Valuing unfamiliar Mediterranean deep-sea ecosystems using visual Q-methodology

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Abstract: Monetary valuation of non-market environmental goods and services such as marine ecosystems is a difficult task, usually approached by stated preference methods. Valuation results are often unstable since preferences for unfamiliar, often highly abstract and complex environmental goods depend on the level of previous knowledge of the participant stakeholders and the information provided to them. In this paper, Q methodology has been applied to explore subjective perspectives on Mediterranean deep sea, which is among the least explored environment in the world. The participant sample consisted in eight Ph.D. students, half of which with a Marine Life Sciences degree. They were asked to perform a Q-sorting experiment, and rank a Q sample of thirty-six underwater photographs of the marine wildlife, landscapes, and ecosystems in the Mediterranean deep sea. Photographs were sorted by each topic according to a subjective priority relative to: a) a personal overall view; b) their perception of the potential interest for fishermen; and c) as if they were fishermen. The study revealed three distinct discourses on the subjective importance of deep-sea ecosystems in the Mediterranean Sea: "Noah's Ark Fans", "Ecosystem Functions Supporters" and "Deep Coral Lovers". Data analysis showed that the main differences between factors could be related to the experience and the cultural background of the participants. This study improved our knowledge about individuals' perceptions on Mediterranean deep-sea ecosystems and represents a preliminary step for their monetary valuation.

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H.D. Smith

Editor-in-chief,

Marine Policy

Dear colleague,

Please find enclosed the revised manuscript entitled: “Valuing unfamiliar Mediterranean deep-sea ecosystems using visual Q-methodology”.

We hope we have tackled all issues asked for by reviewers including editorial notes in a satisfactory way.

Regarding the first figure, we provide a version in B/W as well as in colour, since we had yet no response from Elsevier about costing.

Sincerely,

Raffaele Zanoli, M.A., Ph.D.

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***Detailed Response to Reviewers**

Response to reviewers & copy-editing notes

We revised the manuscript according to the reviewers comments and the copy-editing requirements:

1. the use of the first person ('we') was eliminated (pg 2: lines 6, 16-17; pg3: line29, 36,56; pg 7: line 2, 60, pg8: line 20; pg 9: line 1)
2. Final sentence of Introduction was moved up, to avoid single sentence paragraphs.
3. Separate files for figures and tables were uploaded;
4. We have submitted figures in grayscale for the printed version of the Journal. The colour figure is provided for the online version since we have received no answers yet to our query regarding pricing of colour printing.

According to the review suggestion we further modified the following:

On page 4, line 55: The authors do a good job of describing Q methodology. Early in the Methods section (page 4, line 55), the authors mention “concourse.” A brief description of what a concourse is would help our understanding. → *A brief description of what a concourse is was added “that is the overall population of elements about the subject under investigation”*

On page 6 the authors indicate that the images where grouped “into a-priori theoretical categories,” i.e., a structured, deductive design. There categories seem quite simple – focus on species or habitat. What “theoretical categories” of theory is this representing? Did they get this from the literature review? Or, did they notice this categories after they collected all the images and thus created a structured, inductive (not deductive) Q sample?-→ *We thank the reviewer fot having suggested to clarify this, Indeed, the design was deductive. We now present the theoretical foundation for our choice and we introduced a citation: “The collected images were grouped into a-priori, deductive categories. Two categories, including both the abiotic and the biotic components of an ecosystem, were created to depict the relevant characteristics of the marine environment and the life it hosts, and to ensure the representativeness of the Q sample. Images were selected and classified according to two visual themes – focus on “species” or “habitat” – and two levels, “pristine” or “polluted” elements. Uniqueness or rarity of species and habitats are the two main criteria that define the vulnerability of a marine ecosystem (FAO, 2009), while the degradation to pristine to polluted is a simple representation of the outcome of a vulnerability threat. The polluted level was then omitted from the Q Sample, because from the literature (Arnold, 2004) it was already known that the public has a common negative perception of these elements, and this could have affected the respondent’s viewpoints.”*

On page 7 the authors indicate that “four condition of instructions” were used, but I believe that only three (3) is the correct number. → *Yes, that was a mistake, thanks for spotting this: ‘four’ was replaced with ‘three’.*

On page 8 line 56: There is a mismatch between the “nor important or unimportant” pile and the -4 anchor of “least important.” The negative -4 anchor should be “most unimportant.” Q sorts generally go from most negative to most positive, not from least to most.--> *Yes, thanks for spotting this, the anchor was now correctly translated.*

*Title Page (WITH Author Details)

VALUING UNFAMILIAR MEDITERRANEAN DEEP-SEA ECOSYSTEMS USING VISUAL Q-METHODOLOGY

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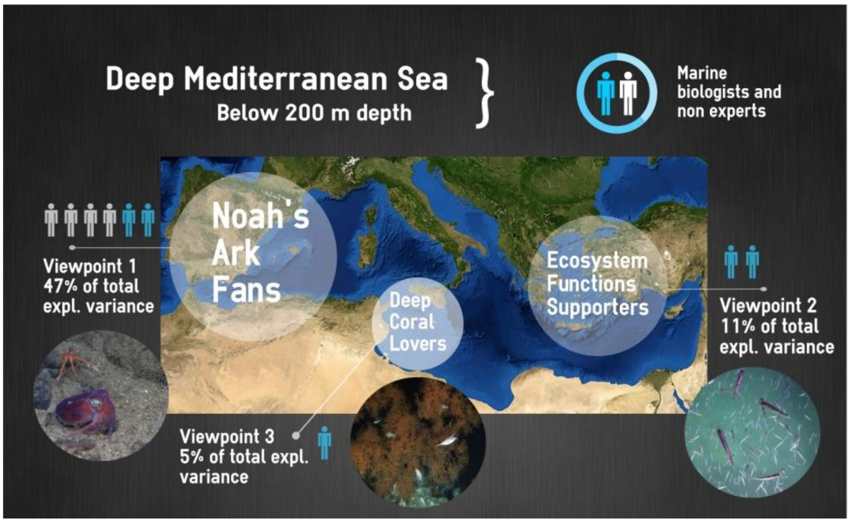
Graphical abstract

Three main subjective viewpoints regarding the conservation priorities for the deep Mediterranean Sea were revealed using Q-methodology. The different importance assigned to single species and habitats contributed to distinguish the points of view.



