs or allocating public funds to stimulate transformative changes require knowing which actors would be in the position to lead that role. We also included obstacles for SSF sustainability and their link with the main knowledge gaps in analyzing transformative changes of Galician SSF.

We selected two specific case studies to better understand which actors are advocating for transformational change of Galician SSF, for what purposes, and to what expected outcomes, but also to understand where profound changes in the structures, processes, rules, and norms of ocean governance are currently underway. We purposefully selected these case studies because they

illustrate transformations towards different governance approaches (rights-based and conservation-based) as well as because they are also dealing with different challenges of transformational phases (e.g., preparing, navigating and building resilience); (Herrfahrdt-Pähle *et al.*, 2020).

Publications on SSF in Galicia have been scarce until the 21st century (Figure 8). However, during the last two decades of this century, an average of 31 ± 4.2 (S.D.) publications per decade have been published in relation to this topic. In 2020, a maximum of 6 scientific articles were published.

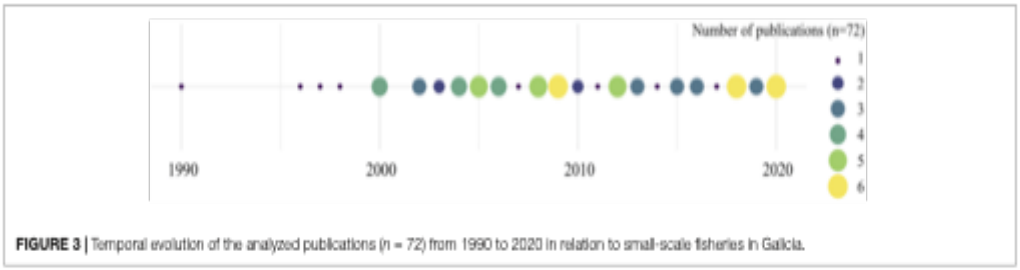

Figure 8. Temporal evolution of the analyzed publications (n=72) from 1990–2020 in relation to SSF in Galicia.

A total of 72 publications were analyzed from 1990 to 2020 in relation to SSF in Galicia according to the type of publication (conceptual, empirical, and/or review), type of data used (interviews, models, official data, and/or other), type of analysis (quantitative and/or qualitative), scale (local, regional, national, or global), species studied (several species or a single species) and dimension (economic, environmental, governmental, and/or social); (Figure 9).

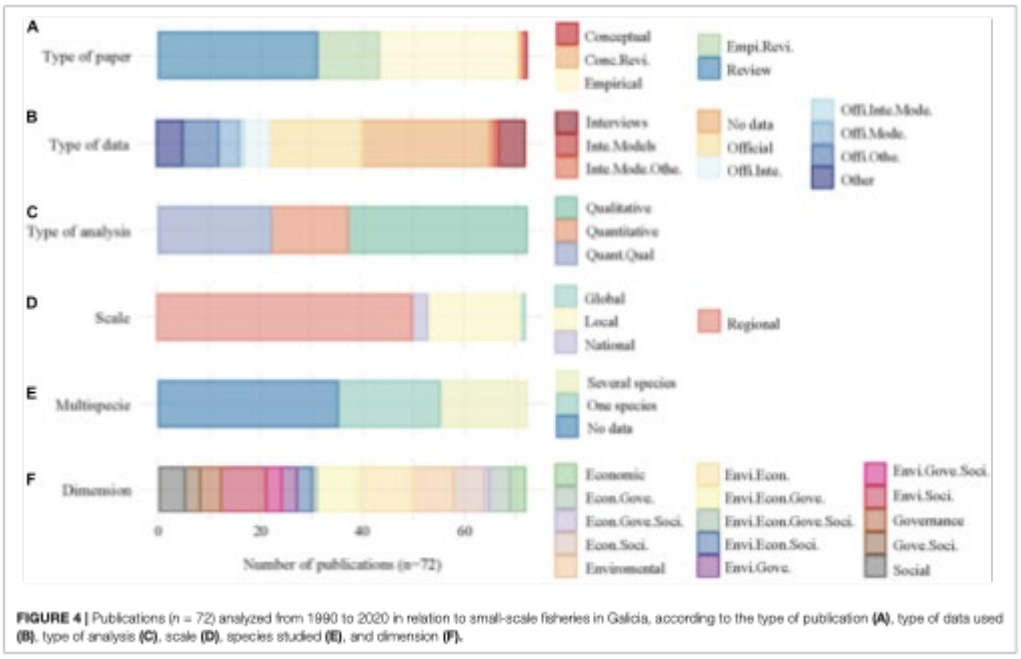

Figure 9. Publications (n=72) analyzed from 1990 to 2020 in relation to small-scale fisheries in Galicia, according to the type of publication (A), type of data used (B), type of analysis (C), scale (D), species studied (E) and dimension (F).

We also document transformative changes of smallScale fisheries by focusing on two case studies: the Galician shellfishing on foot (marisqueo a pie) and the Marine Reserve for Fishing Interest Os Miñarzos (Lira).

Shellfish species can be harvested from vessels or through manual harvest during low tides. On-foot shellfishing (marisqueo a pie), an expression used to refer to shellfish gathering at accessible intertidal areas during low tides by using a variety of clam rakes and hoes, is mostly carried out by women, while shellfishing from vessels is performed mostly by men in subtidal areas. Under the preparation phase, Xunta de Galicia has managed coastal fishery activities for the last 50 years, while the Spanish Government manages fisheries in external waters, i.e., outside the imaginary lines connecting the main capes of the Galician shoreline. During the 1960s–1980s, coinciding with a general increase in the number of shell-fishers, market demand, and economic value of shellfish species, the regional administration introduced step-by-step new regulations to rationalize and manage the activity. In the early 1980s, Spain initiated a process of decentralization, entering into the navigation phase, and with this came the creation of distinct Autonomous Communities.

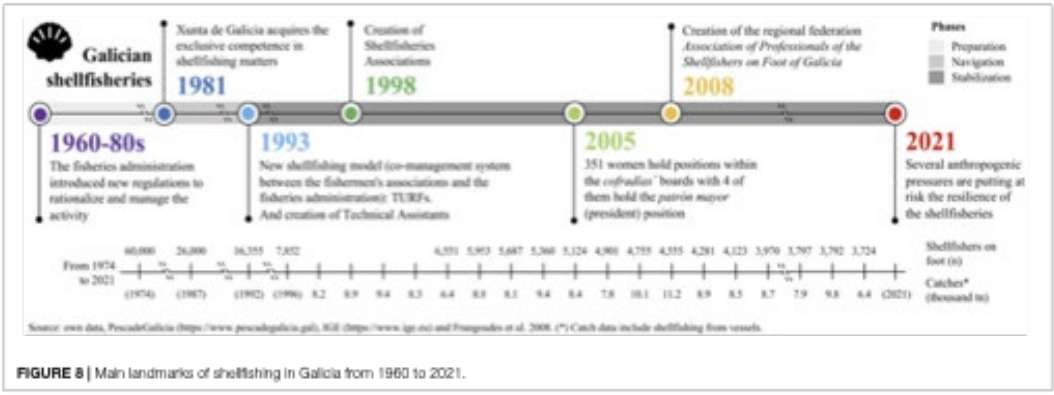

Figure 10. Main landmarks of shell-fishing in Galicia from 1960 to 2021.

