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Guidance for stakeholder consultation to support national ecosystem services assessment: A case study from French marine assessment

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Abstract :

In line with international frameworks and following the example of other countries, France conducted a national ecosystem services (ES) assessment in 2012. National assessments are intended to be both comprehensive and useful. In practice, these objectives are conflicting and difficult to reach, leading the experts in charge of the assessment to allocate effort according to their own priorities. In the case of the marine part of the French ES assessment, we consulted stakeholders at the national scale to better connect the assessment to the interest of the end-users. We implemented a participatory approach based on a combination of workshops and online questionnaires. We collected stakeholder's perception of (i) ES bundle; (ii) hierarchization of issues; (iii) specific issues of concern; and (iv) research needs for different types of marine ecosystems and groups of species. The results of the consultation assisted the assessment process in selecting key issues that necessitate in-depth analysis, and identifying discrepancies between stakeholders' perceptions and the scientific knowledge that need to be addressed. Stakeholders' perceptions were also mobilized as an additional source of data to inform decision-makers regarding the state of ecosystems and their ES. In the end, this work underlines the importance of stakeholder's consultation to support ES assessment and provides guidance for its implementation in the future. Our results can also inform research needs to support the conservation of marine ecosystems.

Keywords : National ecosystem assessment, Marine and coastal ecosystem services, Participative approach, Strategic evaluation

1 Introduction

The modern history of ecosystem services (ES) can be traced back to the 1970s and 80s (Braat and De Groot, 2012) when scholars concerned by the global environmental crisis renewed research approaches to address this issue. Complex system theory and thermodynamics were used in ecology for understanding the functions of nature (e.g., Odum, 1971) and the role of energy flows (e.g., Odum and Odum, 1981), and in economics to emphasize the limits of human-induced growth processes (e.g., Georgescu-Roegen, 1971; Daly, 1973). Conservation biology also, which had emerged in reaction to the extinction of living resources, alerted on the absence of substitutes for ES (Ehrlich and Mooney, 1983). Based on these works, the rationale for the scientific use of the ES concept evolved towards analysing how biodiversity losses affect ecosystem functions that underpin critical services for human wellbeing (Braat and De Groot, 2012). However, the inclusion of the ES approach in the policy agenda was triggered years later by the Millennium Ecosystem Assessment (Gómez-Baggethun et al., 2010). Indeed, it spread the definition of ES as the contributions of ecosystem structures and functions to human well-being, and organising the analytical framework into four main categories (MEA, 2005) in view to promoting ES awareness, furthering science and aiding decision-making and management (Mooney and Mace, 2009; Guerry et al., 2015). The institutionalisation of the ES framework was then strengthened through (i) its extension into the economic arena with the publication of international expertise such as the "Cost of Policy Inaction for Biodiversity" (Braat and ten Brik, 2008) and "The Economics of Ecosystems and Biodiversity" (TEEB, 2010) and, above all, (ii) its adoption by intergovernmental organisations notably with the creation of the Intergovernmental Platform on Biodiversity and Ecosystem Services in 2012 (Díaz et al., 2018). Finally, ES have been included as a policy rationale for biodiversity conservation as illustrated by the strategic goal D of the Strategic Plan for Biodiversity and the Aichi Targets of the Convention on Biological Diversity (CBD): "enhance the benefits to all from biodiversity and ecosystem services". The transposition of the CBD objectives at national levels has led many countries to undertake ES assessment at the national scale (e.g. UK NEA, 2014 in UK; Blasi et al., 2017 in Italy; Bukvareva et al., 2017 in Russia; Ohsawa et al., 2018 in Japan). National ES assessment can be seen as "top-down" assessment, implemented as a translation of global (e.g., Aichi Targets) or regional (e.g., EU Biodiversity Strategy) policies regarding biodiversity with the objective of producing indicators that can fit within a harmonized framework to facilitate comparison across countries and integration into global syntheses (Schröter et al., 2016).

Consistent with these efforts, in 2012 the French Ministry of the Environment launched a major national assessment of ecosystems and ES called 'French Assessment of Ecosystems and Ecosystem

Services', hereafter referred to as EFESE (CGDD, 2020). The task was divided into 6 workgroups representing broad sets of ecosystems; the content of this paper was built using the results produced by the workgroup on marine ecosystems, hereafter referred to as EFESE-marine (Mongruel et al., 2019). The scope of the EFESE-marine assessment encompasses all marine and coastal ecosystems of waters under French jurisdiction (Figure 1), making the work particularly challenging. Indeed, France has the second largest exclusive economic zone (11 000 000 km²), covering three oceans (Atlantic, Pacific and Indian) and both hemispheres. As a result, France hosts a large portion of world marine biodiversity and ecosystems (Goulletquer et al., 2013), especially due to its overseas territories which constitute 97% of French waters.

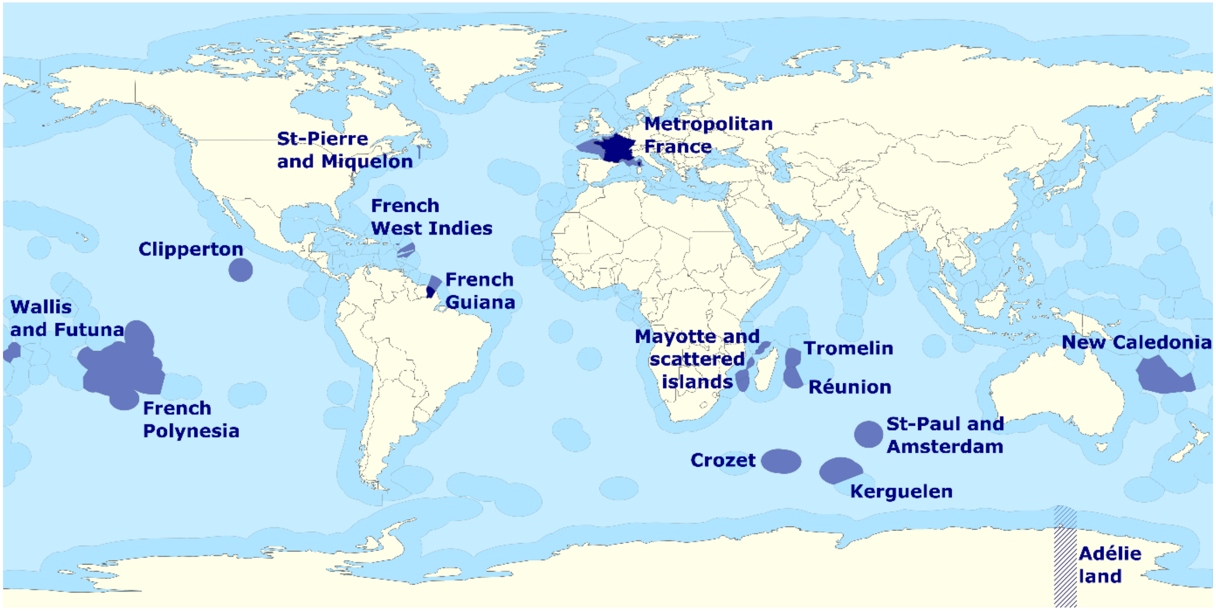


Figure 1 – Perimeter of the EFESE-Marine study (Source of map font: B1mbo under CC BY-SA 3.0 CL License)
The marine portion of the Adélie land (in blue stripes) is not part of French EEZ but included in the assessment.