HIGHLIGHTS

- Q-methodology was used for the first time to study people's subjectivity on deep sea.
- Three main viewpoints on the importance of deep Mediterranean Sea were revealed.
- Background affected both individuals' perspectives and capability of changing mind.
- Biodiversity emerged as a shared conservation priority.

1 Introduction

Ecosystem goods and services are defined as "benefits human population derive, directly or indirectly, from ecosystem functions" [1]. They play a crucial role in sustaining people's well-being [2]. But ecosystems, increasingly exploited and damaged by humans, are at risk for the sustainable provision of ecosystem goods and services in the future [3]. Especially for services, often not traded on markets, (i.e. public goods), the absence of a price is improperly assumed as an absence of value [4]. Nevertheless, valuing both the benefits derived and the costs sustained when degrading the ecosystems may represent an important way to take their values into account during a decision making processes [5]. Estimating the value of marine resources it's not to be intended as a commodification of nature. By contrast, it is an attempt to move towards a more sustainable development [2]. This is the idea behind the ecosystem service approach in which social, economic and ecological perspectives are integrated [6].

An exponential number of investigations on the valuation of ecosystem goods and services have been published in the last two decades, contributing to significantly improve our knowledge on the value of natural capital [7]. Valuation methods have also been greatly refined [8]. However, numerous gaps still remain in understanding the real value of a wide range of benefits from the ecosystem functions [9].

Although oceans cover more than 70% of the Earth, studies of marine systems are much less abundant than the terrestrial ones [10]. Especially open and deep oceans are rarely valued, albeit representing the largest environments on our planet. Lack of scientific knowledge and legislative gaps are two of the main reasons that prevent their assessment and favour their overexploitation. But also, a generalised lack of reliable methodologies make it difficult to value ecosystem goods and services provided by oceans and deep sea: a) the absence of these goods and services in the markets restricts the application of market-based methods; b) not observable people's behaviour prevents the use of revealed preference methods; c) the scarcity of primary studies impedes to utilize the value transfer methods. In addition, hypothetical bias and no familiarity with these environments must be taken in account when facing the application of stated preference methods. Finally, option and quasi-option values are often difficult to estimate [11], albeit they likely constitute an important component of the total value of poorly known environments such as deep sea.

The present study focuses on the perception of Mediterranean deep-sea ecosystems. As mentioned before, deep sea represents the world's largest environment; nevertheless, it is largely unexplored [12]. It has been seen for a long time as a vast desert. Nowadays it's known that deep sea provides for one of the highest levels of biodiversity on our planet [13-14] and for a wide variety of ecosystem services. Some of these ecosystem services are unique, irreplaceable, and play a key role in sustaining human well-being [15-16]. Unfortunately, due to the technological development and the depletion of shallow-water resources, deep sea ecosystems are increasingly exploited [2,17] and, unexpectedly, greatly affected by anthropogenic stressors and climate changes [18-21]. In addition, once impacted, the costs for the restoration of deep-sea ecosystems are much higher than those estimated for shallow-water ones [22].

According to the literature [23] there is not a shared view of the marine environment or a common knowledge of its benefits. Estimating non-market values of deep- sea ecosystem services is therefore problematic, unless a clearer picture of which attributes of these ecosystems influence those who are valuing is provided [11].

In this paper, Stephenson's [24-25] Q-methodology was applied to improve our knowledge of stakeholders perceptions about the marine environment as a tool for pre-design qualitative research to support non-market valuation [26-27]. Compared to other more traditional approaches (focus groups, stakeholders workshops, mini-surveys, direct observation, etc.) Q-methodology offers a more systematic, structured approach that combines the benefits of both qualitative and quantitative research. Besides, Q-methodology allows drawing information from a small sample of stakeholders and still obtaining statistically valid results. Developed as a means of systematically and holistically identifying types of viewpoints about a topic, Q-methodology focuses on correlations between individuals (not between variables). Factor analysis is used to group the people with similar opinions. Usually Q-methodology is based on sorting written statements, and less frequently images. In this paper images were used to partially overcome the unfamiliarity of remote marine ecosystem.

The paper is organized as follows: section two describes the need for distinguishing among different type of stakeholders when studying the perception of unfamiliar ecosystems such as the deep sea. Section three describes the Visual Q-methodology and the data. Section 4 reports the results and the last sections discusses the implication of Q methodology results for further non-market valuation studies on deep sea ecosystem services.

While MacDonald et al. [28] have applied Q-methodology to the seafood sector, the study reported in this paper constitutes the first application of Q-methodology to deep sea.

2 Viewpoints on unfamiliar environments: the case of deep-sea ecosystems

Past research on perceptions of the marine environment and its biodiversity emphasised differences in public perceptions and the researchers' views [23]. These differences are to be ascribed to the public being not well versed on environmental problems and having a low knowledge about ocean issues [29]. The proximity to the sea was also found to affect the perceptions of the public towards the state of the marine environment [30-31]. People reporting limited interaction with coastal environments and those not developing environmental values feel far from the problems faced in coastal and marine areas [29].

