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How do coastal residents perceive past and future changes in a Mediterranean lagoon ecosystem services?

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Abstract :

Coastal ecosystems provide a wide range of ecosystem services (ES) subject to strong human pressure and are included in conservation policies that aim to increase their resilience. Implementing resilience measures requires knowledge of the public perceptions of social-ecological systems so that commitment to environmental protection may be enhanced. Few studies address public perception of the evolution of social-ecological systems and integrate the diversity of ES (regulating, provisioning and cultural). This article is based on a survey of 476 inhabitants and deals with their perceptions of past (50 years) and future (+15 years) ES. It focuses on the Thau lagoon (French Mediterranean) that offers many ES and where managers prioritize traditional uses such as shellfish farming and fishing. Respondents' answers were compared with the results of scientists' and experts' evaluations to assess the level of public knowledge. The results indicate consistency in the qualitative and quantitative responses of local residents concerning the long-term evolution of ES and show them to have a fairly sound knowledge. However, there are some differences in trends with substantial variation for several ES probably related to judgement or anchoring biases. Furthermore, a majority of local residents had a mixed perception of local structuring ES. This innovative approach to the perceptions of ES momentum suggests that improved conservation policies must: (i) take into account the different communication and awareness requirements of people and (ii) integrate local knowledge through dialogue.

Highlights

► Assessment of the coastal residents perception of past and future ecosystem services representative of coastal lagoons. ► The coastal residents survey show a fairly sound knowledge of the long-term evolution of ecosystem services (ES). ► Coastal residents perceived differences only between the past two periods and the current period. ► Residents' qualitative and quantitative responses on long-term trend were consistent for 5 out of the 8 ES studied. ► Most coastal residents considered diversified ES to be important, with a slight fall in future projections.

Keywords : Ecosystem services, coastal lagoon, dynamic approach, perceptions environmental management

1. INTRODUCTION

Coastal ecosystems provide a wide range of ecosystem services (ES) facing strong human pressure and are the subject of conservation policies that aim to promote their restoration and resilience in the face of global change. In line with the Integrated Coastal Zone Management (ICZM) approach put into practice for the past two decades, these integrated and dialogue-based policies draw heavily on the involvement of the stakeholders, users and citizens concerned with ecosystems. Designing and implementing the measures to increase resilience requires some knowledge of the public perceptions of social-ecological systems. Indeed, taking into account the public perception is likely to enhance the commitment of users and citizens to environmental protection and facilitate the integration of local knowledge (Olsson and Folke, 2001; Tengo et al., 2017; Folke et al., 2005; Jacob et al., 2021). These approaches also help to identify the factors of acceptability of conservation policies (Zang et al., 2019; Wang et al., 2021; Torres et al., 2021; Mandel et al., 2021).

As a rule, the citizens' profiles are defined according to their perceptions and the determining factors of these perceptions are identified so as to then shape behaviour. As the case may be, the emphasis is on individual factors arising from socio-demographic characteristics and other factors such as the relationship with nature or the relational value (Sandifer et al., 2015; Pereira et al., 2020; Garcia-Rodriguez et al., 2021) or the attachment to the place (Lewicka, 2011). In other cases, collective factors such as norms and social interactions are examined (Farrow et al., 2017). These studies help rank the perceived importance of ES and increase awareness of their contribution to public well-being and the environmental quality of the regions. However, few studies analyse users' and citizens' perceptions of ES temporal evolution. The aim of such studies is to identify to what extent they are aware of changes and in particular of the degradation of some ES.

Recent reviews of work on ES show that this dynamic approach to perceptions is original (Zang et al., 2019; Wang et al., 2012; Torres et al., 2021; Mandel et al., 2021). As a rule, dynamic approaches focus on the changes in the importance and spatial distribution of ES bundles and more generally on ES supply in relation to use evolution, urbanisation and land occupation and/or landscape transformation (Burkhard et al., 2014; Rova et al., 2019). It is therefore possible to define historical spatial models of ES bundles including socio-economic and ecological determining factors (Gou et al., 2021). This type of approach is usually undertaken over one or two decades and relies on geographical information systems to examine the types of change and their impact on ES supply (Hu et al., 2021; Xu et al., 2022) and on the multifunctionality of the regions based on landscape indices (Pilgallo and Scorza, 2021).

Few studies involve a historical approach to ES. Inácio et al. (2018) discuss the evolution of ES flows in two Baltic lagoons and Kroll et al. (2012) analyse the evolution of ES demand in a German region. Another example is the work of Baranano et al. (2022) in Spain, who analysed the evolution of knowledge of the functions of seagrass beds based on a survey of 823 people and a review of newspaper articles published over the last 160 years. They show that degradation behaviour is correlated with the lack of memory of the past importance of SE. In other types of approaches, long-term analysis (often over a hundred-year period) addresses priorities in the forms of exploitation and/or the conservation of some services by analysing news articles (Fernandez et al., 2022) and/or surveying stakeholders. Examples of such long-term analyses are the evolution of ES considered of the highest priority according to the management strategies of the Banc d'Arguin National Park in Mauritania (Abdel Hamid 2018) or the uses and trade-offs of the local residents in the ES of two semi-arid catchment basins in southwest Spain (Inieta-Arandia et al., 2014). In some cases, the study focuses on the evolution of objectives and evaluation criteria, for example the evolution of the definition of the good ecological status of a Mediterranean lagoon by Erostate et al. (2021). These authors contrast the current criteria and the two-century evolution of endogenic and exogenic conditions for the smooth running of the studied hydrosystem. These approaches, more qualitative,

help piece together the temporal evolution of management priorities, governance mechanisms, the structuring process of the actor network and the types of conflict.

There are very few studies that deal with a wide range of ES (Torres et al., 2021; Mandel et al., 2021). There appears to be no work on the evolution of public perceptions based on large-scale surveys, other than some monographs on specific ES and the work of Costadone et al. (2021) who observed a sound knowledge of water quality evolution (60% of respondents).

In this context, this article proposes an original approach. It reports on a survey aiming to understand local residents' perceptions of the evolution all the ES provided by the Thau lagoon. The Thau lagoon is located in the South of France along the Mediterranean coast. It offers multiple ES and the priority, since the 1990s, has been the preservation of traditional uses (shellfish farming and fishing) endangered by the degradation in water quality while responding to demands for uses' diversification in the promotion of recreational ES. Local authorities have been working on water treatment systems and have implemented an ICZM approach. The rationale of the survey was to consider that conservation policy acceptability depends on public awareness of both the role of ES and their evolution. Indeed, awareness of their degradation validates the measures taken for their conservation or restoration and the need for control and limitation actions when faced with an increasing demand for some ES. More precisely as regards users' and citizens' perceptions, we make the following two assumptions. First it is assumed that local residents perceive evolution trends of main ES. Second, maintaining ES diversity is assumed to be a prerequisite for the social-ecological system resilience (Biggs et al., 2012, 2015), and the survey therefore also examine the diversity of ES categories considered to be the most important by local residents. To this end, we interviewed local residents on their perceptions of ES at different times: distant past (50 years), recent past (30 years) and foreseeable future (+ 10 to 15 years). This type of memory-based approach involves specific protocols and samples adapted to the timescales used.

2. EXPERIMENTAL DESIGN

2.1. The main characteristics of the study site and ES selection

The Thau lagoon (Figure 1) is both the largest lagoon of the Occitanie region (6 900 ha and 4.5 m deep on average) and the main site of marine farming in the French Mediterranean. Maintaining this historical trend of marine farming and fishing is at the heart of the integrated management public policies. The latter state that these activities are the watchdog of the ecosystem quality. Nonetheless, as for all coastal areas, the residential economy, tourism and recreational activities are becoming increasingly important. The selection of ES for the survey was done in three steps. First, we implemented a selection of 25 ES relevant to the Thau lagoon from the list of 59 biotic ES in the CICES V5.1 classification (Haines-Young and Potschin 2018). Next, stakeholders from nine key organizations involved in the management of the territory – hereafter referred to as “experts” –, were interviewed on changes in ES provision in the Thau lagoon and identified four negligible ES (see Appendix 1 for the list of stakeholder organizations interviewed). Finally, on the remaining 21 ES, a multidisciplinary team of five scientists specialised in the study site selected the most relevant ES and grouped them into ES with explicit names to facilitate communication with the residents during the survey. This process resulted in the selection of eight ES with a quasi-balanced partition between the three reference categories: provisioning, regulating and cultural (Table 1).

Table 1. List of the eight ES studied and corresponding ES according to CICES typology (Haines-Young and Potschin 2018).

