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Application of the ecosystem service concept at a small-scale: The cases of coralligenous habitats in the North-western Mediterranean Sea

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ABSTRACT

The understanding of ecosystem services is essential to support sustainable use and preservation of ecosystems. Coralligenous habitats, main contributors of the Mediterranean marine biodiversity, are yet understudied in term of services provided. This study presents an original small-scale approach to investigate the services provided by coralligenous habitats of a French study area consisting of two marine sites (Marseille and Port-Cros sites) in order to cover two contrasted anthropogenic pressure despite the small-scale. Our results are based on the opinions of 43 experts who ranked 15 services in terms of existence and level of importance for human well-being: supporting ecological functions were considered the most important, then provisioning and cultural services. Regulating services were considered uncertain due to a lack of knowledge. The small-scale approach highlighted a need for a referential frame to determine the existence of services (e.g. geographical and temporal scales, benefits and beneficiaries levels).

1. Introduction

Coralligenous habitats are considered to be some of the more complex marine habitats [Paoli et al., 2016b] and their 1666 species (at least) 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. However, services from marine ecosystems are less studied than those of terrestrial ecosystems [Beaumont et al., 2007] and there is almost no literature dealing with ecosystem services provided by coralligenous habitats [Paoli et al., 2016a], while there is a relative abundance of literature on ecosystem services provided by other marine habitats: seagrasses [Vassallo et al., 2013; 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 identified them in Marseille, coralligenous habitats have been the subject of a relatively small number of studies, which has been increasing in the last decade. Since the review of Ballesteros [2006], various indicators have been created during the last five years specifically to measure the health status of coralligenous habitats [Cahill et al., 2017, 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 literature dealing with the economics aspect of coralligenous habitats is in its infancy [Paoli et al., 2016a].

Coralligenous habitats are encountered along most of the Mediterranean coasts but they are mainly studied in the Northwestern region. Fig. 1 shows typical coralligenous habitats of Marseille. Coralligenous habitats have been observed 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 used 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]. Coralligenous habitats are threatened by large-scale events, waste waters [Hong, 1980], physical impacts from diving [Garrabou et al., 1998; Harmelin and Marinopoulos, 1994] or fishery activities [Bell, 1983; Garcia-Rubies and Zabala, 1990] and invasive species [Piazzi et al., 2005]. Recent studies showed that sea acidification is also a threat to coralligenous habitats [Martin and Gattuso, 2009; Martin et al., 2013; Nash et al., 2016]. Their extremely slow development makes their recovery from these impacts very limited. In this study we focused on sites in the Northwestern Mediterranean Sea where coralligenous habitats are

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

closest to the surface, which favours their observation and interaction with human beings.

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 Millennium Ecosystem Assessment (MEA) [2005], the proceeding of The Economics of Ecosystems and Biodiversity (TEEB, 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. However, these classifications can lead to some confusion when the economic contributions of ecosystem services are assessed. That is why 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. 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 at a local scale.

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". The goal of the present study is to apply the ecosystem service concept to a complex and relatively unknown ecosystem at an operational management scale. We broke this down into two objectives. First we aimed to identify ecosystem services provided by coralligenous habitats at small-scale. Second we aimed to identify criteria of existence and importance of ecosystem services and used them to rank the services. The study area consisted of two French marine sites contrasted in anthropogenic pressure in order to cover the two situations despite the small-scale. The methodology was based on the opinions of 43 experts collected through three complementary survey methods: semi-directive interviews, an online questionnaire and workshops.

2. Materials and methods

2.1. Study area

The study area consisted of two French marine sites that we called "Marseille site" and "Port-Cros site". The distance between these two sites is about 100 km (about 62 miles). The so-called Marseille site encompassed the coastal and marine zone from Martigues to La Ciotat, including the Côte Bleue marine park (existing since 1983) and the Calanques national park (existing since 2012). The Port-Cros site included the marine core and adjacent area of Port-Cros national park (existing since 1963). Fig. 2 displays the two sites, and indicates the location of coralligenous habitats and the marine protected areas. Marseille and Port-Cros present similarities in terms of coralligenous habitats but differences in terms of anthropogenic pressure, 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 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. These particularities make them different from coralligenous habitats of other locations in the Mediterranean Sea. There is an abundance of historical ecological data in those areas [Marion, 1883; Pérès and Picard, 1951; Hong, 1980, 1982; Witkowski et al., 2016]. Marseille is the second largest city in France with about 869,800 inhabitants (INSEE, 2015). This city is located in a "*département*"[1] of almost 2 million inhabitants and is the first French Mediterranean harbor. Next to Port-Cros site, the main city, Hyères, counts about 57,500 inhabitants in a "*département*" of about 1 million inhabitants. Thus, human impacts on natural environment are likely to be much higher in the Marseille site than in the Port-Cros site. 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 (but more regulated in Port-Cros), while professional artisanal fishing activities are declining. A recent study identified differences between the bay of Marseille and the Port Cros national park area (including coralligenous habitats [Cahill et al., 2017]): Port-Cros coralligenous displayed particularly high intraspecific genetic diversity (shared with

[1] Département: a French administrative division.