Previous studies tended to focus on wilderness and environmental issues affecting the health of marine ecosystems as perceived by both the public and the stakeholders all around the world [32]. Nevertheless, while the researchers found many threats that could damage marine habitats in both coastal and deep-sea environments, usually people have a restricted understanding of the importance and the environmental problems of marine resources [33]. Both the public and the marine stakeholders mostly focus on few treats, highly visible and near the shore [34]. Among the most serious concerns the public often highlights marine pollution, litter and large scale industrialization, and only recently mention over-fishing and habitat destruction [35].

Scientists - having a better knowledge of the marine environment - perceive some threats to the oceans as more dangerous than others, while non-experts and other stakeholders may have a different perception. In Europe, for example, Potts et al. [34] surveyed seven thousands individuals from seven countries to conclude that despite some country differences, there is a comprehension gap between actual and perceived threats. The ocean health and species loss, having a low priority for the public, are perceived by researchers as serious issues to be managed. Furthermore, aspects causing irreversible threats and long lasting changes to marine environments – in term of species, habitats and stability – are mostly related to climate change, over-fishing and eutrophication caused by agriculture and intensification in costal human activity. When looking to the benefits, the most important public values of the sea are the food resources and it's scenic value.

Almost none of the above mentioned studies analysed perceptions of the deep-sea environments. Few of them investigated the public knowledge of the deeper sea only as a portion of the marine environment [23] and did not go in detail on perceptions of the marine resource; the deep sea is almost unknown and not easily experienced by most of the public.

Friedrich et al. [31] in a survey on perception of shark and shark fisheries, recognised knowledge, attitudes and values as the variables influencing public involvement in marine issues and environmental values. Once again familiarity with the marine habitat, the species and their environment is the necessary precondition to shape the perceptions of the public towards the marine environment. This issue will be addressed in the remaining sections.

As conservation programs need public support, it's crucial to know how the people perceive the deep sea: what characteristics the citizens believe it possesses, and which human viewpoints might be considered critically important issues to be investigated. By analysing the viewpoints of subjects with different level of familiarity on marine ecosystems and simulating viewpoint of different stakeholders, understanding of the importance of non-marketed as well as marketed ecosystem services provided by the deep-sea environments, can be enlarged.

3 Methods

3.1 Visual Q-methodology

William Stephenson developed Q-methodology in a letter to Nature (1935). In Stephenson's approach, factor analysis switches from variables to persons to be factorised. In the last decade Q-methodology, originally developed in psychology, has been applied in several fields of research (i.e. social science, political science and ecology), generating great interest.

Q-methodology [36-37] requires participant to rank-order a selection of items (called Q sample) – which are a representation of a concourse, that is the overall population of elements about the subject under investigation– into a predefined distribution, according to a specific condition of instruction. Once collected, all Q sorts are correlated (Q sort by Q sort) generating a correlation matrix that is subsequently factor analysed and rotated. The emerging factors are then interpreted in order to describe the participants' subjectivity revealed by each of them. Each factor identifies a distinct point of view, and those people who have ordered the items in a similar way are grouped into the same factor. While in other research applications using factor analysis, factor interpretation is based on factor loadings, in Q interpretation proceeds on the basis of factor scores [37]. Each factor score is a weighted average of the scores given to that statement by the Q sorts related to that factor [38]. It indicates the relation between each item and a specific factor. The power of Q-methodology is that it allows revealing respondents' subjectivity, which becomes measurable by the Q sorting process. Factors becomes *subjective operants* – in Stephenson's words – since they are not dependent on the concourse or Q Sample selection procedures but are manifestations of the sorters' personal viewpoints [39].

Although Q-methodology usually involves the use of verbal items – statements – non-verbal stimuli were used in Q-methodology since the early times, albeit more seldom [40]. The images are traditionally applied in child studies – especially if the P set includes children as young as three or four years [41-43] – because of the easiness of the sorting procedure with images instead of words. A review of literature identified a small group of applications of Q-methodology with non-verbal items in other fields of research far from educational psychology and involving some form of environmental site or landscape assessment [26,40,44-46].

According to Daniel [47] sorting images or photographs, unlike common written statements, is an easy and understandable task that does not require a complex cognitive process. In recent years images, more than words, influenced consumer behaviour and communications tools [48]. Images, more than the verbal stimuli, are expected to elicit higher emotional reactions, but how this process is activated is not yet clear. Although several neuro-scientific studies indicate the processing superiority of images as compared to words [49-50], the debate is still open. According to some researchers the process through which our memory elaborates visual stimuli is more likely to persist in our mind in a realistic way and it can be directly experienced [50-51] According to others, there is no strong difference between images and words [52]. The limbic and paralimbic regions – i.e the amygdale and the hippocampus – differently react to different stimulus types (images or words). Visual stimuli are connected to a great activation of the right-sided structures [53], while the elaboration of words is associated to a great activation of the left hemisphere [54]. Nevertheless, differences between feelings generated by images rather than by words [52] are only apparent.

In this study non-verbal items (images) were preferred to written items, because images are likely to be more effective when an unfamiliar environment is going to be represented. The evaluation of a specific environmental site using images is subordinate to the interaction of an individual with a specific place [46] and images don't confuse visual quality assessments with the observer preferences, because they represent the location as it is. This aspect is important, inasmuch it facilitates common people, who haven't the proper scientific knowledge on a matter, to express their points of view. For this reason combing Q-methodology with images can be a better way to reveal individuals' perspectives on a landscape [55], especially if this is unfamiliar for the majority of people.

