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Application of the Ecosystem Service Concept to a Local-Scale: The Cases of Coralligenous Habitats in the North-Western Mediterranean Sea

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Abstract

In an era when we witness the erosion of biodiversity it is essential to understand the benefits provided by ecosystems and find ways to maintain them. The concept of ecosystem service has been applied in this perspective, but mainly in large-scale surveys and on terrestrial ecosystems. The primary objective of this project is to validate the inclusion of the concept of ecosystem service as a useful input to local (small-scale) community decision making in the marine environment. A second objective is to define the beneficial services provided to local areas by the coralligenous habitats. The application of the concept of ecosystem service at a local scale is more appropriate to local regulatory and management issues. This research was focused on the complex and threatened coralligenous habitats, about which the benefits and services provided are relatively little understood. To address these issues and get around the paucity of prior research, we collected the opinions of 43 experts for two marine sites (Bay of Marseille and Port-Cros National Park) on 15 services using interviews, an online questionnaire and workshops. This work validated 10 services: the most evident were "food", "diving sites", "research" and "inspiration". We also showed that even in very close-by sites, slight differences in the bundle of services may occur, and we highlighted knowledge gaps especially concerning those services (so-called regulating services) that help to regulate environmental impacts of other phenomena. This work concluded that there is a strong need to employ a referential frame to identify and then estimate services based on local criteria such as: geographical and temporal scale, size of the population of beneficiaries, value of the benefits, and state of ecosystem well-being. These results are a basis for further evaluation of these ecosystem services and can indicate their positive contribution to local decision-making concerning the regulation and management of coralligenous habitats.

Keywords: experts knowledge, Marseille, Port-Cros, appraisals, interviews, workshops, questionnaire, coralligenous habitats, ecosystem services, local-scale, concept application.

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1 Introduction

Coralligenous habitats are considered to be some of the more complex marine habitats [Paoli *et al.*, 2016] and their at least 1666 species reported by Ballesteros [2006] contribute actively to the biodiversity of the Mediterranean sea. Such great biodiversity and coastal location suggest that these habitats provide many ecosystem services. Studying these services helps to fill a gap in the literature: services from marine ecosystems are less studied than those of terrestrial ecosystems [Beaumont *et al.*, 2007]. There is almost no literature dealing with ecosystem services provided by coralligenous habitats while there is a relative abundance of literature on ecosystem services provided by other marine habitats: seagrasses [Nordlund *et al.*, 2016], coral reefs [Moberg and Folke, 1999], deep marine ecosystems [Armstrong *et al.*, 2012], coastal ecosystems [Liquete *et al.*, 2013].

Since Marion [1883] first described them in Marseille, coralligenous habitats have been the subject of a relatively small but rapidly increasing number of studies. The main studies are referenced in Ballesteros [2006]. Besides, during the last five years some indicators have been created specifically to measure the status of coralligenous habitats [Deter *et al.*, 2012, Gatti *et al.,* 2015, Doxa *et al*. 2016, and Sartoretto *et al.,* 2017]. These indicators confirm the interest of ecologists in coralligenous habitats, while there is still no literature dealing with the economics aspect of coralligenous habitats.

Coralligenous habitats are encountered along most of the Mediterranean coasts but they are mainly studied in the North-western region. Figure 1 show typical coralligenous habitats of Marseille. Existing from 20 m to 120 m under the surface of the sea [Ballesteros, 2006], these

habitats are very complex and heterogeneous assemblages, which differ from one Mediterranean region to another. Thus ecologists hardly agree on a common definition. In this study we use the most consensual definition of coralligenous habitats: *hard substrates of biogenic origin that are mainly produced by the accumulation of calcareous encrusting algae growing in dim light conditions*, and *unique calcareous formations of biogenic origin in Mediterranean benthic environments* [Ballesteros, 2006]. As reviewed by Ballesteros [2006] coralligenous habitats are threatened by large-scale events, waste waters [Hong, 1980]., physical impacts from diving [Garrabou *et al*., 1998 ; Harmelin & Marinopoulos, 1994]or fishery activities [Bell, 1983 ; Garcia-Rubies & Zabala, 1990] and invasive species [Piazzi *et al.,* 2005]. And more recent studies showed that sea acidification is also a threat to coralligenous habitats [Martin *et al.,* 2009, 2013; Nash *et al.,* 2016]. Their extremely slow development make their recovery from these impacts very limited. In this study we focused on sites in the North-western Mediterranean Sea where coralligenous habitats are closest to the surface, which favors their observation and interaction with human beings.

Figure 1: Typical coralligenous habitats of Marseille. Photocredits : Frédéric Zuberer (OSU Pythéas)

The concept of ecosystem services has been used since the 1960's in order to raise awareness of human dependency on nature and the need to preserve nature for the sake of human well-being. The Millenium Ecosystem Assessment (MEA) [2005], the proceeding of The Economics of Ecosystems and Biodiversity (TEEB) [UNEP (United Nations Environment Programme), 2010] and the Common International Classification of Ecosystem Services (CICES) [Haines-Young and Potschin, 2010] show a common international and cross-disciplinary academic effort to define and classify ecosystem services in order to facilitate their assessment. However, there is a break between the MEA-TEEB and the CICES concerning both the definition and the classification of ecosystem services. The MEA and TEEB adopted wide understandings of ecosystem services and both included *supporting services* as a category of ecosystem services. Respectively, ecosystem services are defined by the MEA as *benefits that ecosystems provide* and by TEEB as *the direct and indirect contributions of ecosystems to human well-being*. These definitions are coherent with a classification of ecosystem services into four categories: provisioning, regulating, cultural and supporting. However, these wide definitions and classifications can lead to some confusion when the economic contributions of ecosystem services are assessed. In the prospect of undertaking an economic valuation, the CICES followed the more restrictive definition of ecosystem service proposed by Boyd and Banzhaf [2007] with the aim to avoid double-counting of some categories: *components of nature, directly enjoyed, consumed, or used to yield human well-being*. In this study we opted to include the supporting services, since our aim at this step was not to make an economic valuation but to gather the maximum available knowledge regarding the services provided by coralligenous habitats and to test the application of the concept of ecosystem service with experts on local sites. However, we consider the definition of Boyd and Banzhaf [2007] more suitable for further economic valuation.

As underlined by Levrel *et al.* [2017], *one of the main issues with the concept of ecosystem services is its absence on the ground in concrete operational decision-making*. An aim of the present study is to apply the ecosystem service concept to a complex and relatively unknown ecosystem at an operational management scale. To accomplish this we identified the bundle of ecosystem services provided by coralligenous habitats in the sites of the Marseille bay and the Port-Cros national park. The small-scale of this project enabled us to work with a common reference of coralligenous habitats despite their variability. It also enabled the investigation of practical issues since stakeholders could be identified precisely and we could gather experts who had a deep knowledge of the site. We gathered expert opinions on the ecosystem services regarding their importance and their possible variation from one location to another. This was done through complementary methods: interviews, an online questionnaire and workshops.