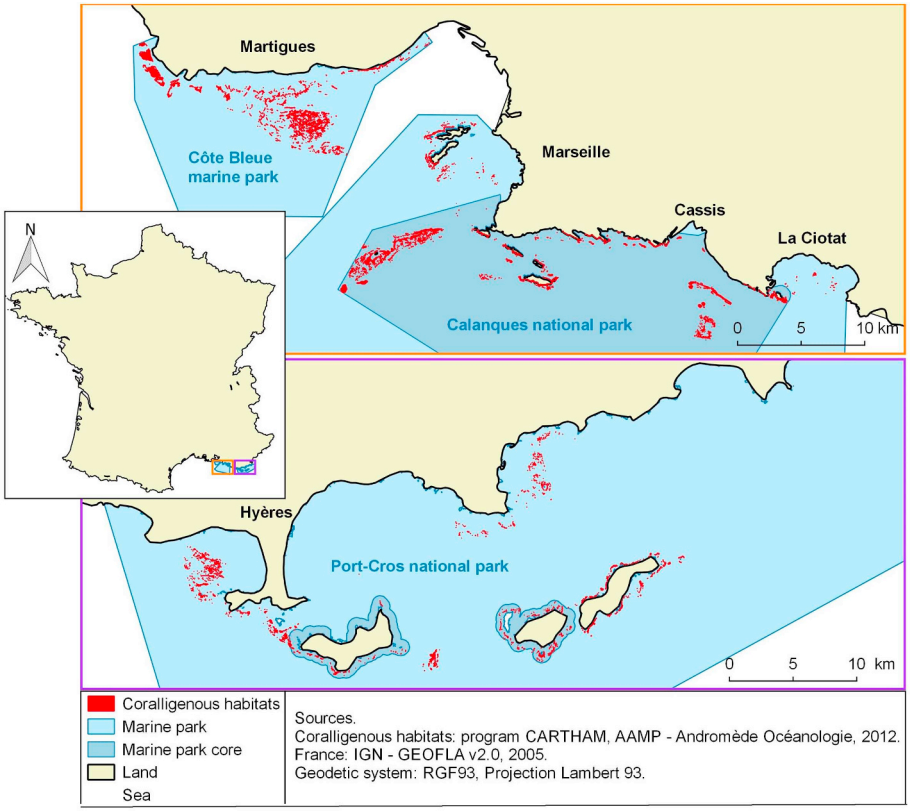

Fig. 2. Map of the two studied areas. Top: the Marseille site (including the bay of Marseille, the marine park of the Côte Bleue and the national park of the Calanques). Down: the Port-Cros site (including the national park of Port-Cros and its marine adjacent area in the bay of Hyères). The park core is the most protected area and regulated by specific regulations.

Corsica, another insular and preserved location), which was suggested to be a consequence of a lower human pressure (e.g. much lower population density) in these areas. Various indicators of impacts also confirm a higher pristineness of the Port-Cros site, although there is considerable variation in environment quality within the Bay of Marseille (and between it and the Calanques) [Deter et al., 2012; Sartoretto et al., 2017].

2.2. Preliminary list of ecosystem services based on literature

The literature search was performed before the survey in order to identify potential ecosystem services provided by coralligenous habitats as a list to be completed and validated thanks to expert's unpublished knowledge. The literature was investigated in 2015 to identify services to submit to experts during the survey.

The literature search included peer-reviewed articles available on Google Scholar, reports available in the studied protected marine areas and scientific books. The only document that explicitly mentioned the ecosystem services provided by coralligenous habitats was Mangos et al. [2010]. This was a large-scale project that estimated the economic benefits of five marine ecosystems at the Mediterranean Basin scale. This work contrasted with our objective, which was to validate the existence of ecosystem services provided by a specific ecosystem at a small-scale. Some ecosystem services provided by coralligenous habitats can be identified thanks to other studies which did not mention explicitly ecosystem services, or did mention ecosystem services that are provided by other ecosystems sharing with coralligenous habitats the relevant characteristics implied in the supply of the service mentioned. A preliminary list of ecosystem services potentially provided by coralligenous habitats was assembled from the literature independently from location. The preliminary list was completed with the input from experts' interviews (the first step of our survey). Then, a list including 15 ecosystem services was submitted to the experts via the online questionnaire (the second step of our survey) and/or during workshops (the third step of our survey).

2.3. Expert survey

Since the literature search revealed few studies clearly describing the ecosystem services provided by coralligenous habitats, a survey was implemented based on an expert panel of 43 individuals. The survey was carried out between October 2015 and June 2016 and included three sequential steps: at first, individual face-to-face interviews to identify and describe the ecosystem services, then, an online questionnaire to start the validation process and at last, workshops to finally validate a list of services and their importance. 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. Our survey protocol was inspired by the methods Delphi and focus groups. Skulmoski and Hartman [2007] described Delphi as a method that uses several rounds of survey among a panel of experts to reach a consensus, and is “a flexible research technique well suited when there is incomplete knowledge about a phenomenon”. All the 43 experts answered the online questionnaire, but only 8 of them were interviewed face-to-face and 16 participated to the workshops. Among the 8 experts interviewed, 2 (researchers) participated also to the workshops; the others (mainly fishermen) were not available for the workshops. The detailed process of the expert survey is displayed in Fig. 3.