3.2 Data

Images illustrating some key "biological elements" of the Mediterranean deep-sea ecosystems were selected from different kind of sources. Photo galleries of international organizations focusing on ocean conservation, photos taken from previous research projects designed for studying deep-sea ecosystems, and marine biology experts' personal photo archives were searched to represent different deep-sea sites and conditions. Over one hundred photographs were collected for the concourse. To have a complete portrait of the topic under investigation according to principles of Q-methodology [36,40-41], the Fisher's [56] experimental design principles were applied. The collected images were grouped into *a-priori,* deductive categories. Two categories, including both the abiotic and the biotic components of an ecosystem, were created to depict the relevant characteristics of the marine environment and the life it hosts, and to ensure the representativeness of the Q sample. Images were selected and classified according to two visual themes – focus on "species" or "habitat" – and two levels, "pristine" or "polluted" elements. Uniqueness or rarity of species and habitats are the two main criteria that define the vulnerability of a marine ecosystem [57], while the degradation to pristine to polluted is a simple representation of the outcome of a vulnerability threat. The polluted level was then omitted from the Q Sample, because from the literature [23] it was already known that the public has a common negative perception of these elements, and this could have affected the respondent's viewpoints. By applying this approach eighteen photographs were selected for each of the two themes: the "pristine species" and the "pristine habitats". Thirty-six images were included in the Q sample (Figure 1).

< Insert FIGURE 1 about here>

The Q Sample was pre-tested with a pilot study that involved two PhD students: one in Marine Biology and one in Engineering. To simulate the subjects' viewpoints under different scenarios, during this pilot, three conditions of instruction were tested. The first condition was: "Please examine the set of thirty-six photographs representing Mediterranean deep-sea ecosystems (i.e. below 200 metres depth). We are asking you to image that an imminent natural disaster is going to destroy the entire Mediterranean Sea and you can save only a *limited,* but *not predetermined,* number of elements that characterize the Mediterranean deep-sea ecosystems, reported as photographs in the assigned numbered cards. You will be asked to sort these photographs based on <your own> point of view in terms of what is important to <you>, or in other words, rank the items according to the order in which <you> would save them. Remember that we are interested in your opinion and that there are neither right nor wrong answers. The cards' numbers are randomly assigned". The same scheme was maintained for the other two conditions of instruction, where participants were asked to rank the same images according to various simulated stakeholders' viewpoints: sorting them trying to favour fishermen' interests (2nd condition); and, finally, sorting them as if they were themselves fishermen (3rd condition). The objective was to obtain feedbacks on the people's comprehension of the different instructions and to test the perceived quality of the pictures. Experts not participating to the concourse preparation were also involved in refining the image selection and provide a good representation of Mediterranean deep-sea ecosystems.

After the pilot test, some of the pictures were replaced to improve the homogeneity of the set of photos in terms of image quality. Some images were removed because they showed objects unavailable in Mediterranean deep sea or already represented in other pictures (duplicates). By applying different conditions of instructions we guided the participants for sorting the photographs a) basing on the subject's personal viewpoint (the above cited 1st condition); b) favouring the fishermen' interests (the above cited 2nd condition); and c) as a fisherman would likely sort (the above cited 3rd condition).

This approach, by having each participant sorting the images under different conditions of instruction at different times [58], allowed us to select only a limited number of respondents and also to determine whether the subjective perceptions changed under different conditions. An intensive person sample (P set) of eight people was selected "to establish the existence of a factor for purposes of comparing one factor with another" [36]. This number – and the associated number of sorts – was defined based on the saturation approach to purposeful sampling [59]: recruiting new subjects was stopped when the new sorts did not add new relevant information to the factors.

As the notion of validity of the P set – the number of respondents to be included in a Q study – has no place in a Q methodology study and "its composition is more nearly theoretical or dimensional [60] than random or accidental" [36], we specially focussed on the breadth and diversity of the perspectives to be included in the participant sample [61]. For these reasons, people were not randomly selected, as in quantitative surveys, but were conveniently chosen to include different perspectives. Since this study aimed at understanding people's points of view on the Mediterranean deep-sea ecosystems, the participant sample was structured to include respondents theoretically relevant to the problem under consideration [62]. Therefore, the design of the P set was guided by the previous considerations on the level of expertise and knowledge of the subjects: subjects were divided in two numerically equal groups according to the level of familiarity of the subjects with deep-sea ecosystems.

Four PhD students in Marine Biology and four of other faculties at the Università Politecnica delle Marche, located in Ancona (central Italy) were selected. The first group included: one student in developmental biology and fishing, one in marine zoology, one in phytobiology and marine botany, one in marine microbiology and molecular biology. The second group was composed of non-marine PhD students: two from the faculty of Engineering, one from the faculty of Agriculture, and one from the faculty of Science.

Both groups shared a good level of general scientific knowledge (being all students in scientific faculties) but only the first group was previously exposed to deep-sea habitats and species.

In order to reduce time and cost, participants were recruited approaching them on the university premises.

A total of twenty-four final Q sorts were obtained and analysed like independent perspectives as expressed by twenty-four different people.