2 Materials and methods

2.1 Locations

The two study locations were the "Marseille site" and the "Port-Cros site". The Marseille site encompassed the coastal and marine zone from Martigues to La Ciotat, including the Côte Bleue marine park and the Calanques national park. The Port-Cros site included the marine core and adjacent area of Port-Cros national park. Figure 2 displays the two studied sites, and indicates the location of coralligenous habitats and the marine protected areas. We chose Marseille and Port-Cros because they present similarities in terms of coralligenous habitats but differences in terms of economic and social contexts. Both sites harbor abundant coralligenous habitats, considered as some of the most beautiful across the French Mediterranean coast [Tribot *et al.*, 2016]. Those

coralligenous habitats can be considered to be quite homogeneous compared to other coralligenous habitats along the Mediterranean coasts. They are mostly on vertical cliffs, between depths of 20 m and 50 m [Hong, 1980, Laborel, 1961], and their communities are often dominated by gorgonians. Both sites include marine protected areas but with varying ages: the Port-Cros national park (since 1963), the Calanques national park (since 2012), and the marine park of the Côte Bleue (since 1983). There is an abundance of historical ecological data in those areas [Marion, 1883, Pérès and Picard, 1951, Hong, 1980, 1982, Witkowski *et al.*, 2016]. Human impact is much higher in the Marseille site than in the Port-Cros site. Marseille is the second largest city in France with about 852,000 inhabitants (INSEE, 2012). This city is located in a department of almost 2 million inhabitants and is the first French Mediterranean harbor. At the Port-Cros site, the main town, Hyères, counts about 56,000 inhabitants in a *département* of only about 1 million inhabitants. Both sites include islands where most of the coralligenous habitats are found.. Marseille islands are closer to the mainland than Port-Cros islands, thus the former are more accessible than the latter. In both sites diving activities are intense and regulated while professional artisanal fishing activities are regulated and declining.

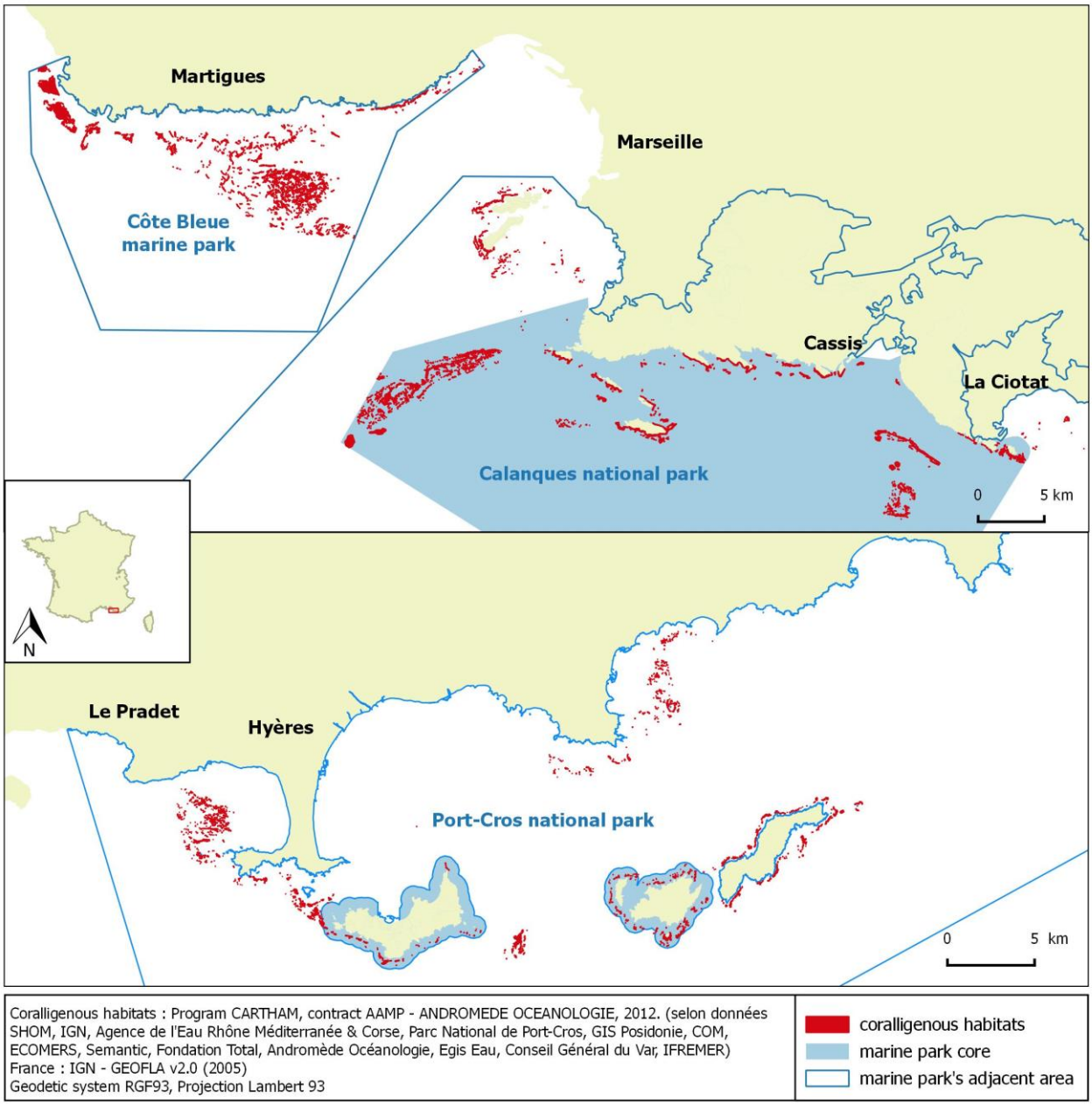

Figure 2: Map of the two studied areas. Top: the Marseille site (including the bay of Marseille, the marine park of the Côte Bleue and the national park of the Calanques). Down: the Port-Cros site (including the national park of Port-Cros and its marine adjacent area in the bay of Hyères).

2.2 Preliminary list of ecosystem services based on literature

The literature was investigated in 2015 previously to the survey in order to identify services to submit in the online questionnaire. The literature published in 2016 was added ex-post to completed our review but could not be a basis for the experts survey. Our literature review included peer-reviewed articles available on Google Scholar and on the CNRS portal, reports on the studied protected marine areas and books. The only document which explicitly mentioned the ecosystem services provided by coralligenous habitats were the ones written by Mangos *et al.* [2010], which was a large scale project that estimated the economic benefits of five marine ecosystems in the entire Mediterranean Basin. This work contrasted with our objective, which was to validate the existence of ecosystem services provided by a specific ecosystem at a small-scale. Other references suggested, in different terms, some ecosystem services provided by coralligenous habitats, or mentioned ecosystem services provided by other ecosystems sharing with coralligenous habitats the relevant characteristics implied in the supply of the service mentioned (table 1).

A preliminary list of ecosystem services potentially provided by coralligenous habitats was assembled from the literature and was completed with input from expert interviews. This list included 15 ecosystem services, which were submitted to the 43 experts via the online questionnaire and the workshops. The ecosystem services included in the preliminary list are presented in the table 2. The preliminary list was established independent of location.