But it was not until 1993 when the Galician government, with fishing powers since 1981, introduced a fundamental transformative change entering into the stabilization phase: a new model for shellfishing, promoting a co-management system between cofradías and fisheries administration, advised by scientists, based on TURFs over a large area and its resources. Although these changes have been institutionalized within the new governance regime, the shellfishing activity is currently under several anthropogenic and social pressures which are putting at risk the capacity to build resilience. The increasing market pressure due to the high national and international seafood demand is driving shellfishers to harvest Japanese carpet shell (Ruditapes philippinarum), an invasive species with better resistance to deal with environmental changes which has been introduced in the 1980s in Galician bays.

After the abrupt shock and the huge impacts of the Prestige oil spill in 2002, artisanal fishers from Lira (north-central coast of Galicia) initiated a process or preparation phase to create a 'Marine Reserve of Fishing Interest' (hereinafter referred to as MPA to simplify) that concluded with its formalization in April 2007, with the name of 'Os Miñarzos' (Figure 11).

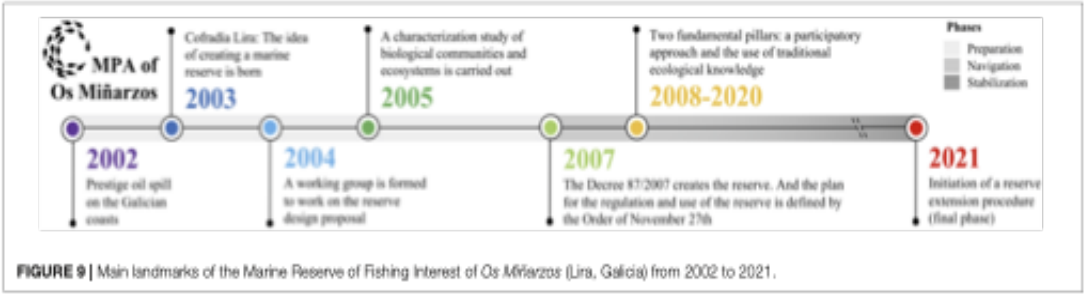

Figure 11. Main landmarks of the Marine Reserve of Fishing Interest of Os Miñarzos (Lira, Galicia) from 2002 to 2021.

Under the Fisheries Law of the Xunta de Galicia (Law 11/2008, December 3, of Galician Fishing), marine reserves of fishing interest are tools for the management of fishing resources and conservation of marine ecosystems. In the process of creating the MPA of Os Miñarzos, fishers have taken an active participation in the design and collectively defined the most suitable management plans for sustainable fishing within the reserve (Pascual-Fernández *et al.*, 2020), which led to a greater acceptability and compliance of norms, entering into the navigation phase.

More than 10 years after its full implementation, the transformative change that took place since the creation of the MPA not only had repercussions on fishing practices, but also on the beliefs and social values of the main fishers, scientists and representatives of the regional administration involved in the Management Body of the MPA. The latter provided the foundations for the stabilization phase. Trust and cooperation, essential elements to successfully govern common pool resources, have been improved since fishers provide data and participate in different monitoring programs. There has also been a notable reduction of conflicts and mistrust between the administration and the fisheries sector, favouring that most decisions concerning fishing activities within the MPA are taken by consensus. Another sign of progress was the collective behaviour of local fishers working within the MPA who, after the decision of the regional administration to discontinue financially supporting the surveillance to the area in 2010, continued with the inertia of social norms to comply with the fisheries law, even 2 years after that decision.

This process of collective construction has also been complex and not exempt from tensions and contested actions from some cofradías and fishers, since it is necessary to not only trust in the MPA but also to increase the fisheries sector commitment to sustainability targets. Indeed, currently there are obstacles putting at risk the consolidation of the stabilization phase, namely the reduction of the public budget to cover costs for surveillance allocated by the regional administration and the lack of support from some cofradías fishing in the MPA.

Finally, WGRMES have been advancing in the linkages between transformative changes and healthier diets carried out by Custodio *et al.* (2021). Halophytes are salt-tolerant plants that survive and reproduce in environments with salt concentrations exceeding 200 mM of sodium chloride. These previously underutilized wild plants are emerging as new saline crops across the globe that can be used for human nutrition in a larger scale and as raw material for the production of other goods such as biosalt, vegetable oil, biofuel, and bioethanol and the extraction of bioactive secondary metabolites.

Edible halophytes with economic potential include *Salicornia* spp. and *Sarcocornia* spp. (common names: glasswort, sea asparagus, samphire), *Halimione portulacoides* and *Sesuvium portulacastrum* (sea purslanes), *Aster tripolium* (sea aster), *Batis maritima* (saltwort), *Mesembryanthemum crystallinum* (ice plant), just to name a few. The commercial production of halophytes can be established not only under agricultural settings but also under an integrated aquaculture framework known as Integrated Multi-Trophic Aquaculture (IMTA), which is characterized as the enhanced pro-

duction of aquatic organisms, with complementary ecosystem functions, that are trophically connected by demonstrated nutrient flows. Seafood consumers value an IMTA approach to aquaculture farmingand, in the context of the European Union (EU), halophytes may easily become an environmentally and economically attractive functional group for IMTA to help boost an EU sector that is struggling to keep up with the global growth trends. The diversification of aquaculture products using native species is advocated by the Food and Agriculture Organization of the United Nations (FAO) and several halophytes considered good candidates for IMTA are also native to the European flora, further supporting their study as novel marine (sea)food products to be added to the growing collection of organisms cultivated under IMTA.

Halophytes can be sold as minimally processed fresh-cut vegetables in ready-to-use formats that are increasingly popular among consumers and can be an important source of biosalt. Biosalt is characterized as being of vegetable origin with a low-sodium profile balanced with other minerals, rich in nutrients and bioactive substances, and helpful in the prevention of hypertension and other cardiovascular diseases, therefore halophyte consumption could have broader implications in human health.

Unhealthy salt consumption is a generalized pattern across the globe, as 181 out of 187 countries present estimated mean levels of sodium intake that exceed World Health Organization (WHO) recommendations. In Portugal, where the present study was performed, high salt-intake is the dietary risk-factor that most contributes to the burden of disease. The average citizen consumes an excess of 3 grams of salt per day above the maximum of 5 grams recommended by WHO, with an estimated 36 - 42% of the population suffering from hypertension. The elder population (> 65 years old) is of concern, featuring a prevalence of hypertension of about 75%. Incidence of obesity is also positively correlated with high salt-intake, and recent estimates suggest that about 29% of the adult population is obese and 20% of adolescents are overweight or obese.

The urgent need to promote healthy eating habits, paired with national and EU policy goals to facilitate healthy food environments, means that uncovering evidence on the value of salt-alternatives such as edible halophytes is critical. In 2012, Portugal implemented the first national food and nutrition policy - the National Programme for the Promotion of Healthy Eating (PNPAS), which was considered one of the eight priority programs to be carried out by the Ministry of Health. Later, in 2017, the Integrated Strategy for the Promotion of Healthy Eating (EIPAS) policy was published as a Law to promote healthy food habits in the country (Despacho n. 11418/2017) and in which several actions specifically mention halophytes (Salicornia) as salt alternatives that must be explored.