Participants were asked to begin sorting the 36 images, according to the condition of instruction on duty, into three piles: photographs less important to them; photograph of average importance – nor important or unimportant; and finally, photographs most important. Once all of the images were grouped into piles, participants were asked to select the four images more characteristic of each of the extremes and to rank-order photographs from ‘most important’ (+4) to ‘most unimportant’ (-4) in a Q sorting distribution by working alternately from opposite ends of the distribution. The sorting procedure ended in the middle – the location of average importance. A forced rectangular distribution (Figure 2), instead of a quasi-normal one, was applied [63]. This peculiar shape was chosen to simplify the participants sorting process. Being the deep sea an unfamiliar environment for most of people, it was easier for them to sort the images by having more positions at the two extremes of the grid. According to the literature this shape of the Q sorting distribution, is expected to have an insignificant impact on the factor structure, both methodologically and statistically [64-66]. Once completed their Q sort, respondents were asked to copy the ID number of each photographs into the corresponding boxes of a valuation grid and to provide their motivations for those photographs placed under the column +4 and -4. Q sorts were collected face-to-face and individually and each respondent was convened every two-three days to obtain independent Q sorts for the different conditions of instruction.

< Insert FIGURE 2 about here>

4 Results

Centroid factor analysis and a varimax rotation [37,67] were applied using the PQMethod software specifically developed for Q methodology [68]. The twenty-four Q sorts were correlated (sort by sort) in order to produce the matrix of cross-correlations subjected to factor analysis [36]. Similar Q sorts, in which images were ranked in a similar way, were identified and grouped into the same factor. The revealed factors identified different points of view relating to the topic under investigation. Brown’s rule [36] was used to extract the correct number of factors. According to this rule, factors with at least two factor loadings – correlations between Q sorts – statistically significant at the 0.05 level, i.e. those exceeding ± 0.33 ($\pm 1.96 \times$ standard error [SE]; with SE = $1/\sqrt{}$ (No. of photographs)) were extracted. According to the Kaiser-Guttman criterion [69-70], the factor’s eigenvalues were also considered; only those factors with eigenvalues greater than one were selected. By taking into account the above cited rules, three factors, explaining 63% of the study variance, were extracted. They were: Noah's Ark Fans, Ecosystem Functions Supporters, and Deep Coral Lovers. The majority of sorts loaded into the first factor (eighteen Q sorts); the second and the third factor accounted for four and two sorts, respectively. Although the first factor accounted for most of the explained total variance (Table 1), this three-factor solution was selected because each factor clearly defines distinct points of view that deserved to be described separately.

< Insert TABLE 1 about here>

The selection of the correct number of factors was also supported by the definition of a scheme reporting how each Q sort moved across factors when the number of Q sorts progressively increased. This process was applied to the two, three and four factors solutions. When increasing the number of Q sorts, the three factors solution was confirmed to be the best option. In this solution Q sort loadings tended to remain more stable than in the two or four factor solutions. Besides, this solution was the most meaningful when it comes to factor interpretation [71].

Observing the participants' choices when replying to different conditions of instruction, it was possible to note that all the non-marine biologists uniquely loaded into factor 1, while the marine biologists loaded in different ways according to the condition of instruction. In particular: three of them loaded into factor 2 and one into factor 3 when instructed by the first condition; two loaded into factor 1, one into factor 2 and one into factor 3 when sorting according to the second condition of instruction; all of them loaded into factor 1 when the third condition instruction was assigned.

Factor scores for distinguishing images (those distinguishing one factor from all the other factors [62]) and consensus images (i.e. similarly liked or disliked among the 3 factors) are reported in Table 2 and Table 3.

< Insert TABLE 2 about here>

< Insert TABLE 3 about here>

4.1 Interpretation of the factors

This section presents detailed results for each factor by developing an interpretation mainly based on the top and the bottom-ranked distinguishing images, and on the motivations reported by the participants during the post sort interviews.

4.1.1 Factor 1: Noah's Ark Fans

This factor explains 47% of the total variance. The top ranked photographs (Images 5, 6, 9, 26, 28 and 33) contain species typical of Mediterranean deep-sea ecosystems (e.g. octopus, fishes, crabs). The selected images represent close-up of single species, which are likely more easily understood than unfamiliar (Images 2, 14, 20 and 29) and complex habitats (Images 4 and 30). For example: regarding image 14, the non-biologist N3 declared "I don't know exactly what this image represents, but I think that it is not important"; and regarding image 20 the non-biologist N6 stated "This sea floor appears empty to me, there is no life". For people belonged to this factor, coral species are relatively unimportant (Images 10, 27 and 32). In addition, it's important to highlight that great importance is given to those species that are targets for fishing industry. This aspect emerged from the participants' words: for example, in relation to image 26 the non-biologist N1 said "These species are important because they have a relevant commercial value". Generally speaking, habitats are less important for this factor.

4.1.2 Factor 2: Ecosystem Functions Supporters

Factor 2 accounts for four Q sorts and 11% of the explained total variance. This factor underlines the importance of saving both species and habitats (Images 2, 6, 24, 25, 28, 30 and 36). In particular, priority is given to the preservation of those habitats that host peculiar communities (Image 2) and to the promotion of the deep-sea biodiversity (Image 30). Species belonging to different trophic levels (Images 3, 6, 11, 24 and 36) are valued because they could guarantee the maintenance of complex feeding interactions among the species within deep-sea communities. Some explanatory sentences were: "This rare habitat hosts a peculiar biodiversity" (Biologist B2 - regarding image 2); "These elements are at the base of the trophic chain, if we lose them we also lose species of higher trophic levels" (Biologist B4 - regarding images 2 and 30); "This is a primary food resource" (Biologist B3 - regarding image 24); and "Sharks are top predators and for this reason they have a key role in the ecosystem" (Biologist B2 - regarding image 36). Low importance is assigned to those habitats that are considered to host a lower level of biodiversity (Images 14, 19 and 20).