168 *Table 1: Literature supporting the existence of ecosystem services provided by coralligenous habitats.*
169 *In grey: literature published after our survey with experts.*

Ecosystem service	Illustrating references	Comments
Food	Harmelin 1990, Mangos *et al.* 2010, INPN MNHN 1170-14, Witkowski 2016, Paoli *et al.* 2016	Targeted species are not only found only in coralligenous habitats even it it might be their preferable habitats. Fishing is usually done not directly on coralligenous habitats but at the edge. Mangos *et al*. Provide a rough estimation of quantities of species caught over coralligenous habitats, using FAO data and expert knowledge to determine the species distribution between habitats.
Red coral production	Liverino 1989, Ascione 1993, Santangelo *et al.* 1993, Santangelo and Abbiati 2001, Paolini 2004, Ballesteros 2006, Tsounis *et al.* 2007, Mangos *et al*. 2010, Allemand 2012, Paoli *et al.* 2016.	Red corals can be found in coralligenous habitats, but not only there. For many years, they have been over-exploited and with impacting tools. Nowadays there are regulations for the harvesting (in France basal diameter must be over 7mm, depth>50m). Red corals have also a strong cultural value in the Mediterranean basin, and divers enjoy to see it alive as well.
Diving spot	Harmelin 1993, Mangos *et al.* 2010 , Chauvez *et al*. 2012., Plouvier 2015, Paoli *et al.* 2016.	From depth 0 to 60 m corallgenous habitats are commonly reachable and targetted by recreational divers enjoying their spectacular landscapes, built by gorgonians and orther macro and colored fixed specied, and the dense populations of macro vertebrates gravitating around.
Support for scientific discoveries	Jares-Erijman et al. 1991, Ballesteros 2006, Leal *et al*. 2012,,Paoli *et al*. 2016, Jaspars *et al.* 2016.	Ballesteros reported 1666 specied and 250 scientific references about coralligenous habitats previous to 2006. Many substances, useful to an anthropogenic point of view, can be extracted from organisms thriving in animal forests (eg. anticancer, anti-inflammatory, HIV treatments). The families of sponges and cnidarians are known have a potential to provide active compounds, and most of the species well represented in coralligenous habitats are still not analyzed. For example *Crambe crambe* provides the crambescidins (antiviral and cytotoxic compounds). Scientists can also use bio-constructions to track changes in the marine environment.
Aesthetic, inspiration	Mangos *et al.* 2010, Tribot et al. 2016, Paoli *et al.* 2016	Coralligenous habitats are very rich in colours, structures, species. Divers take pictures of it and share their images. Coralligenous habitats are often represented in underwater photographic competition.
Biodiversity existence	Ballesteros 2006, Mangos *et al.* 2010.	Biodiversity may be consider as cultural service in the sense that people can give it an existence value for itself, and not consider the use they can make of it. But usually it is not considered as a service but as the ecosysm structure.
Carbon sequestration	Mangos *et al.* 2010, Paoli *et al*. 2016	Bioconstructions of calcareous organisms use carbon to build their calcareous squeleton. They may act as carbon sink.
Water filtration	Mangos *et al.* 2010, Paoli *et al*. 2016	Corals, sponges and other filter feeders contribute to the absorption of suspended particulate matter.
Coast stabilization	Cesar *et al.* 2004, Paoli *et al*. 2016	This service has been reported for reef type ecosytems such as coral reef
Bio-indicator	Sartoretto *et al.* 2017	Indexcor is an indicator which use coralligenous habitats to indicate the water quality.
Nursery	Mangos *et al.* 2010, Paoli *et al*. 2016.	As coastal habitats with a very complex structure which constitute refuges for species, coralligenous habitats may provide nurseries and spawning beds to halieutic species. But this function is hard to study since juveniles are difficult to find cavities.
Habitat and refuge	Ballesteros 2006, Paoli *et al.* 2016.	Ballesteros report the species living in coralligenous habitats. Paoli *et al*., confirm that the great structural complexity provide habitats to various species.

170 *Table 2: Definition of the 15 services submitted in the online questionnaire.*

CICES themes	Ecosystem service short name	Definition of the ecosystem service
Provisionning	**Food**	Wild stocks of species that professional fishermen fish, restaurants serve, people eat and savour. Species examples : *Scorpaena scrofa, Palinurus elephas , Homarus gammarus.*
	Red coral	Wild stocks of red corals that professional coral fishermen harvest, jewellers shape and sell, people enjoy as ornemental or jewellery.
	Aquarium	Wild stock of individuals exceptionnally captured for public aquariums.
Cultural and social	**Diving spot**	Landscape and biodiversity for divers enjoyment.
	Angling spot	Species that recreational spearfishermen enjoy.
	Spearfishing spot	Landscape and species that spearfishers enjoy.
	Research	Support for scientific discoveries (ecology, biology, medicine, …)
	Inspiration	Enjoyment and inspiration by aesthetic caracteristics through in situ visit or media.
	Biodiversity	Enjoyment of coralligenous specific biodiversity.
Regulation and maintenance	**Carbon sequestration**	Global climate regulation by carbon sequestration.
	Water filtration	Biological filtration of pollutants by filters.
	Coastline stabilization	Protection from the erosion of the coastline by physical caracteristics of the bioconcretioned reefs.
	Bio-indicator	Indication on the quality of local environment.
	Nursery	Essential habitat for juveniles which use other habitats for the other stage of their life cycle.
	Habitat and refuge	Favourite habitat and refuge for some species.

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2.3 Expert survey

Since the literature review revealed few studies clearly describing the ecosystem services provided by coralligenous habitats, an expert survey was employed to expand our understanding of them. We carried out the survey between October 2015 and June 2016 in three steps: individual face-to-face interviews, an online questionnaire and workshops (table 2). This three-step approach enabled us to gather individual and shared points of view, and to handle open and closed answers in a funnel-shaped way. All the 43 experts answered the online questionnaire, but only 8 of them were interviewed face-to-face and 16 participated to the workshops. Our survey protocol was inspired by the Delphi method: a method that uses several rounds of survey amongst a panel of experts to reach a consensus, and is *a flexible research technique well suited when there is incomplete knowledge about a phenomenon* [Skulmoski and Hartman, 2007]. This method involves obtaining individual points of views through an iteration process in which participants are aware of the answers of other participants. The detailed process of the expert survey is displayed in figure 3.

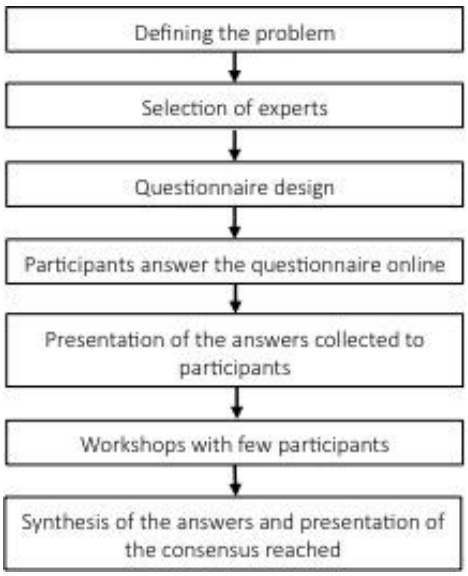


Figure 3: Protocol applied for the survey, inspired from the Delphi method.

2.3.1 Experts panel

Following Krueger *et al.* [2012] we considered as an expert any person having *relevant and extensive knowledge or in-depth experience in relation to* coralligenous habitats and/or their use or management in one or both of the sites studied. The expert pool was formed by 43 individuals from Marseille (25) and Port-Cros (18) sites. They were selected for their profiles: researchers (ecologist or economist), managers of marine protected areas, professional artisanal fishermen, representatives of diving activities (federation or structures), divers, and people monitoring coralligenous habitats. Their distribution among profiles and sites is presented in table 3.

Table 3: Profiles of the 18 experts of prot-Cros site and 25 experts of Marseille site. An expert can corresponds to several profiles.