National ES assessments have to cope with a double objective of comprehensiveness – i.e. to provide a complete diagnosis of the state of ecosystems and the associated level of ES – and usefulness – i.e. to provide information that can directly inform managers and decision-makers. However, top-down ES assessments are confronted by certain issues that bring these objectives into conflict with each other and make their operationalization problematic. Firstly, national ES assessments have relatively broad objectives: as a result, they do not provide direct problem-solving information (Schröter et al., 2016). The outcomes of national ES assessments are therefore limited to raising political awareness regarding the general state of biodiversity and the associated critical issues whose impacts on policies are only visible in the long-term (Waylen and Young, 2014; Allison and Brown, 2017). Secondly, there is no consensus regarding the principles that should govern ES assessment (Barnaud and Antona, 2013; Schröter et al., 2014a; Kull et al., 2015). The nebulous and flexible nature of the ES concept leads to neither a completely normative nor rationale framework which can limit their utilization (Jordan and Russel, 2014). Thirdly, in the case of marine ecosystems, ES assessments face a general lack of data compared to terrestrial ecosystems regarding both the state of ecosystems (Maes et al., 2016) and the benefits that societies derive from ES flows (Austen et al., 2019). ES assessments for marine ecosystems are thus generally oriented toward particular habitats (e.g., mangroves, coral reefs) and a limited number of ES (mainly food provision by fisheries, water purification, coastal protection and recreation; Liquete et al., 2013), providing a simplistic vision of the diversity of marine ecosystems and the ES they provide. Finally, top-down assessments are generally built on the integration of existing knowledge. They follow a “supply-driven” paradigm where the production of knowledge originates more from researchers’ interests than it does from policy demand (Honey-Rosés and Pendleton 2013; Marre and Billé, 2019). Indeed, given the time (2 years) and effort (1 FTE and 8 main contributors) allocated to EFESE-marine, the assessment was basically oriented toward a “supply-driven” paradigm. It was intended to be based on a review of existing studies, supplemented by scientific expertise mobilized through workshops and direct contributions in the final report. In practice, these issues translate into a matter of research effort allocation in order to make sure that the most relevant knowledge would also be used to address the most important questions from the stakeholders’ viewpoint. In this perspective, we complemented the national ES assessment with a strategic evaluation in order to make it the best compromise between usefulness and comprehensiveness. This work provides guidance on how consultation of stakeholders should be implemented to support national ES assessment.

This strategic evaluation necessarily relies on the involvement of stakeholders in the assessment process. Understanding the expectations of the potential users of marine ES assessments allows them to take better account of the divergence in stakeholders' values and beliefs and increases the legitimacy of scientific outputs (Drakou et al, 2017). However, stakeholders are rarely involved when it comes to national ES assessments. This can be explained by the nature of top-down assessment and by the operational difficulty of selecting and involving stakeholders. Indeed, as large-scale assessments do not target any specific audience, the potential users of ES assessments are generally not involved in the assessment process (Waylen and Young, 2014). In the case of the EFESE-marine assessment we conducted a consultation of stakeholders at the national scale with the objective of strategically distributing research effort according to the interests of the end-users. Hence, we intended to shift from a “supply-driven” to a “demand-driven” paradigm for some parts of the national marine ES assessment. To this end, we adapted a decision-making framework to help researchers prioritize the further ES in-depth assessments according to social demands, and used it during a stakeholder consultation, that we conducted following a Delphi process.

2 Materials and Methods

2.1 Consultation design

We built on the work of Pendleton et al. (2015), who developed a decision-support framework called TRIAGE to help researchers calibrate their ES assessment regarding management needs. TRIAGE assumes that in order to improve the efficacy of practices of managing and protecting marine ecosystems, an assessment must focus on elements that fulfil most of the following criteria (Pendleton et al., 2015). (1) Importance: questioning the rationale that underlies the needs for assessment and the scope of the assessment. (2) Exposure to drivers of changes: the assessment of an ES that would not be exposed to drivers of change would have a limited interest. (3) Possibility of action: the assessment scale has to match the management scale. An important point is that TRIAGE not only prioritizes ecosystem assessment, but it is also a way to involve stakeholders in the broader assessment while capturing their perception of ecological issues related to marine ecosystems and ES. It could thus facilitate the operationalization of the study and its use in decision-making. Initially, TRIAGE was developed to tailor the assessment of marine ES to management needs at a local scale[1]. Its application to EFESE-marine national assessment necessitated an adaptation of the approach regarding both its structure and its process of implementation.

At a local scale, TRIAGE is applied through workshops involving local stakeholders. Its implementation at a national scale - with participants scattered over the entire territory - implied an adaptation of the consultation mode. As a result, we used an internet survey, allowing the involvement of geographically scattered participants. We then implemented TRIAGE using a Delphi process, which is a decision-making tool that consists in submitting a questionnaire several times to an expert panel, in order to find consensus on complex matters. The Delphi process is defined as an approach that reveals and refines the judgement of a group and whose core principle is the fact that the judgement of a group is more relevant when uncertainty is high (Kaynak et McCauley, 1984). It is perfectly consistent with the objective of TRIAGE, which is to strategically prioritize assessment issues based on the expertise of stakeholders. We applied two iterations in order to maximize response rates considering the number of experts interviewed and the timing of the study.

[1] See for example Martin et al., 2018 and Hooper et al., 2017 for assessments that have been initially framed using the TRIAGE methodology.

2.2 Population targeted and consultation steps

The implementation of a Delphi process requires setting up an expert committee. According to the methodology, an expert group is a group of people who possess professional authority on the studied question (Brockhoff, 1975). We considered two types of experts. First, experts who play a role in representing economic, environmental, social and political marine issues at the national level: the marine members of the EFESE National Stakeholders Committee (n = 115); this committee originates from the governance of the EFESE program. Second, experts who endorse this function at the regional scale: the members of Seaboard Councils (n = 291). Created in 2011, Seaboard Councils are consultative bodies that give an opinion regarding the implementation of the Marine Strategy Framework Directive and the Maritime Spatial Planning Directive. In France, expert committees in charge of addressing environmental issues are organized in five categories to represent the diversity of socio-economic issues: (1) State and public agencies, (2) local authorities, (3) professionals, (4) professional unions and (5) environmental NGOs.

We conducted the consultation in three phases (Table 1). Phase 1 consisted of the organization of a workshop in Paris involving stakeholders at the national scale involved in the EFESE National Stakeholders Committee. This workshop was necessary in the process to allow us to build the framework of the consultation[2]. This first meeting also allowed us to obtain initial material for the analysis, particularly for the design of the questionnaire. Indeed, we built a typology of marine ecosystems and their ES (Table 2) that would be more oriented toward communicating with the public than the one based on scientific data that was used in the EFESE-marine report (See Supplementary material S1 for the correspondence between these two typologies). Consequently, the different categories are not homogeneous with a mix of ecosystems and group of species (hereafter type of ecosystem).

Table 1 - Organization of the consultation process

Consultation phases	Steps of the consultation	Stakeholders targeted	Participation	Timing
Phase 1 – Workshop	• Workshop with national stakeholders • Design of the questionnaire	EFESE National Stakeholders Committee (n = 115)	22	April – June 2016

[2] Human and Davies (2010) established that stakeholders' involvement in aiding the design of a scientific program requires a clear framework regarding the objectives and the limits of the assessment to be useful.

Phase 2 – Online questionnaire #1	• First round of the online questionnaire • Reception and processing of first results	EFESE National Stakeholders Committee and members of Seaboard councils (n = 406)	97	July – September 2016
Phase 3 – Online questionnaire #2	• Presentation of first results to the participants of the first round • Second round of the online consultation	Stakeholders participating in phase 2 (n = 97)	67[a]	January – February 2017

[a] : The results of phase 3 integrate the results of phase 2 for respondents that did not answer phase 3.

Table 2 – List of the ecosystem types and species groups and list of the ES used in the online questionnaire.

Ecosystems types or species groups	ES
Beaches and associated dunes	Production of food from the sea
Seagrass meadows	Production of genetic material
Soft substrate areas	Production of non-food related material
Estuaries	Water quality regulation
Lagoons and salt marshes	Coastal protection
Tropical coral reefs	Climate regulation
Mangroves	Recreation and leisure support
Protected species	Pleasant landscape contribution
Extensive aquaculture production zones	Cultural and territorial identity contribution
Deep ecosystems	
Commercial species	
Plankton	
Rocky substrate areas	

In phase 2, we sent the first online questionnaire to the experts using an online survey platform. Figure 2 presents the structure of the questionnaire. It begins with a few introductive general questions (Box 'A' in Figure 2). The core section of the questionnaire consists in a series of questions organized in two parts for each type of ecosystem (Box 'B'). The first part aimed at hierarchizing our 13 ecosystems and groups of species. Consistent with the 3 criteria of the TRIAGE, we asked the respondents to give their opinion on: (1) the importance for the good functioning of the marine environment, (2) the exposure to drivers of change and (3) the possibility of action. To express their judgement, experts were asked to use a semi-quantitative scale including four modalities: Very strong

[4], Strong [3], Intermediate [2] to Weak [1]. In addition, for each type of ecosystem, we asked the respondents to specify the particular locations that present the strongest ecological concern. This last question also had the objective of helping the respondents to have a concrete representation of the type of ecosystem in mind before answering the questions. The second part of the questionnaire focused on the hierarchization of ES. This part is restricted to stakeholders that feel qualified on the given type of ecosystem. We expected to increase the relevance of answers and avoid a "do not know" response choice. For each type of ecosystem, the respondents had to rate the importance of the various ES (on the same 1 to 4 scale plus 0, pointing the absence of the ES). In addition, we asked the respondents to indicate any potential need for more knowledge. The questionnaire ends with open questions about (1) missing type of ecosystem, (2) missing ES and (3) general observation to improve the EFESE-marine assessment (Box 'C').