4.1.3 Factor 3: Deep Coral Lovers

In this factor, two Q sorts – by the same subject – explain 5% of the total variance. This factor was retained since it provide a separate (expert) viewpoint that associates great interest to habitats with coral reefs and sponge fields (Images 4, 12, 22, 32, 10 and 29). Probably, these habitats were chosen for their capability of increasing the complexity of environment, providing nursery for a wide variety of species and enhancing deep-sea biodiversity. Some deep-water corals can also provide paleoclimatic information related to marine environment and useful for predicting future scenarios. This viewpoint is supported by the sentence: "Thanks to these habitat-forming species complex habitats are created; if we lose them we also lose a great number of related species" (Biologist B1 – regarding images 4 and 22). Images reporting single species (Images 1, 26 and 28) and scarcity of forms of life (Images 19 and 25) were not considered important to be saved by the subjects belonging to this factor.

5 Discussion and conclusion

A considerable variety of viewpoints dealing with the Mediterranean deep-sea ecosystems were identified. The different background of the participants emerged directly through their sorts and it was captured inside the emerging factors. The three relevant participants discourses – Noah's Ark Fans, Ecosystem Functions Supporters and Deep Coral Lovers – completely represented what was really important for people who participated to the sorting experiment.

In terms of species and habitats conservation, the concept of “biodiversity” was mentioned many times during the post-sort discussions, by both the non-marine biologist and the marine biologists, as a priority aspect to be preserved. However, it is important to note that the word “biodiversity” was interpreted in two different ways: according to the non-biologists’ view, “biodiversity” was uniquely associated to the variety of the species belonging to the ‘animal kingdom’; by contrast, the marine biologists associated this concept to the preservation of the genetic, species and ecosystem diversity.

In general, results showed a low consensus among the factors, when looking to positive items, with the exceptions of images 3 (shrimp) and 36 (shark), due to their economic value for fishermen and their functional role in the ecosystem. This was also supported by relatively low correlations between factors: correlation between Factor 1 and 2 is 0.4838, between Factor 1 and 3 is -0.1823, and between Factor 2 and 3 is -0.1073. Regarding the negative items, only one strong agreement was found on image 19, which represented a soft bottom. This image was rejected by all factors, because it appeared devoid of living organisms.

The Noah's Ark Fans group, in which can be noted a strong emphasis in saving those species typical of Mediterranean deep-sea ecosystems (especially those relevant for the fishing industry), expressed the viewpoints of all non-biologists (independently from conditions of instruction) and of the marine biologists when they were asked to think as if they were a fishermen. It’s interesting to note that, although non-marine biologists included in the P set had different education, they shared a common point of view of deep sea, suggesting that their background didn’t matter. Moreover, their low scientific knowledge on this environment likely caused that they loaded into a single factor despite they were following different instructions. The possible explanation was that they expressed uniquely their own viewpoint, and the unfamiliarity of the framework didn’t allow them to put themselves in others’ shoes. On the contrary, the scientific background of the marine biologists allowed them to express distinct opinions when sorting basing on both the same and different conditions of instruction. Looking to this first factor, those marine elements identified as ‘animals’ were preferred to other species. In addition, corals, often not recognised as ‘fauna’ by non-marine biologists, but as ‘flora’, were often omitted from the priorities. According to the answers provided by some participants at the end of the sorting procedure, but also looking at their difficulties during the sorting procedure, the non-expert subjects did not recognise what those images showed. As a consequence these images were usually chosen as the least important. The same phenomenon emerges from literature [72]: people usually have difficulties in recognizing corals and have a poor understanding of what corals are.

Another reason that could explain the high preference for images with only animals in the first factor is associated with the role covered by those species for the fishing industry. Most of them were thought to be valuable for fishermen, even when they have no commercial value.

By contrast, the role of both habitats and species, rather than single species, was recognized by the majority of marine biologists who participated to the study, as identified by the Ecosystem Functions Supporters group. According to this second factor, the priority was given to save different habitats, from the cold seeps to the rocky bottom and the coral reefs, hosting peculiar communities, and different kind of species, because of their role in the marine food web. These aspects were supported by the participants’ explanations associated to this second factor. Summing up, this group of marine biologists wished to preserve those key elements, which would sustain the ecological health of deep-sea ecosystems, namely habitats in which animals can live, feed and reproduce themselves and species from primary producers (e.g. chemosynthetic microorganisms) to top predators (e.g. sharks). Basically, the idea was to conserve an ecosystem as a whole, rather than single species of high trophic levels, such as in the first factor, that alone unlikely could guarantee the maintenance of ecosystem functions.

As well as the Ecosystem Functions Supporters, the Deep Coral Lovers group showed a very strong emphasis on the importance of the habitats. This third factor, including two Q sorts both completed by the same marine biologist, gave the priority to preserving the cold-water corals and the sponge fields and guarantee the provision of their services to future generations. These environments are considered as hot-spots of biodiversity, but they are also refuges and nursery areas for several species, including the commercial ones [73]. These habitats can be sources of molecular compounds potentially useful in several fields, for example pharmaceutics [74]. Some of the coral species can also represent archives, which can be used to assess climate conditions about past centuries and to forecasts future climate scenarios [75].

Observing people’s response when they were asked to sort according to different conditions of instruction, all participants shared a common viewpoint and grouped into the same factor, uniquely when they sorted as fishermen would likely do (third condition of instruction). All respondents thought that the priority for a fisherman is preserving mainly the commercial species. Furthermore it is noteworthy that non-expert participants, having less knowledge about the marine environment, always loaded into the first factor – Noah's Ark Fans – when sorting according to different condition of instruction. Non-marine biologists did not change their viewpoint, presumably because they are less familiar and have no information about the topic under investigation.