2.3.1. Experts selection

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. 43 individuals from the study sites formed the expert pool: Marseille (25) and Port-Cros (18). They were selected for their profiles: researchers (ecologist or economist), managers of marine protected areas, professional artisanal fishermen, representatives of diving activities (federation or diving structures), professional divers, and people monitoring coralligenous habitats. Their distribution among profiles and sites is presented in Table 1. Our panel represented most of the available expertise since the

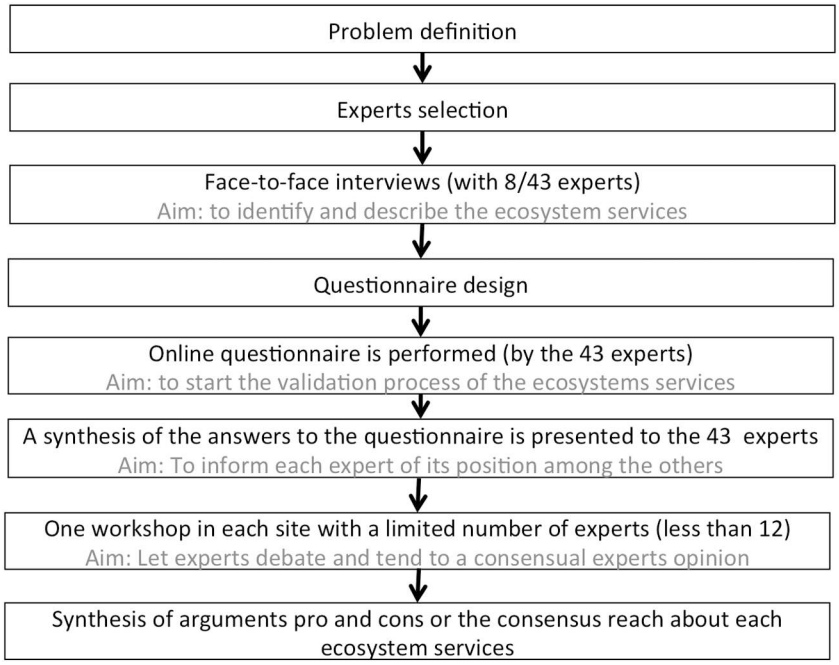

Fig. 3. Protocol applied for the survey.

Table 1
Profiles of the 18 experts of Port-Cros site (PC) and 25 experts of Marseille site (MRS).
An expert can correspond 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

43 experts represent a large part of the total number of experts that could potentially participate.

2.3.2. Interviews

8 out of 43 experts were interviewed. Only few interviews were carried out because the total number of experts in the two localities is small. 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[2] selected represented the diversity of fishing practices, targeted species and sites. Interviews were carried out to obtain some deep knowledge that could not be gathered through online questionnaire or workshop. The interviews helped to complete the preliminary list of ecosystem services and to confirm our findings from the literature. Thus it was a preliminary step to prepare the online questionnaire and workshops. Interviews were conducted individually face-to-face in a semi-directive way, lasting between 40 and 90 min, and were recorded and transcribed. The interviews were conducted as follow. In the first part the expert had to presence his own experience about coralligenous habitats and his activity (fishing, diving, research). In the second part of the interview the expert had to present his definitions of coralligenous habitats and ecosystem services and compare them with definitions given by the interviewer. Thereafter each expert was asked about the list of services provided by coralligenous habitat and to describe the most relevant services according to its experience.

2.3.3. Online questionnaire

The questionnaire was performed online, using the software © LimeSurvey (version 2.06+ Build 150731). It contained 25 questions grouped in 6 parts: vocabulary issues, list of services, importance of services, pressures, management, and respondents' profiles. The entire questionnaire is available as supplementary material. The online questionnaire was fully completed by the 43 experts who each answered about one of the sites. Respondents took 30 min on average to answer the questions. In this paper we focus on the list of services and their importance.[3] Thus we were interested in two main issues: first the validation of ecosystem services and second the importance and ranking of ecosystem services.

2.3.3.1. Rankings in order to validate the existence of ecosystem services. The first issue was treated as follows: the list of 15 ecosystem services was provided to the expert. After each item, the expert is given the following question "Is this an ecosystem service provided by coralligenous habitats?" A Likert-type scale with a set of five answers was offered to each respondent: Yes I'm sure/Yes I think/I don't know/No I don't think so/No I'm sure it's not. To aggregate individual answers, the following process was implemented: we ranked

[2] In many cases their professional constraints prevented them from attending the workshops, but they were able to grant us in-situ interviews earlier in the survey procedure.

[3] These are Parts 2 and 3 of the questionnaire.

the services according to the frequency of answers across the 43 experts. Three different rankings[4] among modalities were considered: A) a ranking that gave priority to positive answers, B) a ranking that gave priority to negative answers, C) a ranking that gave priority to the degree of certainty of answer. We ranked the 15 services according to each previous ranking of modalities. This allowed us to consider ranking consistency and to determine *ex post* frequency thresholds in order to classify the 15 ecosystem services. Thresholds were chosen in such a way that consistency in each category of services be maximized.

2.3.3.2. Rankings of the importance of ecosystem services. To explore this issue, we used a set of four questions in the online questionnaire. First, experts were asked to state a level of importance of services provided in the studied site through the following question "According to you, how important is this service [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, thereafter experts had to select at least six services that they considered as main services provided by coralligenous habitats in the studied site. Then, experts had to rank those six services from 1 to 6: "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 "do not know" was automatically generated and included in the analysis. We got three different rankings about importance that allowed us to explore the consistency of ranking. 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".

2.3.3.3. Further analyses. In order to cross-reference the results from questions about existence and importance we transformed the modalities of acceptance into scores from 1 to 5, and the modalities of importance from 1 to 4. For each ecosystem services, the mean and median scores of the 43 answers were then calculated to analyse correlation between both items "existence" and "importance". 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.

2.3.4. Workshops

We conducted a one-day workshop in each study site: 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 the Port-Cros site. The main objective of the workshops was to help the interpretation of the answers obtained through the online questionnaire, and to investigate disagreements. Experts were encouraged to debate, especially about the controversial points, and to seek consensual answers. The workshop focused on the validation of the ecosystem services and their importance: we presented a synthesis of the answers to the online questionnaire; we then animate a debate on non-consensual answers between experts and ended by a vote by show of hand.

