Not just an engineering problem: the role of knowledge and understanding of ecosystem services for adaptive management of coastal erosion

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Abstract

Coastal ecosystems are recognized as important providers of ecosystem services such as carbon storage, increased fish productivity, and wave energy reduction. In a context of climate change, coastal ecosystems are exposed to erosion and subject to coastal squeeze, even as they provide natural coastal protection against extreme weather. While civil engineering solutions often take centre stage in mitigating coastal erosion and protecting infrastructure from storms and sea level rise, we seek to explore the social dimension of adaptive management of socio-ecological systems and more specifically the role of knowledge and learning. Using an ecosystem services (ES) framework, we provide a first evaluation of local stakeholders' perceptions of coastal habitats in maritime Quebec. The findings demonstrate the importance of a social approach for coastal ES valuation, in particular in addressing the complex question of cultural ES. A better understanding of the links between coastal stakeholders and their natural environment can help decision-makers and practitioners design conservation management and coastal adaptation measures mainstreaming the role of coastal habitats. Nevertheless, a change towards a socio-

ecological perspective will require long-lasting processes that build on social capacities, such as flexible institutions and multilevel governance systems.

Keywords

Adaptive governance – social dimension – coastal erosion – ecosystem services – coastal habitats – stakeholders' perception

1. Introduction

The importance of coastal ecosystems – and the services they provide – has been widely recognized in the scientific literature (Barbier et al., 2011; Costanza et al., 2014). Although extensive literature is available on the subject, the information presented in ecosystem services' studies can still be questioned in terms of relevance for decision-making (Wright et al., 2017). Improving the understanding of the complex interrelationships between social and natural systems in particular in the relation to community perceptions of well-being can provide useful insights for decision-making processes (de Souza Queiros et al., 2017).

Coastal ecosystems supply nursery areas for fisheries as well as for species that are considered threatened (Beck et al., 2001; Nellis et al., 2003). Representing only 0.2% of oceanic surfaces, marine vegetated habitats contribute to 45% of carbon sinks in marine sediments (Duarte et al., 2013) and can contribute to "blue carbon" by mitigating anthropogenic CO_2 emissions through fixing carbon from the atmosphere (Rohr et al., 2018; Taillardat et al., 2018). For instance, eelgrass – also called "keystone" ecosystem – is considered an indicator of overall quality of coastal ecosystems, reducing the presence of pathogenic bacteria for invertebrates and vertebrates, including those impacting human health (Lamb et al., 2017). Shellfish beds have a great cultural and commercial importance for coastal communities and in particular for Indigenous groups (Joyce and Canessa, 2009). Tidal marshes and sandy habitats can absorb wave energy and reduce erosion and submersion risks of coastal municipalities (Gedan et al., 2011). Rocky shores, with their high productivity and structurally complex systems, provide feeding areas for birds and fish, and nursery grounds for fish and mobile invertebrates; they also form natural coastal defenses (Branch et al., 2008). Macroalgae also provide, among others, elevated secondary production and diversity (Cimon and Cusson, 2018; Lemieux and Cusson, 2014), nutrient cycling, energy capture and flow, and coastal defense (Smale et al., 2013). However, in the context of climate change, the reduction of sea ice and ice foot – a wall of ice formed on the intertidal zone – in cold regions (Corriveau et al., 2019; Overeem et al., 2011) exposes the coast to more storm events (Ruest et al., 2016). The acceleration of sea level rise also has important consequences for coastal zones (Kopp et al., 2016). The response of populations to protect themselves and their infrastructures from coastal hazards

has resulted in an increase in coastal defense structures over the past decades (Dugan et al., 2011; Gittman et al., 2015).The combined effects of this rise in sea level and the growth of shoreline armoring exacerbates the phenomenon of "coastal squeeze": the surface loss of an ecosystem due to physical constraints that limit its migration further inland in a context of sea level rise (Pontee, 2013; Doody, 2004). Coastal squeeze would have more serious effects on coastal ecosystems located between terrestrial and marine areas like beaches and tidal marshes. It is therefore paradoxical to note that the defense structures traditionally put in place (hard rigid structure) to reduce coastal risks have impacts on coastal ecosystems (Cooper et al., 2020; Gittman et al., 2016) while coastal habitats and their ecosystem services (ES) can be considered as an interesting means to adapt to coastal erosion (Arkema et al., 2013).

Discussions on coastal adaptation often focus on the exposure of infrastructures and buildings to storms and sea level rise and the civil engineering solutions that could mitigate these events (Lloyd et al., 2013). Indeed, as raised by Borsje et al. (2011), coastal protection has long been approached by decision-makers from a traditional economic-social-engineering perspective that does not consider coastal ecosystems neither as an exposed issue nor as a mitigation solution. One explanation offered by Lithgow et al. (2017) is that the understanding of the economic dependence on ecosystems services, and an appreciation of how they may be impacted by economic activities is greater among the scientific community than among decision-makers. This gap of perceptions between scientists and decision-makers hinders a transition towards more resilient[1] coastal management. Thus, Lithgow et al. (2017) advise interdisciplinary and exchange of knowledge between scientists and decision-makers. This could encourage a shift from relying on conventional engineering solutions where the dynamic nature of the coast is not fully considered to coastal zone management framework that takes into account the socio-ecological dynamics of coastal systems (Martinez et al., 2017).

In this study, we adopt an integrated approach that recognizes the interdependencies between environmental, human, and technological factors (Pahl-Wostl, 2007), in contrast to a perspective that frames resilience solely in socio-economic terms. We build on the approach of adaptive governance, which aims to manage uncertainty and complexity of socio-ecological systems[2], and in particular explore the social dimension of ecosystem management (Dietz et al., 2003; Walker et al., 2004; Folke et al., 2005; Folke, 2006). The social capacity to respond to environmental change is recognized to be crucial for the adaptive governance of complex social-ecological systems, and consists of four interacting aspects[3]

[1] Resilience can be defined as “the extent to which a system can absorb recurrent natural and human perturbations and continue to regenerate without slowly degrading or even unexpectedly flipping into less desirable states” (Folke et al., 2004)

[2] Social-ecological systems are “integrated complex adaptive systems in which social and ecological subsystems are coupled and interdependent, each a function of the other, expressed in a series of mutual feedback relationships” (Berkes, 2017).

[3] The four aspects of the social capacity to respond to environmental change are: (i) promoting knowledge and understanding of resource and ecosystem dynamics, (ii) integrating ecological knowledge into adaptive management practices through continuous testing, monitoring and re-evaluation to enhance adaptive responses, (iii) supporting flexible institutions and multilevel governance systems through adaptive co-management among user

104 (Folke et al., 2005). In this article, we focus on the first aspect of the social response to environmental
105 change: knowledge, learning, and their practical applications, where mobilizing and combining differ-
106 ent knowledge systems and learning environments can "enhance the capacity for dealing with complex
107 adaptive systems and uncertainty" (Folke et al. 2005). This depends on scientific knowledge and local
108 knowledge, the latter stemming from everyday practice and developed over long periods of interaction
109 between communities and local ecosystems (Folke et al., 2005).

110 In describing a socio-ecological resilience framework for coastal planning, Lloyd et al. (2013) argue
111 for a perspective that can observe interlinked systems of people (e.g. communities, interest groups,
112 decision-makers) and ecosystems (e.g. marine coastal environments). They identify social learning as
113 a prerequisite for devising adaptive natural resource governance. Underlining this point, Lebel et al.
114 (2010) argue that social learning has the ability to generate "new knowledge, shared understanding,
115 trust and, ultimately, collective action".

116 This articles explores the social dimension of adaptive management of socio-ecological systems and
117 more specifically the role of knowledge and learning regarding ES of coastal habitats in Quebec, Can-
118 ada. We examine how ES valuation through a social approach could help mainstreaming the role of
119 coastal ES in conservation actions and coastal erosion management. A better understanding of the links
120 between stakeholders and their natural environment can help decision-makers and practitioners design
121 management measures that take into account environmental features. This can in turn contribute to a
122 move away from traditional approaches that do not integrate the ecological system. A participatory
123 process involving local stakeholders was designed to support social learning of ecosystem services
124 through sharing of different perspectives in a trusting environment. Providing a first evaluation of local
125 stakeholders' perceptions of coastal ecosystems in Quebec, we show how an in-depth understanding of
126 coastal ES from coastal stakeholders constitutes an opportunity to both inform conservation measures
127 and move beyond the predominant economic-social-engineering perspective to coastal adaptation. First,
128 we present the methodology we developed to gather actors' preferences regarding ES through work-
129 shops (Section 2). Then, we present the results of the workshops we organized (Section 3). Lastly, we
130 discuss the complexity of coastal ES valuation, in particular regarding cultural ES and its importance
131 for informing conservation and coastal hazards management (Section 4).

132

133 ## 2. Methodology

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groups or communities, government agencies, and nongovernmental organizations and (iv) dealing with external perturbations, uncertainty and surprise (Folke et al. 2005).

2.1 Study area and description of the scope of the project

Here, we define maritime Quebec as the territory comprising the St. Lawrence upper estuary and a share of the Gulf, including the administrative regions of the Côte-Nord (except Anticosti island), Bas-Saint-Laurent, and Gaspésie-Îles-de-la-Madeleine, which total 3,220 km of coasts, 38% of which are currently affected by coastal erosion (Drejza et al., 2014). Quebec's east coasts have been particularly impacted by severe storms over the last two decades, causing damage to infrastructure including in October and December 2005, December 2010, and December 2016 (Bernatchez et al., 2011; Didier et al., 2015). Without new adaptation solutions or the maintenance of existing ones, 5,426 buildings, 295 km of roads and 26 km of railways could be exposed to erosion, representing a property value of 1.5 billion CAD (2014) by 2065 (Bernatchez et al., 2015). Although most residents are very aware of the link between climate change and coastal erosion, "most respondents favor massive and hard structures even if they recognize that they may have a major impact on coastal dynamics" (Friesinger and Bernatchez, 2010). A recent analysis by Sauvé et al. (2020) suggests a change, between 2010 and 2017, in the perceptions of coastal citizens and coastal managers, who are inclined to favor soft techniques, but this change does not however seem to materialize in adaptation measures, as the amount of hard coastal protection structures has increased along Quebec's coastlines during the same period.

Our study is part of a wider action research project, *Résilience côtière* (2018-2024), initiated to support municipalities and Regional County Municipalities (RCMs)[4] of the St. Lawrence estuary and gulf in Quebec in their adaptation to coastal hazards in the context of climate change. The project aims to increase the resilience of socio-ecological systems through the provision of tools in line with the needs expressed by stakeholders and thus to improve decision-making of communities regarding (i) land use planning, (ii) ecosystems' protection and (iii) adaptation solutions' choices.

2.2 Ecosystems and ES mapping

We selected four ecosystems representative of the diversity of coastal ecosystems encountered in maritime Quebec and present in each of the four investigated regions: beaches, eelgrass and tidal marshes (for all 4 workshops on ES preferences organized for our study) and the fourth was adapted to each workshop location and involved the presence of macroalgae (rocky coasts with macroalgae predominance, foreshores with macroalgae, and cliffs and rocky foreshores with macroalgae; see Annex 1).

We identified how each coastal territory was used by building on data collected previously at an earlier stage of the project through participatory mapping. This phase of participatory mapping first involved initial workshops attended by a total of 149 people from different stakeholder organizations (see Table

[4] Regional county municipalities are a supralocal type of regional municipality, and act as the local municipality in unorganized territories within their borders

1 for the types of organizations) and was then followed by individual meetings with more than 600 coastal inhabitants. The initial workshops were held in each of the 9 RCMs of the study area. During the workshops, we projected aerial photographs and maps of each region using the GIS software, ArcGis, for small groups of five to ten people. The participants then indicated the uses of the area, which was then directly digitized. This approach, more dynamic than a paper map, turned out to be very effective since we could zoom in and move around on the screen to places of interest. A similar kind of exercise was then carried out in the individual meetings with coastal inhabitants, during which more specific questions were asked regarding past and current uses and their perceived evolution. Significant geomatics work was done to structure this database, where the uses of coastal territories were classified according to different categories of activities (socio-cultural, scientific or educational, recreational, commercial exploitation of resources), sites (of high socio-cultural value, of ecological interest, recreational, heritage) and infrastructure (using the typology of property utilization in Quebec[5]). We then selected only the "uses" associated directly with an ecosystem. To ensure the validity of our classification and selection of ES, we compared it to the classification of Liquete et al. (2013) which reviewed 145 papers that specifically assessed marine and coastal ES and proposed a correspondence of their suggested integrated classification of marine and coastal ES with previous classifications, namely Millennium Ecosystem Assessment (MEA, 2005), Beaumont et al. (2007), The Economics of Ecosystems and Biodiversity (TEEB, 2010) and the Common International Classification of Ecosystem Services version 3 – CICES (Haines-Young and Potschin, 2011). To integrate the data we had on sites of ecological interest, we added two categories – habitat and supporting ES – from the TEEB classification. Annex 1 lists the classifications used. In order to further define data on heritage sites, we added categories such as wrecks, archaeological sites, and high socio-cultural value sites in cultural ES. For some regions where winter activities were highly cited during the participatory mapping, we also displayed them in subsequent workshops on ES preferences that were organized for our study.

2.3 Workshops on ES preferences

We organized four workshops in 2019 and 2020, bringing together a total of 104 people[6]. In each workshop, local stakeholders from two or three RCMs were invited (Figure 1). The choice to pool some

[5] https://www.mamh.gouv.qc.ca/evaluation-fonciere/manuel-devaluation-fonciere-du-quebec/codes-dutilisation-des-biens-fonds/

[6] During the first phase of the *Résilience côtière* project before 2019, workshops were organized to collect the needs expressed by local stakeholders in relation to infrastructures and population security and coastal ecosystems' protection. Needs regarding communication, sensitisation, information, data access and regulation adaptation ranked first. Workshops on the subject have been organised regularly since 2017. This has created a strong dynamic around the issue of coastal protection. In each of the fours workshops, each institution was represented by at least one stakeholder. Although an institution has multiple and intersecting interests, it can be considered as a unified entity in some respect. So even if the absence of certain participants could introduce a bias, the main trends were captured.

RCMs and to locate the workshops in some cities was done according to geographic similarities between RCMs, data availability (during the workshop, maps displaying exposure of infrastructure to the audience had to be developed by team members of the project) and convenience of location for stakeholders (travelling distance had to be minimized to facilitate people's attendance). Four workshops were then organized:

- Baie-Comeau workshop, which included the RCMs of Haute-Côte-Nord and Manicouagan
- Sept-Iles workshop, which included the RCMs of Sept-Rivières and Minganie
- Sainte-Anne-des-Monts workshop, which included the RCMs of Mitis, Matanie and Haute-Gaspésie
- Gaspé workshop, which included the RCMs of Côte-de-Gaspé and Rocher-Percé

Baie-Comeau and Sept-Iles territories are referred later as North Shore (of Saint-Lawrence river) while Sainte-Anne-des-Monts and Gaspé territories as South Shore.