However, for halophytes to fully reveal their potential as new marine vegetables and deliver their health benefits, they must first and foremost be accepted by consumers. Consumer surveys are important methods to leverage the acceptance of new foods and were previously employed to assess European consumers' preferences regarding, for instance, duckweed, insects, and jellyfish products. Concerning halophyte products, consumer studies are still lacking in the scientific literature.

The city of Aveiro, a historically and culturally distinguished region of marine-salt production is experiencing an introduction of Salicornia products by local specialty shops and was chosen to be the sampling location of the present study. Using a structured survey, the present work aimed to understand consumers' preferences regarding vegetable and halophytes consumption, their willingness-to-pay (WTP) for halophyte products, and identify potential consumer segments to facilitate the successful introduction of halophyte products and inform nationwide initiatives. Results from the present study can advise future halophyte and IMTA producers, sellers, and policymakers on pricing, marketing, and communication strategies to successfully introduce these new marine vegetables into consumers' diets and inspire the replication of this approach elsewhere.

Consumer responses were collected via in-person interviews in the city of Aveiro, Portugal, at two point-of-purchase locations: a municipal market and a supermarket. A total of 268 consumers were successfully surveyed between 30 April to 9 May and between 18 September to 26 April 2019. Each interview lasted approximately 5 to 10 minutes and the questions were asked in Portuguese. A pre-test survey was executed on March 10th at a local market where 20 randomly selected people were interviewed. Based on the results of the pre-test, the duration and number of questions were reduced to decrease fatigue and increase willingness to participate and wording/sentences were reformulated to improve understanding of questions. The final questionnaire that supported the interviews was divided into three sections: (1) food-related habits questions; (2) product-related questions and WTP; and (3) socio-demographic questions.

Participants were asked to rate their level of agreement with each item/question on a 7-point Likert scale labeled as 1= totally disagree, 2= disagree, 3= somewhat disagree, 4= neither agree nor disagree, 5= somewhat agree, 6= agree and 7= totally agree. Cronbach's alpha (CA) was used to assess the internal consistency of the measuring items from each construct (see Table 4).

Table 4. Food-Related Lifestyle (FRL) dimensions and corresponding items.

Core dimension	Items	Cronbach's alpha (95% conf. int.)
1. Innovation	1.1. I love to try recipes from different countries 1.2. I like to try new foods that I have never tasted before 1.3. I look for ways to prepare unusual meals	0.72 – 0.80
2. Involvement	2.1. Eating and food is an important part of my social life 2.2. Decisions on what to eat and drink are very important for me 2.3. Eating and drinking are a continuous source of joy for me	0.58 – 0.70 †
3. Responsibility	3.1. I try to choose food produced with minimal impact on the environment 3.2. I am concerned about the conditions under which the food I buy is produced 3.3. I try to choose food that is produced in a sustainable way	0.72 – 0.80

† Dropping item 2.2 improved CA (95% c.i. = 0.67 – 0.77). Therefore, the compiste score of 'involvement' did not consider item 2.2.

The Aveiro region has a population size of 362 598 inhabitants (2018, www.pordata.pt) and, assuming a confidence level of 95%, the margin of error of the sample (n= 268) is 6.0%. In other words, sample statistics will be within 6 percentage points of the real population value 95% of the time. The characterization of the sample based on all responses is presented in Table 5.

Table 5. Frequency distribution and descriptive statistics of responses (n= 268)

Question	Option (*categorical var.*)	Statistic	
		fre-quency (%)	mean ± s.d.
Section 1 - Food-related questions			
What percentage of your daily diet is composed of vegetable products?			47.2 ± 19.7
Do you diversify your vegetable intake in your day-to-day diet?	*No*	10.2	
	Yes	89.8	
I try to choose food produced with minimal impact on the environment (Likert scale 1 - 7)			5.3 ± 1.3
I love to try recipes from different countries (Likert scale 1 - 7)			5.3 ± 1.6
Eating and food are an important part of my social life (Likert scale 1 - 7)			5.6 ± 1.3
I am concerned about the conditions under which the food I buy is produced (Likert scale 1 - 7)			5.6 ± 1.3
I like to try new foods that I have never tasted before (Likert scale 1 - 7)			5.3 ± 1.4
Decisions on what to eat and drink are very important to me (Likert scale 1 - 7)			6.1 ± 1.0
I try to choose food that is produced in a sustainable way (Likert scale 1 - 7)			5.2 ± 1.4
I look for ways to prepare unusual meals (Likert scale 1 - 7)			4.3 ± 1.5
Eating and drinking are a continuous source of joy for me (Likert scale 1 - 7)			5.7 ± 1.4
Section 2 - Product-related questions and willingness-to-pay			
Do you know what halophyte plants are?	*No*	87.1	
	Yes	12.9	
Did you ever consume halophytes before (e.g. Salicornia)?	*No*	70.4	
	Yes	29.6	
Would you like to try this product [package with 50 g fresh Salicornia]?	*No*	28.4	
	Yes	71.6	
How much did you like the taste of this product (1-7) (n= 205)			5.8 ± 1.2
What is the maximum price in € you would be willing to pay for this product [package 50 g fresh Salicornia]? (n= 264, outliers removed)			2.1 ± 1.1
Section 3 - Sociodemographic questions			
What is your gender?	*Female*	57.5	
	Male	42.5	
How old are you?	*18-29*	22.8	
	30-39	18.3	

	40-49	17.2	
	50-59	16.8	
	>60	25.0	
What is your level of education?	*Secondary school or less*	47.0	
	University	53.0	
What is your employment status?	*Employee*	42.6	
	Self-employed	12.7	
	Unemployed	7.1	
	Retired	22.4	
	Student	11.6	
	Other	3.7	
What is your monthly income (€)?	*0-599*	27.2	
	600-1000	33.2	
	1001-2000	31.3	
	2001-3000	6.3	
	>3000	1.9	
What is the size of your household (number of members)?			2.7 ± 1.3

Briefly, the sample is slightly over-represented by female respondents (57.5%) and the most represented age groups are the elderly (≥ 60 years old, 25.0%) followed by young adults (18–29 years old, 22.8%). The sample is evenly distributed between secondary (47.0%) and higher educations (53.0%) and 59.0% of respondents have some sort of employment, either through hire (42.6%), self-employment (12.7%), or other formats (e.g. research grants) (3.7%). The non-employed respondents comprise 41.0% of the sample, distributed across retirees (22.4%), students (11.6%), and unemployed (7.1%). More than half of respondents earn below 1000 € per month (60.5 %) (the average salary in Portugal in 2018 was approximately 970 €; www.pordata.pt), out of which 27.2% received less than the 2019 minimum wage of 600 € per month (note that 80.8% of respondents in this category also belong to 'non-employed' categories). Respondents earning above 2000 € per month comprised 8.2% of the sample.

The cluster analysis was performed using the composite FRL scores from each construct and the average scores in the total sample were: 'involvement' = 5.8, 'innovation' = 5.0, and 'responsibility' = 5.4. Before running the 'k-means clustering' algorithm, the number of clusters (k) to be computed must be chosen and the 'within-cluster-sum-of-squares' (WCSS) method was used to select the appropriate k, determined to be k = 3. The graphical representation of the 'k-means clustering' analysis is presented in Figure 12.