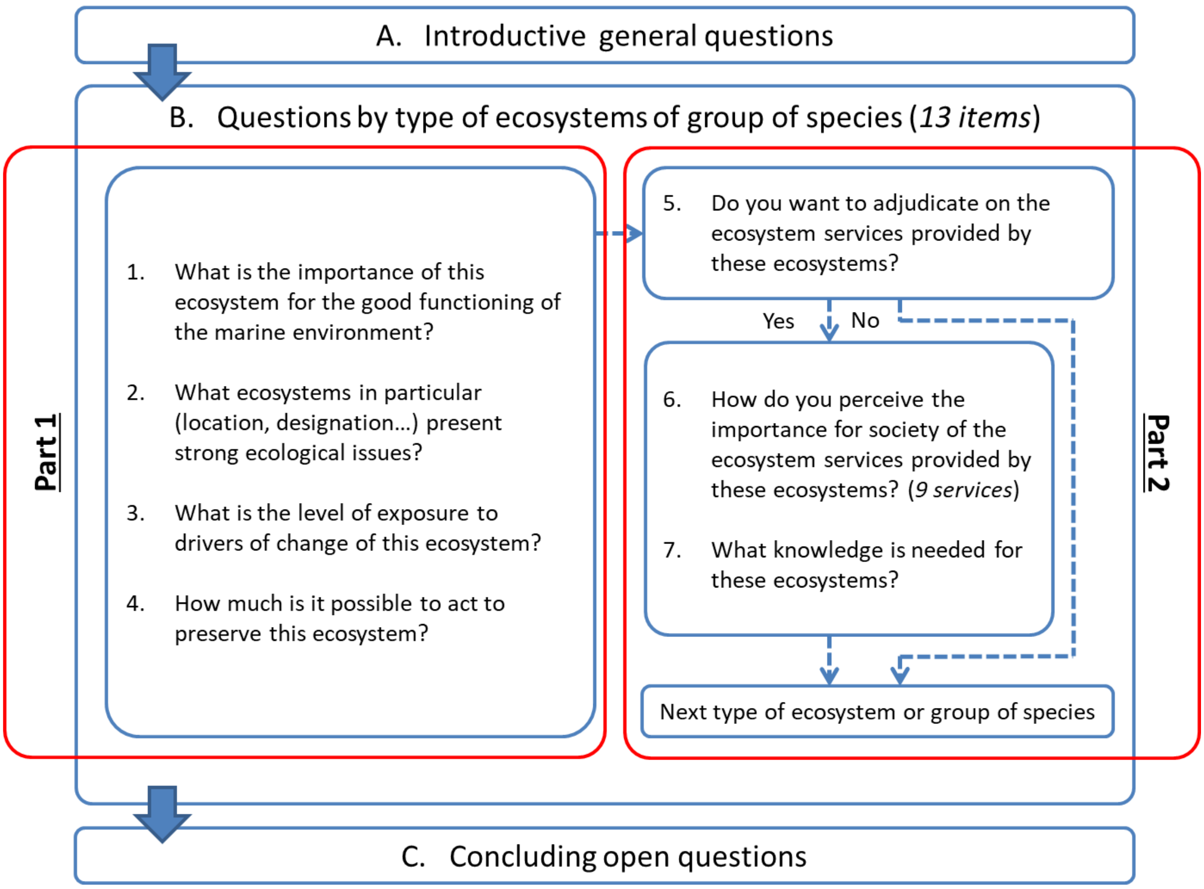


Figure 2 - Organisation of the online questionnaire during phase 2.

In phase 3, we sent a second questionnaire to the stakeholders that answered phase 2 (Figure 3Figure 3). In accordance with a Delphi process, the respondent had to re-evaluate their judgement in the light of the results of the previous questionnaire. We informed the respondents that without answers in phase 3, we would keep the answers given in phase 2 (details on the number of respondents that revised their judgement are available in Supplementary Material S2). First, we presented the results for the three criteria (importance, exposure to drivers of change and possibility of action) in the form of a ranking. We asked the respondents to give their opinion on the ranking and to potentially revise their opinion expressed in phase 2 (Box ‘A’ in Figure 3). Second, we presented the results of the importance of ES using radar charts and an interpretative text, then we asked the respondents to comment on the radar and the interpretation and to potentially revise their opinions expressed in phase 2 (Box ‘B’). Finally, for each type of ecosystems we presented a selection of specific location or denomination of concern (an issue of concern was kept from phase 2 if it was proposed by more than two respondents). The respondents can validate their importance (with checkboxes) and possibly add specific issues (Box ‘C’).

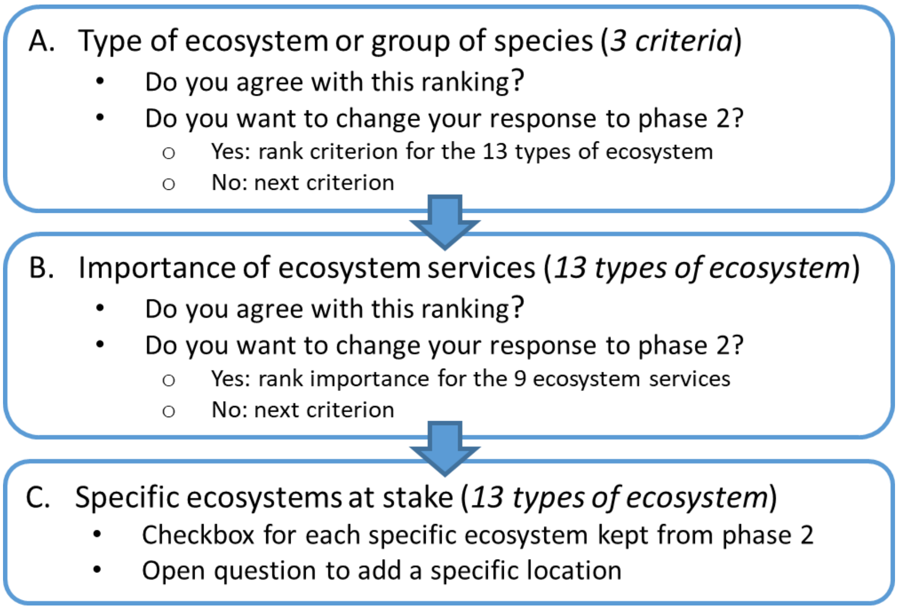


Figure 3 - Organisation of the online questionnaire during phase 3

2.3 Analysis of answers

To analyse answers regarding the perception of ES, we built radar charts based on the average rating and wrote interpretative texts. In addition, we conducted a Principal Components Analysis (PCA) using R and FactoMineR package. PCA was conducted on the mean value of the different ES (9 variables) for each type of ecosystem (13 individuals). We conducted a hierarchical clustering of the different types of ecosystem to identify clusters. We present the data and the detailed results of the PCA in Supplementary Materials S4.