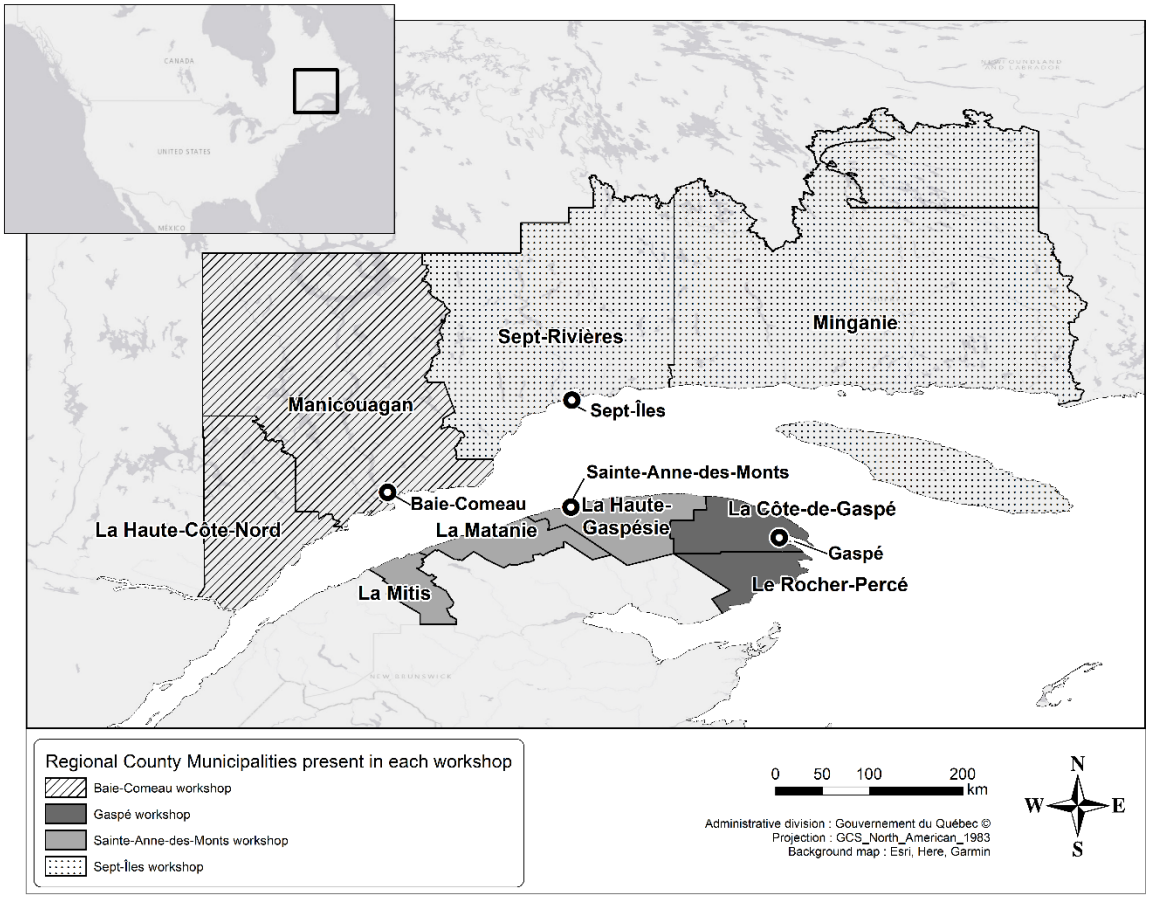


Figure 1: Map of the different Regional County Municipalities present in each workshop. The bolded circle indicates the workshop locations

Stakeholders were representative of different regional and provincial ministries (environment; home affairs; public security; forest, wildlife and parks; energy and natural resources; transportation), federal

natural parks, environmental NGOs, watershed management organizations, Regional Environmental Council, Regional County Municipalities, and municipalities (Table 1).

Table 1: Number of participants for each workshop, with a typology of their respective institutional background

	Baie-Comeau	**Sept-Iles**	**Sainte-Anne-des-Monts**	**Gaspé**	**Total per institution**	**% of total participants**
Municipality	6	8	11	5	30	29%
Environmental Organization - Env Org	4	6	3	3	16	15%
Transport Ministry	1	1	1	9	12	12%
Regional County Municipality - RCM	0	5	4	1	10	10%
First Nations	5	2	0	0	7	7%
Public Security Ministry	0	2	3	2	7	7%
Environmental Ministry - Env Min	2	1	2	3	8	8%
Municipal Affairs Ministry	1	1	0	1	3	3%
Natural Ressources and Energy Ministry - Energy Min	1	1	0	1	3	3%
Health and Social Services Ministry - Health Min	1	0	1	0	2	2%
National Park	0	1	0	1	2	2%
Non-Governmental Organization – NGO	0	0	1	1	2	2%
Forest, Fauna and Park Ministry - Forest Min	0	1	0	0	1	1%
Indigenous Services Ministry	0	0	1	0	1	1%
Total per workshop	21	29	27	27	104	

As part of the larger *Résilience côtière* project, daylong workshops in four different regions were organized with several sessions (mostly related to engineering solutions for adaptation to coastal erosion). One session of 1.5 hours focused on the values associated with coastal ecosystem services (ES) through

219 a participatory method. Through a 30-minute presentation, we first introduced the concept of ES and
220 the benefit of using it for characterizing impacts and dependencies of communities on coastal ecosys-
221 tems. We also explained the different approaches that could be undertaken for the assessment of ES
222 values (social, economic and biophysical approaches). For each workshop, four ecosystems encoun-
223 tered in the region were presented in their regional context and their associated ES were detailed. In-
224 deed, although stakeholders had a rather good understanding of the uses related to the coast, they usually
225 had difficulties to associate them with a specific ecosystem. During workshops, a social approach to
226 assess ES was used to elucidate the value stakeholders assigned to the different services.

227 We drew from Lopes and Videira's participatory approach (2016) to scoping ES with stakeholders.
228 First, we organized discussion tables around the four ecosystems. Each discussion table then had a 15-
229 minute group discussion[7], supported by a poster (see Figure 2), to:

230 (i) detail the ES they value the more (Annex 1)
231 (ii) explain how they would assess them[8]
232 (iii) prioritize the top three services in each sphere: ecological (values linked to functional
233 integrity, health or resilience of an ecosystem to sustain life; De Groot et al., 2010),
234 social (values related to the way all ecosystem service values are culturally constructed
235 and contextualized; Brondizio et al., 2010) and economic (importance of an ecosystem
236 and its ES expressed in monetary terms).

237 At the end of this hour of discussion, they were asked to vote with tokens, within each ecosystem pre-
238 sented, for the three services they value the most in each sphere. Finally, they were asked to select the
239 three ecosystems they would like to see as priorities for conservation, giving each first, second or third
240 priority.

[7] Notes were taken from the recordings of the discussions. Arguments used by participants were then organized by category of ES for each habitat. Then, within each category of ES, the rational explaining the valuation of the different spheres was described. The quotes reported in Section 3.6 represent the views of the majority and arose from a consensus.

[8] This could consist of time spent practicing an activity, frequency of utilization, additional income earned thanks to a provisioning service, etc.

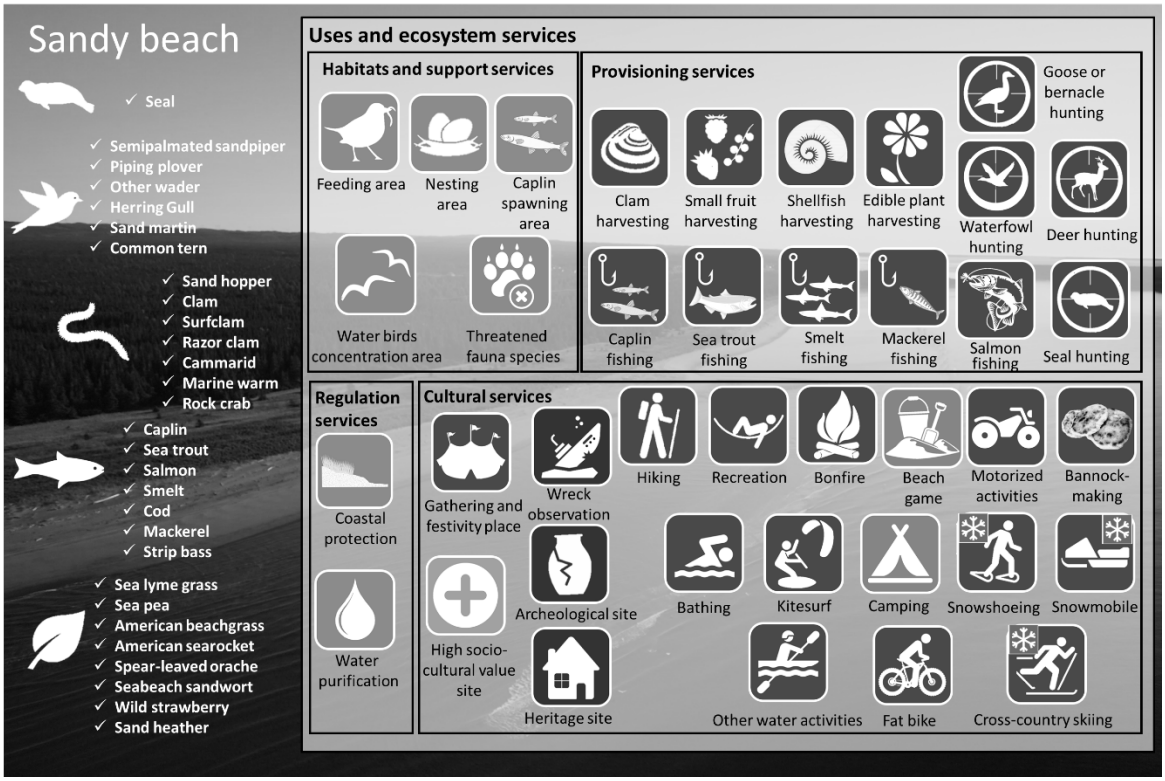


Figure 2: Example of a poster representing the ecosystem services associated with a sandy beach

Two different tools were used to visualize the voting data: pivot tables in excel and multiple correspondence analysis (MCA, FactorMinR) in R Studio – a multivariate method that analyses the systematic patterns of variations of categorical data whose properties of reducing dimensions helped in visualizing our data. The transcriptions of stakeholders' discourse and rationale during discussion tables was also used to complement the analysis of the votes[9].

3. Results at the overall scale of the maritime Quebec

3.1 The most popular ES by type of ecosystems and the associated spheres

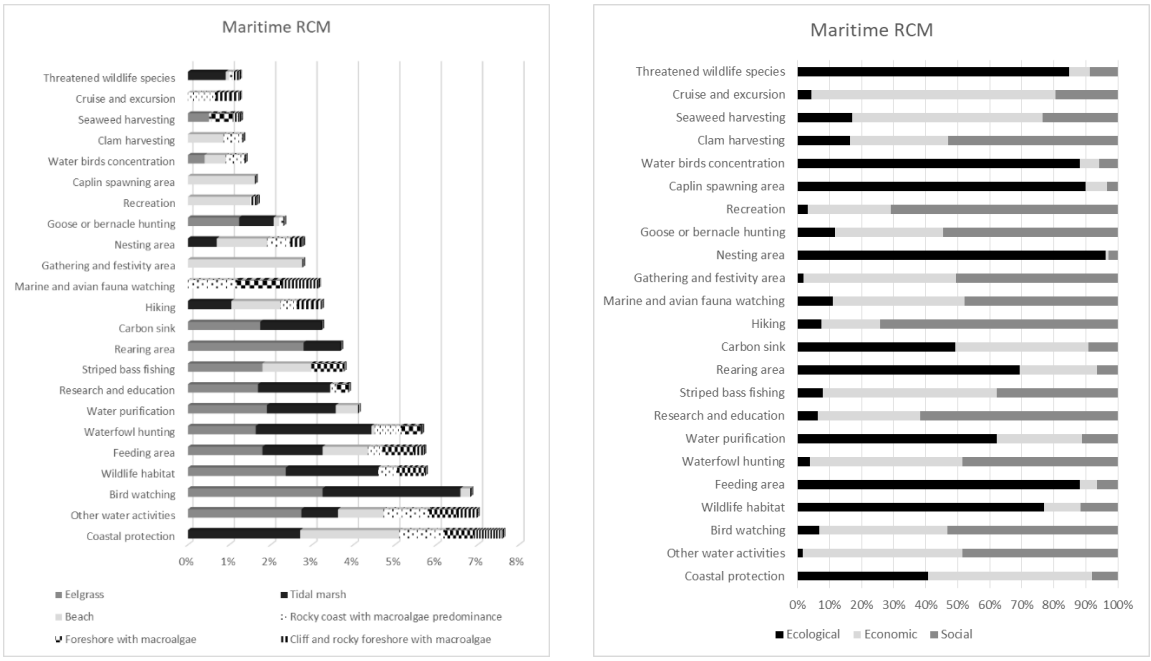
[9] Notes were taken from the recordings of the discussions. Arguments used by participants were then organized by category of ES for each habitat. Then, within each category of ES, the rational explaining the valuation of the different spheres was described.

First, we analyzed the results at the scale of all RCM concerned by the 4 workshops. We selected the ES that received 80% of the votes[10] (Figure 3). The ES that only received less than 20% of the votes were excluded from the analysis. Regulating (18%) and provisioning (19%) services were less represented than the other categories. The most popular ES were eelgrass (29%), tidal marshes (28%) and, to a lower extent, beaches (20%).

The six most popular ES were coastal protection (regulating ES), other water activities[11] (cultural ES), bird watching (cultural ES), wildlife habitats (provisioning ES), feeding areas (provisioning ES), and waterfowl hunting (cultural ES). In their responses, participants considered some ES to be present in different ecosystems, this was the case for coastal protection (regulating ES), other water activities (cultural ES), and feeding areas (provisioning ES). But some ES were linked to very specific ecosystems: gatherings and festivities (cultural ES) and caplin spawning areas on beaches (provisioning ES); others were present in only two ecosystems, such as rearing areas (provisioning ES) and carbon sinks (regulating ES).

People acknowledged all three spheres of value in the workshop: economic, social, and ecological. For example, of the six ES that received the most votes, the economic sphere was found to explain more than 40% of the values attributed to coastal protection, other water activities, bird watching, and waterfowl hunting. However, the ecological sphere explained more than 40% of the values of coastal protection, wildlife habitat, and feeding areas. The social sphere was deemed of significant value accounting for more than 48% of other water activities, bird watching and waterfowl hunting.

[10] The selection of ES displayed during workshops was based on a broad consultation among coastal inhabitants regardless of how many times this ES was cited. So some ES may be very marginal.
[11] Other water activities represent all water activities other than bathing and diving/free diving. They mostly refer to kayaking, as paddle boarding, kite-surfing and surfing are less popular.