[4] This approach is in the spirit of a lexicographical order where consumer ranks buddle of goods first according to the quantity of good 1 whatever the quantities of the other goods; if two bundles have the same quantity of good 1, then the consumer compares quantities of good 2 and so on.

3. Results

3.1. Preliminary list of 15 ecosystem services selected from literature search and experts interviews

The 15 ecosystem services identified through the literature review and the interviews of experts are presented in the Table 2.

3.2. Validation and importance of ecosystem services according to experts' answers to the online questionnaire

3.2.1. Validation of the existence of ecosystem services

The first result of the online questionnaire was the ranking of the 15 ecosystem services according to the validation status given by the 43 experts. Analysis of the answers to the online questionnaire indicated four status categories of services with respect to the experts' opinion as follows. As observed in Fig. 4, the merging of services in categories is consistent regardless of the rankings of modalities chosen (see cases A, B, and C). For instance, in the category 1, labelled "unanimously validated services", were included the services that gather only positive answers with more than 90% of experts being sure of their answer. In the category 2, labelled "services accepted by the majority", were included services gathering more than 80% of positive answers, and not falling in the category 1. In the category 3, labelled "uncertain services", were included services not falling in the previous categories and gathering more than 20% of "I don't know" answers and fewer than 10% of negative answers. In the category 4, labelled "services refuted by the majority", we put services gathering more negative and uncertain than positive answers.

3.2.2. Rankings of the importance of the ecosystem services

A second result from the online questionnaire was that the three methods of rankings converged to a unique ranking of importance of the 15 ecosystem services. It must be underlined that the 15 services of the preliminary list were selected at least by one expert to be a part of *the most important* service (see Fig. 6) and also to be of *strong importance* (see Fig. 5). The ranking of services made through the answers to different questions about importance of ecosystem services are presented in Figs. 5, 6 and Table 3. The services classified as most important were "biodiversity" and "habitat and refuge". The services "diving", "research", "nursery", "inspiration" and "food" were classified as "services of strong importance". The services "red coral" and "carbon sequestration" were classified as services of medium importance. Finally, the services "water filtration", "angling", "spearfishing", "aquarium" and "coast stabilization" were classified as services of low importance. Only the service "bio-indicator" was 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. As a general remark we highlight that experts considered supporting services as the most important, then provisioning and cultural services. Regulating services were placed after, but experts recognized a lack of knowledge concerning the input-output related to the ecological processes underlying these services.

3.2.3. Correlation analyse

A third result is a positive relationship between validation and importance of ecosystem service, displayed in Fig. 7. This figure distinguishes services validated and very important ("biodiversity", "habitat and refuge", "bio-indicator", "research", "diving", "inspiration" and "nursery"), services validated and of medium importance ("food", "red coral", "angling" and "spearfishing"), services controversially validated and ranked ("carbon sequestration" and "aquarium"), and services not validated ("water filtration" and "coast stabilization").

Table 2
Preliminary list of 15 potential ecosystem services provided by coralligenous habitats, submitted to experts via the survey.

	Definitions	Illustrating references	Comments
Provisioning ecosystem services			
Food	Wild stocks of species that professional fishermen fish, restaurants serve, people eat and savour. Species examples: *Scorpaena scrofa, Palinurus elephas, Homarus gammarus.*	Harmelin, 1990, Mangos et al., 2010, Witkowski et al., 2016, INPN-MNHN 1170–14.	Targeted species are not only found in coralligenous habitats even 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	Wild stocks of red corals that professional coral fishermen harvest, jewelers shape and sell, people enjoy as ornamental or jewelry.	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	Red corals can be found in coralligenous habitats, but also in caves, crevices, and rocky walls. For many years, they have been over-exploited with impacting tools. Nowadays there are regulations for the harvesting (in France red coral harvested must have a basal diameter over 7 mm and be at depth over 50 m). Red corals have also a strong cultural value in the Mediterranean basin, and divers enjoy seeing it alive.
Aquarium	Wild stock of individuals exceptionally captured for public aquariums.	Pers. comm.	
Regulating ecosystem services			
Carbon sequestration	Global climate regulation by carbon sequestration.	Mangos et al., 2010.	Bioconstructions of calcareous organisms use carbon to build their calcareous squeleton. They may act as a carbon sink.
Water filtration	Biological filtration of pollutants by filters.	Mangos et al., 2010.	Coralligenous habitats are rich in filters such as sponges that may absorb organic waste.
Coastline stabilization	Protection from the erosion of the coastline by the physical barrier made by the bioconcretioned reefs.	Cesar and Beukering, 2004, Paoli et al., 2016a	This service has been reported for reef type ecosystems such as coral reefs.
Bio-indicator	Indication on the quality of local environment.	Sartoretto et al., 2017	Indexcor is an indicator which use coralligenous habitats to indicate the water quality.
Cultural ecosystem services			
Diving spot	Landscape and biodiversity for divers enjoyment.	Harmelin, 1993, Mangos et al., 2010, Scorsonelli et al., 2012, Robert and Plouvier, 2017.	From depth 0 to 60 m coralligenous habitats are commonly reachable and targeted by recreational divers enjoying their landscapes and the dense populations of macro vertebrates gravitating around.
Angling spot	Species that recreational spearfishermen enjoy.		
Spearfishing spot	Landscape and species that spearfishers enjoy.		
Research	Support for scientific discoveries (ecology, biology, medicine, or other)	Ballesteros, 2006, Leal et al., 2012, Jares-Erijman et al., 1991,Paoli et al., 2016a, Jaspars et al., 2016	Ballesteros reported 1666 species and 250 scientific studies about coralligenous habitats previous to 2006. Moreover, many substances, useful to an anthropogenic point of view, can be extracted from organisms thriving in animal forests (e.g. 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 not analyzed yet. For example, *Crambe crambe* provides the crambescidins: antiviral and cytotoxic compounds.
Inspiration	Enjoyment and inspiration by aesthetic characteristics through in situ visit or media.	Tribot et al., 2016, Mangos et al., 2010.	Coralligenous habitats are very rich in colors, landscapes and species. Divers take pictures of it and share their images. Coralligenous habitats are often represented in underwater photographic competition.
Biodiversity	Enjoyment of coralligenous specific biodiversity.	Ballesteros, 2006, Mangos et al., 2010.	Biodiversity may be considered as a 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 ecosystem structure.
Supporting ecosystem services			
Nursery	Essential habitat for juveniles that use other habitats for the other stage of their life cycle.	Mangos et al., 2010.	It is a function not a service according to the CICES. Mangos et al. assume that coralligenous habitats provide nurseries and spawning beds to halieutic species and thus contribute to the service "food provisioning" provided by other ecosystems.
Habitat and refuge	Habitat or refuge of species.		It is a function not a service according to the CICES. As coastal habitats with a very complex structure, coralligenous habitats constitute refuges for species.