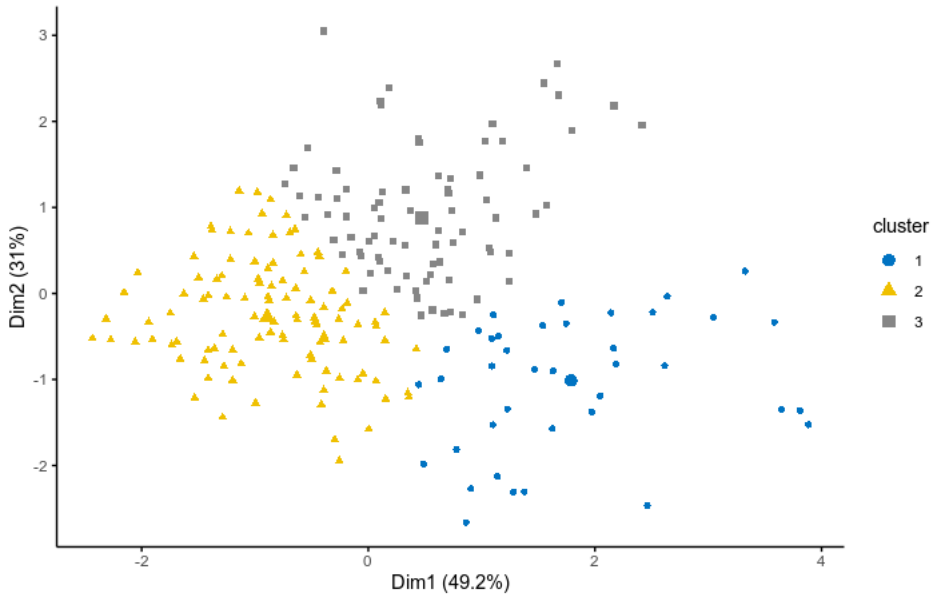

Figure 12. Cluster analysis grouped consumers according to their FRL scores and the three clusters significantly differed regarding the three constructs (Table 6). Cluster 2 (48.5% of respondents) is the most *innovative* and *responsible* segment, compared with the other clusters. Cluster 1 (21.6% of respondents) is the least *innovative* and *involved* and Cluster 3 (32.6% of respondents) is the least *responsible*. Clusters 2 and 3 are similar in terms of their *involvement* with food. Given the FRL segmentation attributes of each defined cluster, consumer segments will be designated as follows: Cluster 1 - 'conservative consumer', Cluster 2 - 'adventurous consumer', and Cluster 3 - 'careless consumer'.

These three designations correspond roughly to the conservative, adventurous and careless segments referred to in the FRL literature. Compared with the total sample, the 'conservative consumer' is less innovative (score= 3.6) and involved (4.0) than the average consumer but equally responsible (5.5). The 'careless consumer' is more involved (6.0) than the average consumer, but less innovative (4.8) and responsible (4.2). The 'adventurous consumer' is more involved (6.1), responsible (6.1), and innovative (5.7) in all aspects of food than the average consumer. Regarding vegetable consumption, the 'careless consumer' incorporates fewer vegetables in its diet (38%) than the other segments (48–53%). In terms of reported diversification of vegetable intake, the highest rate of positive responses was observed in the 'adventurous consumer' (96% responded yes) and the highest rate of negative responses was observed in the 'careless consumer' (17.4% responded no).

Table 6. Characterization of the consumer segments defined by 'k-means clustering'. Test-statistic for numerical variables: Kruskal-Wallis test and Wilcoxon rank-sum test for pairwise comparison; for categorical variables: Fisher's exact test (differences in proportions).

Variable		Cluster 1 **Conservative consumer** (n= 57; 21.6%)	Cluster 2 **Adventurous consumer** (n= 121; 48.5%)	Cluster 3 **Careless consumer** (n= 86; 32.6%)
Continuous		Mean ± standard deviation		
Willingness to Pay for 50 g fresh Salicornia (€)		2.1 ± 1.3	2.2 ± 1.0	1.9 ± 0.9
Vegetables in the diet (%) *		48.3 ± 19.4 [a]	53.3 ± 18.5 [a]	38.1 ± 18.1 [b]
FRL dimension 1: Innovation* (Likert scale: 1 - 7)		3.6 ± 1.3 [a]	5.7 ± 0.7 [b]	4.8 ± 1.0 [c]
FRL dimension 2: Involvement * (Likert scale: 1 - 7)		4.0 ± 1.8 [a]	6.1 ± 0.8 [b]	6.0 ± 0.7 [b]
FRL dimension 3: Responsibility * (Likert scale: 1 - 7)		5.5 ± 0.8 [a]	6.1 ± 0.6 [b]	4.2 ± 0.8 [c]
Demographic continuous variables				
Household members		2.6 ± 1.5	2.7 ± 1.2	2.8 ± 1.4
Categorical		Proportion of counts		
Diversify vegetable intake *	Yes : No	50 : 7 [ab]	116 : 5 [a]	71 : 15 [b]
Knows what a halophyte is	Yes : No	7 : 50	77 : 103	9 : 77
Ate a halophyte before	Yes : No	19 : 38	35 : 86	24 : 62
Tried the product	Yes : No	39 : 18	90 : 31	60 : 26
Demographic categorical variables				
Gender *	Female : Male	39 : 18 [a]	76 : 45 [a]	37 : 49 [b]
Age† *	18-29 : 30-59	9 : 20 [ab]	21 : 77 [a]	29 : 41 [b]
	18-29 : > 60	9 : 28 [a]	21 : 23 [ab]	29 : 16 [b]
	30-59 : > 60	20 : 28 [a]	77 : 23 [b]	41 : 16 [b]
Education	Sec. school : Univ.	30 : 27	52 : 69	41 : 45
Employment status† *	Employed[1] : Non-employed[2]	26 : 31 [a]	79 : 42 [b]	50 : 36 [ab]
Monthly income†	< 1000 : > 1000	42 : 15	67 : 54	49 : 37

* Fisher's test shows the proportion of responses is different across lifestyle segments ($p < 0.05$)

[a,b,c] different letters represent significant difference between clusters ($p < 0.05$)

† number of categories reduced (merged)

[1] pooled categories: 'employee", 'self-employed' and 'other'

[2] pooled categories: 'unemployed", 'retired' and 'student'

Consumption and willingness to pay TP for halophytes

In general, most respondents had never previously heard the term 'halophyte', as only 13% were familiar with its definition. Nonetheless, about 30% answered that they had consumed a halophyte at least once before the survey (all reported Salicornia as the halophyte they had previously consumed). When asked if they wanted to test the product, 72% of respondents answered positively (39% of the respondents that responded negatively had already tried Salicornia before and were likely aware of their experience). Those who tested the product were asked their level of agreement with the sentence "I like the product" (on a Likert-scale of 1 to 7 as defined in the Material and Methods section) and 68% responded "agree" (score 6) and "totally agree" (score 7).