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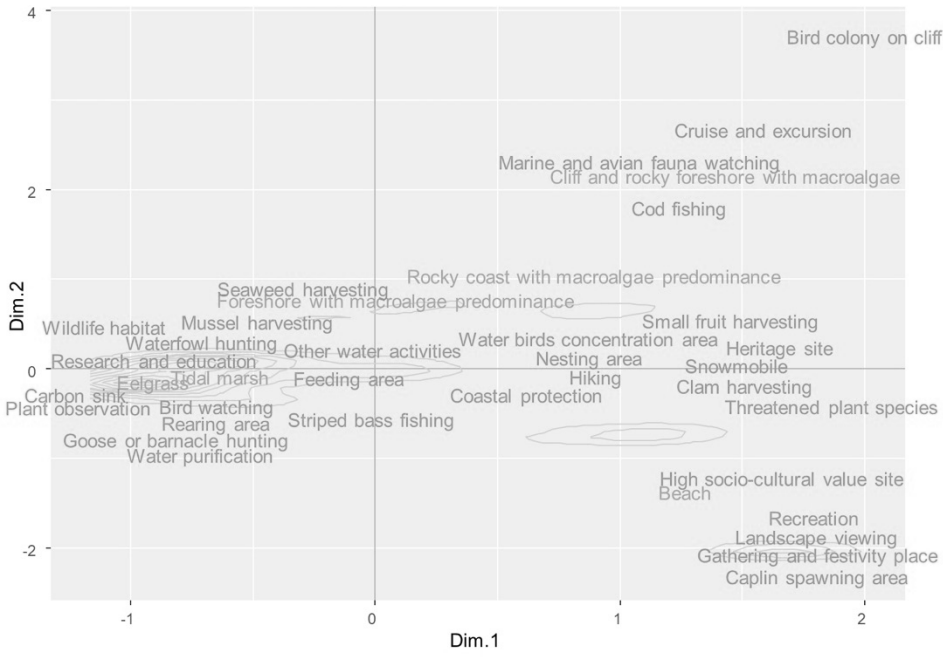
275 *Figure 3: Percentage of votes per ES and the ecosystem(s) that provide(s) them (left), percentage of the associated sphere*
276 *of valuation within ES (right) for the ES that gathered 80% of the votes.*

277

278 Eelgrass and tidal marsh were considered to be very similar in terms of ES and also foreshore and rocky
279 coast with macroalgae predominance also display similar ES (Figure 4).



280

281 *Figure 4: Multiple Correspondence Analysis of ES and the ecosystem(s) that provide(s) them (Dim1: 4.74; Dim2: 4.40). Since*
282 *some individuals are overlapped, we added some density curves to see those zones that are highly concentrated.*

283 Figure 5 highlights the close relationship between the different spheres. Indeed, some ES such as rearing
284 area, water purification, carbon sink and coastal protection were acknowledged for both their ecological

value and their economic value. Most provisioning services (clam and mussel harvesting, goose and barnacle hunting, small fruit harvesting) were considered of high value for the social sphere as they are part of the "coastal culture", others like waterfowl hunting or striped bass fishing were equally or more important for the local economy. A lot of cultural ES were considered to have high social value, such as hiking, recreation, research and education (as a way to raise awareness for the importance of coastal ecosystems), and plant observation. Although practiced by locals, some recreational activities were also valued economically as they attract tourists in the region, such as marine and avian watching, bird watching, and landscape viewing and other water activities. Though there were ES that were mainly valued ecologically (e.g. nesting, feeding and birds concentration areas, wildlife habitat). During group discussions (see Section 3.6), participants regarded this ecologically valued ES as the basis of all the other ES, highlighting the strong relationship between healthy ecosystems and the diversity of ES seen as socially and economically valued.

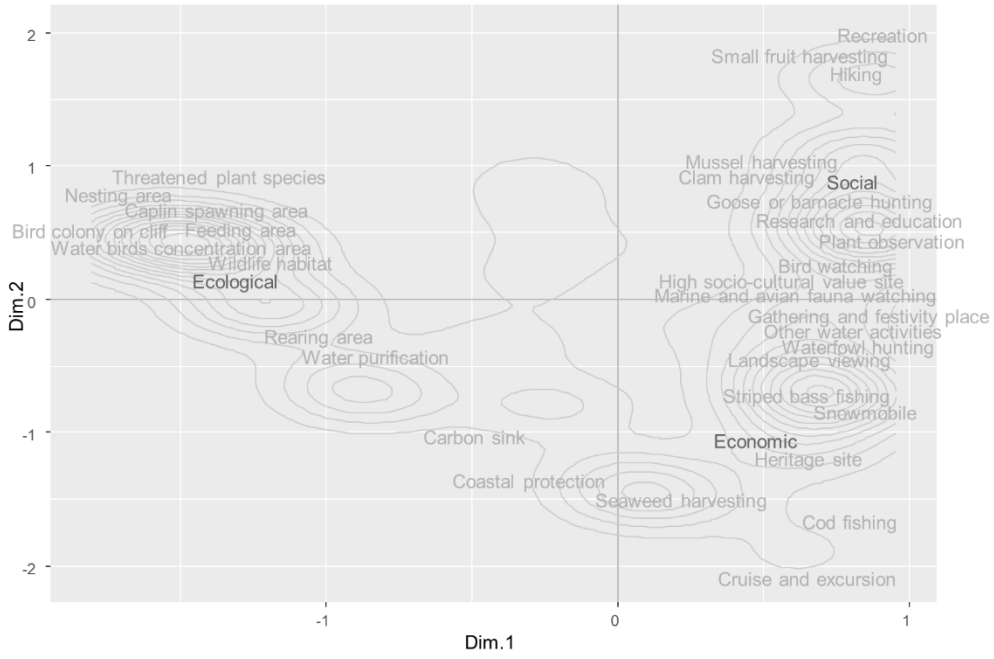


Figure 5: MCA of ES and their associated spheres (Dim1: 5.21; Dim2: 3.91)

3.2 Regional differences and categories of ES

When we look at regional differences in voting preferences, we observe some similarities between Gaspé and Sept-Iles regions in terms of the valuation of ES. The Gaspé region valued supporting ES the most while Sept-Iles and Sainte-Anne-des-Monts regions valued the provisioning ES more (Table 2). The Sainte-Anne-des-Monts region favored cultural ES but was the least interested in regulating ES.

Table 2: ES categories valued by each of the 4 regions

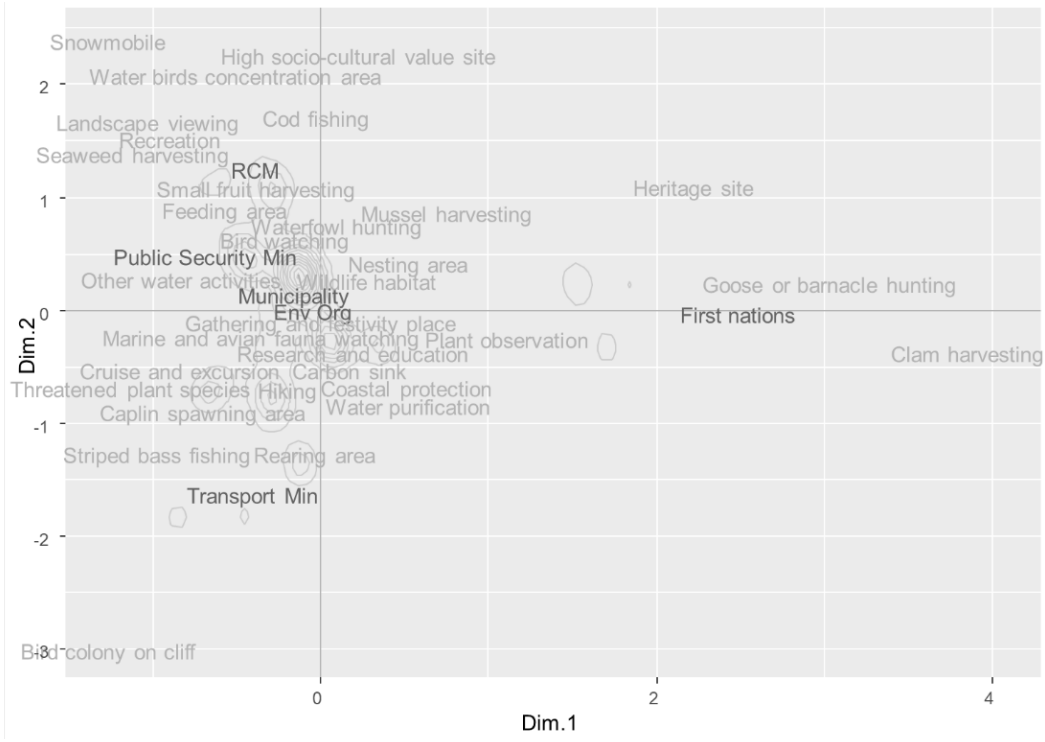
RCM	Supporting ES	Provisioning ES	Regulating ES	Cultural ES
Haute-Côte-Nord et Manicouagan	23%	17%	21%	39%
Sept-Rivières et Minganie	23%	22%	20%	35%
Mitis, Matanie and Haute-Gaspésie	24%	21%	12%	43%
Côte-de-Gaspé and Rocher-Percé	30%	14%	21%	35%
TOTAL	25%	19%	18%	38%

307

308 **3.3 The role of institutional belonging in the selection of ES**

309 We analyzed the votes of institutions that account for at least 7% of the participants[12] (municipalities:
310 29%, environmental organizations: 15%, Ministry of Transportation: 12%, RCM: 10%, Ministry of
311 Public Security: 7%, and First Nations[13]: 7%, accounting for 79% of the participants). We observed that
312 participants linked to municipalities and environmental organizations valued quite similar ecosystem
313 services, from cultural (40% and 38% respectively) to supporting (24% and 25% respectively) (Figure
314 6 and Figure 7). RCMs and Ministry of Public Security representatives were also similar, valuing cul-
315 tural ES (39% and 41% respectively) and supporting ES (29% and 27% respectively). People from the
316 Ministry of transportation valued regulating ES more than people from institutions (23%). First Nations
317 clearly stand out from the other groups; although they are interested in cultural ES at 33%, they also
318 valued provisioning ES (26%) and regulating ES (25%). All of these stakeholders valued cultural ES at
319 38%, supporting ES at 25%, provisioning ES at 19%, and regulating ES at 18%.

[12] The Ministry of Environment has not been included in the analysis although their representatives represent 8% of the participants, as the same person responsible for the Resilience project was present at each of the 4 workshops.
[13] The Canadian Constitution Act recognises 3 groups of Aboriginal peoples: First Nations (North American Indians), Inuit and Métis.



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321 *Figure 6: MCA of institutional preferences regarding ES (Dim1: 3.5; Dim2: 3.4)*

322

323 *Figure 7: Institutional preferences regarding ES categories (Dim1: 13.8; Dim2: 13.4)*

324

325 **3.4 Analysis of the most popular ES and their associated spheres of valuation according**
326 **to ecosystems**

For each ecosystem, we selected the six most popular ES and their associated spheres of valuation (Figure 8). For eelgrass, the three spheres of valuation were rather balanced with the ecological sphere having a slightly higher valuation. For beach ecosystems, 43% was linked to ecological value mainly due to high values associated with the caplin spawning area and nesting area, 32% to economic and 25% to social. For tidal marshes, the three spheres of valuation were quite balanced with a slightly higher economic valuation. Foreshores with macroalgae were perceived to be more in the ecological sphere of valuation, displaying feeding and wildlife habitat. Rocky coasts with macroalgae predominance were linked to economic and social values due to strong cultural ES (marine and avian watching, other water activities, cruises and excursions). Cliffs and rocky foreshores with macroalgae were also acknowledged for their economic and social values, as providers of recreation activities.

Figure 8: The six most valued ES per ecosystem and their associated spheres of valuation

3.5 Stakeholders' preferences regarding conservation priorities

Going further, participants' preferences for which ecosystem to conserve were also analyzed:

- The first priority for conservation was given to beaches (43%) and then tidal marshes (29%)
- Second priority was given to tidal marshes (32%) and then eelgrass (26%)
- Third priority was given to eelgrass (32%), followed by beaches (22%) and tidal marshes (21%).

All conservation priorities considered, rocky coasts and foreshores with macroalgae received around 19% of the vote, which is below eelgrass (24%), which was voted as the third priority.

We also examined the influence of participants' institutional affiliation (we concentrate here only on the votes of institutions that account for at least 7% of the participants) in their choice of conservation priorities (Figure 9). We noticed that the Ministry of Transport seemed to have a greater preference for cliff and rocky foreshore with macroalgae but this might be due to the over-representation of this institution at the workshop in Gaspé, where the national road mainly runs along this type of ecosystem. Environmental organizations and municipalities were more concerned about beaches (31%), followed by eelgrass (27%) and tidal marshes (27%). It is also interesting to note that First Nations attached greater value to the rocky coasts with macroalgae (this ecosystem records less than 10% of the votes of other stakeholders' categories).

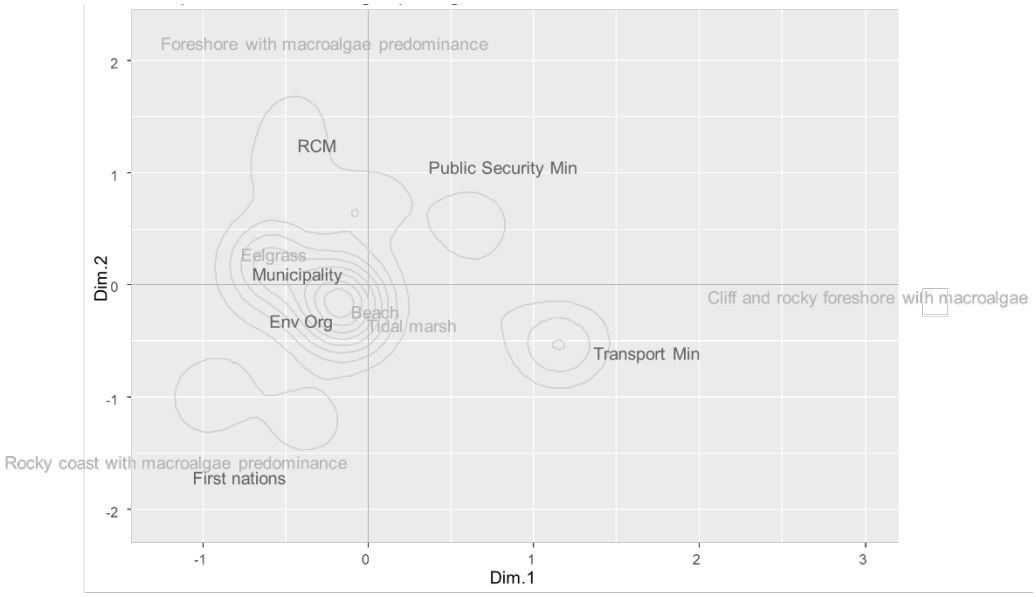

Figure 9: MCA of conservation priorities per institution (all priorities are taken into account, only institutions that account for at least 7% of all participants are represented) (Dim1: 12.85; Dim2: 11.86)

3.6 Roundtable discussions about the values of different categories of ES

Discussion themes concerning coastal ES and the different values assigned to them are reported in Table 3. We present the different ES valued by ES categories within each ecosystem. The results show the arguments used by participants explaining why they value a particular ES in relation to a sphere (social and economic). The ecological sphere was mainly mentioned in relation to habitats for a large variety of species in the case of tidal marshes, for birds (e.g. feeding area for goose or barnacles) and for fish around eelgrass and for birds (murrelet, puffin) and marine mammals concerning cliffs and rocky coast.