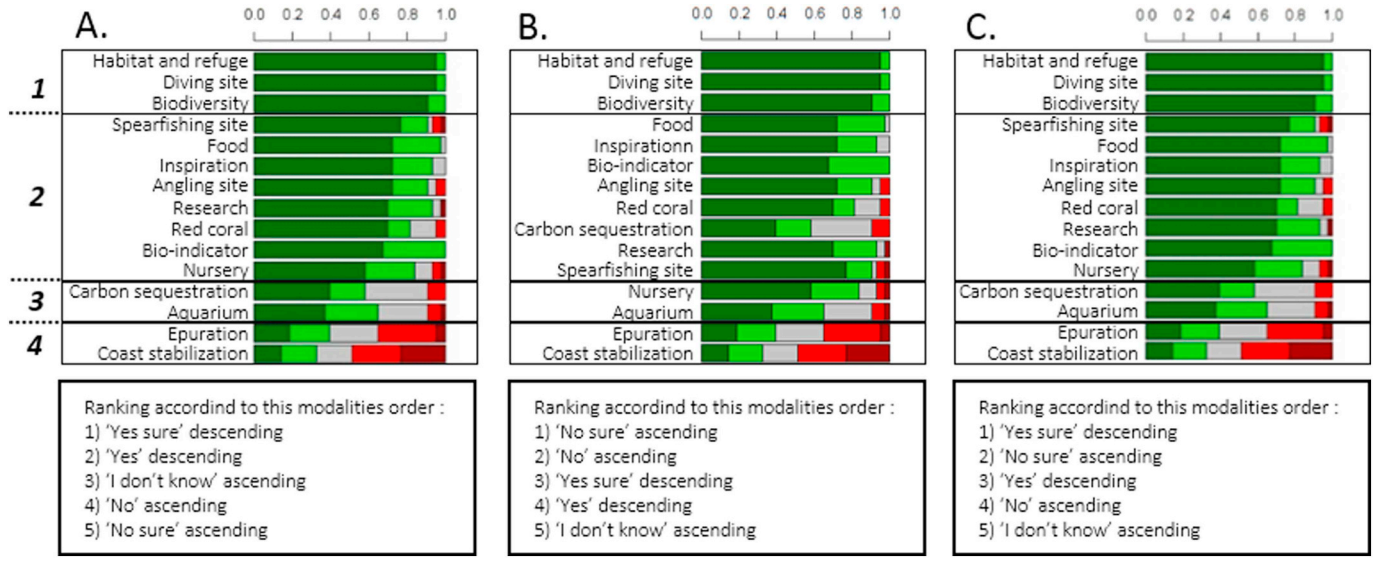

Fig. 4. Answers to the question 3 "Is this an ecosystem service provided by coralligenous habitats?" of the online questionnaire. The three cases (A, B, C) corresponds to three possibilities of ranking the modalities.

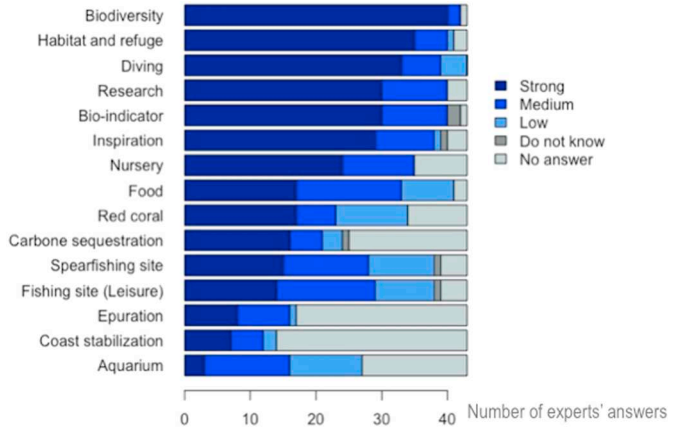

Fig. 5. Experts' answers to the question 5 of the online questionnaire "According to you, how important is this service [in the studied site]?". The status "no answer" was generated automatically when an expert did not select the service in the question 3.