Category	Services (and code given for this study)	CICES code
Provisioning	Shellfish production (A1)	1.1.4.1
	Fishing (fish and shellfish) (A2)	1.1.6.1
Regulating	Flora, fauna and aquatic biodiversity conservation (R1)	2.2.2.3
	Regulation of nutrient abundance and food chain balance (R2)	2.2.4.2 + 2.2.5.2
	Regulation of water quality (R3)	2.1.1.2 + 2.1.1.1
Cultural	Recreational and sporting activities (diving, hunting, canoe, kite surfing, windsurfing...) (C1)	3.1.1.1
	Landscapes, walks and nature observation (C2)	3.1.1.2 + 3.1.2.4
	Contribution to culture and local heritage (history, image and identity of the area) (C3)	3.1.2.3

2.2. Questionnaire design and survey process

The questionnaire aimed to identify the perceptions by the residents of the current and past importance of the eight ES selected (see the 57 questions in Appendix 2). It included a specific module for the dynamic evaluation of ES and additional modules to identify the determining factors of these perceptions (place of residence and attachment to the area, relationship with nature, uses related to the lagoon, commitment towards the environment and socio-demographic characteristics). To facilitate statistical processing, the majority of questions involved a cardinal evaluation of importance on a scale from 0 to 10. In parallel, we also asked respondents open-ended questions about key dates of change and about events or factors they thought might be responsible for these changes. Finally, it should be noted that because the term ES is relatively unknown by the public at large, we used the term “role” of the lagoon.

Given the COVID pandemic context, the survey was undertaken both face-to-face in four towns in close proximity to the lagoon (45%) and online (Sphinx Déclic software (55%)). The face-to-face surveys were undertaken on the street, through chance encounters but with different ages and genders and by publishing a connecting link in an information article in the local newspaper. Four towns were selected to vary the profiles according to the importance of tourism (Marseillan and Sète) and fishing and shellfish farming activities (Bouzigues and Mèze) (the location of these towns is shown on Figure 1). The survey lasted from the beginning of June until mid-July 2021. In total, 476 residents were interviewed and represented less than 1% of the population of the four towns (64 249 inhabitants, INSEE 2016). A simplified quota method was applied during the final stages of the face-to-face interviews to correct for selection bias (mainly due to the volunteer sampling of the online survey) on the basis of gender and age to approximate the characteristics of the population. There were no significant differences between the profiles of respondents to the face-to-face and online surveys. Estimated variances of the average scores given by the respondents associated with sample size were calculated according to Frontier (1982) (see Appendix 4). It is possible to compare the socio-demographic characteristics of the respondents with the average characteristics of the four towns (bearing in mind that some respondents resided in other communes in the zone). We note relatively similar characteristics with 48% of respondents being women (vs 53% on average for the four towns), an average age of 60 years (vs 55 years), 50% retired (vs 40%), 20% with a high level of education (vs 8%) and an average monthly income of 3 150 € (vs 3 730 €).

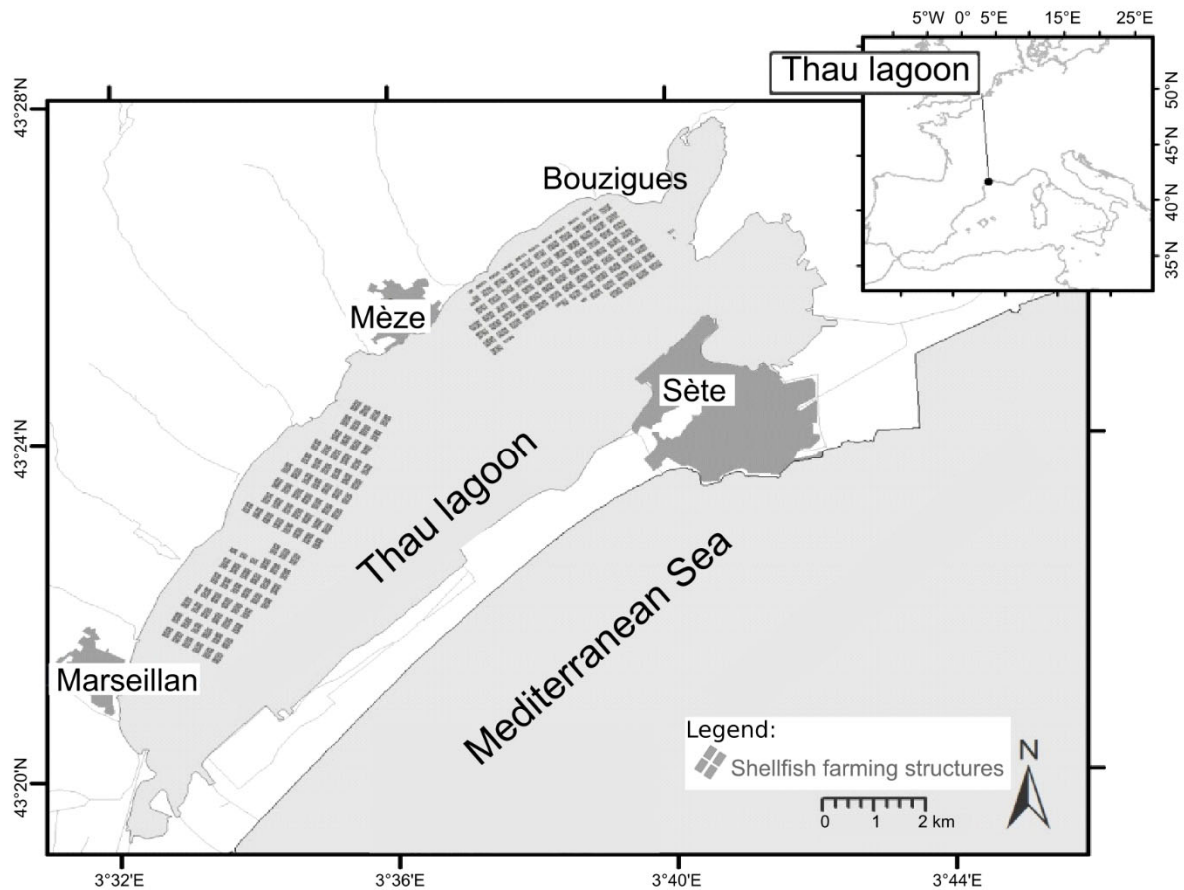


Figure 1. Location of the Thau lagoon and the 4 towns in the survey.

2.3. Integration of perceptions over time and data processing partition into subsamples

The integration of past perceptions is complex due to memory bias and differences related to age and duration of stay in the area. The coast's very attractive nature leads to positive migration flows and significant demographic growth resulting in a high number of new residents. Therefore, the age of people is not always correlated with the time they have spent in the region.

Prior to the survey, a specific protocol was designed for the retrospective approach, which resulted in the definition of three reference periods based on literature review and expert judgements (Derolez et al., under review). Period 1 was from 1970 to 1989 (distant past), 2 from 1990 to 2004 (recent past) and 3 for the current period from 2005 to 2018. The cut-off dates correspond to key events identified from an analysis of both documents (historical timelines) and quantitative data (Derolez et al., under review): restructuring of shellfish developments from 1970, major production crisis due to salmonella in shellfish in 1989, creation of an integrated inter-town management structure in 2005.

Concerning the retrospective part of the questionnaire, respondents had to successively:

1. evaluate, from 0 to 10 the importance of the eight ES for the current period (period 3, 2005-2018);
2. define the trend from simple diagrams in order to help the recall process (upward/downward/stable or extremely variable) (Figure 2);
3. propose an evaluation of the past importance of each of the eight ES in line with the trend selected;
4. give dates of change and events or factors that might explain these changes.

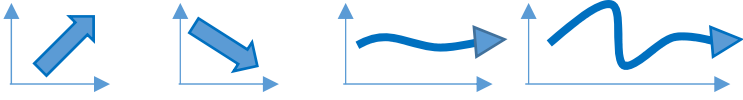
<p>Current importance (score from 0 to 10)</p>	<p>What type of evolution? Upward, downward, virtually stable, extremely variable</p> 	<p>Past importance (score from 0 to 10)</p>	<p>With what event or date do you associate the change?</p>
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Figure 2. Diagrams shown to respondents to illustrate the evolution of each ES.

Given the memory biases, it was not realistic and relevant to ask for several past evaluations for the different periods. Therefore, we asked for a single past evaluation which was then allocated to one of the two past reference periods 1 and 2. Affiliation to period 1 or 2 has been decided on the basis of the number of years spent in the region and the age of respondents at these periods. We considered that respondents were able to perceive the past importance of ES if they had reached the age of 15 during the reference period. This age threshold is in France the age of entry into high school (“*lycée*”), students attending have had prior lessons about and visits of the region as part of some of their curriculum. Hence, while past evaluations were based on samples that were reduced (new residents being excluded) and distinct (depending on the age and the period), current period evaluations concerned all respondents (N=476). In total, 176 respondents for period 1 and 123 respondents for period 2 (for a total of 299 for the past evaluation) gave exhaustive answers to the questions concerning the past evolution of ES.

As regards the evolution of ES in the foreseeable future, respondents were not asked to evaluate the cardinal importance for the prospective period of 10 to 15 years as it was more difficult to imagine. Respondents had to choose the four services out of eight that they considered would become the most important in the future. Some respondents chose more than four, therefore we reduced the sample to those who had strictly complied with the instructions in order to work on a homogeneous data set (respondents having all selected four ES). Hence, the prospective analysis examined a subsample of 287 respondents.