Although the roundtables brought some interesting feedback that were facilitated by the distinction made between the three spheres of valuation (ecological, economic, and social), some participants stressed that all three spheres were interrelated and that describing the issue through ecological and economic spheres was not always relevant nor easy to discriminate. Indeed, living close to the St. Lawrence marine system provides to the local population with a "feeling of well-being" and a "sense of belonging and pride" exemplified by "I live in a sort of paradise", "I have salty water in my veins" and "people who leave the North Shore have a sense of lack regarding the river". They tend to express their view of ecosystems from a holistic perspective, referring to a general sense of well-being.

381 *Table 3: Economic (Eco) and social (Soc) values associated with coastal ES according to local stakeholders (specific ES are underlined, ecosystems' type are in brackets and the main arguments*
382 *given by stakeholders are bolded). The quotes reported in this table represent the views of the majority.*

Ecosystem services	Stakeholders' arguments	Value sphere
HABITAT AND SUPPORTING SERVICES		
Habitats (Rearing area)	**Benefitting fisheries** (lobsters fishing is a **very lucrative commercial activity** in Gaspé region) (eelgrass, cliffs and rocky coast) and **watching of marine mammals** (through food networks) but difficulty in assessing its contribution (tidal marshes).	Eco
PROVISIONING SERVICES		
Clam harvesting	Only found on the North Shore as a **commercial activity** (beach).	Eco
Collection of small fruits	Promoted lately but **marginal economic valorization** on Sept-Iles region (beach).	Eco
Striped bass fishing	Supplanting recreational cod and caplin fishing on the South Shore, near beaches and rocky foreshore with macroalgae and valued both **socially and economically** (game fishing usually triggers related expenses contributing to the regional economy).	Eco & Soc
High social value of provisioning ES: "way of life", at the basis of a "sense of belonging" and an important element for "mental health" and thus represent a high social value. A participant on the North Shore mentioned: "you'd better enjoy hunting, fishing and nature when you come here".		Soc
Fishing and shellfish harvesting	<u>Recreational caplin fishing</u>: **strong tradition** especially on the North Shore and important negative impact of caplins reduction on the community. <u>Fishing and shellfish harvesting</u>: **low economic value** but **a high cultural value** (except for commercial activities such as clams harvesting or salmon, cod fishing on the Côte-Nord and lobster on the Gaspésie).	<u>Soc</u>

Hunting	Waterfowl hunting: a **strong traditional recreational activity** practiced by locals that also provide **inter-generational transmission** opportunity and important for **food autonomy** for First Nations (tidal Marsh) Waterfowl and seal hunting also practiced near rocky coast (in Gaspé region) (foreshore with macroalgae)	Soc
Collection of edible seaweed or plants or small fruit	Mainly for **self-consumption** and **a social and a family transmission** activity (tidal marshes, foreshore with macroalgae, rocky coast)	Soc
REGULATING SERVICES		
Coastal protection[14]	**Loss of taxes and local sources of earnings** due to a decrease in residential development, uses and related infrastructure located along the beach. **Increased attractiveness and economic benefits** of properties built near tidal marsh in Gaspé and of secondary house on rocky coast.	Eco
	Negative social impact as it used to be a « dream to own a property by the beach, dream that turned out to be a nightmare ». **Peace of mind** related to this new location for properties "without the burden of knowing that the sea is going to knock at your door" and **decrease in problems linked to mental health** undergone by some coastal populations (tidal marshes and foreshore with macroalgae).	Soc
CULTURAL SERVICES		
Water sports (kayaking, surf and	**Attract economic benefits through tourism** in North and South Shores especially in Gaspésie region, one of the main tourist destinations of Quebec during summer. Most touristic infrastructures are close to the beach.	Eco & Soc

[14] Coastal protection was the regulating ES mainly discussed and was viewed as increasingly degraded in the case of beaches.

paddle board, kite surf)	Linked to wildlife observation, nice visibility and quietness of eelgrass environment. But **difficulties in separating the contribution of eelgrass to site selection** by practitioners as value can also arise from rocky shore nearby. **Less potential** for recreational activities. Diving activities: within macroalgae/kelp beds **practiced by locals** on Sainte-Anne-des-Monts region.	
Wildlife observation	On the North Shore, whale, seal and bird watching constitute a **very important industry**, especially through kayaking and cruise and excursion (rocky coast). This **economic activities** can benefit directly First Nations in Essipit. Seals observation: considered as important in Sainte-Anne-des-Monts region (beach). Bird watching: **Attracting outsiders** and thus can provide some income locally (tidal marshes).	Eco
	Presented as at the core of their **well-being and quality of life** and as a crucial element for **cohesion, exchanges and transmission within the community**. Bird watching especially of endemic species: **Popular activity among locals** practiced individually or within an association (tidal marshes). Marine and avian fauna watching: **Knowledge transmission** for locals especially among First Nations elderly people in Pessamit (rocky coasts).	Soc
Landscape viewing	Attractiveness from both **a social and an economic point of view** (tidal marshes). High **aesthetical value** and one of the **main attractions for tourists** in Gaspé region: "landscape signature" or "ambassadors" of for the Gaspésie region, "key aspect that Gaspésie is renowned for" as it "can't be substitute by other sceneries", "its uniqueness" and "its invaluable character" (cliffs)	Eco & Soc

Gathering, festivity and recreation places	**Highly socially valued by local communities**, **a cultural cement**, a strong element of "sense of belonging" but also a "cultural transmission location" and a source of well-being for families and communities, a key component of their identity (beach).	Soc
Patrimonial site	**Traditional ceremonies** at the beginning of winter for Innus from Pessamit (beach). On the North Shore, archaeological sites and wrecks even mapped are **not very well known by locals** and thus not valued.	Soc
Awareness raising and education	Viewed as an opportunity for eelgrass and existing for tidal marshes (e.g. interpretation centre in Pointe-aux-Outardes).	Soc

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4. Discussion

4.1 Importance of the valuation of coastal ecosystem services by local stakeholders

Creating a shared understanding of the importance of coastal ecosystems is crucial for adaptive governance of coastal resilience. Local communities' knowledge of ES is increasingly being incorporated into scientific literature (See special issue in *Ecosystem Services*: Gasparatos et al., 2019). However, when the time comes to implement conservation and management measures, the importance of local actors is seldom considered (Boyer-Villemaire et al., 2014). The involvement of coastal communities is recognized as crucial for sustainable conservation and management practices (Chan et al., 2019). Approaches to the valuation of ES that consider the multiple and diverse values have been encouraged by scholars and practitioners (Pascual et al., 2017; Chan et al., 2016; TEEB, 2010). But as mentioned by Lau et al. (2019), assessing the importance of coastal ES for coastal communities can be challenging due to (i) the diversity of coastal ES, comprising both terrestrial and marine services across multiple categories (ii) the inappropriateness of monetary valuation techniques to capture culturally specific attributions of value and (iii) the difference in ES values held by people within communities.

In their review of 145 articles assessing marine and coastal ES, Liquete et al. (2013) found that social studies were underrepresented (only 5%) compared to biophysical ones (41%), multidisciplinary approaches (35%), and economic valuations (19%). Assessment of ES is mainly done through surveys and interviews which, as mentioned by Lopes and Videira (2019) lack “the ability to integrate social actors in group discussions regarding the problem definition”. Moreover, in the review of Liquete et al. (2013), it appears that the number of ES assessed in each paper was only one ES in half of the reviewed articles, 39% included between 2 and 5 services, and the remaining 13% assessed 6 or more ES. Building on initial scoping of ES with local population, we have proposed here a social assessment of 70 ES on average through a participatory approach among local stakeholders, highlighting their diversity and the multiple associated values. We interrogated social capacity of coastal stakeholders to respond to environmental change through co-production of knowledge. Supporting shared visions and fostering effective participation and deliberation during the workshops can in turn contribute to social learning. We brought new factual knowledge through the use of ES concept to emphasize their interconnections with ecosystems. We also gathered their preferences in terms of ES and we interrogated their value systems in order to better understand the rationale and meaning behind the assessment.

4.2 The contribution of coastal ES to coastal populations’ well-being

To discuss the results of our study, we here rely on Chan et al.'s (2019) triangle framework, which links ES to three dimensions of well-being. Indeed, throughout the workshops, participants expressed their

view of ecosystems from a holistic perspective, referring in several instances to a general sense of well-being. The acknowledgement of common understanding of well-being arising from coastal habitats can be considered as an outcome of the participatory process. The three dimensions of social well-being mentioned in Chan et al.'s triangle rely on the following declination of White (2009):

- Material wellbeing expressed in tangible terms (e.g., physical resources, financial resources, assets, shelter);
- Relational wellbeing (e.g. social relations, access to public goods, personal relationships, and attitudes in life);
- Subjective wellbeing depicted in intangible terms including individual perceptions (e.g., of material, social, and human position), cultural values (e.g., ideologies, beliefs), aspirations, and happiness.

In the triangle framework of Chan et al. (2019), provisioning ES is at the basis of material wellbeing (one of the triangle summits) and cultural ES being at the centre of the lower foundation of the triangle formed by intangible social dimensions: subjective wellbeing and relational wellbeing. Supporting and regulating ES are crucial for the delivery of most other services. Among the ES gathering 80 % of the votes, cultural ones constituted 38% of the votes, supporting ES 25%, and regulating and provisioning around 18%.

Our study shows that participants had a good understanding of the links between habitat and supporting services and the other ES categories and thus highly valued habitat and supporting ES. Indeed, they mentioned that their protection was crucial for the provision of other ES: "without it, everything will disappear", "if you protect the foundation, other activities will be protected", "ecological value is the foundation of other values, as it offers a lot of activities and thus social and economic values". Participants suggested better quantifying the contribution of these habitats to provisioning services (fisheries and hunting stocks), cultural services (wildlife and plants' observation) by proposing an economic value derived from these ES. Discussions around regulating services focused mainly on coastal protection. To assess this ES, in addition to the importance of economic values (e.g. avoided costs), they insisted on social benefits such as ensuring peace of mind and good mental health.

Participants valued cultural ES highly as they are part of their culture, providing opportunities for social interaction and transmission within families and communities (associated with relational well-being) and ensuring well-being, mental and physical health to coastal populations (related to subjective well-being). We can link these findings to a consideration made by some First Nations' members who explained that according to Innus the value derives from the good and from the potential for cultural transmission brought by something and not from economic value. Landscape was mentioned as an important feature, associated with coastal ecosystems providing aesthetical, spiritual and meditational experience, explaining the attractiveness of the coastline for locals and tourists, a location where they live and practice diverse activities. Some people also referred to the well-being stemming from the fact they

know the ecosystem exist, the existence value. Stakeholders mentioned that the value of cultural services arose from the diversity of available recreational activities and thus assessing the value of a single activity was not relevant. For instance, tourists are attracted by a bundle of activities and evaluating the contribution of one cultural activity to the overall attractiveness of the region would be difficult.

In the triangle framework of Chan et al. (2019), provisioning ES is associated with material, relational and subjective well-being, which was also observed in our study. Economic value as related to provisioning ES remains rather marginal, except for First Nations who rely on them for their livelihood and their food autonomy. Nevertheless, their social value was widely recognized among participants, as these ES are part of coastal culture and important for their mental health, providing gathering, exchanges and transmission opportunities. It is quite similar to what was mentioned by Lau et al. (2019) where cultural ES tended to be ranked and rated lower that direct provisioning services in part because provisioning ES contribute to cultural values like bequest.

4.3 The crucial role of cultural ES and the complexity of their definition

Our study shows that provisioning, cultural and even regulating ES could all provide similar types of value with intangible and non-material dimensions. This challenges the common definition of ES that refers to material (for provisioning, regulating and supporting ES) and non-material values (for cultural ES). This category of so-called cultural ES that aims at integrating immaterial aspects of valuation, other than the one that can be biophysically or economically measured is challenging (Pröpper and Haupts, 2014; Small et al., 2017). In order to overcome this problem, we refer to Chan et al. (2012a) who proposed to distinguish between services, benefits, and values. They define cultural ES "inclusively as ecosystems' contributions to the non-material benefits (e.g., capabilities and experiences) that arise from human-ecosystem relationships" which thus overlaps with other categories of ES as defined in MEA (2005) and may lead to an issue of double-counting only if these four master categories are used for accounting purposes. This approach allows for a better characterization of cultural ES, which goes beyond ecosystem-based recreation and landscape scenic beauty, which have been mostly well-captured in economic valuation (Chan et al., 2012b). One of the most highly valued ES in our study, water activities, could have been categorized in terms of economic valuation as it is easily identified and widely distributed in all types of coastal ecosystems and whose economic benefits are easily assessed. Nevertheless, cultural ES associated with spiritual values, cultural identity, social cohesion, and heritage values were often rendered invisible in management and conservation plans. Cultural services receive the most focus from stakeholders, despite the challenges associated with valuing and managing them (Klain et al., 2014). Intangible and non-material dimensions of ES can matter to people more than the material benefit deriving from ES but have been rendered invisible in most ES management. This is the case of provisioning ES in our study.

Indeed, stakeholders seem to value the way of life linked to fishing, shellfish and small fruit harvesting or waterfowl hunting more than ES linked to food provisioning. This has been very well demonstrated in the article of Chan et al. (2012b) through an example related to First Nations' communities, where fishing was proved to provide knowledge and cultural identity. This could apply equally to other coastal communities. Monetary valuations of market goods associated with the provision of fish would likely fail to capture this: "ecosystems produce benefits through services, and those benefits matter to people and decision-making in many ways insufficiently represented by monetary valuation" (Chan et al., 2012a). Our approach allows for a better understanding of the diversity of values in question. During the roundtable discussions, participants acknowledged the strong link between their way of life and their surrounding natural environment. As mentioned by Reed et al. (2010), changes in understanding that go beyond the individual and occur through social interactions is one of the essential outcomes of social learning. These results highlight the importance of investigating social perceptions of ES to complement ecological and economic approaches to assess the value of ES. We thus accessed different types of knowledge and understanding linked to coastal habitats.