Table 3
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

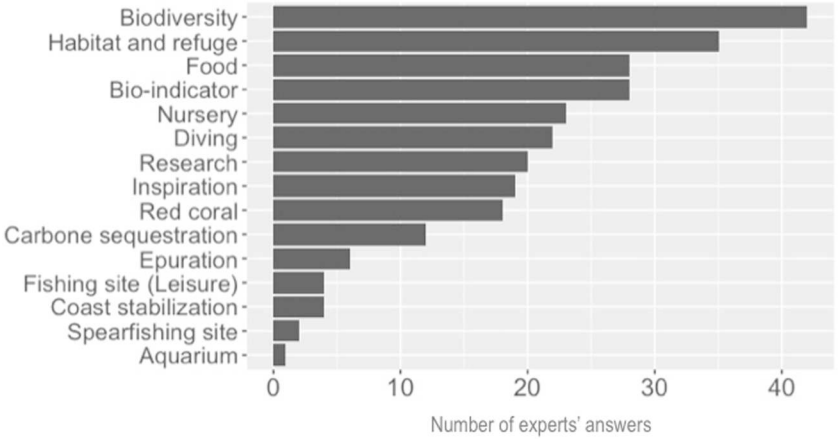

Fig. 6. Number of experts who selected each service at question 9 ("Select the most important services") of the questionnaire. Experts must select at least 6 services and could select only the services they previously selected as "existing" services in the previous question 3.

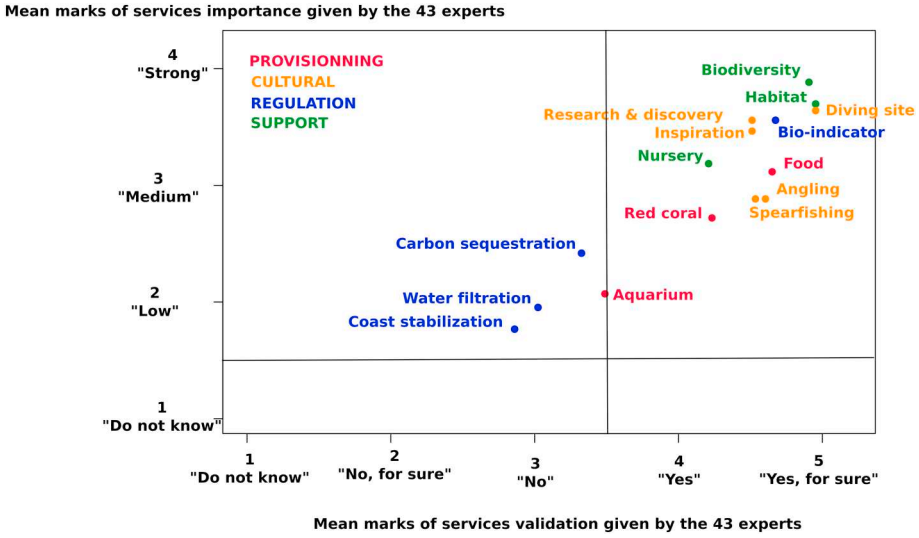

Fig. 7. Mean of the scores given by the 43 experts concerning the validation of ecosystem services (answers to the question 3:"Is it an ecosystem service provided by coralligenous habitats?") and the importance of the ecosystem services (answers to the question 5 "How important is this ecosystem service?")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

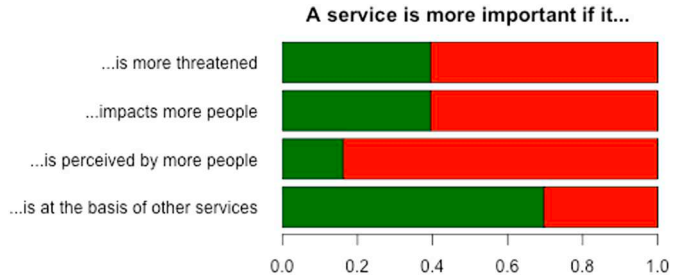

Fig. 8. Percentage of experts who declared that they used the criterion in their ranking of the importance of services. Legend: green = yes, red = no. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.2.4. Criteria of importance of the ecosystem services

Finally the online questionnaire revealed that a criterion was widely shared by expert to rank the services: "a service is more important if it is at the basis of other services". It was 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 Fig. 8). These results confirm that experts placed the supporting services at the head of the ranking.

3.2.5. Little divergences observed between Marseille and Port-Cros

Among the fifteen ecosystem services, there are only little divergences between the experts' opinions of Marseille (25 experts) and Port-Cros (18 experts) concerning main issues "validation of services" and "importance of services" from 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% of 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 (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 (Fischer exact p-value = 0.0059).