Researchers						**MPA managers**		**Other professions**			
Ecologists		Economists		Others				Diving structure		Artisanal fishermen	
MRS	PC	MRS	PC	MRS	PC	MRS	PC	MRS	PC	MRS	PC
11	2	3	0	0	1	5	5	2	1	2	3

2.3.2 Interviews

Interviews were carried out to obtain some deep knowledge that could not be gathered through questionnaires or focus groups. The interviews helped to complete the preliminary list of ecosystem services and to confirm our findings from the literature. It was also a preliminary step to prepare the questionnaire. While the absolute number of experts were few, the total number of experts in these two locales is very small. Our panel thus represented most of the available expertise. The experts selected for the interviews had very specific knowledge on at least one of the following subjects: artisanal fishery (including red coral), diving, coralligenous habitats general ecology or characteristics of a taxonomic group (algae, sponges, fishes, red coral). The fishermen

209 selected represented the diversity of fishing practices, targeted species and sites. In many cases
210 their professional constraints prevented them from attending the workshops, but they were able
211 to grant us in-situ interviews. Interviews were conducted individually face-to-face in a semi-
212 directive way, lasting between 40 and 90 minutes, and were recorded and transcribed.
213
214 **2.3.3 Questionnaire**
215 The questionnaire was performed online, using the software © Limesurvey (version 2.06+ Build
216 150731). It contained 25 questions grouped in 6 parts: vocabulary issues, list of services,
217 importance of services, pressures, management, and respondents' profiles. The entire
218 questionnaire is available on demand. In this paper we focus on 2 parts of the online
219 questionnaire: the list of services and their importance. Most of the closed questions followed a
220 Likert-type scale with five levels. The online questionnaire was fully completed by the 43 experts
221 who each answered about one of the sites. Respondents took 30 minutes on average to answer
222 the questions.
223
224 **Acceptance of ecosystem services.** This issue was treated in question 3 "Is this an ecosystem
225 service provided by coralligenous habitats?". We rank-ordered the services according to the
226 frequencies of answers and applied a like-lexicographical method on the five modalities of
227 answers: Yes I'm sure/ Yes I think/I don't know/No I don't think so/No I'm sure it's not. We tested
228 different hierarchies of modalities (presented in the figure 4), when applying the lexicographical
229 order, to test the ranking consistency. Regarding the frequency thresholds we classified the 15
230 services *a posteriori* in four acceptance categories. We chose the thresholds between categories in
231 such a way as to maximize the consistency of the groups. As observed in figure 4, the merging of

services in categories are consistent regardless of the hierarchy of modalities chosen (see cases A, B, and C). In the first class we included the services with the highest frequencies of positive answers. Those services were considered to be provided by coralligenous habitats by all experts: more than 90% of them were sure of their answer. In the second class we included services gathering more than 80% of positive answers, independent of the status in the first class. In the third class we included services not falling in the previous classes and gathering more than 20% of "I don't know" answers and fewer than 10% of negative answers. In the fourth class we put services gathering more negative and uncertain than positive answers.

Importance and ranking of ecosystem services. To explore this aspect, we used a set of four questions in the online questionnaire. First, (through question 5) experts were asked to state a level of importance of services provided in the studied site. A Likert-type scale with a set of four items ("strong importance", "medium importance", "low importance" and "Do not know") was used. To confirm this judgment, later in the questionnaire (through question 9) experts had to select at least six services that they considered as main services provided by coralligeneous habitats in the studied site. Finally (in question 10), experts had to rank these services: "1" for the most important, "2" for the subsequent service, and so on. When experts didn't select a service in the first part of the questionnaire, this service was not proposed to them for the following questions and thus the item "no answer" was automatically generated and included in the analysis.

Services were ordered three times according to the answers obtained through the three questions dealing with importance (questions 5, 9 and 10) and we compared the results displayed in figures 5 and 6 and table 4. Figure 5 displays the services ranked according to the frequencies of the answers obtained through the question 5, ordered as follow: "strong", "medium", "low", "I don't

know", and "no answer". As a cross-check of these results, a second question dealing with importance (question 9) ranked the services according to the number of experts who select them as most important. The results of this are displayed in figure 6. Then, we aggregated the individuals rankings obtained from the last question dealing with importance (question 10) by putting in first position the service mostly placed in this position, then in second position (respectively third, etc...) the service placed mostly in first or second position in the individuals rankings (respectively in first, second or third, and so on) : see table 4.

Lastly, a question enabled exploration of the specific meaning of "importance" to each expert. Each of them was asked to define his/her own criterion of importance, the one s/he used to rank services. We proposed four definitions of importance as follows: a service is more important if…"it is at the basis of other services" / "it is perceived by more people" / "it impacts more people" / "it is more threatened". The experts didn't reveal any other definitions of importance in the online questionnaire but they discussed this issue during the workshops.

Further analyses. Our panel of experts was limited (43 individuals) but represented most of the relevant experts of the sites. We conducted basic statistical analysis of the answers collected via the online questionnaire: frequencies, mean and median, and a test of independence. In order to cross-reference the results from questions about acceptance and importance we transformed the modalities of acceptance into scores from 1 to 5, and the modalities of importance from 1 to 4. The mean and median scores of the 43 answers were then calculated. The plots of these results are displayed in the figures 8 and 9. A comparison of the results of different groups of experts representing the two geographical groups (Marseille and Port-Cros) was undertaken using the Fisher exact test. The results of this test are discussed in section 3.3 of this report.

2.3.4 Workshops

The main objective of the workshops was to help the interpretation of the answers obtained through the online questionnaire, and to more deeply investigate differences. Experts were encouraged to discuss especially the controversial points and seek consensual answers. We conducted two one-day workshops: one took place on the 3rd of December 2015 including 11 experts from the Marseille site; a second took place on the 16th of June 2016 with 6 experts from Port-Cros.

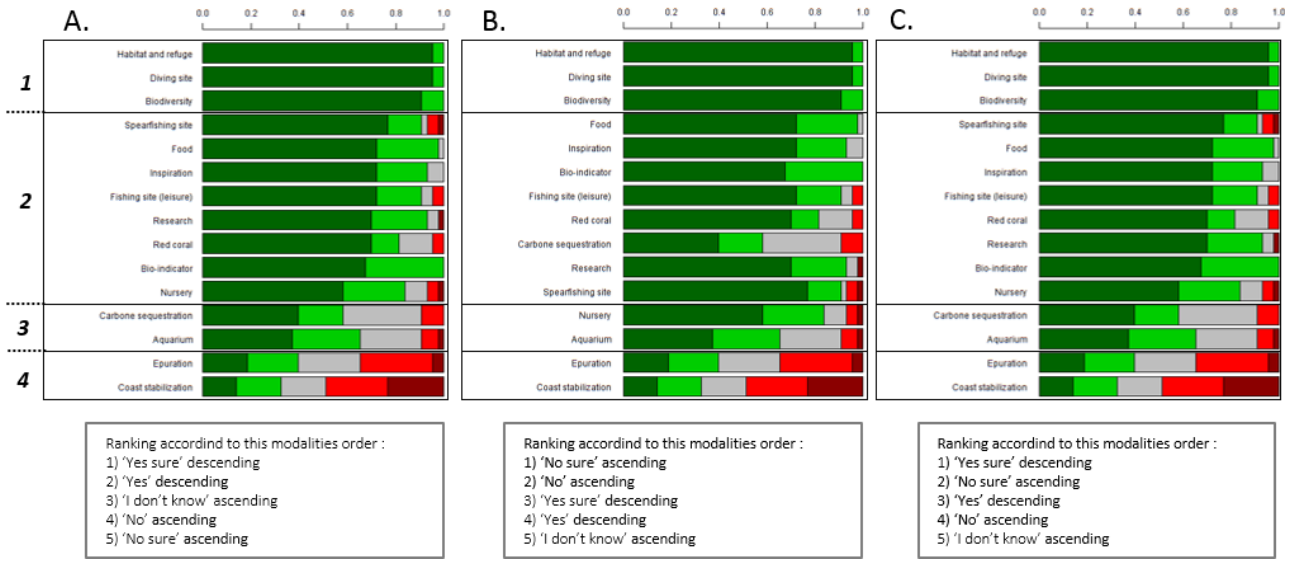
This last step of our survey protocol allowed us to get precise information about the ecosystem services available at each of the study sites. Thus, we were able to compare results obtained from both study sites in terms of ecosystem services perceived by the expert panel as actually provided by coralligenous habitats at this small scale.