We hierarchized the different types of ecosystem according to their average ranking for each criterion (importance, exposure to drivers of change, possibility of action). To go further, we conducted a Factorial Correspondence Analysis (FCA) using the R and FactoMineR package. We carried out a chisquared test to control the independence of our variables ($\chi^2 = 937.6$ and p-value << 0.001), concluding with the possibility to apply FCA to our data. We conducted FCA on the three criteria, each divided into five modalities (very-strong, strong, medium, weak, no-opinion) giving 15 variables. We applied a hierarchical clustering on the principal components to assist the comparison of the different types of ecosystem. We present the data and the detailed results of the FCA in Supplementary Material S5.

For issues of concern, we started by building a score based on the occurrence of each issue in the questionnaires. Then we ranked those scores to build three categories of issues: (1) primary issues were mentioned by more than a third of the respondents; (2) secondary issues were mentioned by more than 3 respondents; (3) overlapping issues were mentioned for different types of ecosystem (the methodology and data used for category building is detailed in Supplementary Material S6). We finally represented the issues on a map to facilitate their readability.

We collected the knowledge needs with open questions. We conducted a textual analysis of the different answers using IRAMUTEQ software. IRAMUTEQ allows classifying textual elements based on “top-down” hierarchical classification and FCA (Chaves et al., 2017). We present the details and data of the textual analysis in Supplementary Material S7. We conducted a bibliometric analysis using the Web of Science research tool to compare the knowledge needs to the actual state of research on French marine ecosystems. Bibliometric analysis was adapted from the assessment of “knowledge production” of the EFESE-Marine report (Mongruel et al., 2019; p. 269). We built Research inquiries from a generic list of keywords to target only “French marine and coastal ecosystems” aggregated with a list of keywords for each ecosystem type and for each research field, resulting in 39 inquiries. We provide details of the bibliographic research in Supplementary Material S8.

2.4 Representativeness of the study population

In phase 2, we collected 96 completed answers to the first questionnaire (response rate: 23%). In phase 3, we received 67 revised answers. The representativeness of the consultation is presented in Table 3. All categories of representatives are present in our consultation with a small under representation of national state representatives in favour of NGOs and economic sector representatives in relation to the targeted population.

Table 3 – Representativeness of our consultation in relation to the contacted population

Representative of…	Questionnaire phase 2	Questionnaire phase 3	Population contacted
Local authorities	12%	14%	16%
National state	21%	16%	26%
NGO	28%	31%	21%

Economic sector	32%	31%	29%
Employees	7%	8%	8%

We can also assess the representativeness of the consultation in relation to the geographical scope of the expertise (Table 4). We are obliged to underline the absence of expertise concerning non-tropical and/or uninhabited overseas territories (Saint-Pierre-et-Miquelon; French Southern and Antarctic Lands; Clipperton) in consultative committees.

Table 4 – Scope of the expertise (more than one response per respondent allowed).

Scope of the expertise	Number of experts
Global ocean	17 (18%)
European seas	24 (25%)
Atlantic (metropolitan)	58 (60%)
Mediterranean Sea	32 (33%)
Tropical overseas	23 (23%)
Non tropical and/or uninhabited overseas	0 (0%)

3 Results

The results of the stakeholder consultations are presented according to the following logical order: first we examine the perception of ecosystem service bundles, second the hierarchization of ecosystems at stake, third the perception of issues of concern and finally the research need.

3.1 Perception of ecosystem service bundles

In phase 3, we presented the analyses of the perception of ES bundles in the form of radar charts (Figure 4) and an interpretative text (Supplementary Material S3); on average, 16% of the respondents revised their judgement. The ES with the highest mean rating was Provision of food while the lowest was Provision of non-food related material.

Figure 4, allows comparing the shape of the ES bundles associated with each type of ecosystem and Figure 5 synthesizes the results of a PCA (See Supplementary material S4 for the detailed results of the PCA). The selected factorial plane explains 77% of the variance (42.2% for Dim1 and 34.8% for Dim2). On the horizontal axis we find ecosystems associated with water quality and climate regulation and the provision of biogenic material (on the left part of the factorial plane) and ecosystems more associated with cultural services (on the right part). The vertical axis is positively correlated with all the variables, but notably with the three regulation services, provision of material and landscape. Hierarchical clustering suggests three clusters. The first cluster is characterized by lower scores for cultural ES and for coastal protection ('A' in Figure 5): it includes plankton and deep ecosystems. The second cluster groups ecosystems with a higher score in the contribution to pleasant landscape and in coastal protection ('B'): it includes estuaries, lagoon and salt marshes, mangrove, seagrass beds, tropical coral reefs, rocky substrate areas, and soft substrate areas. Finally, ecosystems in the third cluster have lower scores for regulation of water quality and climate ('C'): it includes beaches and associated dunes, protected species, commercial species, and extensive aquaculture zones.

Crossing the visual interpretation of radar charts (Figure 4) and the PCA results (Figure 5) we propose two categories of ecosystems. Firstly, "generalist" ecosystems contribute to all categories of ES (corresponding to cluster 'B' of the PCA). They can be ordered regarding the magnitude of their bundle (from top to bottom): tropical coral reefs, mangroves, lagoons, rocky substrates, estuaries, soft substrate areas and seagrass beds. Secondly, "specialist" ecosystems have a heterogeneous bundle, contributing to specific categories of ES (corresponding to cluster 'A' and 'C' of the PCA). In this category, 'commercial species' and 'extensive aquaculture zone' are specialized in food provision, 'plankton' and 'deep ecosystems' in climate regulation and water quality and in the provision of biogenic material, and 'beaches and associated coastal dunes' and 'protected species' in cultural services.

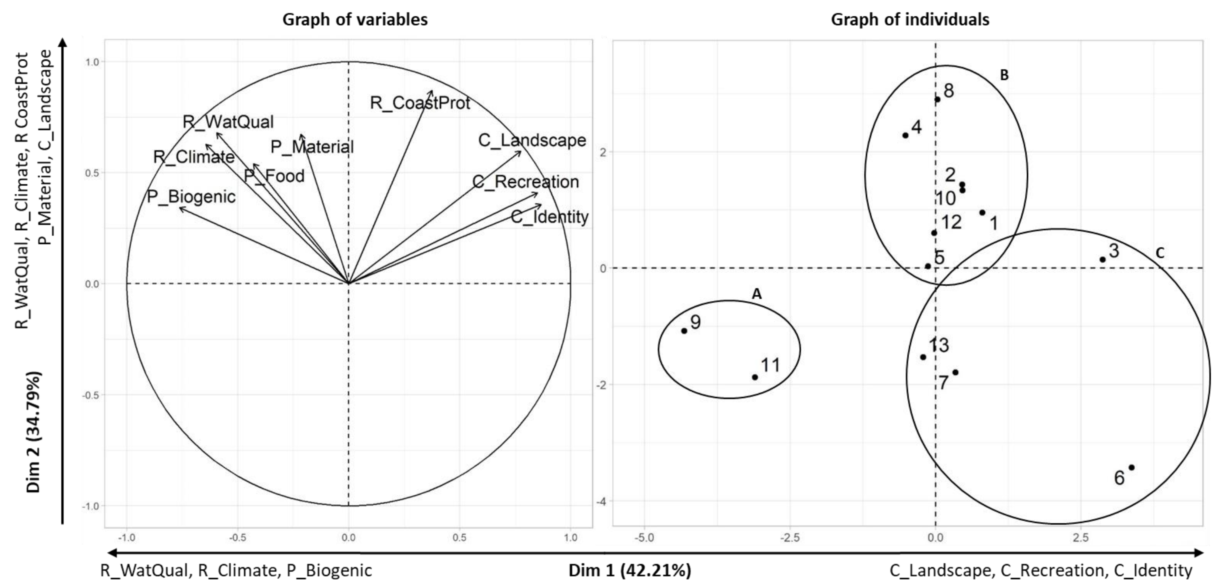


Figure 5 – Results of the PCA for the organization of the factorial plane according to the different variables (left) and the position of the different ecosystems and groups of species on the factorial plane (right) [1: Estuaries; 2: Lagoon and salt marshes; 3: Beaches and associated dunes; 4: Mangrove; 5: Seagrass beds; 6: Protected species; 7: Commercial species; 8: Tropical coral reefs; 9: Plankton; 10: Rocky substrate areas; 11: Deep ecosystems; 12: Soft substrate areas; 13: Extensive aquaculture zones – P_Food: Provision of food from the sea; P_biogenic: Provision of biogenic material; P_Material: Provision of non-food related material; R_WatQual: Water quality regulation; R_Climate: Climate regulation; R_CoastProt: Coastal protection; C_Recreation: Support for recreational and leisure activities; C_Landscape: Contribution to pleasant landscape; C_Identity: Contribution to cultural and territorial identity]. *The present graphic is the version used to communicate with*

stakeholders. It has received visual treatment to be more communicative; the raw version is presented in Supplementary Material S4.