3.3. Second step of validation and ranking of services: through the workshops

The workshops were the last step of our survey protocol and allowed us to get precise information about the ecosystem services available at each of the study sites according to the experts. During the workshops, the participants collectively revised some of their initial assessments and converged to a consensus. They finally stated that they could only refute the ecosystem service "coast stabilization". Their argument was that coralligenous habitats able to play this role are the flat types, which were not represented in our study sites, and usually are at depths too deep to impact the coastline. They weren't confident enough to categorically refute the other controversial services "water filtration" and "carbon sequestration". The pros argument given by experts for the "carbon sequestration" service is the presence of many calcareous species (especially red algae) in coralligenous habitats, which used carbon to grow and then fossilize. The pros argument given by experts for the service "water filtration" is the presence of many filterers such as sponges. The cons argument for both services is the effective regulating impact of coralligenous habitats at the global Mediterranean scale and the capacity of calcareous species to capture carbon and the time of sequestration is unknown. Thus, these two services remain controversial until the knowledge gaps are filled by focused studies. Experts stated that the services "diving", "food", "inspiration", "research" and "bio-indicator" were actually provided by coralligenous habitats in the study sites, and surely provided by most of the coralligenous habitats all over the Mediterranean Sea. All experts validated "Biodiversity" and "habitat and refuge" as services provided by coralligenous habitats of any type and any site. The services "red coral", "aquarium", "spearfishing", and "angling" were validated with less confidence due to their non-estimated but probably low benefits or low number of beneficiaries. The service "red coral" was provided in one of the study sites. It should be provided in all areas where resources is available and where harvesting is possible. However it may be anecdotal in term of population impacted by the benefits. The same may be true for the service "aquarium" which is certainly even more anecdotal. The services "spearfishing" and "angling" are recreational activities practiced in the studied sites, but the proportion of activity practiced on coralligenous habitats was unknown, it could be either low or high, experts were not able to estimate any tendency. The validation statuses of the 15 ecosystem services presented in the preliminary list are sum up in Table 4.

Table 4
Validation status of the 15 ecosystem services presented in the preliminary list according to experts.

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

4. Discussion

We found that even if less known and quite different, coralligenous habitats provide services quite similar to those provided by coral reefs: food, ornamental and aquarium resources, habitat maintenance, recreation and tourism opportunities [Elliff and Kikuchi, 2017; Moberg and Folke, 1999]. But coralligenous services are quite different from those provided by *Posidonia oceanica* seagrass (considered as one of the most important Mediterranean marine ecosystem together with coralligenous habitats), that are primarily "nursery", "food" and "carbon sequestration" [Campagne et al., 2015]. The study from Paoli et al. [2016a] identified some services provided by coralligenous habitats of Italian sites that are similar to this study: such as "natural medicine availability" (research), "ornaments" (red coral), "landscapes" (diving), "habitat", "storage of energy and matter" (food), and they added the role of sediment and nutrients retention by the planar structure of gorgonians. Paoli et al. [2016a] reported also the controversial status of "waste treatment" (water filtration), "breathable air" (carbon sequestration) and "nursery".

This study focused on a small-scale approach to identify and rank ecosystem services. 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. For the application purpose, our case study highlights the need for a frame of reference to identify ecosystem services. In this 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 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 those needs related to supplementary well-being? For example, the existence of favourable diving spots represents immediate benefits, is essential to the local professionals of diving, and is profitable to divers from local to distant divers. Depending on the population framed, the service would be considered and valuated differently. To this perspective, only studies at small-scales such as the one we implemented can provide meaningful input to policies aimed at managing the local environmental. Apart from the evident positive correlation between existence and importance, we observed slight variations in this correlation. For example the experts mostly accepted the services "spearfishing", "angling" and "red coral" but considered them of medium-low importance. The three activity-related services were considered not being practiced by a large number of people and were not supportive of other services. These results are consistent with the criterion of importance highlighted by experts. We are aware that the criteria of importance of the services must be considered cautiously, and that it is incorrect to balance the importance of a service that is essential for the living of a small part of the population (such as the artisanal fishermen or professional of diving structure), with the importance of services which affect the recreational activities, and with the importance of a service which helps for the maintenance of a healthy environment at an unknown level.

The criterion of importance mostly used by experts was "*a service is more important if it is at the basis of other services*". This suggests that the concerned services are indirect. This criterion is not compatible with the definition of ecosystem services refers to the Common International Classification of Ecosystem Services (CICES) [Haines-Young and Potschin, 2018] program and with an economic valuation perspective. The large number of environmental experts compared to economists may explain this result, since the questionnaire showed that environmental experts mostly didn't take in account the double-counting issue while economists were really aware of it. The two other criteria to decide of the "importance" of an ecosystem service that are mostly cited by experts were "*is perceived by more people*" and "*impacts more people*". These criteria justify the elimination of very anecdotal services. Indeed, the experts confirmed that the service "aquarium" is anecdotal if we consider direct beneficiaries only, that is one fisherman of living organisms in the study sites, but may impact many visitors in public aquariums. Experts did not consider the threatened status as a criterion of importance of a service. The most threatened services, certainly "red coral" and "food", were not ranked based on this criterion, but on the number of beneficiaries.

Since services provided by an ecosystem to human beings crucially depend on the natural and socio-economical environments in which they are provided, the objective of having two locations was to validate ecosystem services provided by coralligenous habitats in different natural and socio-economical environments. However we considered the few significant differences in the services bundle of two nearby sites differently exposed to anthropogenic pressures and for further studies we expect that the comparison between very distant and heterogeneous sites would highlight greater differences in the service bundles. The origin of the differences observed between the two studied sites may come from the "supply side" (morphotypes, ecological communities, accessibility of the coralligenous habitats) or from the "demand side" (peoples' perceptions, cultural habits, size of the local human population), or may arise from contextual constraints as local specific regulations. It can be note that an ecosystem service exists if it is both supplied and demanded. Our results showed that opinions of experts from both sites were divergent for the service "red coral", "nursery", "water filtration" and "coast stabilization". The service "red coral" was more accepted and considered more important by the experts of Marseille than by those of Port-Cros. This result is consistent with the fact that there are four active harvesters of red coral in Marseille area,

and only one in Port-Cros area. Then our survey protocol allows us to identify this difference. Unfortunately, it does not allow us to explain this difference that can be due to a higher presence of exploitable red coral in Marseille, or due to local regulations or to the local socio-economic context. Specific studies combining natural and social sciences should be undertaken to get a robust answer at this small-scale where dataset usually does not exist. Concerning the services "nursery", "water filtration" and "coast stabilization", there are classified as regulating services with large-scale impact. Thus, we consider that the average answer (average of the two sites) is more reliable than site-specific answers because, at the current scientific knowledge, there is no study to support the difference in regulating services provided by two nearby sites.