4.4 Linking ES and ecosystem valuation to inform conservation measures

Analyzing the results of ES valuation and conservation priorities' selection can give insights on the interest of using ES approach for better ecosystem management. Indeed, in a perspective of promoting adaptive governance, links between biodiversity and human well-being should be made more visible (Schultz et al., 2015; Haines-Young & Potschin, 2010). Although participants valued ES provided by less well-known ecosystems such as eelgrass and foreshores with macroalgae (which are less noticeable since they are underwater), they had some difficulties understanding the link between those ecosystems and their uses. Most popular ES are associated with eelgrass (29%), tidal marsh (28%) and then beach (20%). Although the number of ES linked to tidal marsh and eelgrass is lower (between 12 and 15 ES) compared to other coastal ecosystems, their associated value seems more important. We observed that in addition to the acknowledged habitat/supporting and regulating ES provided by eelgrass and tidal marsh (Röhr et al., 2018; Lamb et al., 2017; Duarte et al., 2013; Barbier et al., 2011), these ecosystems were important locations for hunting, fishing, shellfish and plants harvesting, plant and bird observation, and water activities. Tidal marsh and eelgrass tend to provide similar ES.

Though the presentation of the different ecosystems, ES, and subsequent discussion led to important results, there were also some limits to the exercise. Valuing the ES does not necessarily mean valuing the associated ecosystems. Indeed, although the most popular ES were mainly eelgrass and tidal marshes, people prioritized beaches for conservation before tidal marshes and eelgrass. Beach ecosystems have the smallest surface area of coastal ecosystems discussed in the exercise while the number

of their associated ES is the greatest (from 23 to 43 according to the region), followed by rocky foreshore with macroalgae predominance from 12 to 36 ES. For beaches and rocky foreshores, cultural and provisioning ES are very numerous (20 ES on average). The difference between prioritized ES and ecosystems could be explained by the fact that some dimensions of well-being had stronger weight than others (e.g. relational well-being associated with cultural ES in comparison to material well-being linked to provisioning ES) and thus participants may have valued the ecosystem they experience the most and which they could easily picture. Moreover, on both North and South Shores of the St. Lawrence River, people acknowledged the fact that beaches face increasing pressure such as from four wheeled vehicles and wild camping since they are one of the main attractions for tourism. Stakeholders' engagement initiatives that only focus on ES may be ineffective to protect the related ecosystems. There is a need for more awareness raising of their interrelations with coastal habitats and the necessity to engage in long-lasting processes of knowledge exchange. This could be undertaken through thematic projects on subjects of interest for coastal communities. For instance, *Résilience côtière* project brought light to the importance of some habitats for erosion minimization.

The findings show that ecosystem conservation depends strongly on maintaining community ties to ecosystems and ensuring a sustainable use and access to these resources. As Chan et al. (2019) note, "while coastal areas provide important provisioning ES for material wellbeing (e.g., fish as food and an economic resource), these areas also support linked intangible cultural benefits associated with relational and subjective wellbeing (e.g., cultural heritage, spiritual values)". Thus, maintaining these activities is also crucial for conservation purposes. Many participants deplored the drastic decrease in accessible shellfish beds. Indeed, following an absence of sufficient funding for Fisheries Ocean Canada ministry to conduct regular monitoring, precautionary closures of several beds were implemented and thus these activities substantially decreased on the south shore of St. Lawrence. This could have a detrimental impact on the importance of individual and/or shared values of "place" associated with some coastal habitats. This decrease of links with coastal and marine resources is also illustrated by the shift of coastal economies mainly based on marine resources towards a more diversified tourism industry. Indeed, since the collapse of ground fish stocks in early 1990s, the landed volume, or total catch related to these species, has shrunk by half. Currently shrimps, snow crabs and lobsters represent 90% of landing value (MAPAQ, 2018). In Gaspésie-Îles-de-la-Madeleine, 30% to 50% of employment associated with fisheries were lost following the ground fish crisis (Hardy et al., 2008).

In order to inform decision-making regarding conservation and erosion management, it is also important to take into account institutional preferences. Conservation initiatives should integrate the diversity of stakeholders' perceptions to better match actions and communications to specific publics. The aggregation of ES valuation may obscure the interests of different groups within a society or community (Lau et al., 2019). Preferences can vary according to how people use, value, and access ES based on socio-

economic identities like gender, class, and ethnicity (Daw et al., 2011) but also according to their institutional affiliation, whose objectives are described by their mandates and responsibilities towards relevant regulations. Although further studies would be required as some institutions were under-represented in workshops, some interesting trends can be drawn from our study. Members of municipalities and environmental organizations have similar preferences, both valuing supporting and cultural ES. It seems that members of environmental organizations are well anchored in their territories and in close relationship with local municipalities. Municipalities have a tendency to value provisioning ES. The ministry of public security and Regional County Municipalities (RCM) also have common preferences. Concerning First Nations' members, who participated in the North Shore workshops, their preferences differ from other actors in two ways. First, they are the only ones who prioritize the provisioning ES, associated mainly with barnacles, goose and waterfowl hunting, and clam harvesting. Muskrat trapping in coastal marshes was also mentioned. First Nations have a strong connection with nature and their environment, which arises in part from their sources of subsistence, but also from cultural reasons (collection of medicinal plants in the marshes), and spiritual and belief systems (Bernatchez et al., 2012). Second, they are the only ones to have a strong preference for rocky coasts with predominantly tidal flats with macroalgae as a conservation priority. This type of coastal ecosystem has a high biodiversity, biomass, and productivity since it consists of large sandy flats with important shellfish beds, in addition to many boulders where macroalgae grow. They are therefore important areas for birds and fish, and suitable for traditional First Nations' provisioning activities. These differences should be kept in mind when designing conservation actions targeting a specific audience.

4.5 Improving knowledge and learning dimensions of social capacity for better erosion management

These different results help pave the way for adaptive governance of coastal erosion management, moving away from a traditional economic-social-engineering perspective and mainstreaming the role of coastal ES in coastal erosion management. Indeed, coastal protection provided by coastal ecosystems appears as highly valued in all four territories. This result can be explained by the fact that coastal communities strongly experience the impacts of coastal erosion on their territories (Bernatchez et al., 2015) and was further highlighted in the project *Résilience côtière*, which involved workshops in 2018 that raised awareness on the subject. To efficiently deliver this regulating ES, ecosystems need to display good health. Indeed, extensive literature acknowledges the key role played by some coastal ecosystems in protecting coastal populations and infrastructures from erosion and coastal submersion such as tidal marshes, mangroves, beaches, rocky foreshores and coral reef (Gedan et al., 2010; Arkema et al., 2013; Brisson et al., 2014). As mentioned earlier, in Quebec as well as elsewhere, coastal ecosystems are threatened by climate change (Carr et al., 2012; Harley et al., 2006) and human perturbations

(Cloern et al., 2016) through their degradation and their surface reduction (Smale, 2019; Waycott et al., 2009; Orth et al., 2006; MEA. 2005). Although some participants mentioned an increase in eelgrass surface area, worldwide trends still show decreases (Waycott et al., 2009; Orth et al., 2006). Tidal marshes are also eroding in the St. Lawrence estuary (Bernatchez et Dubois, 2004; Allard et al., 2012; Dionne, 1986). Paradoxically, most measures implemented to protect populations and infrastructures from coastal erosion involve hard protection infrastructure, which reduce beach width and alter their capacity of natural protection (Bernatchez and Fraser, 2012; Cooper et al., 2020). Moreover, within the design phase of coastal management infrastructure, coastal ecosystems are often considered as constrains by engineering consulting firms, as engineering works must involve Environmental Impact Assessments (Sauvé et al., 2020). The acknowledgement by local stakeholders of coastal ecosystems as a means of protection against coastal hazards during the workshops interrogates these assumptions and encourages paradigm shifts toward acknowledging the benefits that coastal ecosystems can bring in economic, social and environmental spheres (Barbier et al., 2011; Arkema et al., 2013), instead of relying only on hard defense structures (Osorio-Cano et al., 2019). For instance, beach nourishment as a means of restoring regulating service has been undertaken in a few locations (e.g. Cap-des-Rosiers in Forillon national park, Percé beach, bay of Sept-Îles). In the context of sea level rise, an analysis of the distance between the superior limit of soft-bottom coastal ecosystems in maritime Quebec and the inland physical constraints indicates that 43% of these ecosystems have a migration potential lower than 5 m and that 52% of these constrains are anthropogenic barriers (Bernatchez and Quintin, 2016). Roundtables during our study highlighted a new trend in residential development, where the borders of tidal marshes become more and more attractive as these ecosystems are recognized to reduce wave energy during storm events and submersion while providing a wide range of other ES to citizens. In order to maintain their natural regulating ES in a context of sea level rise, tidal marshes and other ecosystems require accommodation space to migrate (Pontee, 2013; Doody, 2013; Linhoss et al., 2015). Thus, management and conservation measures should not only target these coastal ecosystems but also ensure a buffer zone around them in order to limit coastal squeeze. The importance of coastal ES for local stakeholders shows opportunities to improve the social dimension of adaptive governance, in particular regarding erosion management.

5. Conclusion

Our research offers insights into the potential for increasing knowledge and learning in relation to social capacity to adaptive coastal management in a context of climate change, illustrated by a case study in maritime Quebec. Using the ecosystem services framework, we provided a first evaluation of local stakeholders' perceptions of coastal habitats in Quebec. We demonstrated the importance of a social approach for coastal ES valuation, in particular in addressing the complex question of cultural ES. The

importance of cultural identity and individual and/or shared values of "place" proved to be an important driver of the attachment of stakeholders to coastal habitats. The well-developed understanding of coastal ES from coastal stakeholders and the diverse values they assign to them constitutes an opportunity to both inform conservation measures and to move away from traditional economic-social-engineering perspective to coastal erosion. A socio-ecological lens can build on increasing knowledge, and increasing the capacity for learning and practical experience for local decision-makers. Nevertheless, fostering resilience of coastal populations through integrating coastal ecosystems will require long-lasting processes creating appropriate conditions for improved social learning. Although action research such as our own, based on multi-disciplinary exchanges through the *Résilience côtière* project, has the capacity initiate such changes, adaptive governance of complex social-ecological systems will need to be supported by flexible institutions and multilevel governance systems.

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884

885 Supplementary material

886

887 **Annex 1: Ecosystem services per ecosystem for each workshop**

		Sandy beach	**Tidal marsh**	**Eelgrass**	**Rocky coast with macroalgae predominance**
Baie-Comeau	**Habitats and support**	Caplin spawning area Feeding area Nesting area Resting area Seal resting area	Feeding area Nesting area Threatened fauna species Wildlife habitat	Rearing area Feeding area Wildlife habitat	Feeding area Heronry Nesting area Water birds concentration area Wildlife habitat
	Provisioning	Caplin fishing Clam harvesting Cod fishing Non-living plant harvesting Sea trout fishing Seal hunting Small fruit harvesting Smelt fishing	Edible plant harvesting Goose or barnacle hunting Trapping Waterfowl hunting	Goose ~~or barnacle~~ hunting Seaweed harvesting	Clam harvesting Cod fishing Sea trout fishing Seal hunting Seaweed harvesting Small fruit harvesting Waterfowl hunting Whelk harvesting
	Regulating	Coastal protection Water purification	Carbon sink Coastal protection Water purification	Carbon sink Water purification	Coastal protection
	Cultural	Bathing Bird watching Bonfire	Bird watching Hiking Research and education	Bird watching Diving and free diving Osprey watching	Diving and free diving Hiking Marine and avian fauna watching

		Fat bikes Gathering and festivity place Hiking Motorized activities Other water activities Recreation Seal watching Wreck observation		Other water activities Research and education	Other water activities Research and education Wreck observation
Sept-Iles		**Sandy beach**	**Tidal marsh**	**Eelgrass**	**Rocky coast with macroalgae predominance**
	Habitats and support	Caplin spawning area Feeding area Nesting area Threatened fauna species Water birds concentration area	Feeding area Nesting area Rearing area Threatened fauna species Wildlife habitat	Feeding area Other water activities Rearing area Water birds concentration area Wildlife habitat	Bird colony on cliff Bird colony on islet Feeding area Heronry Nesting area Threatened fauna species Threatened plant species Water birds concentration area
	Provisioning	Caplin fishing Clam harvesting Deer hunting Edible plant harvesting Goose or barnacle hunting Mackerel fishing Salmon fishing Sea trout fishing Seal hunting Shellfish harvesting Small fruit harvesting Smelt fishing Waterfowl hunting	Goose or barnacle hunting Plant harvesting Waterfowl hunting	Goose or barnacle hunting Mussel harvesting Seaweed harvesting Waterfowl hunting	Cod fishing Goose or barnacle hunting Mackerel fishing Mussel harvesting Plant harvesting Sea trout fishing Seal hunting Seaweed harvesting Small fruit harvesting Waterfowl hunting Whelk harvesting
	Regulating	Coastal protection Water purification	Carbon sink Coastal protection Water purification	Carbon sink Water purification	Coastal protection
	Cultural	Archeological site Bannock-making Bathing Beach games Bonfire Camping	Bird watching Hiking Plant observation Research and education	Bird watching Research and education	Archaeological site Climbing Cross-country skiing Cruise and excursion Diving and free diving Heritage site

		Cross-country skiing Fat bike Gathering and festivity place Heritage site High socio-cultural value site Hiking Motorized activities Other water activities Recreation Snowmobile Snowshoeing Wreck observation			High socio-cultural value site Hiking Marine and avian fauna watching Other water activities Snowmobile Snowshoeing Wreck observation
Sainte-Anne-des-Monts		**Gravel and sandy beach**	**Tidal marsh**	**Eelgrass**	**Foreshore with macroalgae predominance**
	Habitats and support	Caplin spawning area Feeding area Nesting area Resting area	Feeding area Threatened fauna species Wildlife habitat	Feeding area Rearing area Wildlife habitat	Feeding area Wildlife habitat
	Provisioning	Caplin fishing Clam harvesting Cod fishing Edible plant harvesting Non-living plant harvesting Sea trout fishing Striped bass fishing	Edible plant harvesting Waterfowl hunting	Seaweed harvesting Striped bass fishing Waterfowl hunting	Mussel harvesting Seaweed harvesting Striped bass fishing Waterfowl hunting
	Regulating	Coastal protection Water purification	Carbon sink Coastal protection Water purification	Carbon sink Water purification	Coastal protection
	Cultural	Bathing Beach games Bonfire Gathering and festivity places Hiking Landscape viewing Motorized activities Other water activities Recreation	Bird watching Other water activities Research and education Trapping	Bird watching Diving and free diving Other water activities Research and education	Diving and free diving Marine and avian fauna watching Other water activities Research and education
Gaspé		**Gravel and sandy beach**	**Tidal marsh**	**Eelgrass**	**Cliff and rocky coast with macroalgae predominance**
	Habi-tats	Caplin spawning area Feeding area	Feeding area Nesting area	Feeding area Rearing area	Bird colony on cliff Bird colony on islet

	Nesting area Resting area Threatened plant species Water birds concentration area	Rearing area Threatened fauna species Wildlife habitat	Water birds concentration area Wildlife habitat	Feeding area Nesting area Seal resting area Threatened fauna species Threatened plant species Water birds concentration area
Provisioning	Clam harvesting Mackerel fishing Sea trout fishing Shellfish harvesting Striped bass fishing	Goose or barnacle hunting Waterfowl hunting	Bird watching Goose or barnacle hunting Striped bass fishing Waterfowl hunting	Mackerel fishing Mussel harvesting Seaweed harvesting Semi-precious stones harvesting Shellfish harvesting Whelk harvesting
Regulating	Coastal protection Water purification	Carbon sink Coastal protection Water purification	Carbon sink Water purification	Coastal protection
Cultural	Archeological site Bathing Beach games Bird watching Bonfire Diving and free diving Fat bikes Gathering and festivity place High socio-cultural value site Hiking Other water activities Recreation Wreck observation	Bird watching Hiking Plant observation Research and education	Diving and free diving Other water activities Research and education	Cruise and excursion Diving and free diving High socio-cultural value site Hiking Marine and avian fauna watching Other water activities Recreation Wreck observation

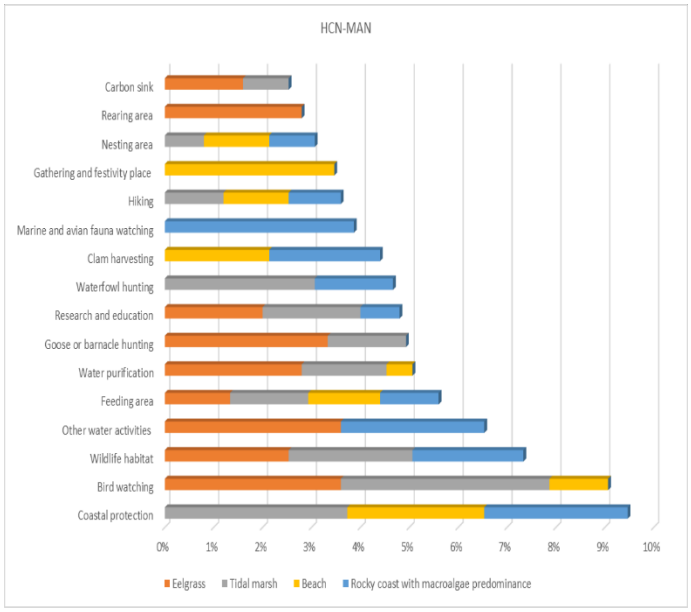
Annex 2: Results at the regional scales

1. The most popular ES by type of ecosystems

We analysed the results by territories. First we were interested in the most popular ES and their associated ecosystems.