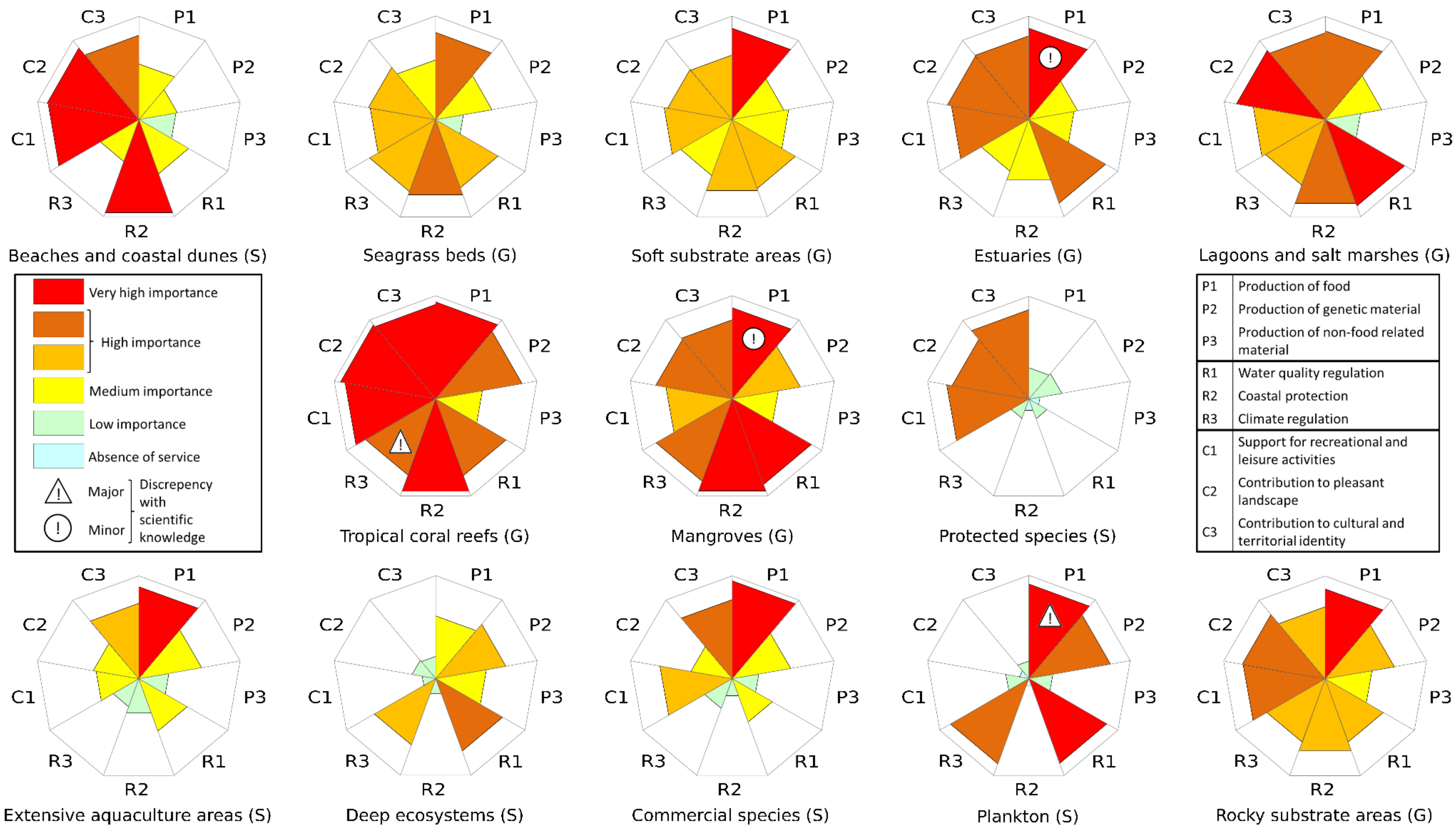


Figure 4 – Radar chart representation of the importance of ES provided by each type of ecosystem (G : “generalist” and S: “specialist”).

3.2 Hierarchization of ecosystems at stake

In phase 3 of the consultation, most of the respondents did not express any divergent opinion or agreed with the rating of ecosystems, which suggests a certain robustness of the results (Table 5). On average, the respondents attributed lower ratings to the possibility of action criterion (mean rating of 2.3) compared to those of ecological importance and the exposure criteria (mean rating of 3.3 and 3.2, respectively).

Table 5 shows the final hierarchization of the type of ecosystems regarding their position in the three rankings. For example, tropical coral reefs and plankton come at the top of the rankings for importance and exposure but at the end of the possibility of action ranking. On the contrary, extensive aquaculture zones have the highest scores for possibility of action but lower importance and exposure to drivers of change. We can see that the largest categories of ecosystems (soft substrate areas, rocky substrate areas and deep ecosystems) always come in the bottom half of the ranking. The other types of ecosystems are more difficult to discriminate.

Table 5 – Results of the hierarchization of the ecosystems and groups of species relative to the criteria of importance, exposure to drivers of change and possibility of action (for each criterion, the first column represents the evolution of the ranking between phases 1 and 2 and the third column, the mean rating obtained by the ecosystem or group of species).

#	Importance			Exposure to drivers of change			Possibility of action		
1	**=**	**Plankton**	**3.8**	**=**	**Tropical coral reefs**	**3.8**	**=**	**Commercial species**	**2.8**
2	=	Tropical coral reefs	3.7	=	Plankton	3.5	↑	Extensive aquaculture zones	2.6
3	=	Seagrass beds	3.6	=	Estuaries	3.5	=	Lagoon and salt marshes	2.6
4	=	Estuaries	3.5	=	Beaches and associated dunes	3.4	↓	Estuaries	2.6
5	=	Mangroves	3.5	↑	Mangroves	3.3	=	Protected species	2.5
6	=	Protected species	3.4	↓	Lagoon and salt marshes	3.3	=	Seagrass beds	2.4
7	=	Lagoon and salt marshes	3.3	=	Commercial species	3.2	=	Mangroves	2.4
8	=	Rocky substrate areas	3.3	=	Seagrass beds	3.2	=	Beaches and associated dunes	2.3
9	=	Deep ecosystems	3.2	=	Protected species	3.2	=	Tropical coral reefs	2.2
10	=	Commercial species	3.2	=	Extensive aquaculture zones	2.9	=	Soft substrate areas	2.1
11	=	Beaches and associated dunes	3.1	=	Rocky substrate areas	2.7	=	Rocky substrate areas	2.1
12	=	Soft substrate areas	2.9	=	Deep ecosystems	2.7	=	Deep ecosystems	2.0
13	=	Extensive aquaculture zones	2.3	=	Soft substrate areas	2.5	=	Plankton	1.8

To go further, Figure 6 synthesizes the results of the FCA (data and detailed results of the FCA are provided in Supplementary material S5). The factorial plane explains 67.7% of the variance. The horizontal axis discriminates individuals regarding their importance and exposure to change (from left to right) and the vertical axis regarding possibility of action and exposure to change (from bottom to top). The hierarchical clustering identifies four clusters regarding the criteria (Cat. on Figure 6). The first cluster (Cat.1) is characterized by very strong importance, very strong exposure to change and low possibility of action; it includes tropical coral reefs, and plankton. The second cluster (Cat.2) is characterized by very strong and strong possibility of action and very strong to strong exposure to change; it includes estuaries, lagoon and salt marshes, beaches and associated dunes, mangrove, seagrass beds, protected species, and commercial species. The third cluster (Cat.3) is characterized by low exposure to change, low possibility to act and strong importance; it includes rocky substrate areas, deep ecosystems, and soft substrate areas. The fourth cluster (Cat.4) is characterized by low to medium importance and is restricted to extensive aquaculture zones.