3 Results

3.1 Acceptance of ecosystem services

Online questionnaire. Analysis of the answers to the online questionnaire indicates that services are distributed across four categories with respect to the experts' opinion as follows (figure 4). The services "habitat and refuge", "diving", and "biodiversity" are the services accepted unanimously (category 1). The services "food", "Inspiration", "spearfishing", "angling", "research", "red coral", and "bio-indicator" are accepted by the majority of experts (category 2). The category 3 corresponds to very uncertain services: the service "aquarium" is consistent in this category while the services "nursery" and "carbon sequestration" are borderline with the category 2. Finally, the

297 services "water filtration" and "coast stabilization" are mostly not accepted by experts (category
298 4).



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300 *Figure 4: Answers to the question 3 "Is this an ecosystem service provided by coralligenous habitats?" of the online questionnaire.*

301

302 **Workshops.** During the workshops, the participants discussed the questionnaire results and
303 collectively revised some of their initial assessments and came to a consensus: they finally stated
304 that they could only refute the ecosystem service "Coast stabilization". Their argument was that
305 the coralligenous habitats that could play this role are the flat types, bioconcretioning, but those
306 usually exist at depths too deep to impact the coastline. They weren't confident enough to
307 categorically refute the other controversial services such as "water filtration" and "carbon
308 sequestration": they mostly agreed on the fact that many species are filter feeders and that
309 calcareous species use carbon to build their skeletons. However they doubted the capacity of
310 coralligenous habitats to impact the global environment and didn't agree on the relative volume
311 occupied by coralligenous habitats compared to other benthic habitats (*Posidonia* meadows was
312 often taken as a reference). Thus, these last two services remain controversial.

3.2 Importance and classification of the ecosystem services

Online questionnaire. All services were selected at least by one expert to be a part of *the most important* (see figure 6) and also to be of *strong importance* (see figure 5). The ranking of services varies with the method used. However according to the concordant results presented in figures 6 and 5 and table 4 there are four distinct categories of importance. We included in this ranking all services presented in the preliminary list.

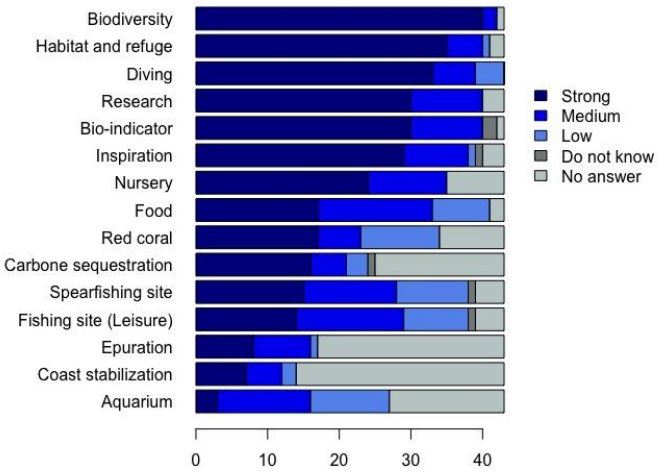

Figure 5: Experts'answers to the question 5 of the online questionnaire "According to you, how important is this service [in the studied site] ?". The status "no answer" was generated automatically when an expert did not select the service in the question 3.

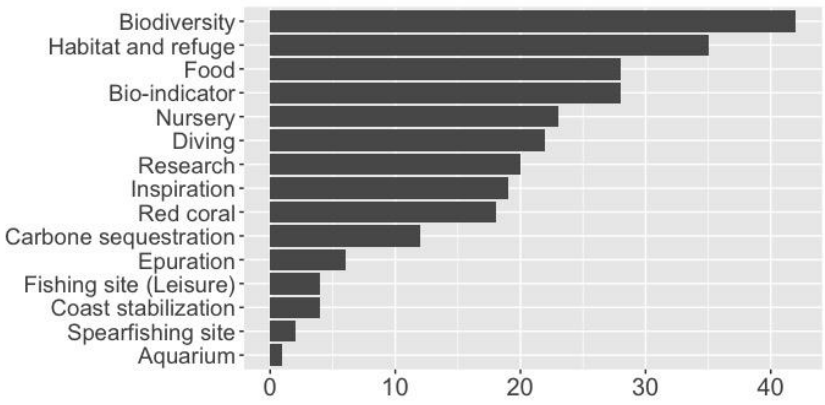

Figure 6: Number of experts who selected each service at question 9 ("Select the most important services") of the questionnaire. Experts must select at least 6 services and could select only the services they previously selected as "existing" services in question 3.

Table 4: Answers obtained from the question 10 of the online questionnaire ("Rank the services you have selected as most important").The table shows the cumulative numbers of positions 1 to 7 in the individual ranking of experts.

	1	1 + 2	1 to 3	1 to 4	1 to 5	1 to 6	1 to 7
Biodiversity	35	37	41	42	42	42	42
Habitat and refuge	5	26	32	35	35	35	35
Nursery	2	7	16	19	22	23	23
Food	0	7	11	19	24	28	28
Diving site	1	4	10	13	16	22	22
Research	1	3	6	9	13	18	20
Inspiration	2	5	7	9	14	17	19
Red coral	3	3	5	10	13	16	18
Carbone sequestration	2	6	7	8	11	12	12
Water filtration	2	3	0	7	8	8	8
Coastline stabilization	1	2	2	2	4	4	4
Angling site	0	1	2	2	3	4	4
Spearfishing site	0	0	0	1	1	2	2
Aquarium	0	0	1	1	1	1	1
Bio-indicator	0	0	0	0	0	0	0

With respect to the experts' opinions, the most important services (category 1) are "biodiversity" and "habitat and refuge": "biodiversity" was selected by 42 experts as part of the most important services ans placed in first position by 35 experts, "habitat and refuge" was selected by 35 experts as part of the most important services and was placed in first position by 5 experts and in second position by 21 experts. The services "diving ", "research", "nursery", "inspiration" and "food" are part of the category 2 that we called "services of strong importance". In the category 3, services of medium importance, we included the services "red coral" and "carbon sequestration". Finally, the services "water filtration", "angling", "spearfishing", "aquarium" and "coast stabilization" were put in category 4: services of low importance. The service "bio-indicator" is subjected to non-concordance between rankings methods: it was selected by 65% of the experts as part of the most important services, was stated of "strong importance" by 68% but then ranked in the last position

when experts had to directly compare it to other services. Thus we didn't attribute to it a consensual level of importance.