2.4. Processing undertaken

2.4.1 Comparison of the evaluations

Local residents’ perceptions of ES were compared to a benchmark table consisting of evaluations of ES flows from scientific data and expert assessments (Table 2; see also Appendix 3 for the references and detailed data). For seven of the eight ES, quantitative data from scientific surveys or official statistics were used to assess the average level of ES provision per period. For one ES (R2), quantitative data were not available, so we used the average of the scores given by the nine experts interviewed (see section 2.2), who were asked to rate the level of ES provided by the lagoon on a scale of 1 to 10 over the three periods. Scientific and official data were standardised on a comparable scale from 0 to 10 (Derolez, 2020; Derolez et al., under review). For ES R3 concerning water quality, the local residents who were interviewed gave a positive evaluation of water quality (an indicator of ecosystem state) interpreted as a decline in the use of the regulating service for water quality (water quality regulating flow) due to decreasing pollution emissions. In order to compare local residents’ and scientists’ scores based on ES flows, the latter were reversed (reverse scale for this ES). The confidence level of scientists’ and experts’ evaluations was estimated as: high when they resulted from scientific surveys or official quantitative data that were well delimited in space and time; moderate when they were supported by official quantitative data with high uncertainty or by expert evaluations with low standard deviation; and low when they resulted from heterogeneous or scarce quantitative data or from expert evaluations with high standard deviation (Table 2). It should be

noted that the confidence level was lower for some cultural services and for the regulation of nutrient abundance and food chain balance.

We compared scientists' and experts' evaluation scores with those of the local residents' perceptions for each ES and each of the three periods using the Wilcoxon test. We also looked for differences in residents' evaluations between periods using the Kruskal-Wallis test (agricolae package, R software).

Table 2. Details of the scientists' and experts' ES flow evaluations by period (scores from 0 to 10), indicator used, evaluation method and confidence level

Ecosystem service	Indicator used to determine the flows of ES	Evaluation method	Flow of ES from 0 to 10 (average per period) (confidence level)		
			Period 1	Period 2	Period 3
Provisioning services					
A1. Shellfish production	Annual shellfish production (t.y ⁻¹)	Official datasets	5.8 <i>(high)</i>	9 <i>(high)</i>	7 <i>(high)</i>
A2. Fishing (fish and shellfish)	Number of active fishers	Official datasets	8.8 <i>(high)</i>	5.6 <i>(high)</i>	3.2 <i>(high)</i>
Regulating services					
R1. Flora, fauna and aquatic biodiversity conservation	Percentage of soft-bottom dominated by marine seagrass.	Scientific surveys	9.2 <i>(high)</i>	7 <i>(high)</i>	6.4 <i>(high)</i>
R2. Regulation of nutrient abundance and food chain balance	Average of 9 expert evaluations	Expert evaluation <i>(with a low standard deviation between them but on average a presence of relatively low duration in the region)</i>	8.2 <i>(low)</i>	7.4 <i>(low)</i>	7.2 <i>(moderate)</i>
R3. Regulation of water quality	Average of 3 indicators from scientific observations: phosphorus flow from the catchment basin, contaminant concentrations in mussels, people discharging wastewater directly in the lagoon	Scientific surveys and official datasets	6.9* <i>(high)</i>	4.4* <i>(high)</i>	2.6* <i>(high)</i>
Cultural services					
C1. Recreational and sporting activities	Number of associations related to aquatic recreational activities	Official datasets <i>(few data available for Period 1)</i>	1.2 <i>(moderate)</i>	2.4 <i>(high)</i>	6.8 <i>(high)</i>
C2. Landscapes, walks and nature observation	Number of associations for the protection of nature	Official datasets <i>(sample of towns therefore a non-exhaustive spatial census)</i>	0.2 <i>(low)</i>	2.8 <i>(moderate)</i>	6.6 <i>(moderate)</i>
C3. Contribution to culture and local heritage	Number of associations for the protection or enhancement of the cultural and linguistic heritage	Heterogeneous data sources	0 <i>(low)</i>	4.8 <i>(moderate)</i>	8 <i>(moderate)</i>

*For R3: in order to compare residents' and scientists' & experts' scores based on ES flows, the latter were reversed (reverse scale).

2.4.2 Diversified nature of particular ES

In line with the ICZM, the management policies pursued in the region advocate to maintain ES diversity as it is considered by managers to be an asset for regional resilience. Therefore, we investigated whether the ES considered to be the most important fell under the three categories established by the CICES. This analysis was undertaken for the past (1 and 2) and current (3) periods. For each respondent we examined the nature of those ES with scores higher than the respondent's average score for the 8 ES. For the future, this analysis relied on the four ES identified by respondents as the most important in the next 10 to 15 years (see section 2.3). If at least one ES of each category was found in the group of ES considered as the most important, it was assumed that the respondent had a diversified perception of ES. The number of respondents in the different periods was then evaluated to assess the evolution of the diversity principle.

2.4.3 Analysis of cited events (text processing of open-ended answers)

To define the spontaneous perceptions of ES evolution, respondents had to identify the factors or events that might explain the evolution observed in each ES (Figure 2). A textual analysis helped categorise similar terms. These categories were then validated by several researchers to reduce subjectivity.

3. MAIN FINDINGS

3.1. Perception of ES evolution

The comparative tests of the residents' evaluations by period show that, for the eight ES, the scores given for the past periods 1 and 2 were not significantly different but those given for the current period 3 differed significantly from past periods' scores (Kruskal-Wallis test, $p < 0.05$).

A comparison of the importance of the roles perceived by local residents on the one hand and scientists and experts on the other shows them to be significantly different except for biodiversity (R1) in period 2 (Wilcoxon test, $p = 0.08$). However, evaluations by residents and the ones by scientists and experts were fairly close for the current period 3, except for fishing, landscape, biodiversity and water quality (ES A2, C2, R1 and R3 on Figure 3). The residents ES role perception departed from that of the scientists and experts for the past periods (1 and 2) much more, in particular for cultural services and water quality and the more distant past (period 1) when local residents' perception of an upward trend was less noticeable. However, local residents tended to under-evaluate the fall in fishing activity. Finally, whilst scientists' and experts' evaluations showed a drop for biodiversity services and nutrient regulation (R1 and R2 services), the respondents perceived an upward trend from the past periods to the current one.

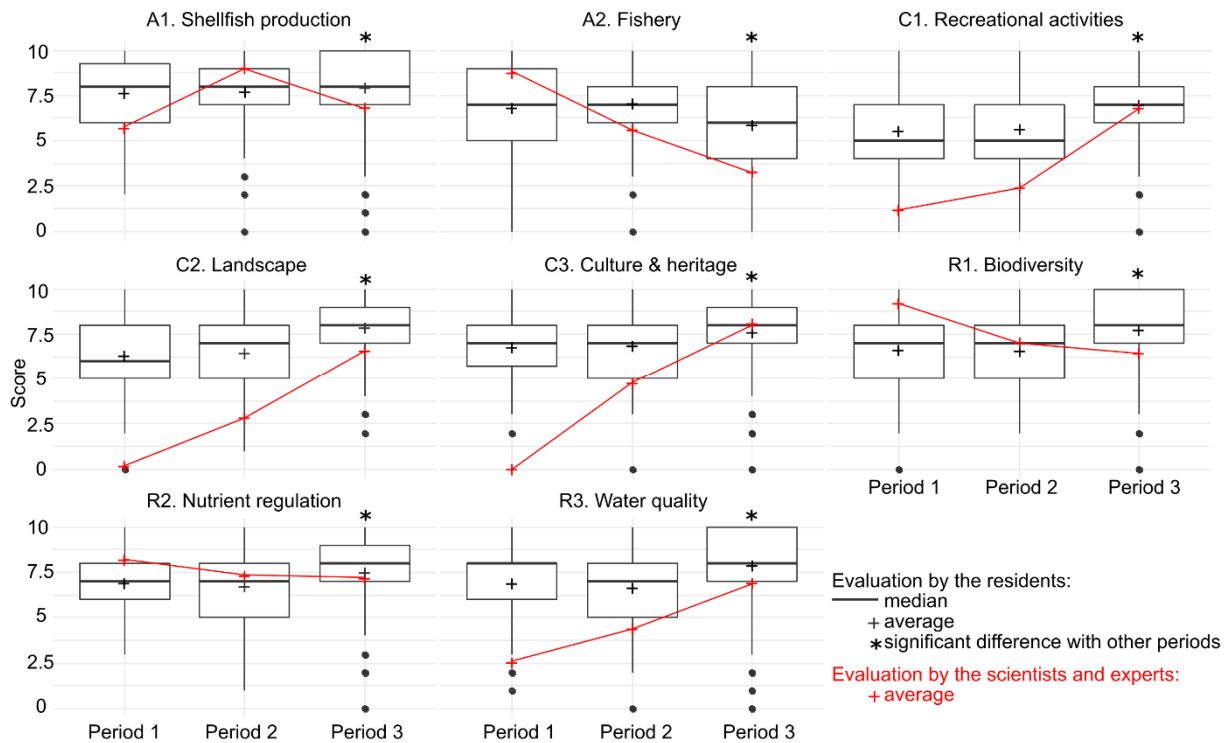


Figure 3. Comparing the evolution from periods 1 to 3 of scores by ecosystem services, in black for residents and in red for scientists and experts.