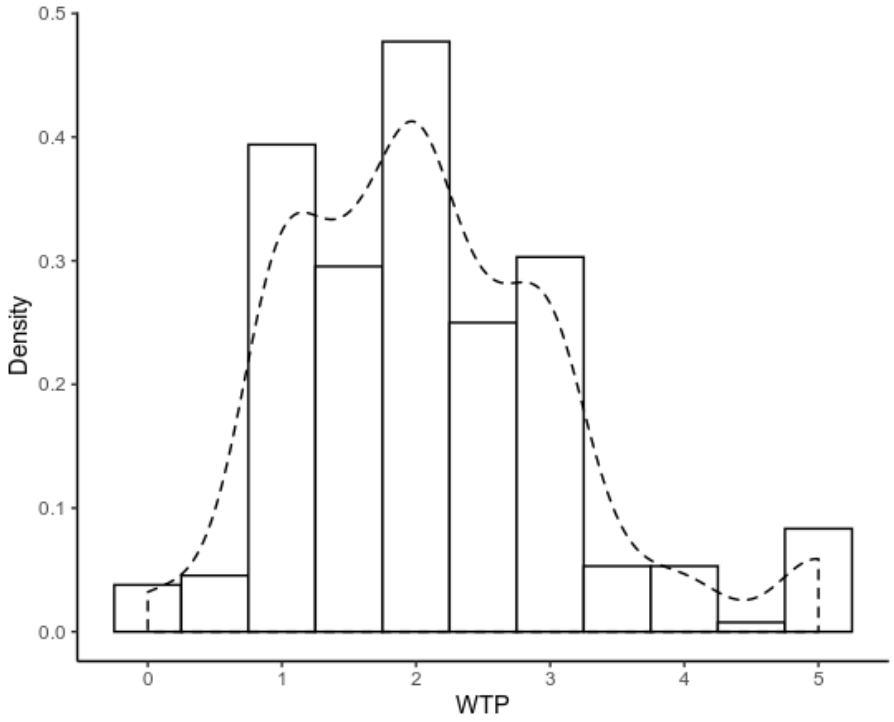

Figure 13. Density distribution of 'willingness-to-pay' responses (n= 264; after removal of outliers and multiple imputation of missing data). Histogram bin-width: 0,5.

Consumers' WTP for a package with 50 grams of fresh Salicornia (discounting outliers) ranged between 0 € and 5.0 €, with the median value being 2.0 € and the average value 2.1 € (Figure 13). The WTP across categorical variables was also computed to determine if any particular category of consumers was willing to pay a higher price (Figure 14). The categories that displayed significant differences in WTP between category levels were 'gender', 'vegetable diversification', and 'product test'. Female consumers were willing to pay more (2.3 €) than males (1.8 €) and those consumers that reported diversifying their vegetable intake were willing to pay more (2.2 €) than those who did not diversify (1.4 €). Respondents who tested the product before WTP elicitation also reported willingness to pay a higher price (2.2 €) than those who did not (1.9 €). Regarding the FRL consumer segments, WTP was not statistically different between them. The 'careless consumer' was willing to pay the least (1.9 €) and the 'adventurous consumer' was willing to pay the most (2.2 €).

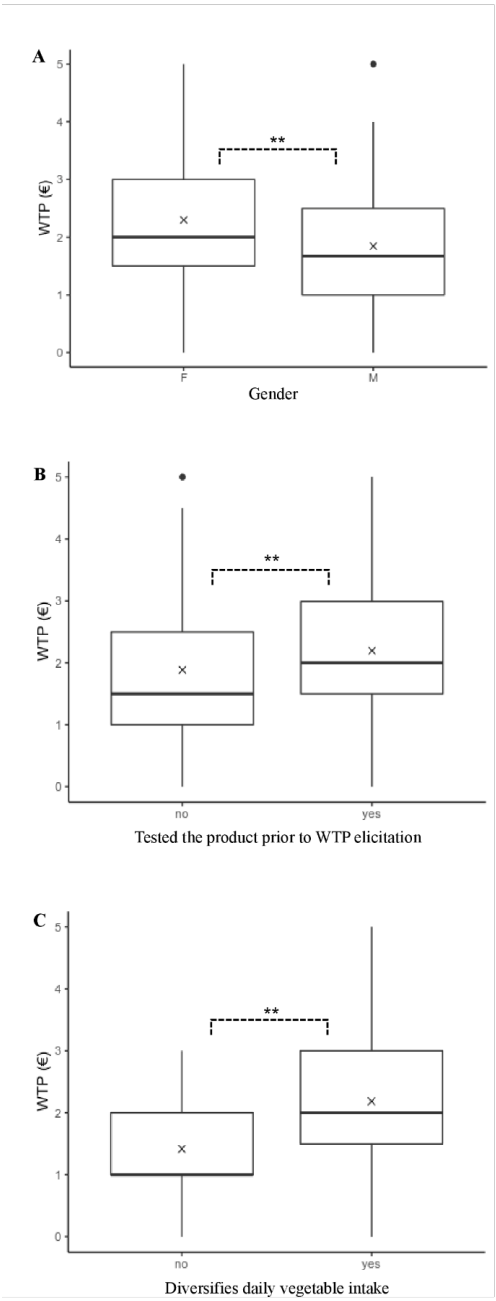

Figure 14. Boxplot representation of 'willingness-to-pay' distribution per category. Only categorical variables with statistically significant differences between levels are displayed (: p < 0.01; ×: mean WTP): A) 'gender', B) 'product test', C) 'vegetable diversification'. Test-statistic: Kruskal-Wallis test and Wilcoxon rank sum test for pairwise comparison.**

5 Evaluate governance and scenarios for sustainable marine ecosystem services (ToR E)

Governance Scenarios

Introduction

In contemporary society, Marine Protected Areas (MPAs) are increasingly expected to justify their existence through the services that they provide to society. Current challenges for MPAs research, and implementation, include understanding the role of MPAs in maintaining ecosystem services, identifying the key cultural services offered by MPAs (Garcia Rodrigues *et al.* 2017). WGRMES is developing a global review of MPAs and their role to maintain marine ES.

Results

A recent paper published by Belgrano *et al.* (2021) present a transdisciplinary approach based on the Delphi method for mapping and evaluating Marine Protected Areas for their ability to protect biodiversity while providing Ecosystem Services (ES) and related human well-being benefits – i.e., the ecosystem outputs from which people benefit. The authors highlight the need to include the human dimensions of marine protection in such assessments, given that the effectiveness of MPAs over time is conditional on the social, cultural and institutional contexts in which MPAs evolve. Belgrano *et al.* (2021) developed an approach to support the Ecosystem-Based Management and highlights the importance of MPAs in achieving restoration, conservation, and sustainable development objectives in relation to EU Directives such as the Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD), and the Common Fisheries Policy (CFP).

Assessing the role of MPAs as an integral part of EBM requires an understanding of the link between the implementation of MPAs and the provision of ES. The knowledge to be used for such analyses includes scientific expertise but can also be based on practical managerial and local users' knowledge. This kind of evaluation entails the need to combine complex data, often beyond the level of what can be captured by unified metrics, and across different spatial and temporal scales. We propose a modified version of the Delphi approach as a way to resolve this challenge. The Delphi approach is typically defined as a forecasting process framework that aims to elicit experts' knowledge and reach consensus among them through a series of carefully designed questionnaires. This approach is well suited to advance our knowledge of the role of MPAs in enhancing and maintaining ESs. It is characterized by a set of reiterative steps which include:

1. Identify a panel of experts to consult and interview. Experts may include scientists with a track-record of publications on MPAs and ES, stakeholders and managers that are currently working on MPAs and have a track-record of their engagement, and users such as recreational fishers.
2. Develop a set of specific questions that help to isolate and rank ES in MPAs, to frame potential scenarios of what might happen if spatial management were to change, and to explore links between changes in MPAs, biodiversity and ESs. The development of these questions is based on the information and methodology established in ICES (2014) and Tam *et al.* (2017) and on a number of assessment criteria rooted in six key elements, which are detailed below.