Both figures 7 and 8 display a positive relationship between acceptance and importance of ecosystem service. Those figures distinguish services accepted and very important ("biodiversity", "habitat and refuge", "bio-indicator", "research", "diving", "inspiration" and "nursery"), services accepted and of medium importance ("food", "red coral", "angling" and "spearfishing"), services controversially accepted and classified ("carbon sequestration" and "aquarium"), and services not accepted ("water filtration" and "coast stabilization").

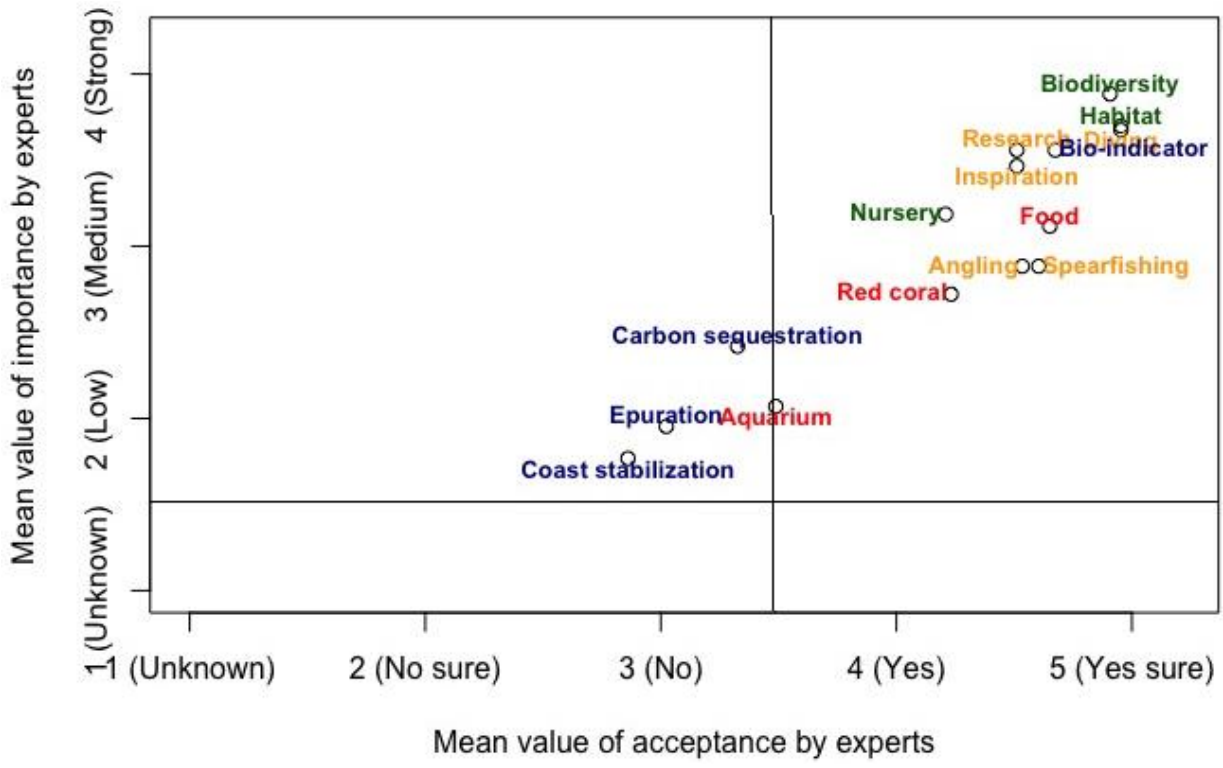

Figure 7: Mean of the scores given by the 43 experts concerning the acceptance of ecosystem services in question 3 ("Is it an ecosystem service provided by coralligenous habitats ?") and the importance of the ecosystem services (answers to the question 5 "How important is this ecosystem service ?") obtained through the online questionnaire).

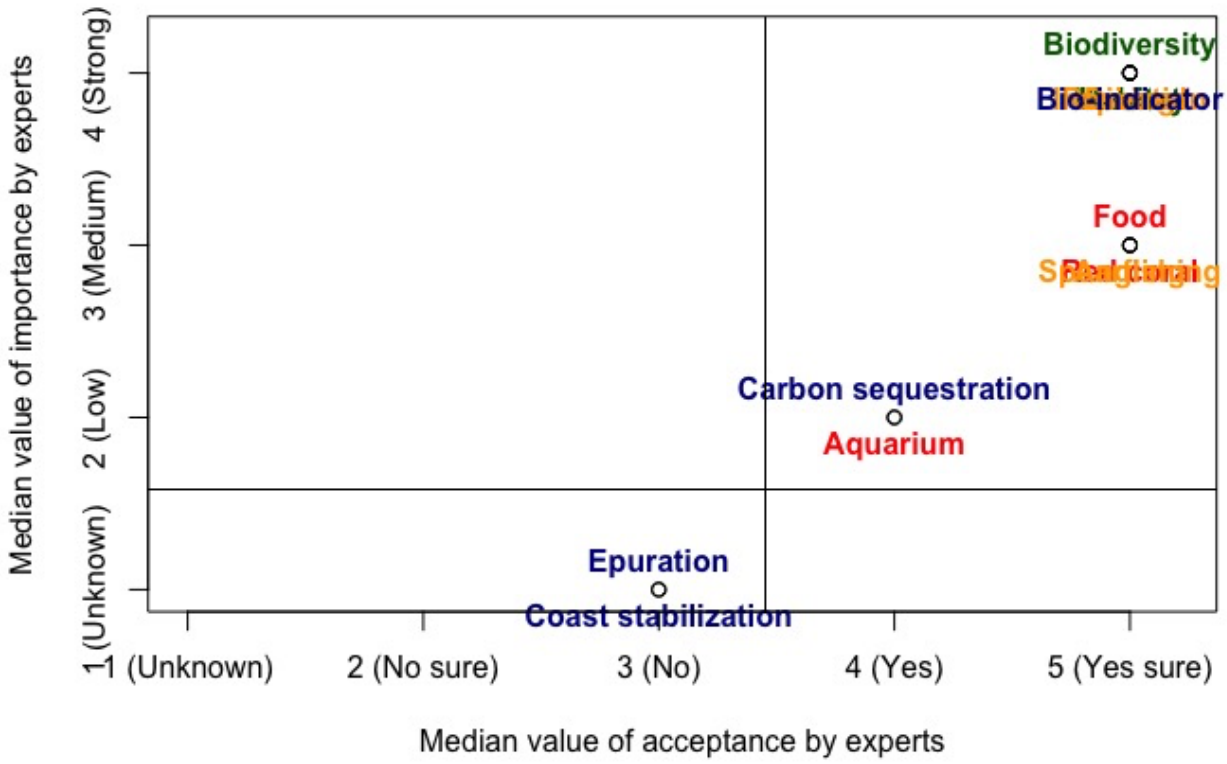

Figure 8: Mean of the scores given by the 43 experts concerning the acceptance of ecosystem services in question 3 ("Is it an ecosystem service provided by coralligenous habitats ?") and the importance of the ecosystem services (answers to the question 5 "How important is this ecosystem service ?") obtained through the online questionnaire).

The criterion mostly used to rank the services according to the declaration of the experts was "*a service is more important if it is at the basis of other services*" (selected by 70% of the experts). 40% of the experts also used the criteria "*impacts more people*" and "*is more threatened*". Only 20% of them declared using the criteria "*is perceived by more people*" (see figure 9). These results confirm that experts placed the supporting services at the head of the ranking.