Our study on the subjective perceptions of Mediterranean deep-sea ecosystems represents a first attempt to understand how to evaluate the perceived benefits of a remote and unfamiliar marine environment. Albeit its intrinsic qualitative nature, this study provides deeper insights into the different viewpoints and stakeholders involved in valuing the Mediterranean deep sea. The opinions of non-experts and of those having a more scientific understanding of the deep-sea ecosystems considerably differ, and more than two perspectives emerged (Noah's Ark Fans, Ecosystem Functions Supporters, and Deep Coral Lovers). Nevertheless, a large consensus emerges when thinking to the provisioning services – i.e. when asking to assess the most important element to be preserved acting as if in the fisherman’s shoe.

Further research is needed to confirm our findings and eventually to fully investigate these perceptions by a larger sample. Since the identified viewpoints are largely connected to the experience and the cultural background of the participants included in the study, it would be interesting to enlarge the original P set. By including different viewpoints – e.g. marine scientists, fishermen etc. – other subjective opinions could be considered and eventually revealed.

On the methodological ground, the application of Q-methodology with images produced interesting results and it was an effective approach for the study of subjective opinions about the deep-sea ecosystems. Individuals’ perspectives on a landscape almost unfamiliar – for the majority of people – could have been hardly revealed via the use of statements. The use of images offered to the participants a more direct representation of the reality. Furthermore, by involving less need for interpretation and semantic processing than words [50], they facilitated the landscape quality assessment. The images, which represent the deep-sea landscape as it is, allowed the participants, to have a clear vision of deep sea locations almost unknown and therefore difficult to evaluate.

The study also has some other theoretical implications. People are not easily changing their mind and behaviour [76], and applying Q-methodology, with different conditions of instruction, the resilience of the participants' individual goal system and its influence on a possible change of behaviour [77] was investigated. The results of the study suggest that changes in behaviour are not easy and that can be powerfully influenced but also hampered by specific individual resistances [76,78]. Only the interviewed marine biologists were able to change their minds according to different viewpoints – e.g. themselves or as they were a fisherman – and their experience; the non-experts having less expertise and knowledge about the topic, were not able to discriminate between different viewpoints and resist to any possible change of perspective.

On the political ground, our study supports the need for improving the communication between scientists and the general public regarding the importance of deep sea. Setting an agenda for increasing the public awareness on the crucial ecosystem goods and services the deep sea provides to the society is an urgent task. It would raise people's support for a more sustainable use of the largest environment on Earth. Overall, a deeper understanding is needed of how people perceive and evaluate the marine resources and how their choices can eventually became more reflective of the complexity and diversity of the services provided – provisioning, cultural, regulating and supporting – by the deep-sea ecosystem [15].

Nevertheless, the expected growth in exploitation of resources in deep sea, paired with more knowledge about the threats and pressures impacting on the system, will require new policy measures stimulating a research agenda for a dynamic valuation of deep-sea goods and service [15]. A reiteration of Q-methodology with images, possibly repeated over time – with its ability to assess the changes in the perception of the landscape visual impacts – may also help to develop more dynamic and effective policies, as postulated by Deignan [79].

Finally, this study contributes to the definition of the key attributes for a choice experiment [26-27], an experimental design in which participants are asked to make choices between different scenarios. For example, attributes referring to ecosystem services of deep-sea biodiversity have to be addressed by abundance of species to avoid protest responses. Habitat diversity is a more complex attribute that may not be fully understood (and valued) by the general public and some categories of stakeholders (e.g. fishermen). Therefore, for the sake of WTP estimation, habitats need to be introduced as attributes directly associated with use or option/quasi-option value e.g. "number of life-saving drugs potentially derived by sponges" or "increased fish stock by preservation of sea-bed trophic system".

To our knowledge, only two studies applied a choice experiment providing monetary value on deep-sea ecosystem services [80-81]. Since, there is an urgent need for a more sustainable management of deep sea [15], a non-monetary preference elicitation study offers a useful highlight to which ecosystem services are salient to stakeholders and that may be the object of further monetary valuation studies.