3. Ask individual panelists to complete a first questionnaire and thus to consider all elements identified in step 2.
4. Analyze results from step 3 and present them to the panel of experts to foster discussions. Questionnaire data can be analyzed using a semi-quantitative approach where each ES deemed relevant for the MPA in question is ranked against each assessment criterion. In such case, a score of zero means that the ES does not meet the criterion, a score of one means that the ES partly meets the criterion, and a score of two means that the ES fully meets the criterion. The ranking score for each ES can then be expressed as a percentage of the maximum possible score, as suggested from other studies.
5. Repeat steps 3 and 4 until consensus among the group is reached.

The use of a combination of individual valuations (step 3) with interactive discussions (intercalibration workshop, step 4) is of particular importance to resolve issues of calibration and varying knowledge levels among experts between different sets of criteria, which can be highly disciplinary. We propose a novel approach to assess the effectiveness of MPAs based on the ES they provide and their links with human well-being. While our approach can be applied to MPAs globally, we consider the MPAs of Sweden as a means of demonstration. The Swedish coast stretches for about 48 000 km, includes numerous rocky archipelagos and a wide range of habitats, and is exposed to different environmental conditions and gradients of human pressures (e.g., shipping, aquaculture production, fishing, and tourism).

The six key elements and related criteria (mentioned in step 2) on which the set of specific questions is to be based are:

i. Availability of Underlying Data to Identify Measurable ES in Each MPA
ii. Links Between ES and Ecosystem Component
iii. Conceptual Links Between ES and the Effectiveness of MPAs
iv. Management Relevance
v. Communication and Public Awareness
vi. Societal Benefits and Distribution Thereof

According to Belgrano *et al.* (2021) Marine Protected Areas can also be seen as key model systems to evaluate ES connections, accounting for biodiversity, social, economic, and biogeochemical metrics. There are open issues to quantify the dimensionality of MPAs to ES/biodiversity connection. Levin's triangle (Levins, 1966) can be useful in this regard. From one side, we would need general models to obtain generalities connecting, for example, MPAs to biodiversity metrics. On the other side, we would need high resolution and (transdisciplinary) data to support the assessment of linkages between ES and socio-economic aspects, to bring accuracy and realism into the analysis to contrast the dimensions needed to take into account many other disciplines into the MPAs to ES connection.

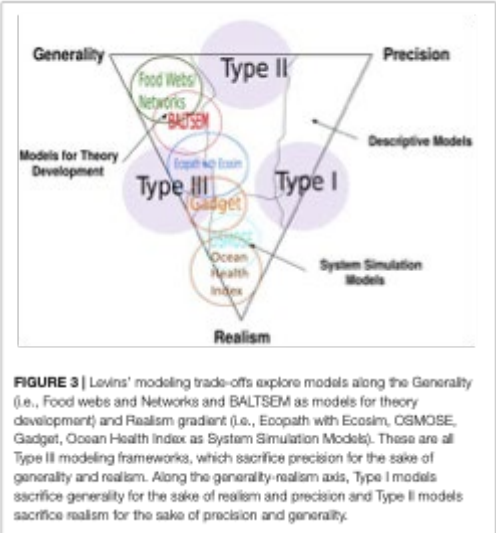

FIGURE 3 | Lovins' modeling trade-offs explore models along the Generality (i.e., Food webs and Networks and BALTSEM as models for theory development) and Realism gradient (i.e., Ecopath with Ecosim, OSMOSE, Gadget, Ocean Health Index as System Simulation Models). These are all Type III modeling frameworks, which sacrifice precision for the sake of generality and realism. Along the generality-realism axis, Type I models sacrifice generality for the sake of realism and precision and Type II models sacrifice realism for the sake of precision and generality.

In addition, the a global review paper (Garcia Rodrigues *et al.* 2017) is currently underway to provide novel information on the 'status quo' of marine ES research undertaken with regards to MPAs by critically reviewing current publications. We searched (Figure 15 and Table 7) for scientific papers published in English between 1950–2018 period in the Web of Scopus, by using the following criteria: "marine OR coast* OR sea* OR gulf OR bay OR ocean) AND "Ecosystem Service" AND (protect* OR park* OR reserve* OR no-take OR sanctuar* OR "conservation unit" OR biosphere". No geographical boundaries were stated in the selection criteria as preliminary test Searches included all articles published until our cut-off date of 31 December 2018. Members of the WGRMES screened 1695 scientific papers and finally selected 81 studies.

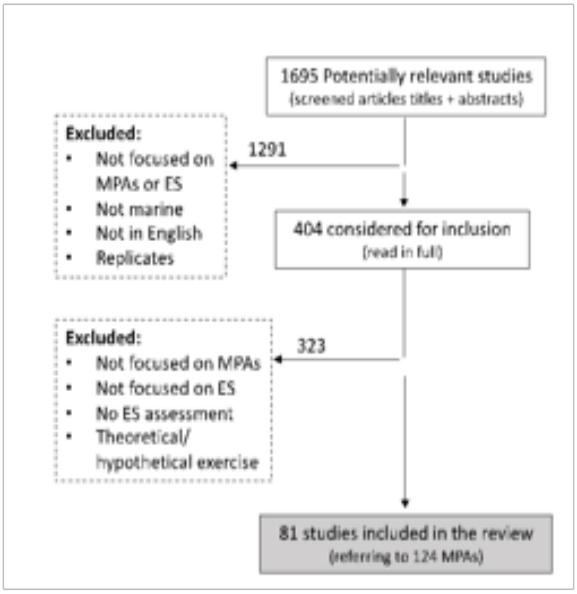

Figure 15. Systematic literature review screening.

Before starting the data collection, we carried out a 'calibration' exercise to attain a uniform data collection procedure among co-authors. This consisted of reviewing a randomly selected publication that had been previously identified for quantitative synthesis. Each co-author assessed this publication individually and subsequently the results were compared against each other. The outcome of the exercise resulted in our template for the data collection process.

Table 7. Variables used for the analysis of the systematic literature review of Marine Protected Areas and ecosystem services.