Baie-Comeau workshop

The most popular ES were mostly encountered in eelgrass and tidal marshes (29%) and in rocky coasts (24%). The six most important ES were coastal protection, bird watching, wildlife habitat, other water activities, feeding area, and water purification (Figure 10). Compared to other regions, clam harvesting seemed to be particularly valued.



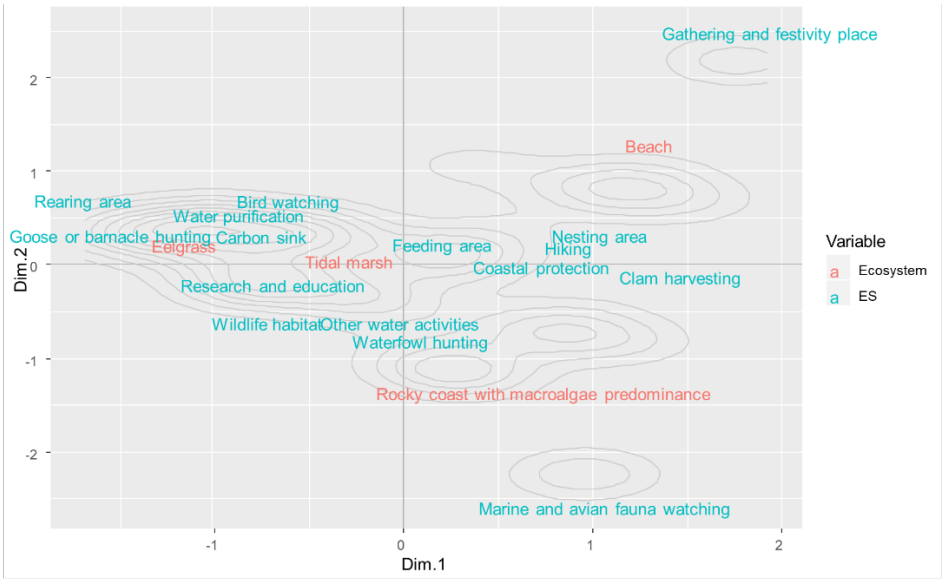
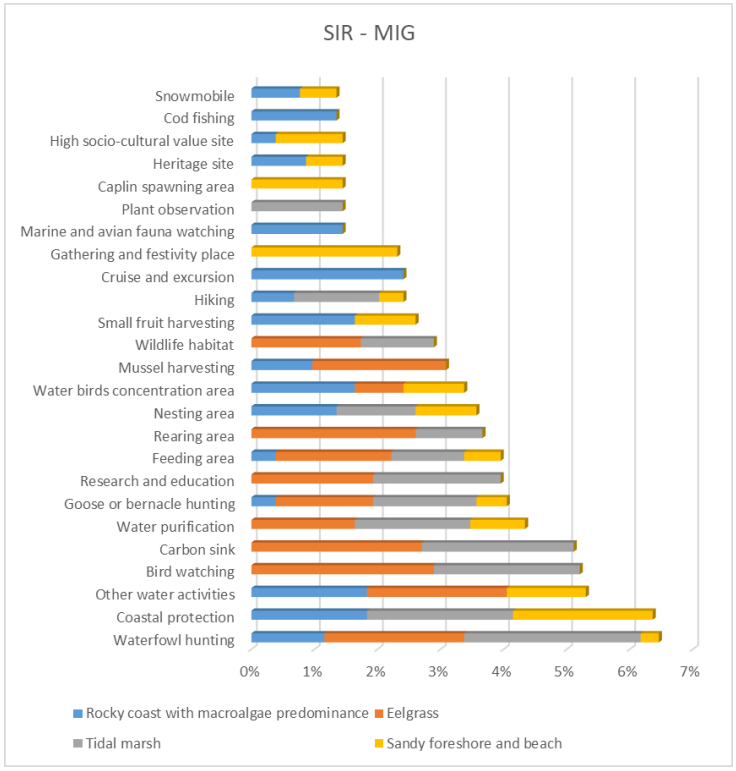


Figure 10: The most valued ES and their associated ecosystems in the Baie-Comeau region (top: pivot table results; bottom: MCA analysis Dim 1: 9.34; Dim 2: 8.44)

Sept-Iles workshop

The most popular ES were found in eelgrass (30%), tidal marshes (28%) and rocky coasts (24%) (Figure 11). The six most important ES were waterfowl hunting, coastal protection, other water activities, bird watching, carbon sink, and water purification. In this region, water birds concentration area, mussel harvesting, small fruit harvesting, plant observation, high socio-cultural value site, heritage site, cod fishing, and snowmobile were valued in particular. Goose or barnacle hunting was more specific to the North Shore than the South Shore of the Saint-Lawrence River. Caplin spawning areas and cruise and excursion were shared with the Gaspé region.



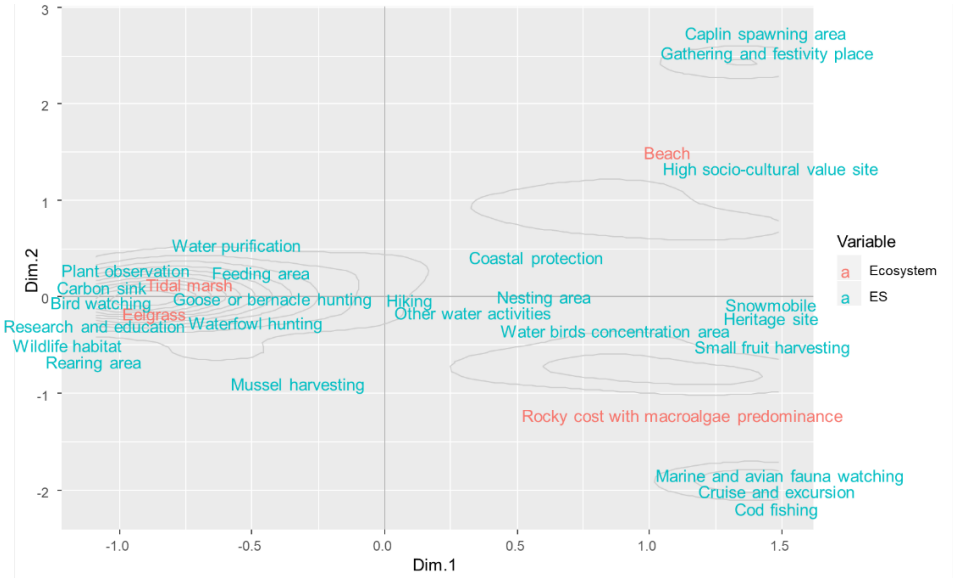
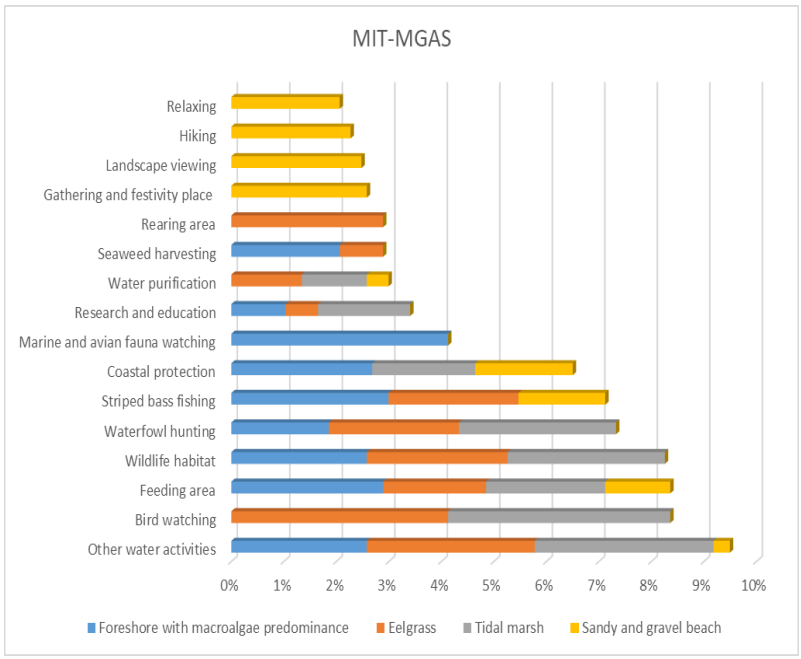


Figure 11: The most valued ES and their associated ecosystems in the Sept-Iles region (top: pivot table results; bottom: MCA analysis Dim 1: 6.46; Dim 2: 5.89)

Saint-Anne-des-Monts workshop

The most valued ES were observed in eelgrass and foreshores with macroalgae (around 28%) and tidal marshes (26%). The six most popular ES were other water activities, bird watching, feeding area, wildlife habitat, waterfowl hunting and striped bass fishing. The ES most particular to this region were landscape viewing, relaxing, seaweed harvesting. Even if coastal protection gathered the same amount of votes in percentage, it ranks less than in other regions.



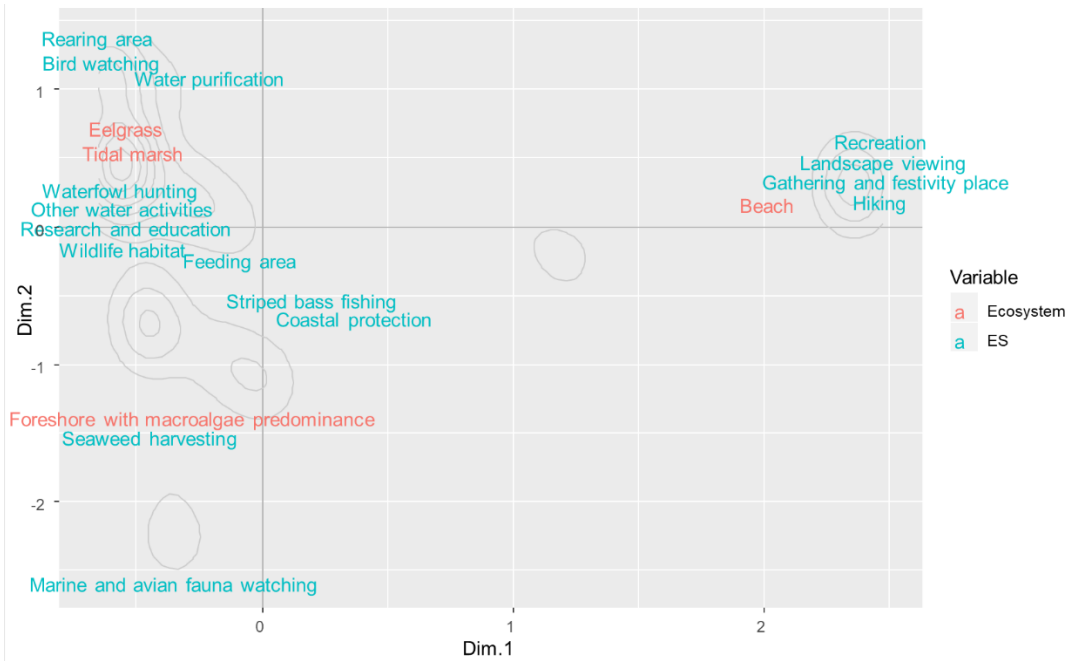
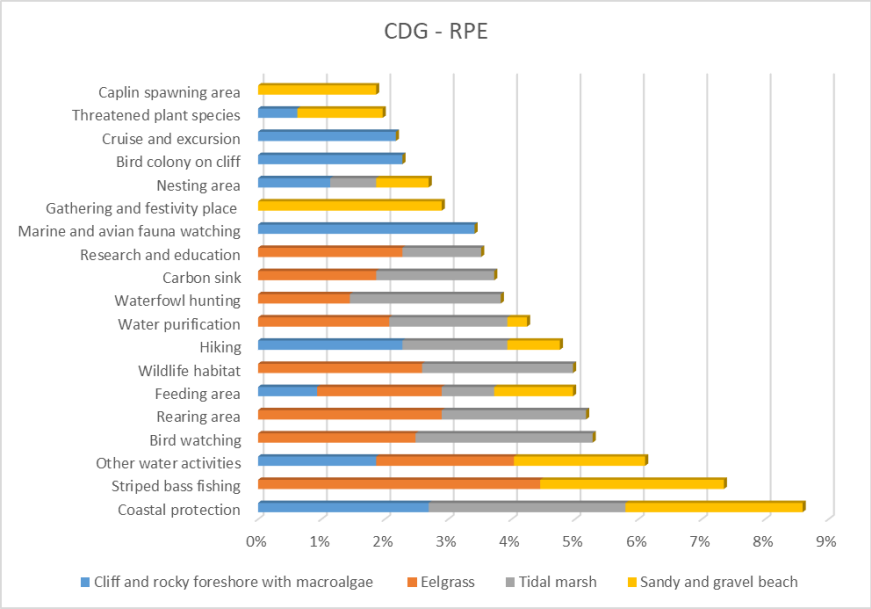
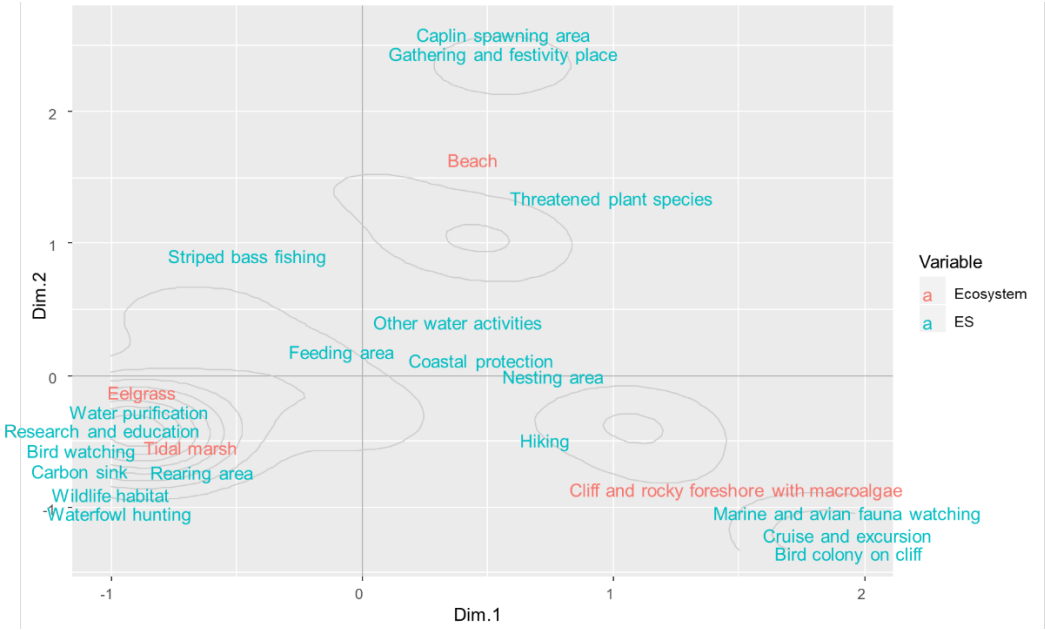