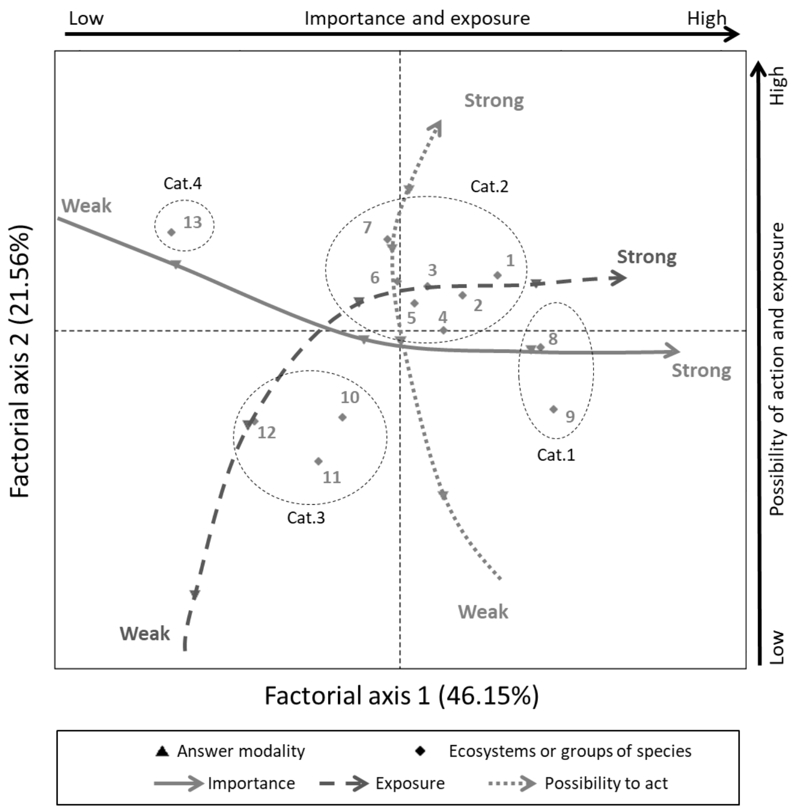


Figure 6 – Results of Factorial Analysis of Correspondence [1: Estuaries; 2: Lagoon and salt marshes; 3: Beaches and associated dunes; 4: Mangrove; 5: Seagrass beds; 6: Protected species; 7: Commercial species; 8: Tropical coral reefs; 9: Plankton; 10: Rocky substrate areas; 11: Deep ecosystems; 12: Soft substrate areas; 13: Extensive aquaculture zones]. *The present graphic is the version used to communicate with the stakeholders. It has received visual treatment to be more communicative; the raw version is presented in Supplementary Material S5.*

3.3 Perception of issues of concern

The refinement of issues of concern shows considerable heterogeneity in the set of labels collected from the stakeholders. This heterogeneity concerns the type of issue (mostly location but also functions or pressures) and the scale of location (from very specific location to administrative region or an entire seaboard). Based on the analysis of the questionnaire of phases 2 and 3, we isolated three different types of issue: primary, secondary and overlapping. Primary and secondary hierarchize issues of concern according to the number of occurrences in the consultation. Overlapping issues concern multiple ecosystems and species (See Supplementary Material S6 for more information on the selection process). For example, in the case of New Caledonia, the respondents mentioned issues of concern for four types of ecosystem (mangroves, tropical coral reefs, lagoons and salt marshes, and protected species), it is thus a territory with multiple "overlapping issues" regarding marine ecosystems. Moreover, many respondents mentioned mangroves and tropical coral reefs, thus they constitute “primary issues” in this territory. We present the issues in Figure 7 to help the reader to understand the distribution of these issues in the French territories.

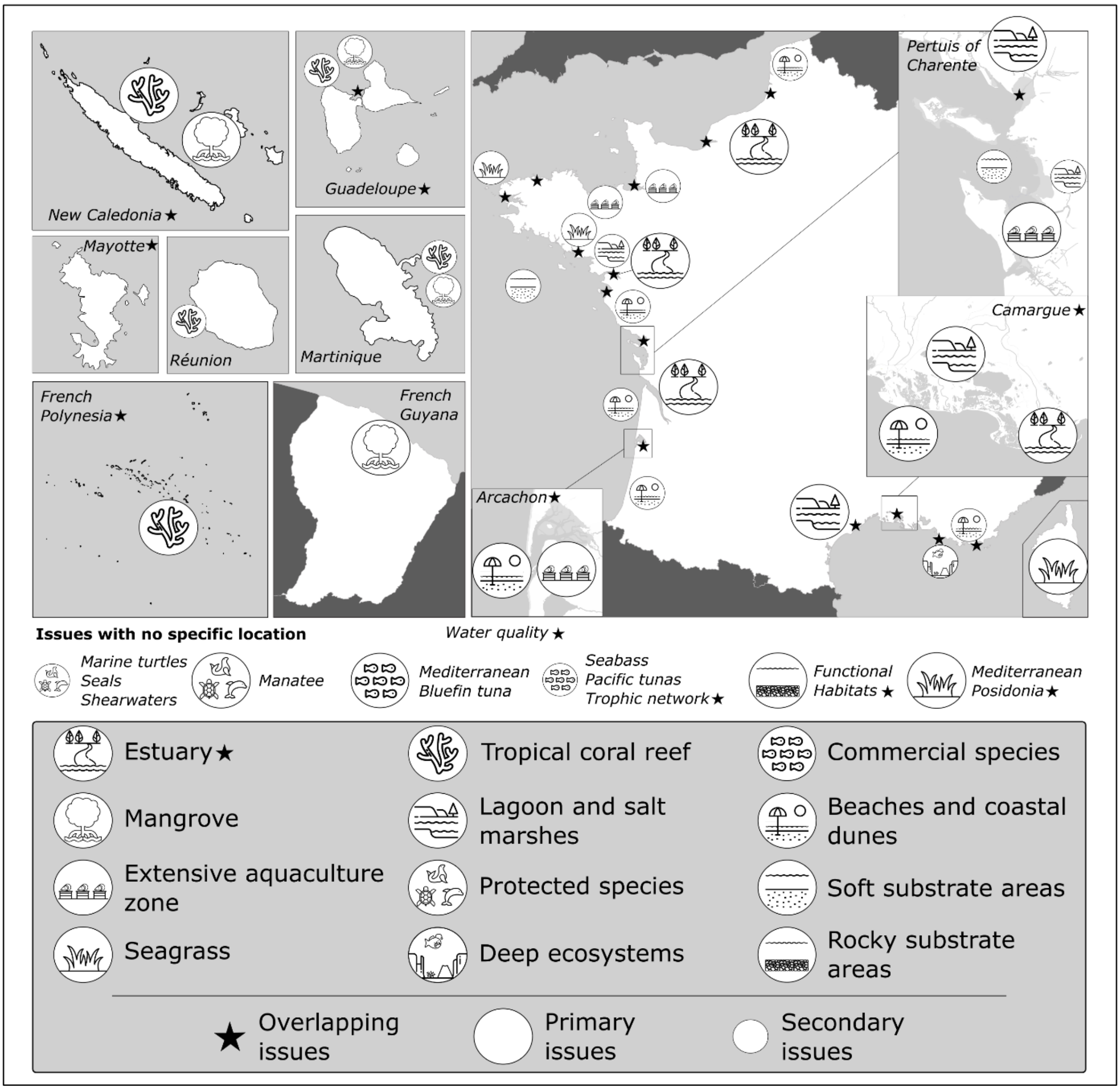
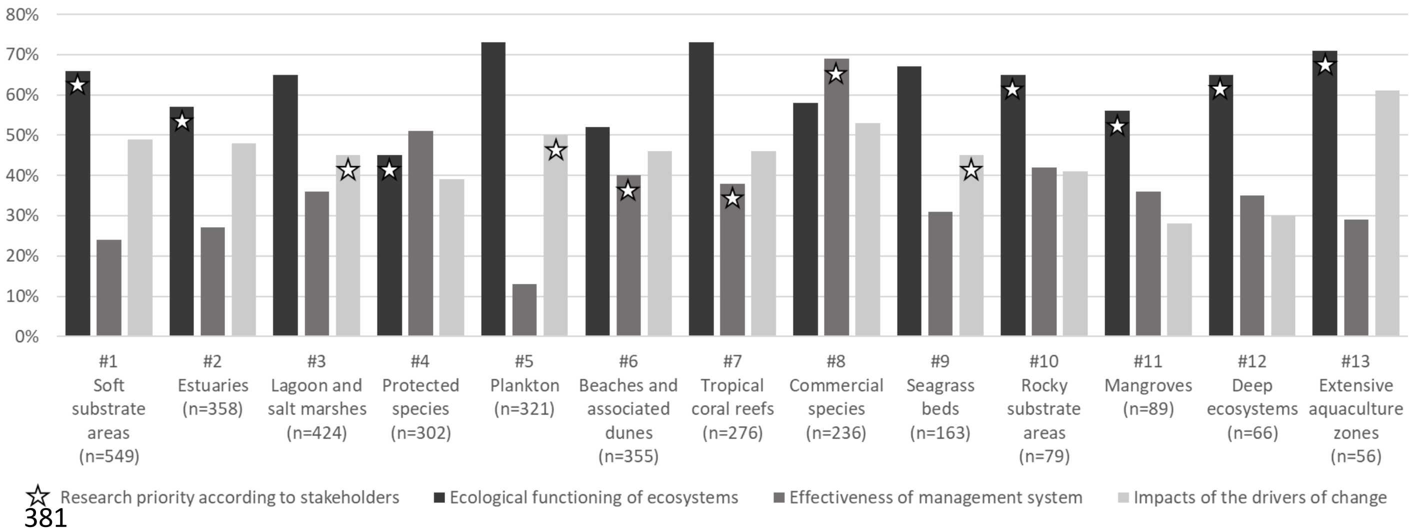