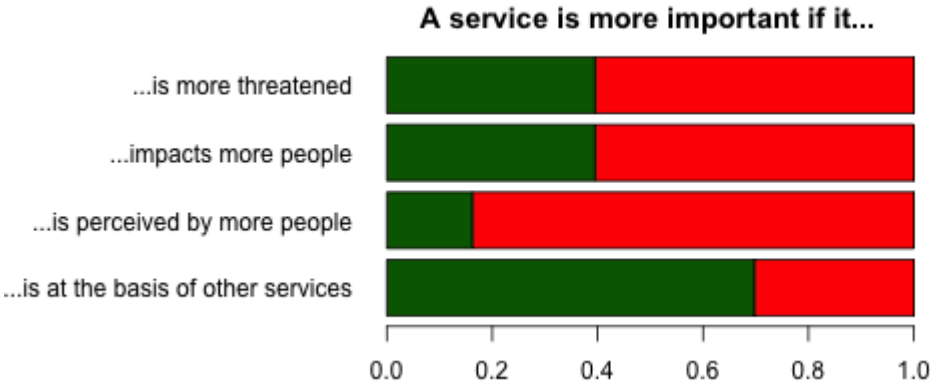

Figure 9: Percentage of experts who declared that they used the criterion in their ranking of the importance of services. Legend : green=yes, red=no.

Workshop. Except as noted above, previous results obtained through the online questionnaire were confirmed during the workshops. It can be noted that the services "water filtration" and "carbon sequestration" were considered to be more likely not significant according to the actual scientific knowledge of the bio-physical mechanisms underlying these services and the volume of water potentially treated by coralligenous habitats compared to the whole Mediterranean Sea.

3.3 Differences in ecosystem services offer among the locations (Marseille *vs* Port-Cros)

Among the fifteen ecosystem services, a divergence for four of them can be observed between the expert opinions of Marseille (25) and Port-Cros (18) concerning the questions 3, 5 and 9 of the online questionnaire: "red coral", "water filtration", "nursery", "coast stabilization". The service "coast stabilization" was the one triggering the most divergent opinions: it was considered as not existing by 72% oh the experts of Marseille but only by 16% of the experts of Port-Cros (Fischer exact p-value = 0.0051). The service "Red coral" was considered existing and important by 96% experts of Marseille while only by 61% experts of Port-Cros (Fischer exact p-value = 0.0062). On the contrary the ecosystem service "water filtration" was considered important by 44% of the

experts of Port-Cros but not by the experts of Marseille (this difference is confirmed by the Fischer exact p-value = 0.0007). Likewise, the service "nursery" was considered important by 83% of the experts of Port-Cros but by only 36% of the experts of Marseille (this difference is confirmed by the Fischer exact p-value = 0.0059)

4 Discussion

Reliance on experts. In the absence of scientific evidence, experts' experience is the best knowledge proxi available even if subjectivity cannot be avoided and if consensus does not guarantee scientific veracity. This study relied on 43 experts for two North-western Mediterranean sites. This sample is significantly more robust than those in other studies treating similar issues at a large scale: for example Beaumont *et al.* [2007] consulted 21 experts about ecosystem services provided by marine ecosystems globally, Nordlund *et al.* [2016] consulted 91 experts to deal with the different types of seagrasses in the whole world.

The list of ecosystem services. Thanks to the experts and literature the status of services proposed in our preliminary list has been established as shown in Figure 10. We can now affirm that the services "diving", "food", "inspiration", "research" and "bio-indicator" are actually provided by coralligenous habitats in the study sites, and surely provided by coralligenous habitats of other sites. Apart from their status of function or service, "biodiversity" and "habitat and refuge" have been validated by all experts to be provided by coralligenous habitats of any type and any site. The services "red coral", "aquarium", "spearfishing", ad "angling" were validated with less confidence

399 due to their unestimated but probably low benefits. The service "red coral" was provided in one of
400 the study sites. It should be provided in all areas well stocked, with possibility of harvesting and
401 human demand. However it may be anecdotal in term of population impacted by the benefits. The
402 same may be true for the service "aquarium" which is certainly even more anecdotal. The services
403 "spearfishing" and "angling" are recreational activities practiced in the studied sites, but the
404 proportion of activity practiced on coralligenous habitats is unknown, it could be either low or
405 high, experts were not able to estimate any tendency. The services (or function) "water filtration",
406 "carbon sequestration" and "nursery" are still controversial pending scientific proof, since we
407 found no reference supporting their effectiveness and even the experience of experts was
408 insufficient to give a probability of effectiveness. The pros argument for the "carbon
409 sequestration" service is the presence of many calcareous species (especially red algae) in
410 coralligenous habitats, which used carbon to grow and then fossilize. The pros argument for the
411 service "water filtration" is the presence of many filterers such as sponges. The cons argument for
412 both is the effective regulating impact of coralligenous habitats at the global Mediterranean scale
413 and the capacity of calcareous species to capture carbon and the time of sequestration are
414 unknown. Apart from its status of function or service, the "nursery" role, as defined by Beck *et al*.
415 [2003], of coralligenous habitats would be verified only after the observations of juveniles living
416 exclusively in coralligenous habitats and moving to another habitat for their adult phase. Juveniles
417 are not easy to observe and identify, thus their observation would need a specific experiment that
418 have not been performed on coralligenous habitats to date. Finally, the service "coast
419 stabilization" was refuted predominantly through the questionnaire and unanimously through the
420 workshops, thus we removed it from the list. The study from Paoli *et al*. [2016] validated some
421 similar services provided by coralligenous habitats of italian sites such as ""natural medicine
422 availability" (research), "ornaments" (red coral), "landscapes" (diving), "habitat", "stockage of

energy and matter" (food), and they added the role of sediment and nutrients retention by the planar structure of gorgonians. Paoli *et al*. [2016] reported also the controversial status of "waste treatment" (water filtration), "breathable air" (carbon sequestration) and "nursery".

Ecosystem service	Status
Food	unanimously validated
Diving spot	unanimously validated
Research	unanimously validated
Inspiration	unanimously validated
Red coral	majoritarly validated
Aquarium	majoritarly validated
Angling spot	majoritarly validated
Spearfishing spot	majoritarly validated
Bio-indicator	majoritarly validated
Biodiversity bequest	majoritarly validated
Carbon sequestration	controversial
Water filtration	controversial
Coast stabilization	refuted
Ecosystem function	**Status**
Habitat and refuge	unanimously validated
Nursery	controversial

Figure 10: Status of the 15 propositions of ecosystem services provided by coralligenous habitats after our study.

Definition of ecosystem service from the perspective of economic valuation. Among the propositions of the preliminary list, all are consistent with the restrictive definition of ecosystem services recommended by Boyd and Banzhaf [2007]. To avoid double counting, "biodiversity", "habitat and refuge" and "nursery" which can also be considered as ecological functions providing a service only indirectly. However, those ecological functions can be considered all together as "lifecycle maintenance" for coralligenous and other species, which appear in the CICES list of ecosystem services (version 4.3 of January 2013), to which people can place non-use values and thus incorporate them into an economic valuation.

436 **Comparison with services provided by other coastal marine ecosystems.** We found that even if
437 less known, coralligenous habitats provide services similar to those provided by coral reefs: food,
438 ornamental and aquarium resources, habitat maintenance, recreation and tourism opportunities
439 [Elliff and Kikuchi, 2017, Moberg and Folke, 1999]. But coralligenous services are quite different
440 from those provided by *Posidonia oceanica* seagrass (considered as one of the most important
441 Mediterranean marine ecosystem together with coralligenous habitats), that are primarily
442 "nursery", "food" and "carbon sequestration" [Campagne *et al*., 2015].