The distribution of the respondents' ratios according to the type of evolution selected (Figure 2 and Table 3) corroborates strongly the types of evolution observed using the score-based analysis but does not integrate some of the nuances highlighted between the past periods 1 and 2 (Figure 3). It is worth noting the mostly downward trend for fishery (A2), the less pronounced changes (upward or near-stable) for nutrient regulation (R2) and to a lesser extent the contribution to culture and heritage (C3). Respondents perceived mainly a marked upward trend for flora and fauna conservation (R1), recreational activities (C1) and landscapes, walks and nature observation (C2) whilst shellfish production (A1) was perceived as stable, in accordance with the score pattern. Concerning the future period, there was a significant increase in the ES "contribution to culture and heritage" that may be interpreted as a wish to maintain the area's identity (Table 3).

Table 3. Types of evolution trend identified by residents and proportion of residents identifying the ES as important in to the future of the lagoon.

Services	Types of evolution trend identified (*)				Proportion residents identifying the ES as important in the future
	Upward	Downward	Near-stable	Very variable	
Shellfish production (A1)	29%	23%	41%	7%	56%
Fishing (fish and shellfish) (A2)	8%	64%	25%	4%	16%
Flora, fauna and aquatic biodiversity conservation (R1)	54%	17%	23%	6%	22%
Regulation of nutrient abundance and food chain balance (R2)	33%	19%	34%	13%	24%
Regulation of water quality (R3)	19%	41%	22%	17%	61%
Recreational and sporting activities (C1)	64%	3%	29%	4%	44%
Landscapes, walks and nature observation (C2)	62%	7%	28%	3%	53%
Contribution to culture and local heritage (C3)	38%	11%	46%	5%	70%

(*) The numbers in bold represent the highest percentages

3.2 Perceptions of drivers of change

Apart from the contribution to culture and heritage (C3 service) which was less often completed, almost half of the respondents involved in the past evaluation provided textual elements on the nature of changes or events responsible for these changes (Table 4). The ES for which the most events were cited (more than half the respondents provided at least one textual element) were: water quality (R3), shellfish production (A1) and recreational and sporting activities (C1). However, these descriptions were very rarely supported by dates (9% of cases). Among the dates given, the year 2000 was the most frequently cited (37% of dates cited), followed by 1990, 2010 and 1970, that is to say markers near the pivotal periods identified by the documentary analysis and the data sets (Derolez et al., under review).

Table 4. Percentage of respondents involved in the past evaluation (N=299) having completed the nature of changes.

A1. Shellfish production	A2. Fishing	R1. Flora, fauna and aquatic biodiversity conservation	R2. Regulation of nutrient abundance and food chain balance
52%	49%	46%	40%
R3. Regulation of water quality	C1. Recreational and sporting activities	C2. Landscapes, walks and nature observation	C3. Contribution to culture and local heritage
53%	52%	46%	33%

Quite often, rather than precise events, respondents mentioned evolutions or trends in terms of improvement or degradation of the state of the lagoon concerning ecosystem services. Their answers, ranked according to their feeling of positive or negative evolution (Figure 4), confirmed the trend revealed by the scores (Figure 3). For example, negative evolutions represented only 4.2% of the terms mentioned for recreational activities and 97.5% for fishing.

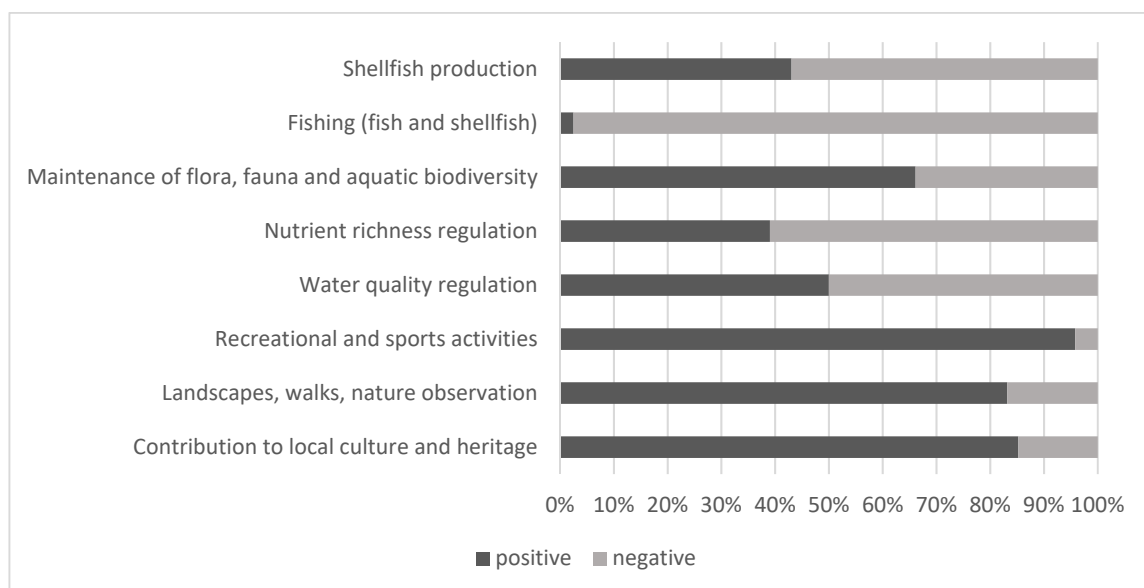


Figure 4. Distribution of the types of terms used for the evolution of the eight ecosystem services (in percentage of respondents' answers).

Depending on the ES, the type of event or factor differed (Table 5) and focused mainly on the nature of the recreational and sporting activities or on physical infrastructure or types of events for the cultural services "landscapes, walks, observation of nature" and for heritage (C2 and C3 services). As regards regulating and provisioning systems, the *malaïgues* (the name given in Occitan to a dystrophic crisis), pollution and climate were the factors of change most commonly cited, to which should be added the issue of sanitation for regulating services (Table 5, words in bold). A growing awareness of the importance of certain cultural and regulating ES should also be noted. Finally, for seven of the eight ES examined, several words mentioned by respondents were in line with adaptation or responses of the social-ecological system (public policy measures, in italic in Table 5), such as sanitation (mentioned for two ES) or awareness (mentioned for five ES).

Table 5. Several types of event cited according to ecosystem services (ES) in percentage of responses given for each ES (the events common to several ES are in bold; the events relating to public policy measures are in italic).

A1. Shellfish production	"Malaïgues" (12%); Pollution (10%); <i>Professionalisation</i> (6%); Growth in demand (6%)
A2. Fishing	Depleting resources (21%); Overfishing (13%); Pollution (6%); Climate (4%)
R1. Flora, fauna and aquatic biodiversity conservation	Awareness (14%); Pollution (12%); <i>Protection</i> (10%); -Urbanisation (7%); Seahorse (6%)
R2. Regulation of nutrient abundance and food chain balance	Pollution (8%); Seaweeds (8%); Sanitation (7%); "Malaïgues" (7%); Seahorse (4%); Climate (7%); Awareness (5%)
R3. Regulation of water quality	"Malaïgues" (11%); <i>Management</i> (8%); Pollution (8%); Sanitation (7%); Climate (7%); Awareness (3%)
C1. Recreational and sporting activities	Sailing (32%); Tourism (19%); <i>Development</i> (19%); Yachting (10%); Awareness (8%)
C2. Landscapes, walks and nature observation	<i>Cycle lanes</i> (43%); <i>Development</i> (23%); Urbanisation (9%); Awareness (8%); Nature (6%)
C3. Contribution to culture and local heritage	<i>Communication</i> (14%); <i>Cultural events</i> (10%); Identity (9%); Heritage (7%); Tourism (7%); <i>Museum</i> (3%)

3.3 Perception of ES diversity

Identifying the different types of ES among the ones considered to be the most important helps to understand the varying nature of perceptions over time (see section 2.4.2). It is worth noting that different perceptions among residents are currently predominant and are on the rise when compared to past periods. The proportion of respondents with a varied perception of ecosystem services (combining all three categories) was 46% for past (periods 1 and 2), 55% for current period and 42% for future (within a 10- to 15-year period). However, there is a fall in respondents having a varied perception of ES for the future, associated with the trend to prioritize cultural ES, especially heritage, and regulation of water quality and shellfish production.

4. DISCUSSION

4.1 Consistency and variability of inhabitants' perceptions

The risk of biases inherent to a temporal approach to perceptions led us to combine the cardinal evaluation of ES importance over time with a typology of evolution trends and with open questions on factors and dates of change. The comparison of the results by ES and by the question formats shows consistency in the respondents' answers. In addition, there is a fair degree of similarity in the terms used by the respondents in their open answers on perceptions whether positive or negative. Triangulating quantitative results (scores) with the type of evolution (trends) reveals consensus on: (i) the degradation of the provisioning service related to fishing (A2); (ii) the progression of cultural services related to recreational and sporting activities (C1) and to walks, landscapes and observation of nature (C2); (iii) to a lesser extent, the upward trend of the regulating service on nutrients (R2). In the end, only three ES showed differences related to the evaluation format: shellfish production, regulation of water quality and contribution to culture and local heritage (Table 6).