Figure 7 – Spatial distribution of the specific issues (Source of map base: IGN 2016 – Open Licence and ©OpenStreetMap contributors; Source of stickers: SVG Repo under CC BY 4.0 Licence).

3.4 Research need

The results were also very heterogeneous regarding research needs according to the different ecosystems and groups of species. Textual analysis conducted on the answers allowed us to identify three high-priority fields of research: (1) the ecological functioning of ecosystems, (2) the effectiveness of management systems, and (3) the impact of the drivers of change (data and detailed results of the textual analysis are available in Supplementary Material S7). From the angle of strategic evaluation, we then associated each type of ecosystem with its main research field based on the stakeholders' perceptions (Figure 8). It is interesting to compare these results with the actual state of research regarding French marine ecosystems. Based on work conducted in the EFESE-marine to assess knowledge production on ES, we conducted a rapid bibliometric analysis (See Supplementary Material S8). We found that the production of knowledge on the ecological functioning of ecosystems is actually the most important research topic for all ecosystems, except for commercial species and protected species for which the focus is on management.

Figure 8 – Result of bibliometric analysis regarding the research priorities identified by the stakeholders' consultation (Percentages indicate the proportion of publication that include keywords associated to each research areas for a given type of ecosystem. Rankings [#] are obtained as a composite indicator build on the number of result obtained in each inquiries looking for ecosystem type (i) in title, (ii) in topic and (iii) in topic without duplicates)



4 Discussion and conclusion

4.1 Strength and weakness of the consultation process

Implementing a consultation for a large-scale ES assessment is challenging since stakeholders are numerous and scattered over a vast territory (Figure 1). We overcame this problem by relying on the use of an online questionnaire that is more flexible to implement at the national scale (Jaligot et al., 2019).

Another challenge is that the integration of the various value systems of experts in decision-making usually requires their involvement in the formulation of the question, the choice of method and the problem statement (Spangerberg et al., 2015). In the EFESE program, the general questioning and the conceptual framework had already been determined by the French Ministry of the Environment; however, the method and the process we carried out in the EFESE-marine working group allowed us to embrace this diversity. Firstly, we applied TRIAGE, developed to hierarchize issues within the framework of ES assessment (Pendleton et al., 2015). The structure of TRIAGE starts with context setting and progressively deepens the questions asked; moreover, its implementation alternates between free text and nominal and ordinal rating, so that we collected different types of answers that were complementary regarding the research objective. Secondly, we applied the Delphi process that implies several iterations, allowing the respondents to step back from one phase to the other and build on collective vision to express their point of view. This method has proved to be useful in reaching consensus (Rowe and Wright, 1999). Finally, we alternated workshops and online questionnaires, which are complementary: workshops are useful as they increase consistency in answers (Singh et al., 2017) but can also foster answers based on conformity and group pressures (Woudenberg, 1991), while online questionnaires guaranteed anonymity that reduces the potential impact of group pressure (Pill, 1971).

Despite these efforts, some precautions must be taken to integrate the consultation results in the EFESE-marine assessment. Firstly, we cannot neglect a possible selection bias regarding the stakeholders interrogated. We pointed out an absence of expertise regarding non-tropical and/or uninhabited overseas territories (Table 4): thus, specific issues only concerned metropolitan and tropical inhabited ecosystems (Figure 7). However, French EEZ (Figure 1) also include polar ecosystems (Adélie land), cold oceanic ecosystems (Saint-Pierre-et-Miquelon) and uninhabited temperate and tropical areas (Saint-Paul and New Amsterdam Islands; Eparse Islands; Clipperton) that seem to have been left out of the scope of consideration in this consultation. We wonder whether this situation reflects a gap in our consultation or the true place of these ecosystems and areas in French consultative forums. Regarding polar ecosystems, it can be explained by their relatively recent exploration in comparison to other types of marine ecosystem (David and Saucède, 2015).

Secondly, the consultation led us to adopt an alternative typology of marine ecosystem, notably combining ecosystems and species. The choice of a typology is always associated with a risk regarding the aggregation of the results. On the one hand, we wanted the typology to be exhaustive, resulting in a risk of overlapping concepts and double counting (Fu et al., 2011). For example, we mixed ecosystems and groups of species, which makes our analysis susceptible to giving a biased image of their relative importance as groups of species are necessarily associated with one or several ecosystems. On the other hand, we wanted the typology to be easily understood and thus limited in number. This led us to mix some specific categories with broader ones that could include different realities. For example, rocky bottom areas can range from seaweed meadows of the littoral or infralittoral (habitat A1 and A3 of EUNIS classification) to faunistic communities of the circalittoral (habitat A4). Another example is the low importance assigned to soft substrate (Table 5) and its relatively narrow ES bundle (Figure 4) should be considered with caution as it occupies a large part of marine surfaces (Thrush et al., 2001). Different stakeholders may have had different ideas about the same object when answering, which could leave us with blind spots in the assessment. However, this problem can be taken into account with the analysis of the issues of concern (Figure 7).

4.2 Integration of the consultation to guide the assessment

We can see some inconsistencies between stakeholders' perception of ES bundles and the state of science. This is notably the case of climate regulation. Stakeholders assess the provision of climate regulation by tropical coral reefs to be high (Figure 4). Scientific studies do not support this assessment. Indeed, coral reefs are more probably neutral in terms of carbon production due to an equilibrium as the precipitation of carbonate (which releases CO_2 into the atmosphere, possibly appearing counter-intuitive for non-scientists) offsets the photosynthetic production of the global ecosystem (Gattuso et al., 1999). To a lesser extent, commercial species are net producers of CO_2 and their contribution to climate regulation should have been null instead of weak. Such inconsistencies show that some issues are poorly stated in public debate and thus poorly understood by society. Therefore, we dedicated particular attention to the question of climate regulation in the EFESE-marine assessment (Mongruel et al., 2019; chapter 10.3 p227).