443 **Differences between sites.** Even in two nearby sites having the same type of coralligenous
444 habitats, our study highlighted a few significant differences in services supply (note that an
445 ecosystem service exists if it is **both** supplied and demanded). This suggests that the comparison
446 between very distant and heterogeneous sites may highlight even greater differences in the
447 service bundles. The origin of these differences may be from the offer side (morphotypes,
448 ecological communities, accessibility of the coralligenous habitats) or from the supply side (for
449 example peoples' perceptions, cultural habits, size of the local human population), or may arise
450 from contextual constraints (local regulations). Our results showed that opinions of experts from
451 both sites were divergent for the service "red coral", "nursery", "water filtration" and "coast
452 stabilization". The service "red coral" was more accepted and considered more important by the
453 experts of Marseille than by those of Port-Cros. We explain that divergence by the fact that there
454 are four active harvesters of red coral in Marseille area, and only one in Port-Cros area. That
455 difference can be due to higher presence of exploitable red coral in Marseille, or due to local
456 regulations or to the local socioeconomic context. Concerning the regulating services "nursery",
457 "water filtration" and "coast stabilization", we consider that the services are not provided

458 differently in both sites but that the divergence is due to experts' profiles since the group of
459 experts of Marseille had proportionally more researchers and naturalists that the group of Port-
460 Cros which was composed primarly of managers, fishermen and professional divers. Thus we do
461 not consider that differences as truly effective, and in this case (when experts' profiles are
462 unbalanced in the compared sites) we consider that the average answer (average of the two sites)
463 is more reliable.

464 **Validation and utility of the small-scale approach.** This research focused on the importance of
465 ecosystem services perceived and utilized by local experts. It assessed the importance granted by
466 experts and discussed their criteria for determining the relative importance of ecosystem services,.
467 The criterion mostly used by experts was "a service is more important if it is at the basis of other
468 services". This criterion is not compatible with the strict definition of Boyd and Banzhaf [2007]
469 since it suggests that the concerned services are indirect. The large number of environmental
470 experts compared to economists may explain this result, since the questionnaire showed that
471 envionmental experts mostly didn't take in account the double-counting issue while economists
472 are really aware of it. However it highlights the essential role of the indirect service of ecosystem
473 maintenance. The two other criteria mostly cited by experts were "*is perceived by more people*"
474 and "*impacts more people*". These criteria justify the elimination of very anecdotal services.
475 Indeed, the experts confirmed that the service "aquarium" is so anecdotal that it could be not
476 considered in the list of services. The basis of this observation is the minimum necessary number
477 of people that should be benefiting the service to validate it. Experts did not consider the
478 threatened status as a criterion of importance of a service. The most threatened services, certainly
479 "red coral" and "food", were not ranked based on this criterion, but on the number of
480 beneficiaries.

We carefully treated the issues of existence and importance separately. However, the results showed an evident positive correlation of the answers to the two questions. This would have been an unexpected result for a large-scale study, but for a small-scale study it confirms that a minimum level of "importance" (in term of global benefits on people) confirms the existence of a service. In most large-scale studies this minimum "level" of importance is not investigated. However when the concept of ecosystem service is applied at a small-scale, the recognized existence of a service yields a ranking of at least a minimum level of importance. The identification of ecosystem services relies essentially on this condition: an ecological function can be considered as a service if and only if it benefits humans. For the application purpose, our case study highlights the need for a frame of reference to identify ecosystem services. In our study we constrained the geographical scale (the two studied sites), but experts triggered on a minimum threshold of population impacted and the perceived value of the benefits to identify ecosystem services. For example the services "red coral" or "aquarium" impact very few local people but possibly have a high value (specially a high economic or/and cultural value) for these people and thus reach a minimum threshold to be considered as a service. The existence of a service "carbon sequestration" might depend on the temporal and geographical frame: the impact might be significant only at large scale and long term. These reflections lead us to think that, for the identification of an ecosystem service, a frame of reference should be calibrated in term of geographical scale, size of population impacted, benefits value and eventually temporal scale. For each of these criteria, a minimum threshold should determine the existence of the service and then its importance can be estimated for each criterion based on the distance from this minimum threshold. The category of well-being impacted should also be specified in order to balance importance: does the service satisfy essential basic needs for survival or only those needs related to supplementary well-being? For example, the existence of favorable diving spots represents immediate benefits only, is essential to the local

505 professionals of diving, and is profitable to divers from local to distant divers. Depending on the
506 population framed, the service would be considered and valuated differently. To this perspective,
507 only studies at small-scales such as the one we implemented, can provide meaningful input to
508 policies aimed at managing the local environmental.

509 Apart from the evident positive correlation between existence and importance, we observed
510 slight variations in this correlation. For example the experts mostly accepted the services
511 "spearfishing", "angling" and "red coral" but considered them of medium-low importance. The
512 three activity-related services were considered to not be practiced by a large number of people
513 and were not supportive of other services. These results are consisten with the criterion of
514 importance highlighted by experts. We are aware that the criteria of importance of the services
515 must be considered cautiously, and that it is incorrect to balance the importance of a service that
516 is essential for the living of a small part of the population (such as the artisanal fishermen or
517 professional of diving structure), with the importance of services which affect the recreational
518 activities, and with the importance of a service which helps for the maintenance of a healthy
519 environment at an unknown level.

520

521 5 Conclusions and perspectives

522 The findings of this work validate the value of Ecosystem Services as a useful input to local
523 community decision making and also help to define the beneficial services provided to local areas

524 by the ecosystems of coralligenous habitat. This study presents a first attempt to list the services
525 provided by coralligenous habitats, validated by a panel of experts, plus a complementary list of
526 potential services that should not be eliminated before further research. Carrying out surveys at
527 local scales allowed us to actually decide on the existence and importance of services in both
528 studied areas. According to the expert panel, we can consider that the major services identified in
529 this study will be likely to be found in other coralligenous sites. Moreover, our survey protocol
530 could be easily extended to other Mediterranean sites to confirm it.

531 Provisioning and cultural services are quite evident and mostly accepted. But there is a
532 significant lack of knowledge about the regulation of some ecosystem services, the importance of
533 which are very uncertain. To start filling the knowledge gap regarding these services, which may be
534 essential if effective, scientific studies in two areas are clearly needed: 1) the capacity of
535 calcareous species to sequester carbon and 2) to quantify the provisioning and cultural services,
536 specific data should be collected about the recreational activities and the resources caught and
537 harvested in coralligenous habitats.

538 The application of the ecosystem service concept to coralligenous habitats at a very local scale
539 showed that the current widespread definition of ecosystem services used for the CICES must be
540 adapted to be applied and that the identification of service should always be based on a referential
541 frame (geography, time, population, benefits scales) to allow concrete operational decision-
542 making. Indeed, our study highlighted few differences in the supplying and perception of services
543 between two close-by sites with relatively similar coralligenous habitats but different socio-
544 economic context. Thus we expect that further studies made in more distant sites involving
545 differences in supply and demand would highlight further site-related differences in the bundle of
546 services.

547 Current knowledge on coralligenous habitats does not allow quantifying precisely the benefits
548 precisely, but is sufficient to use non-market valuation methods for the valuation of some of the
549 services provided.

550

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674 **Software**

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676 /LimeSurvey GmbH, Hamburg, Germany. URL http://www.limesurvey.org

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