Figure 12: The most valued ES and their associated ecosystems in the Sainte-Anne-des-Monts region (top: pivot table results; bottom: MCA analysis Dim 1: 10.09; Dim 2: 7.42)

Gaspé workshop

The most valued ES were eelgrass (30%) and tidal marshes (26%) (Figure 13). The ES considered crucial were coastal protection, striped bass fishing, other water activities, bird watching, and rearing area. The ES most specific to this region were bird colonies on cliffs and threatened plant species. Striped bass fishing was encountered more on the South Shore of the Saint-Lawrence than on the North Shore.





938

939 *Figure 13: The most valued ES and their associated ecosystems in Gaspé region (top: pivot table results; bottom: MCA anal-*
940 *ysis Dim 1: 8.47; Dim 2: 7.78)*

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945 **2. The most popular ES and their associated sphere**

946

947 This section describes the sphere (ecological, economic or social) that participants associated with the
948 ES they value.

949 **Baie-Comeau workshop**

950 Among the six more popular ES, the ecological (45%) and economic spheres (34%) were valued more
951 (Figure 14). Wildlife habitat, feeding, nesting and rearing areas were considered to be of ecological
952 importance. Economic value contributes to 50% of other water activities, bird watching and coastal
953 protection value. Some activities were considered to be highly social: goose and barnacle hunting, re-
954 search and education, waterfowl hunting, clam harvesting, hiking and gathering and festivity place
955 (more than 60% of its value). Interestingly, provisioning services were valued more in social terms than
956 in economic ones.

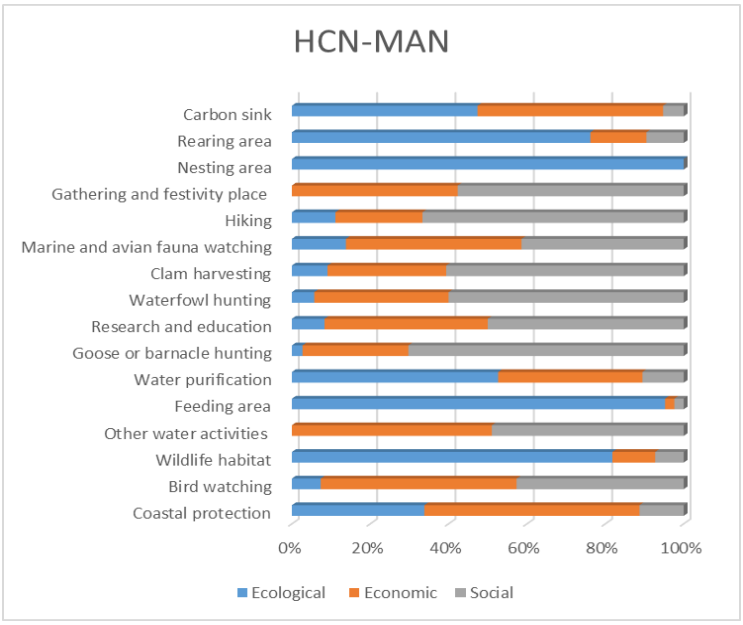
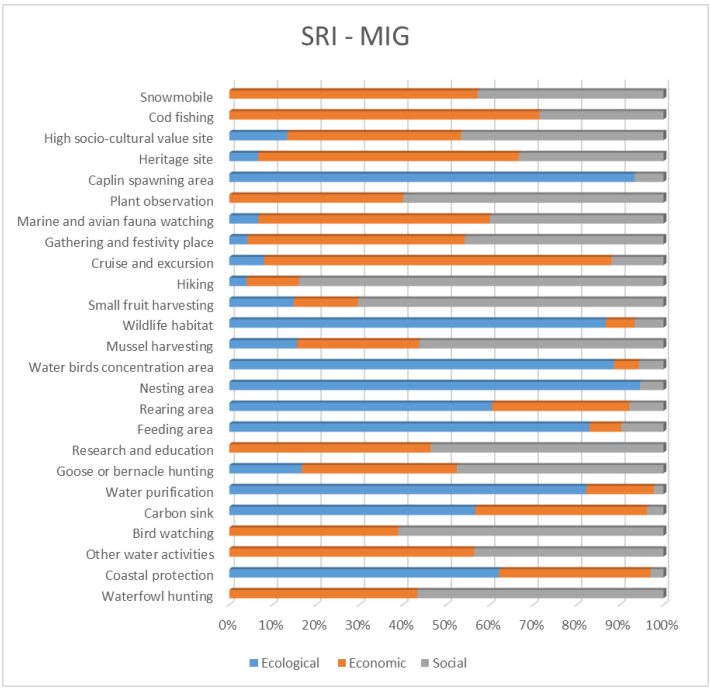


Figure 14: The most valued ES and their associated spheres in the Baie-Comeau region (top: pivot table results; bottom: MCA analysis Dim 1: 10.21; Dim 2: 7.56)

Sept-Iles workshop

Among the six more popular ES, the economic (38%) and ecological spheres (33%) were valued more. Plant observation, small fruit harvesting, hiking and bird watching had 60% of their value linked to the social sphere. Coastal protection, water purification, feeding, rearing and nesting areas, water birds concentration area, wildlife habitat, and caplin spawning area had more than 60% of their value linked to the ecological sphere. Cruise and excursion, heritage site and cod fishing had more than 60% of their value related to the economic sphere. Although waterfowl hunting, other water activities, bird watching, research and education, cod fishing and snowmobiles are important for the regional economy, they are also crucial for building social links within communities.



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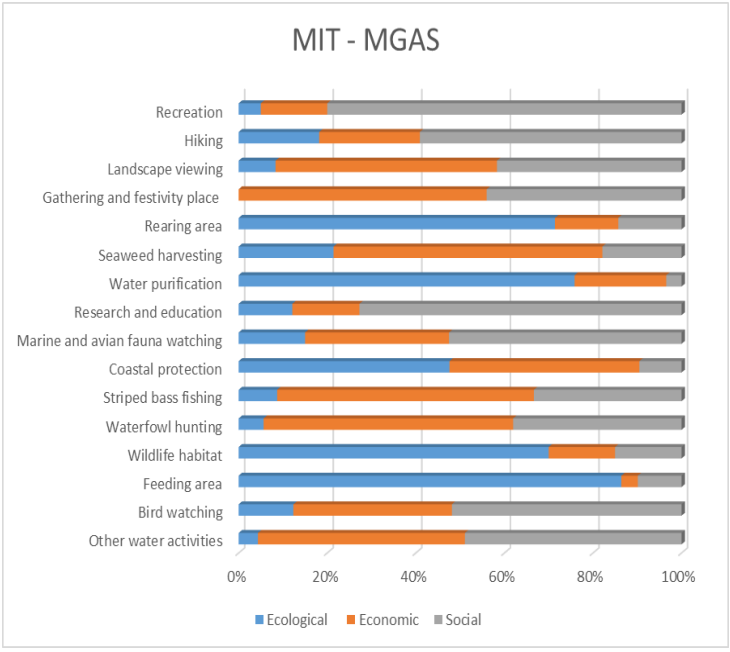
973 *Figure 15: The most valued ES and their associated spheres in the Sept-Iles region (top: pivot table results; bottom: MCA*
974 *analysis Dim 1: 6.80; Dim 2: 5.08)*

975

976 **Sainte-Anne-des-Monts workshop**

977 Among the six more popular ES, the economic (36%) and social spheres (33%) were valued more
978 (Figure 16). Feeding areas and wildlife habitats, water purification, and rearing areas had more than
979 70% of their value linked to the ecological sphere. Waterfowl hunting, striped bass fishing, seaweed
980 harvesting and gathering and festivity places had more than 50% of their value associated with the

economic sphere. Bird watching, marine and avian fauna watching, research and education, hiking, and recreation had more than 50% of their value related to the social sphere.



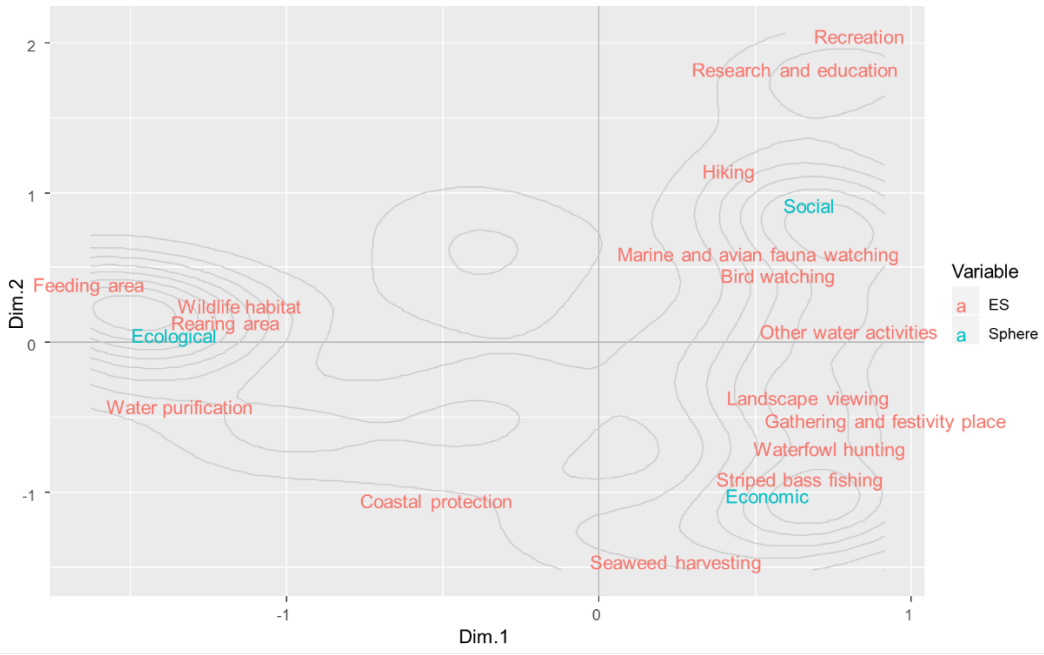


Figure 16: The most valued ES and their associated spheres in the Sainte-Anne-des-Monts region (top: pivot table results; bottom: MCA analysis Dim 1: 9.79; Dim 2: 7.60)

Gaspé workshop

Among the six more popular ES, the economic (39%) and ecological spheres (33%) were more valued (Figure 17). Rearing area, feeding area, wildlife habitat, nesting area, bird colony on cliff, threatened plant species, and caplin spawning area had more than 60% of their value associated with the ecological sphere. Coastal protection and cruise and excursion had 60% of their value linked to economic value. Bird watching, hiking, and research and education had more than 60% of their value related to the social sphere.

Figure 17: The most valued ES and their associated spheres in the Gaspé region (top: pivot table results; bottom: MCA analysis Dim 1: 8.82; Dim 2: 6.83)

3.2.1 An ecosystem perspective of the most popular ES and their associated spheres

Thirdly, for each ecosystem, we selected the six most popular ES and their associated spheres.

Baie-Comeau workshop

For eelgrass, the three spheres of value were quite balanced, with a slightly higher weight in the ecological and social spheres (37 and 33%) (Figure 18). For tidal marsh, economic value prevailed, with 41%, then followed by social (33%). For beach ecosystems, 37% was linked to ecological value, and 34% to economic. For rocky coasts, ecological prevailed with 40%, followed by social with 31%.