	VARIABLE	DESCRIPTION
Information paper	Title	Title of the paper
	Keyword	Keywords in the paper
	Year of publication	Year of publication
	1st author affiliation	1st author affiliation as specified in the paper
	Type of article	Empirical, conceptual, revision
	Dimension	Environmental, economic, social, mixed
	Type of analysis	Quantitative, qualitative, mapping, mixed
	Scale	Local, regional, national, European, other
	Country	Identify the country of the study area
Marine Protected Area	Name	Official of the Marine Protected Area
	Location	Area, municipality, region
	Type of PA	National park, reserve, etc.
	Year of implementation	Year of the creation of the area
	Area (ha or km2)	Area (in ha or Km) - please mention unit
	Type of habitat	mangrove, coral reefs, beach, delta, dunes, other (specify)
	Spatial information	Yes - there is spatial information about the MPA; No - there is no spatial information
	Spatial reference	Official (if any) link to the area
Management of MPA	Success or not	Degree of success (if mentioned in the paper)
	Reasons for success	Leadership of local people, strong institutions, participation of stakeholders, other (specificy)
	Activitites *inside* the PA	Artisanal fisheries, coastal fisheries, recreational fisheries, aquaculture, ecotourism, other (specify)
	Activities *outside* the PA	Artisanal fisheries, coastal fisheries, recreational fisheries, aquaculture, ecotourism, other (specify)
	Fisheries Management system	co-management, ITQs, quota, etc.
MPA Governance	Level of governance	private, local, regional, other (specify)
	Stakeholders' involvement	Low, medium, high
	Existing conflicts (trade-offs)	Yes: there are conflicts within the MPA; No: no conflicts are identified
	Actors of conflicts	Identify the groups in conflict
	Source of conflicts	Identify the reasons for conflict
Ecosystem Services	ES Classification	Millenium Ecosystem Assessment (MEA) | TEEB | CICES | Other (specify)
	Type of ES (provisioning, regulating, supporting and cultural)	Count how many provisioning ES are mentioned
	Trade-off between ES	Count how many provisioning ES are assessed

The variables used to investigate the role of MPAs in their capacity to sustain marine ES and select the final list of papers to review are listed in Table 7. Based on the selection of these variables, we developed a cluster analysis by using selected terms to link different types of marine ES.

For illustrative purposes, the preliminary results of the literature review are shown in Figure 16. The results show that the proximity of nodes indicate a stronger relationship between the different marine ES.

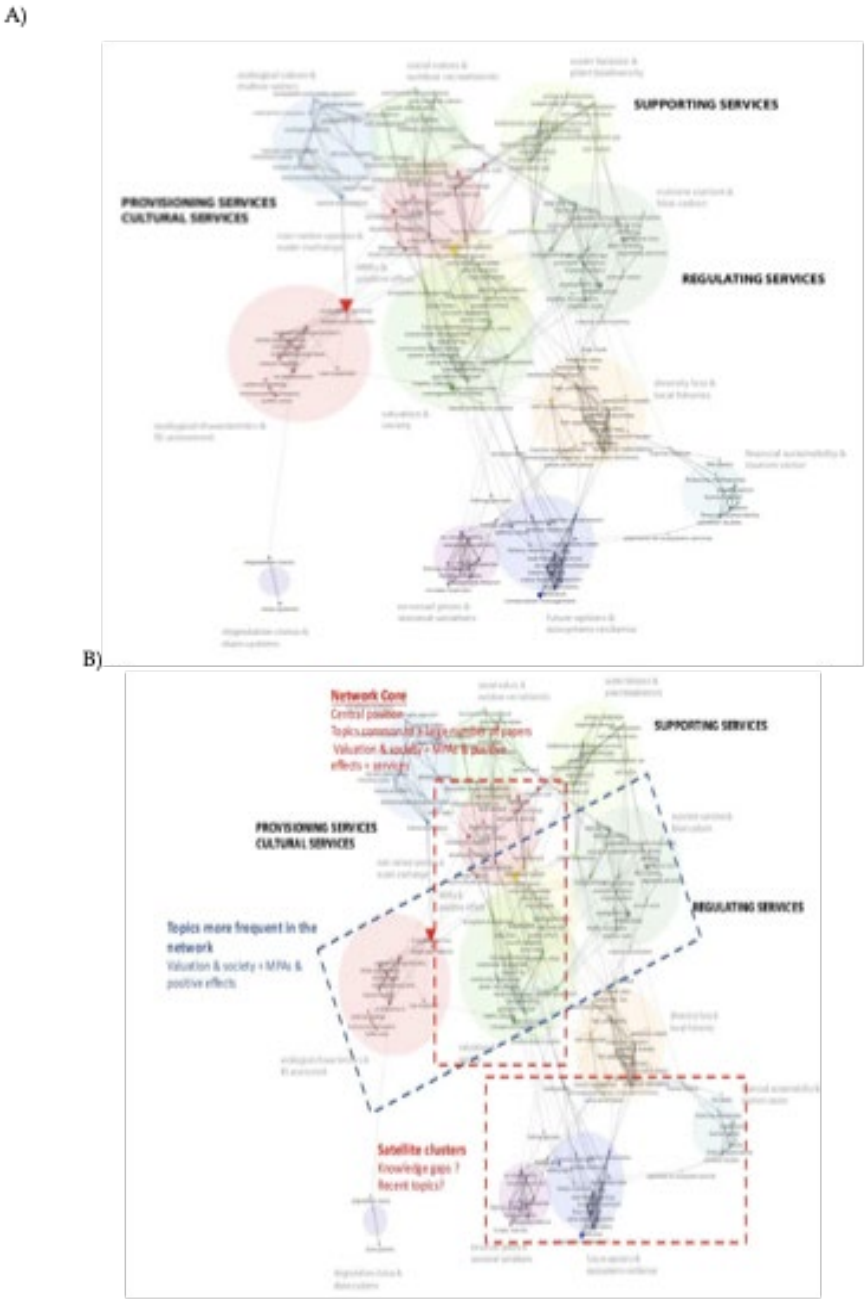

Figure 16. Clusters analysis of ecosystem services and Marine Protected Areas.

The preliminary results indicate that the bigger nodes also indicate the higher frequency of the terms used in each of the scientific papers. Also, the larger clusters of terms suggest a higher mention of them by the authors. The most cited terms were "valuation", "society", "ecological characteristics", and "ecosystem assessment". This research is currently finishing and will be sent to a scientific journal soon.

Cooperation with other WGs

WGRMES have established cooperation with the ICES WGECON and WGSOCIAL to generate synergies during this 3-year period. S. Villasante made a presentation at the WGECON meeting (Paris, France, 11–14 June 2019) and the WGs will be working together on the following topics:

WGRMES–WGECON: Sharing economic information about the data collection from different case studies related to marine and coastal ES from H2020 and national projects initiatives, and datasets.

WGRMES–WGSOCIAL: Sharing economic information about the data collection from different case studies related to marine and coastal ES from H2020 and national projects initiatives, and datasets.

Science highlights

The following PhD thesis on marine ES have been developed and/or (co)supervising by WGRMES members defended during 2019–2020:

Garcia Rodrigues, J. (2019) Human wellbeing in a changing marine social-ecological system: A participatory analysis using the ecosystem services framework. Co- supervisors: Villasante, S., Sousa Pinto, I. University of Santiago de Compostela (Spain).

Custodio, M. (2020) Integration of halophytes production to promote coastal aquacul- ture eco-intensification. Co-supervisors: Lillebo, A., Calado, R., Villasante, S. University of Aveiro (Portugal).

References

Belgrano, A., Novaglio, C., Svedäng, H., Villasante, S., Melián, C.J., Blenckner, T., Bergström, U., Bryhn, A., Bergström, L., Bartolino, V., Sköld, M., Tomczak, M., Wikström, S., Skriver Hansen, A., Linke, S., Richard Emmerson, R., Morf, A., Tönnesson, K. (2020) Mapping and Evaluating Marine Protected Areas and Ecosystem Services: A Transdisciplinary Delphi Forecasting Process Framework. Front. Ecol. Evol., https://doi.org/10.3389/fevo.2021.652492.