Notwithstanding this global analysis of the consistency of answers, it is worth noting an inter-individual variability in residents' quantitative evaluations (see Appendix 4). It was often more pronounced in past evaluations, either for the two periods (distant and recent pasts) in cultural services (C1 and C2) or solely for the recent past i.e. period 2 (C3, R2, and R3) or the distant past i.e. period 1 (A1, A2 and R3). Furthermore, the results from quantitative ES evaluations for the past two periods from the samples based on time spent in the region, were not significantly different. Finally, only a small minority of respondents was able to date the changes they perceived.

In addition to the inherent nature of perceptions, the differences noted in past evolutions can also result from the memory of individuals that generates biases given the determining roles of some key events that are focal points (Schelling, 1981). This type of process is often described in psychology studies as an anchoring bias (Kahneman et al. 1982) highlighting an emotional component in the evaluation process (Sandifer et al., 2015; Pereira et al., 2020; Garcia-Rodriguez et al., 2021). Hence, the historical fishing vocation in the lagoon may explain both an anchoring bias and a judgment bias leading residents to minimise this provisioning ES. Furthermore, in our study where we consider several ES simultaneously, evaluations may not be independent but relate to a reference ES. This interdependence in evaluations is shown by Dewey (2011) who stresses that we assess the relative value of things with respect to a set. In our case, this means that other ES may be assessed with reference to the evolution of the shellfish production ES given its heritage and economic role in the area under study. Finally, some studies in experimental economics show a judgment bias leading to overweight low values and underweight higher ones (Eber and Willinger, 2012). These various biases and evaluation methods obviously introduce an inter-individual variability in local knowledge whilst experts' evaluations rely on dashboards of indicators

that may integrate uncertainties but constitute references shared by experts, except for conflict situations when counter-expertise is necessary.

Table 6. Summary of the evolution trends of ecosystem services perceived by residents (qualitative (A) and quantitative evaluations (B)) and evaluated by scientists and experts (C); consistency between evaluations: (*) between qualitative and quantitative residents' evaluations: low when A and B different; moderate when A and B near identical; high when A and B identical; (**) between residents' and scientist' & experts' evaluations: low when C different from and A and B; moderate when C identical to A or B; high when C identical to A and B.

Services	Residents' evaluations			C. Scientists' and experts' evaluations	Consistency between residents' and scientists' & experts' evaluations (**)
	A. Qualitative (types of trend most cited)	B. Quantitative (different scores between periods 1 and 2 vs period 3)	Consistency in residents' perceptions (*)		
Shellfish production (A1)	Near-stable	Upward	Low	Fluctuating	Low
Fishing (fish and shellfish) (A2)	Downward	Downward	High	Downward	High
Flora, fauna and aquatic diversity conservation (R1)	Upward	Upward	High	Downward	Low
Regulation of nutrient abundance and food chain balance (R2)	Upward - Near-stable	Upward	Moderate	Downward	Low
Regulation of water quality (R3)	Downward	Upward	Low	Upward	Moderate
Recreational and sporting activities (C1)	Upward	Upward	High	Upward	High
Landscapes, walks and nature observation (C2)	Upward	Upward	High	Upward	High
Contribution to culture and local heritage (C3)	Near-stable	Upward	Low	Upward	Moderate

Notwithstanding these memory or anchoring effects, there was paradoxically a great variability in the evaluations of the role given to four of the ES under study (A1, A2, R1 et R3) for the current period, especially fishing that scored the highest inter-individual differences. Although there were more similarities with the scientists' and experts' evaluations for the current period, the special case of biodiversity regulation and its very broad range of species, habitats and processes showed variable evaluations over the three periods. In addition to the possible biases already mentioned, this variability is consistent with the subjectivity of individual perceptions in relation to socio-demographic characteristics and other factors such as topics of interest, level of education, sector of activity, types of use, relationship to nature, attachment to and duration of stay in the area (Rey-Valette et al., 2022). Indeed, the analysis of an overall knowledge index constituted by the sum of the differences between the evaluations of residents and experts shows that the respondents with the best levels of knowledge also have a rather stronger link to nature, tend to live in the commune of Sète, frequent the lagoon more often, are older (>60 years old) and more often married (Rey-Valette et al., submitted). The link between knowledge and frequency of use or, more generally, familiarity with ecosystems, which allows for the constitution of empirical knowledge, is often shown (De Juan et al., 2017; Ahtiainen et al., 2019; Sy et al., 2021; Jacob et al., 2021; Baranano et al., 2022).

Finally, the textual analysis of the facts mentioned by residents showed specificities according to ES and the important role of ecological crises (*malaigues* and pollution) that were common to provisioning and

regulating ES, algal proliferation or the role of climate. The socio-economic factors related to activities and associated developments were the most cited for cultural ES whilst for provisioning and regulating services, raising awareness was mentioned on a recurring basis as a factor of change in the social-ecological system conservation. The several mentions cited by residents in line with public policy measures could be the result, in part, of the large number of participatory forums and awareness-raising actions undertaken by managers and local environmental associations, and receiving local media coverage. These mentions, although not frequent, showed a good perception of the public policy actions undertaken in the region. Despite the absence of precise and even dated events, the analysis of the events mentioned showed that they were consistent with the scientific diagnoses and demonstrated a good knowledge by local residents of the ES momentum.

4.2 Convergence between residents' perceptions and scientists' and experts' evaluations

In addition to the consistency of responses obtained according to the format of the questions put to residents, the differences between evaluations provided by residents and scientists and experts have to be examined (Table 6). Several situations were observed: in fishing (A2) and recreational services related to landscapes (C1 and C2) and, to a lesser extent, in regulation of water quality (R3) and the cultural service related to heritage (C3), there was a high degree of consistency between trends perceived by the residents and those observed by scientists and experts. However, the results were contrasted for the ES of shellfish production (A1) and the services related to biodiversity conservation and regulation of nutrients (R1 and R2). These differences are less significant for the regulating ES on nutrient abundance where scientists' and experts' evaluations had a low confidence level. The results of Baranano et al. (2022) on the particular difficulties of understanding ecological processes for regulatory services can be mentioned here. The fluctuating nature of the evolution of shellfish farming based on official statistics, was probably more difficult to capture for residents than the monotonic upward or downward trend observed for the other seven ES.

In terms of the magnitude of variations, the past importance of cultural services (C1, C2, C3) and of water quality regulation (R3) was greatly over evaluated by local residents. Cultural ES evaluation can be related to residents' practices or observations but monitoring systems are difficult to implement for these ES. The fact that water quality, biodiversity and shellfish farming, which are at the heart of public policies in the area (Derolez, 2020), are heavily publicised introduces an anchoring bias concerning the positive momentum of these ES. The findings of Kosanic and Petzold (2020) on the difficulties of evaluating cultural services are echoed. However, in the case of the Thau lagoon, their evolution is fairly well known, at least for those that are used directly. The importance of fishing, involving a community which is now smaller and less socially integrated than shellfish farming, was both under evaluated by local residents in the distant past, when it was still relatively important, and over evaluated in the current period, which is consistent with the results of experimental economics studies (Eber and Willinger, 2012). Finally, it should be noted that, in addition to perception variability according to ES and the differences in confidence levels of scientists' and experts' evaluations, the comparison of these evaluations also suffers because they are not based on the same type of information.

4.3 How to integrate local knowledge to decision-making

The analysis of local residents' perceptions and knowledge concerning the evolution of ES importance aims to contribute to debates on the factors defining users' pro-environmental behaviour and on including local knowledge into conservation policies (Folke et al., 2005; Costanza, 2004; Jacob et al., 2021). Indeed, whilst the evolution of management practices advocates using concerted approaches, the scope and the effects of these participatory processes are, in addition to the participation formats, determined for the most part by a common knowledge, which makes it possible to share the diagnosis and develop a

consensus on objectives. Tengo et al. (2017) show the significance of this common knowledge in the case of crisis or choice between contrasted alternatives, whilst some authors (Subira-Pérez et al., 2020; Lapointe et al., 2021) attest to the significance of knowledge in individuals' protection behaviour. Depending on whether knowledge is derived from direct experience with ES or is an indirect result of knowledge gained through various means of communication will determine the level of commitment and interest in the conservation of social-ecological systems (Sy et al., 2021).