A second major inconsistency concerned the association of plankton with the supply of food goods production services (Figure 4), which can be explained by its essential role in maintaining the proper functioning of food webs (Kaiser et al., 2011). In the same way, two minor inconsistencies were reflected by the idea that estuaries and mangroves are major suppliers of food, whereas these two types of ecosystem contribute to this service above all by accommodating habitats especially favourable for reproduction and nurseries. These inconsistencies show a misalignment between the perception of stakeholders and the conceptual framework used in EFESE. Ecosystem functions were excluded from the consultation due to conceptual choices imposed by the steering committee of the EFESE program. The rationale was based on the presupposition that, contrary to ES, ecosystem functions are not subject to social demand. In the literature, social demand is usually assessed regarding the benefits ecosystem functions provide to society (Wolff et al., 2015). Under this assumption, the assessment of ecological functions is exposed to the risk of double counting (Fu et al., 2011): as functions underlie the ES, their value is, in a way, embedded in the ES (Barbier et al. 2009). Thus, if social demand is limited to benefits, it is meaningful to reject their valuation. However, some studies give a wider definition of social demand that integrates desires, preferences and wider socio-economic characteristics (Schröter et al., 2014b, Villamagna et al., 2013). It appears that the results of the consultation are more consistent with this vision of social demand. The strongest importance attributed to plankton (Table 5) underlines its critical role at the base of the marine trophic network. Thus, the EFESE-marine team specifically investigated the various forms of demand expressed by society: we identified direct and indirect demands for use but also for conservation of ES, and considered whether or not the demand has an impact on the ecosystem resilience (Mongruel et al., 2019; p. 327).

This study also points out certain disconnections between research needs according to the stakeholders, and the actual research interests (Figure 8). We observed that the hierarchization of ecosystems based on the number of publications associated with each ecosystem does not reflect the priorities expressed by stakeholders. For example, soft bottom areas that come at the end of the rankings in stakeholders' preferences (Table 5) come in first position in terms of research interest. Conversely, tropical coral reefs and plankton, judged positively by the stakeholders, only come in 5th and 7th positions based on bibliometric indicators. One of the objectives of the national ES assessment as a state of the art is to place research priorities before decision-makers. In the EFESE-marine report, knowledge needs also included the preferences of stakeholders identified in the consultation (Mongruel et al., 2019; chapter 16 p.347). We believe that including stakeholders' preferences regarding research programming is also a good opportunity to promote a demand-driven perspective for ecosystem assessments. From this perspective, it is noticeable that although for most ecosystems the stakeholder demand for further knowledge concerns ecological processes, it concerns the management efficiency in the case of coral reefs and the impacts of human pressures in the case of plankton.

The consultation also puts forward the strong linkage of issues with existing conservation frameworks. Indeed, Figure 7, shows the locations of issues of concern that are closely connected with the marine protected area network. For example, the regions of Arcachon and Pertuis in Charente (zooms in Figure 7) are located within the perimeter of a Natural Marine Park, a type of protected area dedicated to the management of marine environments. We investigated this point with a review of the existing management plan on the location mentioned by stakeholders (Mongruel et al., 2019, p.76). In addition, the possibility of action is a structuring variable for the hierarchization of ecosystems (Figure 6). Regarding this criterion, ecosystem ranking follows a gradient corresponding to existing management procedures: starting with ecosystems with the longest management history (commercial species, aquaculture zones, lagoons and estuaries) and finishing with ecosystems that are not specifically managed, particularly because they are exposed to multiple or diffuse pressures (soft substrate areas, rocky substrate areas, deep ecosystems and plankton). In addition, possibility of action seems to be a limiting factor for stakeholders with a mean rating of 2.3 (while ecological importance and exposure criteria reached a mean rating of 3.3 and 3.2 respectively). The significance of the possibility of action for stakeholders highlights a critical variable that should be considered in the knowledge production process. This point was integrated in the prospective section for biodiversity conservation (Mongruel et al., 2019; p.343).

Most of the consultation results are consistent with the state of scientific knowledge. For example, in the case of exposure to change, coral reef is identified as the most exposed ecosystems (Table 5). Then comes a large group[3] that includes coastal ecosystems (estuaries, beaches and sand dunes, mangroves, lagoons and salt marshes and seagrass beds) and the three groups of species (plankton and commercial and protected species). At the end of the ranking we find deep, soft bottom and rocky bottom ecosystems. This ranking is in line with the scientific literature, indeed Halpern et al. (2008) underlined that more than 50% of coral reefs are facing medium high to very high impacts and that, more generally, coastal ecosystems are facing more cumulative impacts than offshore ecosystems. In this perspective, the results of the consultation can be used as a lever to give more weight to key messages for policy makers.

4.3 Integration of the consultation as an element of the assessment

The consultation of stakeholders is also interesting as an additional source of data to inform decision-makers regarding the state of ecosystems and their ES. ES are subject to many controversies about the principles that should govern their assessment (Barnaud and Antona, 2013; Schröter et al., 2014a; Kull et al., 2015)[4], and even more when we consider the production of monetary values[5]. In this context, the expert estimation of ES appears to be an efficient alternative and is considered one of the most popular ES assessment techniques today (Jacobs et al., 2015; Campagne and Roche 2018). Indeed, it provides an answer to the urgency-uncertainty dilemma: “ES research and practice have to balance between scientifically deepened analysis in the face of complexity on the one hand, and pragmatism in the context of fast global ecological resource depletion on the other” (Jacobs et al.,

[3] Score difference between the 1st and 2nd is the same as between 2nd and 9th.

[4] The controversy following the proposal of a new conceptual framework in the IPBES (Diaz et al., 2018) illustrate this situation (see for example Peterson et al., 2019).

[5] Whether it is due to methodological controversies (Vatn and Bromley, 1994; Raudsepp-Hearne et al., 2010), to their potential impact on societies (Gómez-Baggethun and Ruiz-Perez, 2011; Dempsey and Robertson, 2012; Pascual et al., 2014) or to their operationalization (Laurans et al., 2013).

2015, p22). In this kind of situation, expert consultation has proved to be useful to reach consensus on decisions despite uncertainties. Notably, the participation of stakeholders in hierarchization and the refinement of issues can be useful to inform managers in the case where scientific experts struggle to express normative references that could aid decision-making. As such, the consultation results fit within the proposition of a post-normal framework for ES assessment (Ainscough et al., 2018). Concretely, consultations results have also been mobilized in the EFESE-marine report to aid discussion on the perspectives concerning the sustainable trajectories of marine and coastal ecosystems (Mongruel et al., 2019).

Strategic evaluation leads us to hierarchize ecosystems to emphasize some issues. Firstly, the comparison of ES bundles shows a main difference between "generalist" and "specialist" ecosystems (Figure 4) that illustrates the nature of their relationship with society. Secondly, the hierarchization process based on importance, possibility of action and exposure to change allow us to identify four different sets of issues (Figure 6). The 1st set of issues gather tropical coral reefs and plankton (corresponding to cluster 1 of the FCA); their proximity is intriguing as they can be considered respectively as the most iconic and the most generic components of the marine realm. Although it is not surprising that tropical coral reefs come at the top of stakeholders' concerns given the size of their ES bundle, it is interesting to see that plankton shares the same level of concern despite it having a narrower and more specialized ES bundle. Finally, this attraction toward plankton tends to underline the expectation of stakeholders regarding the general functioning of marine ecosystems. In addition, there is an interesting opposition between the second set of issues that gathers coastal ecosystems and well identified groups of species (cluster 2 of the FCA) and the third set of issues that gathers the large benthic ecosystems (cluster 3 of the FCA). This opposition reflects the general idea that coastal ecosystems are more exposed and more easily protected than offshore ecosystems. Finally, the fourth set of issues is that of modified ecosystems dedicated to quasi-exclusive human economic uses (corresponding to cluster 4 of the FCA): this reflects the recent emphasis placed on the question of their acceptance by the public (Mather and Fanning, 2019).

To conclude, this work shows the importance of stakeholder's consultation to support global ES assessments. Stakeholder's perception of ecosystems and their services provides information that is useful to decision makers. Such consultation is also useful to situate the production of knowledge relatively to society. Firstly, it can show that some fields of interest for society are insufficiently covered by scientists (e.g. plankton) and in this way inform future research needs. Secondly, it can also point some discrepancies between the state of scientific knowledge and how it is actually captured by stakeholders (e.g. climate change and coral reef) that need to be addressed in the assessment. In the end, this work will bring relevant guidance for implementing of similar consultations in the future.

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