Belgrano, A. Villasante, S. (2020) Linking Ocean's Benefits to People (OBP) with Integrated Ecosystem Assessments (IEAs). Population Ecology 63(1): 102-107.

Bryce R, Irvine KN, Church A, Fish R, Ranger S, Kenter JO (2016) Subjective well-being indicators for large-scale assessment of cultural ecosystem services. Ecosystem Services 21:258–269.

Carpenter, S.R., Walker, B., Anderies, J.M., Abel, N. (2001) From metaphor to measurement: resilience of what to what? Ecosystems 4, 765-–781.

Custodio, M., Lillebo, A., Calado, R., Villasante, S. (2021) Halophytes as novel marine products – A consumers' perspective in Portugal and policy implications. Marine Policy 133: 104731.

Garcia Rodrigues, J., Villasante, S., Sousa Pinto, I. (2021) Non-material nature's contributions to people from a marine protected area support multiple dimensions of human well-being. Sustainability Science. https://doi.org/10.1007/s11625-021-01021-x

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., … Zlatanova, D. (2015). The IPBES conceptual framework—Connecting nature and people. Current Opinion of Environmental Sustainability, 14, 1– 16.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., … Shirayama, Y. (2018). Assessing nature's contributions to people. Science, 359, 270– 272.

Grafton, Q., Doyen, L., Béné, C., Borgomeo, E., Brooks, K., Chu, L., Cumming, G., Dovers, D., S., Garrick, D., Helfgott, A., Jiang, Q., Katic, P., Kompas, T., Little, L., Matthews, N., Ringler, C., Squires, D., Steinshamn, S., Villasante, S., Wheeler, S.,Williams, J., Wyrwoll, P. (2019) Realizing Resilience for Decision-making. Nature Sustainability 2: 907–913.

Helfgott, A. (2018) Operationalising systemic resilience. European Journal of Operational Research 268, 852-864.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Summary for Policymakers of the Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat.

Ospina-Alvarez *et al.* (2021) A Graph Theory approach to assess nature's contribution to people at a global scale: development and application. Nature Scientific Reports.

Outeiro, L., Ojea, E., García Rodrigues, J., Himes-Cornell, A., Belgrano, A., Lui, Y., Cabecinha, E., Pita, C., Macho, G., Villasante, S. (2017) The role of non-natural capital in the co-production in marine ecosystem services. International Journal of Biodiversity Science, Ecosystem Services & Management 17(3) 13(3): 35-50.

Palomo I, Felipe-Lucia MR, Bennett EM, Martín-López B, Pascual U. (2016) Disentangling the pathways and effects of ecosystem service co-production. Advances in ecological research. In: Woodward G, Bohan D, editors. Ecosystem services: from biodiversity to society, Part 2. Advances in ecological research (Vol. 54). Amsterdam: Elsevier; p. 245–283.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., … Yagi, N. (2017). Valuing nature's contributions to people: the IPBES approach. Current Opinion in Environmental Sustainability, 26–27, 7– 16.

Villasante, S., Tubío, A., Ignacio Gianelli, I., Pita, P., García-Allut, A. (2021) Ever Changing Times: Sustainability Transformations of Galician Small-Scale Fisheries, Front. Mar. Sci. https://doi.org/10.3389/fmars.2021.712819

Annex 1: List of participants

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Annex 2: WGRMES Resolution

The **Working Group on Resilience and Marine Ecosystem Services** (WGRMES), chaired by Sebastian Villasante, Spain, and Andrea Belgrano, Sweden, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2018	19–20 November	Vigo, Spain	Interim report by 15 December	
Year 2019	5–6 September	Gothenburg, Sweden		**Change in Chair:** **Outgoing**: Gonzalo Macho Rivero, Spain **Incoming**: Andrea Belgrano, Sweden
Year 2020	24–27 November	by corresp/ webex	Final report by 15 January 2021 to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
A	To undertake a literature search to assess the current data available to document the resilience of marine ecosystem services	Information and data on marine ES is scarce and not organized. Links to ICES Science Plan 1st, 2nd and 3rd thematic areas, and WGs described above.	1.3; 2.4; 5.8	1 year	-Interim report -Global review paper: Key drivers for resilient small-scale fisheries. - Exploration of potential opportunities for collaboration with EU institutions and fishery organizations -Online repository with results from year (2015-2017)
B	To document the current approaches available in connection to multidimensional valuation of marine ecosystem services	Valuing marine ES is key for policy makers. Regional and local data is lacking in Europe. Links to ICES Science Plan 1st and 2nd Thematic Areas; and WGs described above	4.3; 6.5; 7.1	2 years	-Interim report -Paper review on intrinsic, instrumental and relational values of marine ES -Special Session at ASC 2018 -Special Session at PICES 2018 -Extended version of the online repository
C	To review the available information and to produce a document	Marine ES are co-produced by a mixture of natural capital	4.1; 5.4; 7.7	2 years	-Interim report -Special Session at

	with the co-production of marine ES	andvarious forms of social, human, financial and technological capital. Human intervention in the co-creation of marine ES is a key driver in ES delivery,			ASC 2019 -Special Session at AAA Conference 2019 -Global paper about co-production of marine ES -Special Issue "*Blue Growth under the Antrophocene*"
D	To work on the Special Issue entitled: "Tipping points and social transformations of marine ES"	Document critical changes which facilitate transformations of social groups. Links to ICES Science Plan 1st, 2nd and 3rd thematic areas, and WGs described above and below. Links to the Strategic Initiative on the Human Dimension	2.4; 5.1; 7.3	2 years	-Interim report -Global paper documenting social transformations of marine ES. -Special Session at ASC 2020 -Special Issue "*Tipping points and social transformations of marine ES*"
E	Governance and scenarios for sustainable marine ES	The role of institutions is key to develop assessments of best practices of integrated assessments of marine ES	6.3; 6.6; 7.6	3 years	-Interim report -Global paper on governance of

Summary of the Work Plan

Year 1	Review of existing frameworks, methodologies and tools to study socio-economic dimensions of marine ecosystem services
Year 2	Undestanding of ecological, economic, cultural, social drives of changes of marine ecosystem services
Year 3	Scenarios and policy recommendations for resilient trajectories of marine ecosystem services

Supporting information

Priority	High. The current activities of this Group will lead ICES into issues related to marine ecosystem services, integrating fisheries management and ecosystem services frameworks. Consequently, these activities are considered to have a very high priority.
Resource requirements	None required other than those provided by the host institute.
Participants	The Group is normally attended by some 15 members and guests.
Secretariat facilities	None.
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, WGECO, WGRFS
Linkages to other committees or groups	There is a close working relationship with WGBIODIV, and also EPISG EGs (WGMHM, WGMPCZM, WGSFD), SICCME, WGIMM, WGLMEBP, WGISUR, WGMARS, and BONUS.
Linkages to other organizations	The work of this group is aligned with other global nodes of ES research such as the Ecosystem Services Partnership in which the one of the chair (Dr. Villasante) is also co-leader of the Thematic Working Group "Economic and monetary valuation" and (www.es-partnership.org). The work is also in line with the current Future Earth Program, the Natural Capital Project (http://www.naturalcapitalproject.org/) , ++ and numerous scientific and regulatory governmental and university's departments in ICES countries.