Finally, this study was original by the methodology used in the sense that it simplified the process of collecting responses inspired by the Delphi methodology, but provided information that was relevant and accurate. In the absence of scientific evidence, experts' experience was the best knowledge proxi available even if the process could not avoid a part of subjectivity and if consensus does not guarantee scientific veracity. This study relied on 43 experts for two North-western Mediterranean sites. This sample is at least as 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.

5. Conclusions and perspectives

This study presented a first attempt to list the services provided by coralligenous habitats, validated by a panel of experts, plus a complementary list of potential services that should not be eliminated before further researches. Carrying out surveys at local scales allowed us to actually decide on the existence and importance of services in the study area. According to the expert panel, we can consider that the major services identified in this study (food, red coral, diving site, discovery potential) are very likely to be found in other coralligenous sites. Moreover, our survey protocol could be easily extended to other Mediterranean sites to confirm it.

Provisioning and cultural services are quite evident and mostly accepted. But there is a significant lack of knowledge about the regulation of some ecosystem services, the importance of which is very uncertain. To start filling the knowledge gap regarding these services, which may be essential if effective, scientific studies in two areas are clearly needed: 1) the capacity of calcareous species to sequester carbon and 2) to quantify the provisioning and cultural services, specific data should be collected about the recreational activities and the resources caught and harvested in coralligenous habitats. Moreover, apart from its status of function or service, the "nursery" role, as defined by Beck et al. [2003], of coralligenous habitats could be verified only after the observations of juveniles living exclusively in coralligenous habitats and moving to another habitat for their adult phase. Juveniles are not easy to observe and identify, thus their observation would need a specific experiment that have not been performed on coralligenous habitats to date.

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

However, even if current knowledge on coralligenous habitats does not allow quantifying precisely the benefits precisely, it is sufficient to use non-market valuation methods for the valuation of most of the services provided. Thus, an attempt of valuation was made after this study in the same study area [Thierry de Ville d'Avray, 2018].

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2018.10.057.

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Software

LimeSurvey Version 2.06+ Build 150731. An Open Source Survey Tool. LimeSurvey GmbH, Hamburg, Germany. URL http://www.limesurvey.org.

The online questionnaire : parts 1, 2, 3 and 6

n1 : Number of participants answering the particular question about Marseille area
n2 : Number of participants answering the particular question about Port-Cros area
N : Sum of participants answering the particular question

Questions	Answers type or choices	n1	n2	N
PART 1 : Vocabulary				
1) In what terms would you refer to coralligenous habitats to general public ?	Free text (*Not compulsory*)	23	18	41
2) In what terms would you refer to ecosystem services to general public	Free text *(Not compulsory)*	25	18	43
PART 2 : Services provided by coralligenous habitats				
3) According to you, are the following ecosystem services provided by coralligenous habitats ? -> ES-list	Multiple choices (5): "Yes I'm sure", "Yes I think", "I don't know", "No, I don't think so", "No, I'm sure" (*Compulsory*)	25	18	43
4) List other services that you think provided by coralligenous habitats	Free text (*Not compulsory*)	9	7	16
5) What level of importance for human well-being do you suspect for each services ? -> Services from ES-list selected at 3).	Multiple choice (3)s : "Strong importance", "Middle importance", "Low importance" (*Not compulsory)*	25	18	43
6) According to you, are coralligenous habitats replaceable ? -> Services from ES-list selected at 3).	Multiple choices (4) : "Irreplaceable : only provided by coralligenous habitats", "Partly replaceable : other habitats can provide the same service but at lower quality or quantity", "Totally replaceable : other habitats provide this service at the same level at least", "I don't know" (*Not compulsory*)	25	18	43
7) indicate alternatives to coralligenous habitats for the following services ES-list	Free text (*Not compulsory*)	25	18	43
8) Comments on part 2	Free text (*Not compulsory*)	11	10	21
PART 3 : Classification of services provided by coralligenous habitats				
9) According to you, which are the most important services ? Select at least 6 service	Multiple choice (15): ES-list (*Not compulsory*)	25	18	43
10) Rank the services that you selected in order of importance ("1" for the most important)	Multiple numerical input (controlled) (*Not compulsory*)	25	18	43

11) On which criterion did you base your ranking ?	Multiple choices (5) : "A service is more important especially as it forms the basis of others", "A service is more important especially as it is perceived by a large population", "A service is more important especially as it impacts a large population", "A service is more important especially as it is threatened", "other reason". (*Not compulsory*)	25	18	43
12) Comments on part 3	Free text (*Not compulsory*)	7	4	11
PART 6 : Respondent profiles				
21) Tick your profiles	Multiple choices () : "Researcher","Marine area manager","Economist","Ecologiste/Biologist", "Professional fisherman","Diving structure","Diver (leisure)","In charge of coralligenous monitoring","In charge of monitoring of activities on coralligenous habitats", "Other" (*Not compulsory*)	25	18	43
22) Are coralligenous habitats your speciality ?	Yes/No (*Not compulsory*)	23	14	37
23) For how long have you work on coralligenous habitats ?	Numerical (*Not compulsory*)	7	1	8
24) What is your main discipline ?	Free text (*Not compulsory*)	16	12	28
25) Comments on part 6	Free text (*Not compulsory*)	8	3	11