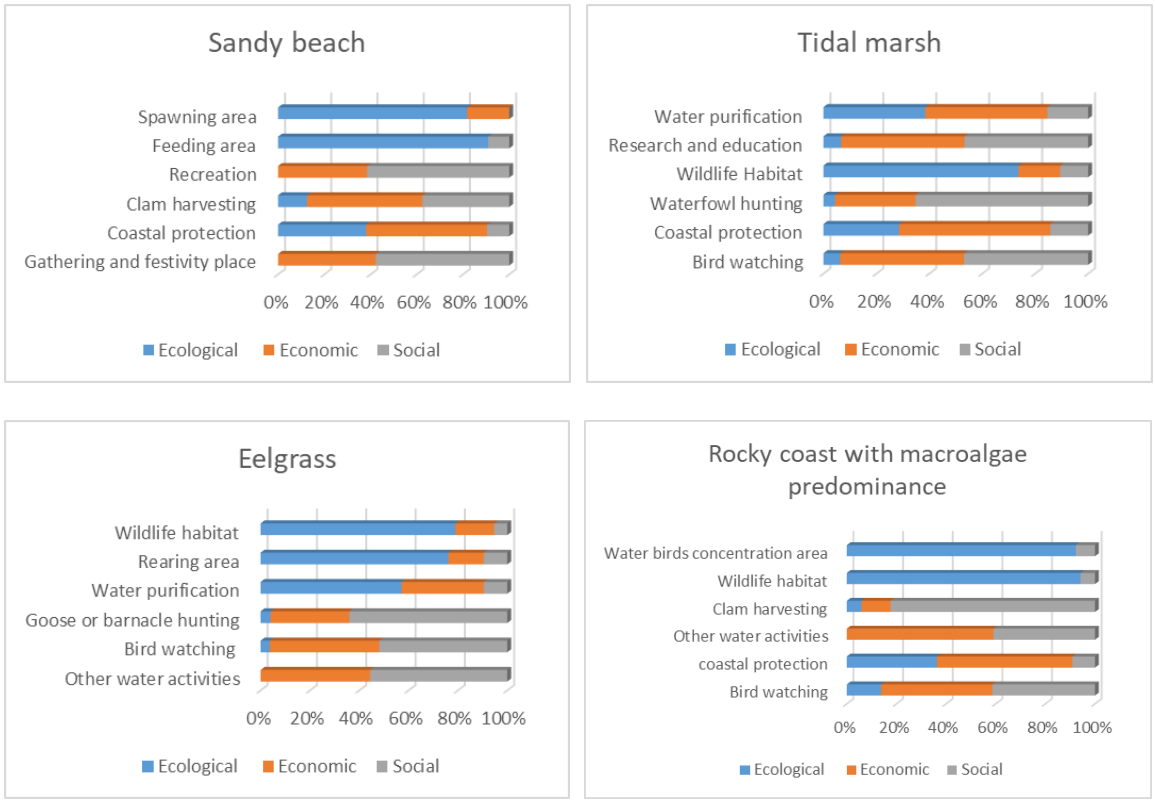


Figure 18: The most valued ES by ecosystems' type and their associated spheres in the Baie-Comeau region

Sept-Iles workshop

For eelgrass, economic and social values prevailed (40 and 37%) (Figure 19). Rocky coast was more linked to economic and social (37 and 33%). For tidal marsh, economic values (37%) were more represented than ecological/social (around 31%). Beaches were recognized for their economic value with 44%, and then for their ecological value with 31%.

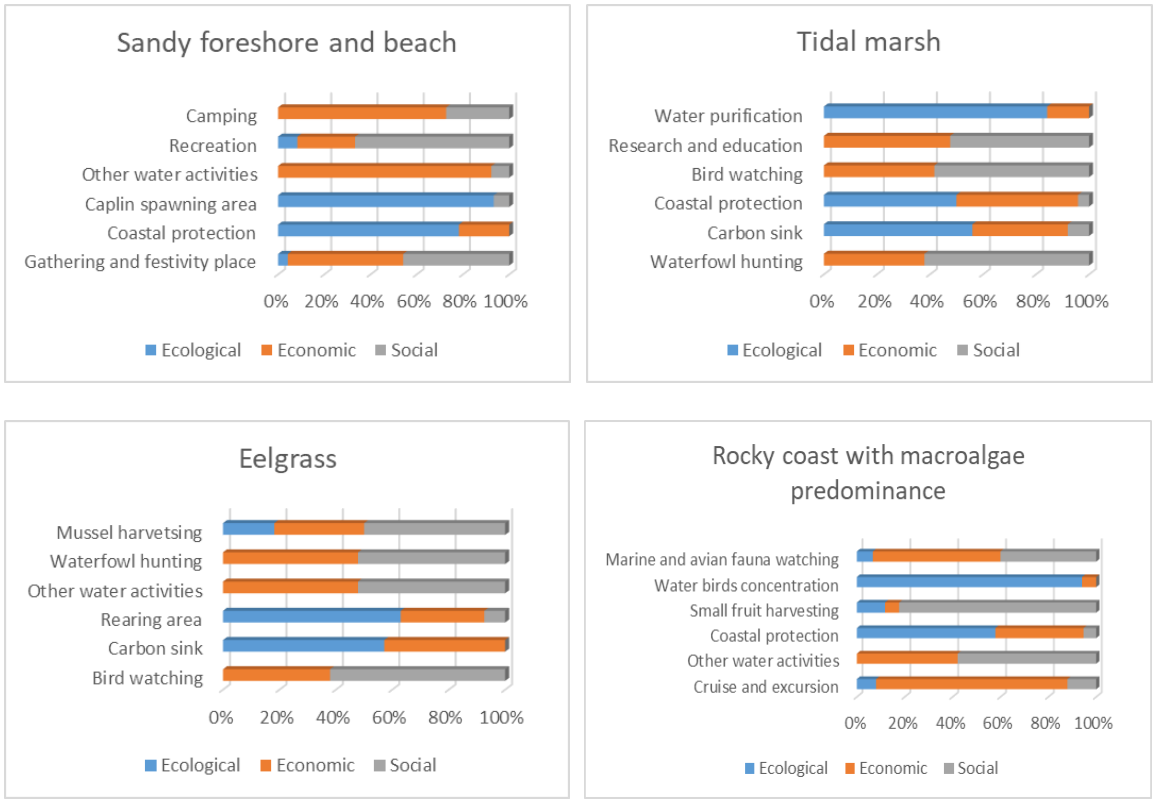
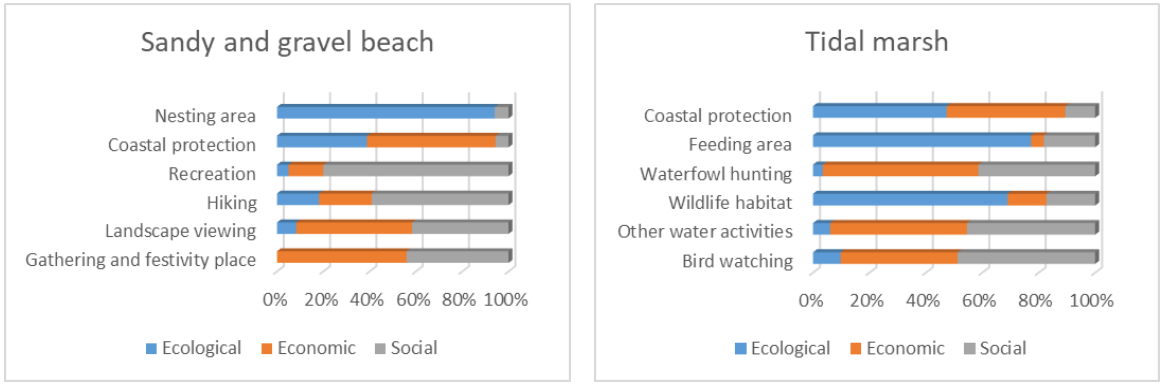


Figure 19: The most valued ES by ecosystems' type and their associated spheres in the Sept-Iles region

Sainte-Anne-des-Monts

Beaches were more related to social value (39%) and economic value (33%) (Figure 20). Tidal marshes were appreciated more for their ecological and economic values (35 and 34%). Eelgrass had higher economic and social values (36%). Foreshore was seen as a provider of ecological values (49%).



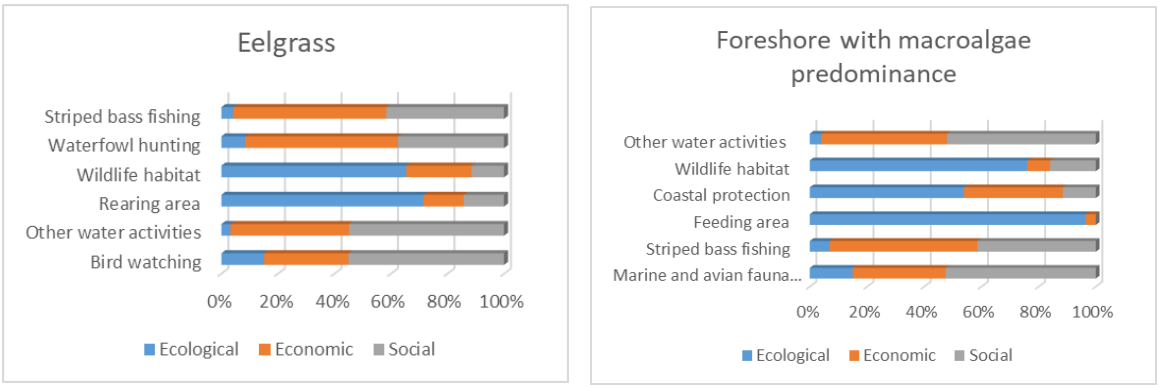


Figure 20: The most valued ES by ecosystems type and their associated spheres in the Sainte-Anne-des-Monts region

Gaspé

Cliffs were considered to provide higher economic (41%) and social value (37%) (Figure 21). Eelgrass was more related to social (42%) and economic values (30%). Tidal marshes had a greater weight in the economic and ecological spheres (39 and 34%). Beaches were considered to provide more economic and social values (39 and 35%).

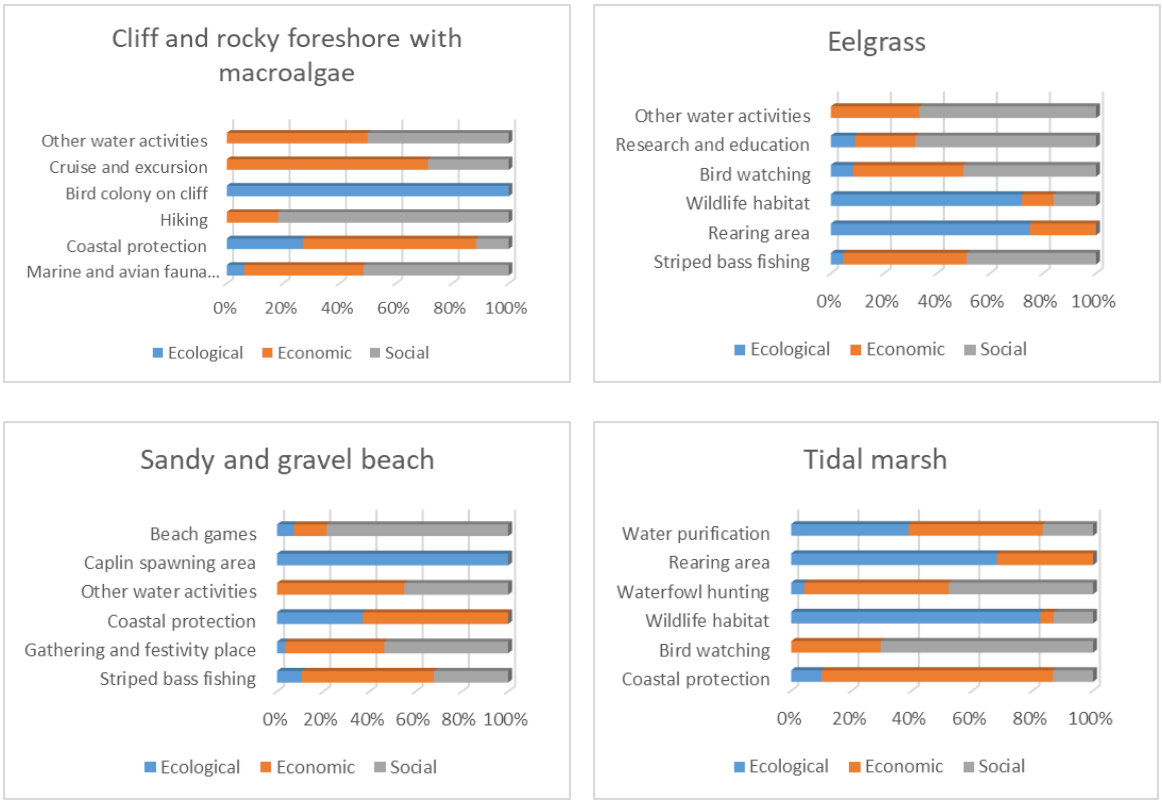


Figure 21: The most valued ES by ecosystems' type and their associated spheres in the Gaspé region

3. Conservation priorities

In the Baie-Comeau region, participants prioritized for conservation:

- first tidal marshes (52%) then beaches (48%)
- secondly, tidal marshes (33%) then eelgrass (29%)
- thirdly, eelgrass (48%) and rocky coast (33%).

In the Sept-Iles region, conservation priorities targeted:

- first, sandy foreshores and beaches (45%) then tidal marshes (28%)
- secondly, tidal marshes (31%) and eelgrass (31%) then sandy beaches (24%)
- thirdly, eelgrass (36%), sandy beaches (31%) and then tidal marshes (24%).

In the Saint-Anne-des-Monts region, stakeholders favoured for conservation:

- First, foreshores with macroalgae predominance (48%) then eelgrass (28%)
- Secondly, eelgrass (32%) and foreshores with macroalgae predominance (28%)
- Thirdly, sandy and gravel beaches (32%) and eelgrass (28%).

In the Gaspé region, conservation priorities were set to:

- First, sandy and gravel beaches (67%) then tidal marshes (30%)
- Secondly, tidal marshes (46%) then sandy and gravel beaches (23%)
- Thirdly, cliffs and rocky foreshores (41%), then eelgrass (26%) and tidal marshes (26%).

We thus observe a preference in the Baie-Comeau, Sept-Iles and Gaspé regions for protecting beaches and tidal marshes but Sept-Iles participants also considered eelgrass to be important (Figure 22). The Sainte-Anne-des-Monts region is the only one to display a strong preference for foreshores with macroalgae predominance.

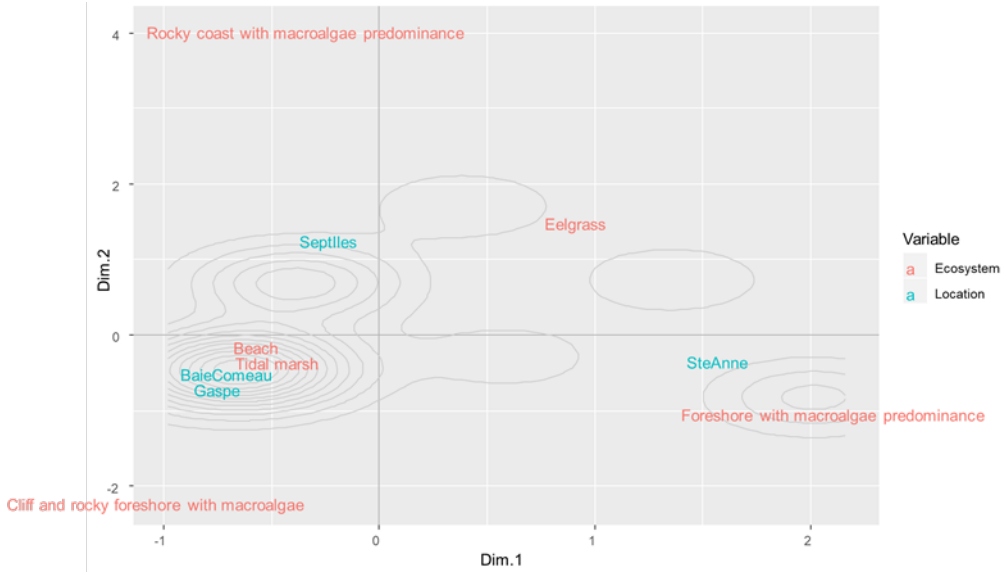


Figure 22: First conservation priority among the different regions (Dim1: 21.7; Dim2: 17.59)

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