This idea of local knowledge may be broken down according to two scales: i) the knowledge of stakeholders involved in the various stages of the decision-making process, who have already usually integrated in part the knowledge of scientists in their field of intervention; ii) the knowledge of the residents, who contribute significantly to the legitimacy and acceptability of the measures implemented. The convergence of knowledge and reference information requires the establishment of information mechanisms such as "participatory observatories" that would centralise and share information whilst also supporting wide-ranging communities of practice using appropriate communication tools (Tonneau and Maurel, 2016; Salles et al., 2021). Perception surveys make it possible to identify differences in knowledge in order to propose awareness-raising policies according to the types of residents' profiles, levels of familiarity and also types of ES (Baranano et al., 2022). Nevertheless, improving SE knowledge processes requires strengthening participatory approaches (Saarikoski et al., 2018; Sy et al., 2021; Jacob et al., 2021) but also awareness-raising formats by developing forms of experimentation such as serious games or citizen science approaches to act on behaviour (Blasiak et al., 2015; Nilsson et al., 2019).

Local residents' and experts' knowledge should thus be reconciled and several means of accessing knowledge should be considered. Indeed, some convergences exist but still need to be improved. For instance, the importance given by a majority of respondents to the ES related to water quality and shellfish production (R3 and A1 services) in the future goes against the downward or stable trends perceived in the periods 1 to 3, but shows a sound awareness of local management objectives, mainly dedicated to the maintenance of traditional activities and to an adequate environmental quality for these activities. In addition, in the context of integrated management policies, maintaining a diversified set of ES appears as a condition for the long-term resilience of the social-ecological system. This entails an overarching knowledge of the situation of the main ES. In that respect, the survey shows that the perceptions of a diversified ES bundle as important for the social-ecological system concern almost half of the respondents (46% to 55%) depending on the period, with a slight fall (42%) in future projections as some people anticipate that the area will become more specialised. This diversified perception of the lagoon ES may be related to the development of new human activities and the growing awareness of the ecosystems' benefits in terms of ecosystem regulation and biodiversity conservation provided by the lagoon, which was originally focused on traditional activities related to provisioning ES.

CONCLUSION

This research documents the evolution of eight structuring ES in the Thau lagoon environment by comparing evolutions perceived by local residents with data coming from scientists' and experts' evaluations. The issue was to explore the awareness and knowledge of local residents concerning these evolutions. This type of dynamic knowledge has seldom been studied and constitutes a fundamental contribution to the development of conservation policies. Indeed, ES evolution is a determining factor in the managers' decision to intervene and also to ensure the appropriation of measures by the public and the users and therefore, in the long run their environmental efficacy. This is because, according to Burdon et al. (2019), the notion of ES facilitates the involvement of users and people in the participatory management process.

The evolution of conservation policies relies increasingly on the promotion of pro-active behaviour. Such behaviours require to raise awareness on the need to intervene, which itself supposes a knowledge of the role of ES and how they evolve over time and therefore to develop individual and collective learning

processes (Zhang et al. 2019; Robinne et al., 2019; Balvanera et al., 2020; Costanza, 2020). However, when seeking to identify trends, it is important to stress that the recurrence of environmental crises (Derolez et al., 2020) renders the definition of past trends more difficult for both residents and stakeholders. Similarly, defining prospective trajectories remains challenging as they can encounter breaking points and radical reconfiguration (Haasnoot et al., 2013) as regards the relative importance of the different ES. Despite these difficulties, the inventory of key events cited by local residents to explain the evolution shows a clear partition between the factors related to ecological or climate evolution and the role played by increasing Human pressure and management and awareness-raising measures. The dynamic nature of our analysis also helps to convey the local residents' raised awareness concerning development and environmental measures.

However, it is worth noting that this type of analysis of knowledge evolution is still at a preliminary stage and in several respects represents a challenge for the survey protocol. In particular, the results showed a high level of variability of perceptions among local residents. This variability may be explained by the differences in socio-demographic profiles and in familiarity with the ecosystems but may also be the result of the type of information used. Sy et al. (2021) identified three sources of information related to ES: i) collected from objective data, ii) arising from personal experience in relation with the use of the relevant ES or iii) guaranteed by specific mechanisms (label for example) for ES relying on complex processes, in particular regulating ES. Notwithstanding the expected variability of perceptions, subjective by nature, our analysis also shows that anchoring and judgment biases may explain in part the high variability of local residents' evaluations for past periods. Despite all these drawbacks, strong convergence was noted in the evaluations concerned with residents' knowledge depending on question formats and between these evaluations and those of scientists and experts.

Finally, this highlighting of the variability of residents' perceptions has many practical implications. First, it helps identify differences in knowledge and therefore, the disparate needs in communication and awareness-raising of local residents. Second, in terms of governance and consultation or dialogues with local residents, this variability means that expanded panels or focus-groups should be used so that perception differences may be integrated. Third, it sheds a new light on the ways for integrating local knowledge through participatory approaches and/or citizen observatories, which is both advocated and increasingly developed (Olsson and Folke, 2001; Tengo et al., 2017; Folke et al., 2005; Jacob et al., 2021). Indeed, it appears important to provide an in-depth analysis of the type of information used and to strengthen the building of collective knowledge and of mechanisms certifying the information (such as labels). Such a collective knowledge could then be widely shared with the stakeholders and experts to create territorial intelligence and with the local residents to facilitate the appropriation of policies.

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ACCEPTED VERSION

Appendix 1. Type and name of the 9 stakeholder organizations interviewed and date of the interviews.

Stakeholder category	Name of the organization	Date of the interviews
Local management organization	Syndicate of the Thau Lagoon (French acronym 'SMBT')	June 21 2019
State representatives	Delegation for the Sea and Coast (French acronym 'DML')	June 19 2019
	Rhône-Mediterranean-Corsica Water Agency (French acronym 'AERMC')	June 27 2019
Representative of the Region for shellfish and fishing	Center for the Promotion of Lagoon and Maritime Activities (French acronym 'Cépralmar')	August 2 2019 and March 24 2020
Research institute	French Research Institute for the Exploitation of the Sea (French acronym 'Ifremer')	February 7 2019
Environmental association	Center for the Promotion of Environmental Initiatives (French acronym 'CPIE')	June 28 2019 and April 2020
Representative of shellfish and fisheries	Regional Mediterranean Shellfish Committee (French acronym 'CRCM')	April 4 2019
	Mèze 'Prud'homie'	October 7 2019
	Regional Committee for Maritime Fisheries in the Mediterranean (French acronym 'CRPMEM')	July 22 2019

Appendix 2. Questionnaire for coastal residents

**SURVEY ON THE EVOLUTION OF PERCEPTIONS OF THE ROLE OF THE THAU LAGOON
BY THE LOCAL POPULATION**

We are carrying out a survey as part of a research project financed by IFREMER and the CNRS. We are trying to establish a diagnosis of how the population perceives the place and role of the Thau Lagoon. There are no right or wrong answers, on the contrary, we are trying to assess the diversity of points of view.

THANK YOU FOR RESPONDING TO THIS SURVEY

A. PLACE OF RESIDENCE

A1. What is your commune of residence (main residence)

<input type="checkbox"/>	Sete	<input type="checkbox"/>	Bouzigues	<input type="checkbox"/>	Mèze	<input type="checkbox"/>	Marseillan
<input type="checkbox"/>	Other: specify						

A2. In what year did you come to live near the Thau Lagoon?

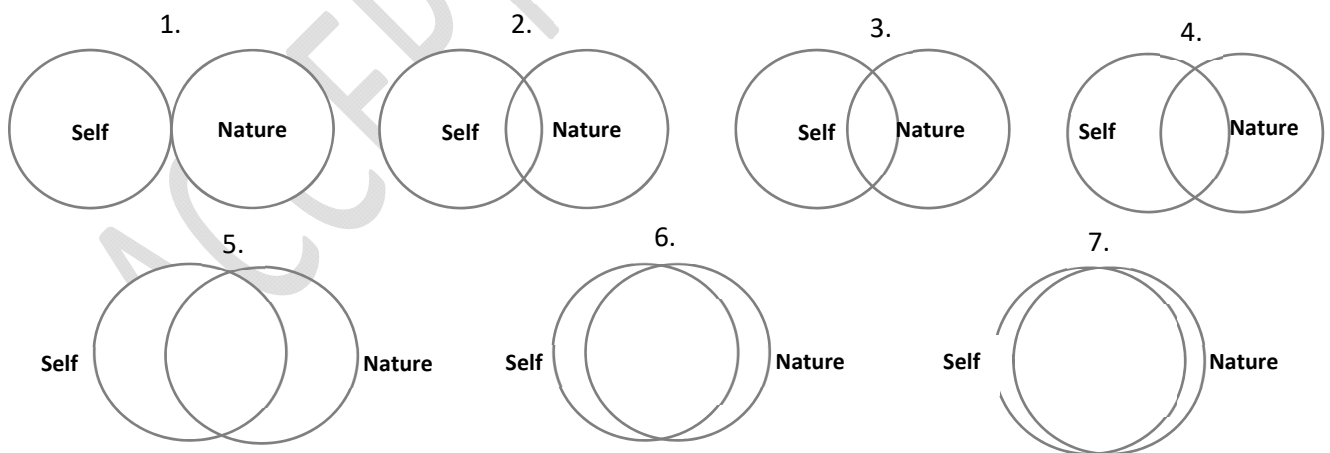
I've lived there forever |__| or give a date |__||| |__|||

A3. What two words come to mind to describe your living environment?

A4. On a scale of 0 (not at all satisfied) to 10 (very satisfied), indicate your satisfaction with the life you currently lead: Score:

B. Links to nature and the pond

B1. From the following figures showing personal connections and closeness to nature, choose the type of connection that best fits your case



B2. In the course of a year, in the context of sporting activities, walks or your professional activity, approximately how many times do you visit the lake or the areas near the Thau Lagoon?

- Never Several times a year Several times a month About 1 time / week More often

When you go to areas near the Thau Lagoon, what activities do you do?

	Tick each activity according to frequency		
	Common	Sometimes	Never
B3. Walking or cycling, hiking, jogging, picnics,			
B4. Birdwatching, plant observation, nature discovery			
B5. Photography, painting			
B6. Recreational fishing			
B7. Hunting			
B8. kitesurfing, windsurfing, boating, kayaking, canoeing, diving...			
B9. Looking for peace, tranquillity, yoga			

On a scale of 0 (minimum) to 10 (maximum), what do you think of the Thau Lagoon?	Score 0 to 10
B10. These areas are valuable to nature independently of man	
B11. I am touched by the beauty of these sites	
B12. walking near the pond allows me to be in connection with nature	
B13. Walking near the pond allows me to relax and be less stressed	
B14. Walking near the pond gives me a sense of self-realisation and fulfilment	

C. perceptions of the environment

On a scale of 0 (minimum) to 10 (maximum) can you rate the importance of the following

	Scores 0 to 10
C1. I devote a lot of time, energy and effort to maintaining the quality of the environment	
C2. Compared to other people I know, I invest a lot in the environment	
C3. I feel concerned about environmental issues	
C4. Ponds are part of our natural heritage and must be preserved	

C5. Do you think you are sufficiently informed about how to behave in order to preserve the environment and biodiversity? **(Score from 0 to 10)**

D. Perception of the roles of the pond

Can you name **TWO words** to describe the Thau Lagoon?

D1. _____ **D2.** _____

Can you name **ONE important event** that has influenced the evolution of the Thau Lagoon?

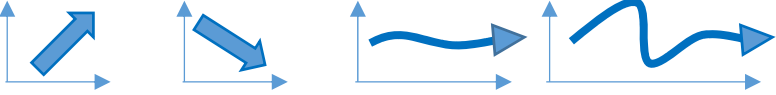
D3. _____

For each of the main roles played by the Thau Lagoon we ask you:

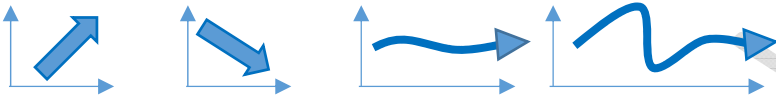
- to evaluate the importance of this role for the territory on a scale from 0 (not important) to 10 (very important).
- to give your point of view on the evolution by selecting one of the four types of curves
- to evaluate from your point of view the importance of this role for the territory compared to now (always on a scale from 0 to 10).

Finally, if the evolution is not stable, we ask you to cite an event or a date that you think accounts for the change


RECREATIONAL AND SPORTS ACTIVITIES (DIVING, HUNTING, CANOEING, KITE SURFING, WINDSURFING...)

<p>Currently important (score from 0 to 10)</p>	<p>What type of development</p> <p>Increasing Decreasing Almost stable Very fluctuating</p> 	<p>Past importance (score from 0 to 10)</p>	<p>To which event or date do you relate the change?</p>
--	---	--	---


LANDSCAPE, WALKING AND NATURE OBSERVATION

<p>Currently important (score from 0 to 10)</p>	<p>What type of development</p> <p>Increasing Decreasing Almost stable Very fluctuating</p> 	<p>Past importance (score from 0 to 10)</p>	<p>To which event or date do you relate the change?</p>
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production of shellfish (oysters and mussels)





<p>Currently important (score from 0 to 10)</p>	<p>What type of development</p> <p>Increasing Decreasing Almost stable Very fluctuating</p> 	<p>Past importance (score from 0 to 10)</p>	<p>To which event or date do you relate the change?</p>
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FISHING (FISH AND SHELLFISH)





<p>Currently important (score from 0 to 10)</p>	<p>What type of development</p> <p>Increasing Decreasing Almost stable Very fluctuating</p> 	<p>Past importance (score from 0 to 10)</p>	<p>To which event or date do you relate the change?</p>
--	---	--	---

REGULATION OF NUTRIENT RICHNESS





(e.g. wetlands and ponds contribute to the growth of aquatic animals through the production of microalgae)

Currently important (score from 0 to 10)	What type of development				Past importance (score from 0 to 10)	To which event or date do you relate the change?
	Increasing	Decreasing	Almost stable	Very fluctuating		
						

CONTRIBUTION TO LOCAL CULTURE AND HERITAGE (history, image and identity of the area)

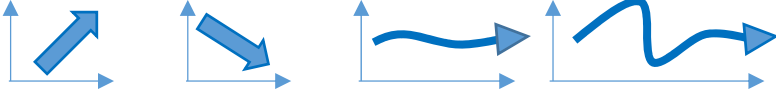
Currently important (score from 0 to 10)	What type of development				Past importance (score from 0 to 10)	To which event or date do you relate the change?
	Increasing	Decreasing	Almost stable	Very fluctuating		
						

MAINTAINING FLORA, FAUNA AND AQUATIC BIODIVERSITY (environmental conservation role)

Currently important (score from 0 to 10)	What type of development				Past importance (score from 0 to 10)	To which event or date do you relate the change?
	Increasing	Decreasing	Almost stable	Very fluctuating		
						

WATER QUALITY REGULATION

(the grass beds and plants in wetlands and ponds play a role in filtering the water and thus contribute to the balance of the aquatic environment)

<p>Currently important (score from 0 to 10)</p>	<p>What type of development</p> <p>Increasing Decreasing Almost stable Very fluctuating</p> 	<p>Past importance (score from 0 to 10)</p>	<p>To which event or date do you relate the change?</p>
--	--	--	--

ACCEPTED VERSION

After these questions about the past, we now ask you to look ahead ten to fifteen years and tick the three or four roles of the pond that will be most important then?

	YES	NO
D13. Recreational and sports activities (diving, hunting, canoeing, kite surfing, windsurfing...)	<input type="checkbox"/>	<input type="checkbox"/>
D14. Landscape, walking and nature observation	<input type="checkbox"/>	<input type="checkbox"/>
D15. Shellfish production (oysters and mussels)	<input type="checkbox"/>	<input type="checkbox"/>
D16. Fishing (fish and shellfish)	<input type="checkbox"/>	<input type="checkbox"/>
D17. Contribution to local culture and heritage	<input type="checkbox"/>	<input type="checkbox"/>
D18. Maintenance of flora, fauna and aquatic biodiversity	<input type="checkbox"/>	<input type="checkbox"/>
D19. Regulation of nutrient richness	<input type="checkbox"/>	<input type="checkbox"/>
D20. Water quality regulation	<input type="checkbox"/>	<input type="checkbox"/>

E. Perceptions of inequality

What do you consider to be the most appropriate objectives for the management of natural environments?

	Score 0 to 10
E1. Provide maximum well-being for all residents	
E2. Preserve resources and the environment	
E3. Favouring the poorest	
E4. Organise incentives in an egalitarian way regardless of the beneficiaries' situation	
E5. Targeting those responsible for the damage as a priority	
E6. Organise incentives in proportion to effort or merit	
E7. Favouring first movers or older activities	

Depending on the type of measures and the location of the inhabitants or professionals, differences in productivity or vulnerability can be observed, leading to inequalities in situations with regard to the environment. Through the following examples, can you assess whether it is necessary to intervene to reduce these inequalities? The question is to **evaluate whether it is important to intervene according to a scale of 10 if it is essential to intervene to 0 if it is not necessary at all.**

Regarding the impact of differences in geographical location

E8. Need to intervene in relation to the different exposure to sources of contaminants between communes (bathing water) and between shellfish growing areas (contamination that may prevent the marketing of shellfish)

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required
10	9	8	7	6	5	4	3	2	1	0

E9. Need to intervene in relation to the different exposure to flooding in different areas

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required

10	9	8	7	6	5	4	3	2	1	0
----	---	---	---	---	---	---	---	---	---	---

E10. Need to intervene in relation to the different access to resources for shellfish production depending on the location of shellfish farms

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required
10	9	8	7	6	5	4	3	2	1	0

Concerning differences in the implementation of public actions

E11. Need to intervene in relation to the over-representation of maritime activities in decision-making bodies

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required
10	9	8	7	6	5	4	3	2	1	0

E12. Need to intervene in relation to the differences in the means allocated by the communities for recreational activities

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required
10	9	8	7	6	5	4	3	2	1	0

E13. Need to intervene in relation to differences in tax contributions according to activities or company size

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required
10	9	8	7	6	5	4	3	2	1	0

E14. Need to intervene in relation to the differences in contributions between residents and tourists or non-local users (e.g. differentiated payments for shuttles or car parks according to origin

Essential intervention	Strongly needed intervention		Intervention rather necessary		Indifferent	Intervention rather not necessary		Strong intervention not required		Intervention not at all required
10	9	8	7	6	5	4	3	2	1	0

E15. In order to reduce inequalities, what type of action do you think should be favoured? (one choice only)

<input type="checkbox"/>	Addressing inequalities related to geographical location through differentiated actions
<input type="checkbox"/>	Ensuring a balanced representation of populations and activities
<input type="checkbox"/>	Take into account the efforts of inhabitants, users or activities to preserve the environment in the proposed taxation or measures

E16. To which type of inequality are you most sensitive?

<input type="checkbox"/>	Income-related social
<input type="checkbox"/>	Environmental quality and differences in living environment
<input type="checkbox"/>	Health and access to care

<input type="checkbox"/>	Access to education
<input type="checkbox"/>	Access to public facilities
<input type="checkbox"/>	Other: specify

F. Perceptions of environmental protection policies in relation to the Thau Lagoon

F1. Do you think that the current policies to maintain the diversity of roles in the Thau lagoon are relevant? **Score from 0 to 10**|__|

What do you think of the management measures carried out in the Thau Lagoon in recent years?

	Score 0 to 10
F2. The institutions that implement them are competent to	
F3. They are consulted with the population	
F4. Managers provide sufficient information to the public	
F5. They integrate social dimensions and inequalities	

How important would you consider the following criteria to be in justifying your trust in an environmental management institution

	Choose only two answers
F6. In-house technical skills and expertise	<input type="checkbox"/>
F7. Importance of links with scientists	<input type="checkbox"/>
F8. Monitoring and steering capacity	<input type="checkbox"/>
F9. Proximity to elected officials	<input type="checkbox"/>
F10. Transparency of choices	<input type="checkbox"/>
F11. Justice of the measures	<input type="checkbox"/>
F12. Consultation and integration of local knowledge	<input type="checkbox"/>

G. Socio-demographic profile

G1. What is your age:

G1BIS. Are you?

<input type="checkbox"/>	A man	<input type="checkbox"/>	A woman
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G2. Are you :

<input type="checkbox"/>	Married, civil union or cohabiting	<input type="checkbox"/>	Single, Widowed or Divorced
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G3. What is your socio-occupational category?

<input type="checkbox"/>	Farmer	<input type="checkbox"/>	Worker
<input type="checkbox"/>	Craftsman, trader, company director	<input type="checkbox"/>	Unemployed
<input type="checkbox"/>	Managers and senior professionals	<input type="checkbox"/>	Student/scholar
<input type="checkbox"/>	Intermediate occupations	<input type="checkbox"/>	Retired
<input type="checkbox"/>	Employee	<input type="checkbox"/>	Other: specify

G4. What is your highest level of education?

- No BEP-CAP BAC BAC +2 BAC + 3 or 4 BAC + 5 and more

G5. During your training, did you take any courses on the environment?

- Yes specialized environmental training Some courses No

G6. Is or was your activity related to the environment? Yes No

G7. Are you a member of an environmental association? Several A single No

G8. Have you ever donated to environmental organisations?

- Often once or twice never

G9. What are the **total monthly resources of your household** (you and your spouse or partner if you are a couple). **This refers to all your resources including family allowances, rents received or other income ...)?**

- <750 750 to €1,000 1,000 to €1,500 1,500 to €2,000
 2,000 to €3,000 3,000 to €4,500 4,500 to €6000 > €6000

1 **Appendix 3.** Flows of the 8 ecosystem services estimated from quantitative indicators, for the periods P1
2 to P3.
3

Category	Ecosystem Service	Indicator used (sources in brackets: see references below*)	Average indicator by period (<i>or of expert evaluations in italics</i>)		
			Period P1 (1970-1989)	Period P2 (1990-2004)	Period P3 (2005-2018)
Provisioning	A1. Shellfish production	Total shellfish production (t.y ⁻¹) ⁽¹⁾	9 282	14 388	11 345
	A2. Fishing	Number of active fishers ⁽²⁾	505	322	186
Regulating	R1. Flora, fauna and aquatic biodiversity conservation	Percentage of soft-bottom dominated by marine seagrass ⁽¹⁾	28.6	21.6	20.0
	R2. Regulation of nutrient abundance and food chain balance	<i>Average estimations by 9 stakeholders</i>	8.2	7.4	7.2
	R3. Regulation of water quality	Average of 3 indicators from environmental monitoring surveys ⁽³⁾ : (R3.1) phosphorus flows from the catchment basin (t.y ⁻¹); (R3.2) average contaminant concentrations in mussels (Cd, Hg, Cu and Pb in mg.kg ⁻¹ of wet weight and HCH in µg.kg ⁻¹ of wet weight; (R3.3) population of the catchment basin not connected to the sanitation system and discharging into the lagoon (inhabitants)	R3.1: 105.0; R3.2: Cd=0.18, Hg=0.02, Cu=1.86, Pb=0.36, HcH=1.32; R3.3: 22 674	R3.1: 65.0; R3.2: Cd=0.15, Hg=0.02, Cu=1.56, Pb=0.21, HcH=0.56; R3.3: 12 395	R3.1: 22.9; R3.2: Cd=0.11, Hg=0.02, Cu=1.42, Pb=0.15, HcH=0.10; R3.3: 7 852

Cultural	C1. Recreational and sporting activities	Number of associations related to water recreational activities (sailing, diving, kitesurfing, water skiing, rowing) ⁽⁴⁾	4.3	11.3	22.5
	C2. Landscapes, walks and nature observation	Number of associations related to nature conservation ⁽⁵⁾	0.25	3.1	7.3
	C3. Contribution to culture and local heritage	Number of associations for the protection and enhancement of cultural and linguistic heritage ⁽⁵⁾	0.05	10.7	17.7

4 * (1) Affaires Maritimes, 1970-1989; Comps, 2000; DML, 2010-2018; (2) Mazouni *et al.*, 1999; Cejpa, 1985; Les
5 Ecologistes de l'Euzière ; Affaires Maritimes 2004, 2005; Cépralmar, 2006; SMBT 2010, 2014; Chaboud et al. 2015;
6 SIH, 2018, 2019; (3) La Jeunesse, 2001; Cépralmar, 2006; Le Ster, 2015; Bec et al., 2018; ROCCH-matière-vivante
7 (Quadrige²); La Jeunesse, 2001; INSEE 2016; Couton et al. 2007; (4) Yellow Pages and telephone or e-mail survey by
8 N. Lautrédou-Audouy; (5) Répertoire National des Associations - Hérault (1970-2006); [https://www.sete.fr/vie-](https://www.sete.fr/vie-quotidienne/la-vie-associative/associations/)
9 [quotidienne/la-vie-associative/associations/](https://www.sete.fr/vie-quotidienne/la-vie-associative/associations/) & website of Balaruc-les-Bains (2018).

10

11 **Appendix 4.** Flows of the 8 ecosystem services estimated by coastal residents for the periods P1 to
12 P3: average scores, standard deviations (in square brackets) and estimated variances (in %)
13 associated with sample size* in italics and brackets.

	Period 1	Period 2	Period 3
A.1 Shellfish production	7.7 [2.0] <i>(0.23%)</i>	7.6 [2.0] <i>(0.33%)</i>	8.0 [2.0] <i>(0.08%)</i>
A.2 Fishing (fish and shellfish)	7.0 [2.2] <i>(0.27%)</i>	7.1 [2.0] <i>(0.33%)</i>	5.9 [2.5] <i>(0.1%)</i>
R1. Flora, fauna and aquatic biodiversity conservation	6.7 [2.2] <i>(0.27%)</i>	6.7 [1.9] <i>(0.30%)</i>	7.8 [1.9] <i>(0.07%)</i>
R2. Regulation of nutrient abundance and food chain balance	7.0 [1.8] <i>(0.21%)</i>	6.7 [1.9] <i>(0.30%)</i>	7.6 [2.0] <i>(0.08%)</i>
R3. Regulation of water quality	7.0 [2.0] <i>(0.23%)</i>	6.7 [2.1] <i>(0.36%)</i>	7.8 [2.0] <i>(0.08%)</i>
C1. Recreational and sporting activities	5.6 [2.2] <i>(0.27%)</i>	5.7 [2.1] <i>(0.36%)</i>	7.0 [1.9] <i>(0.07%)</i>
C2. Landscapes, walks and nature observation	6.3 [2.1] <i>(0.25%)</i>	6.6 [2.1] <i>(0.36%)</i>	7.9 [1.7] <i>(0.06%)</i>
C3. Contribution to culture and local heritage	6.9 [1.8] <i>(0.21%)</i>	6.9 [2.0] <i>(0.33%)</i>	7.6 [1.8] <i>(0.07%)</i>

14 * calculated with the formula proposed by Frontier (1982) for simple random sampling: $Var(\bar{X}_n) = (1 - f) \frac{\hat{\sigma}^2}{n}$,
15 with f: sampling effort and n: sample size.

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