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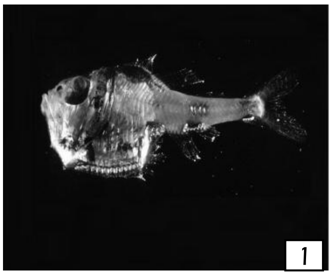
Figures in B&W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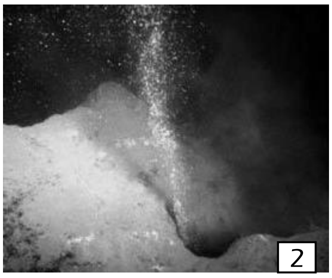
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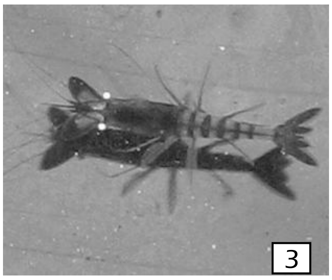
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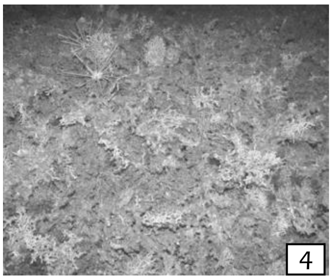
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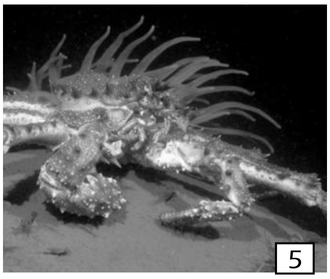
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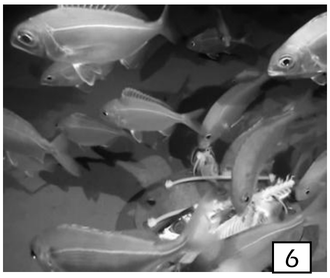
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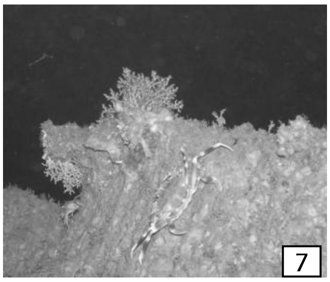
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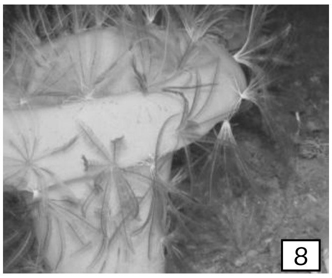
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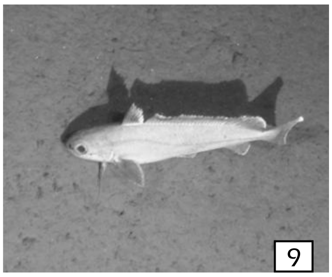
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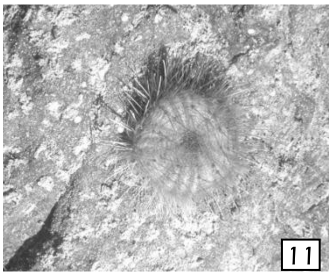
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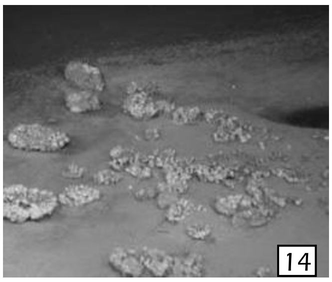
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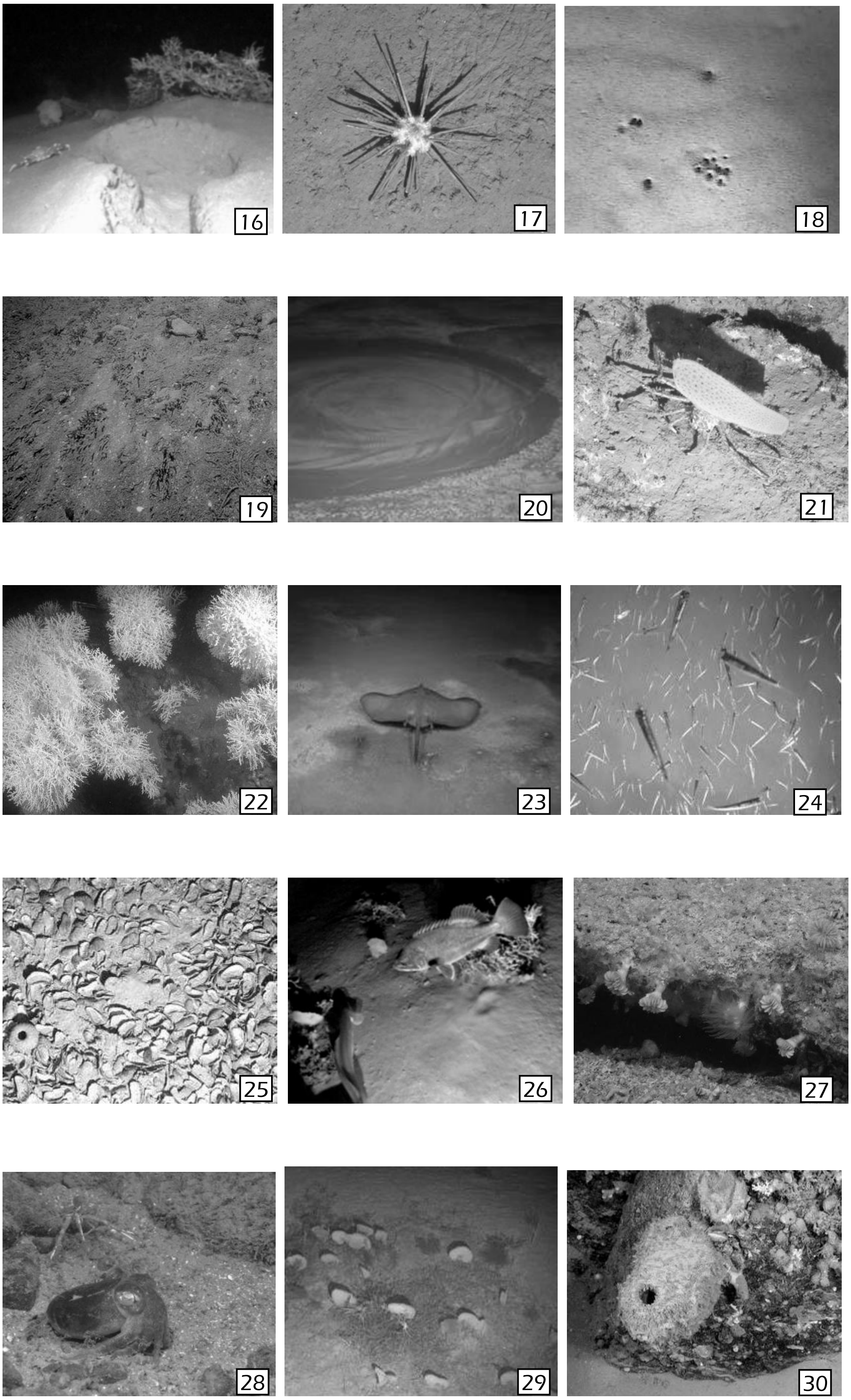
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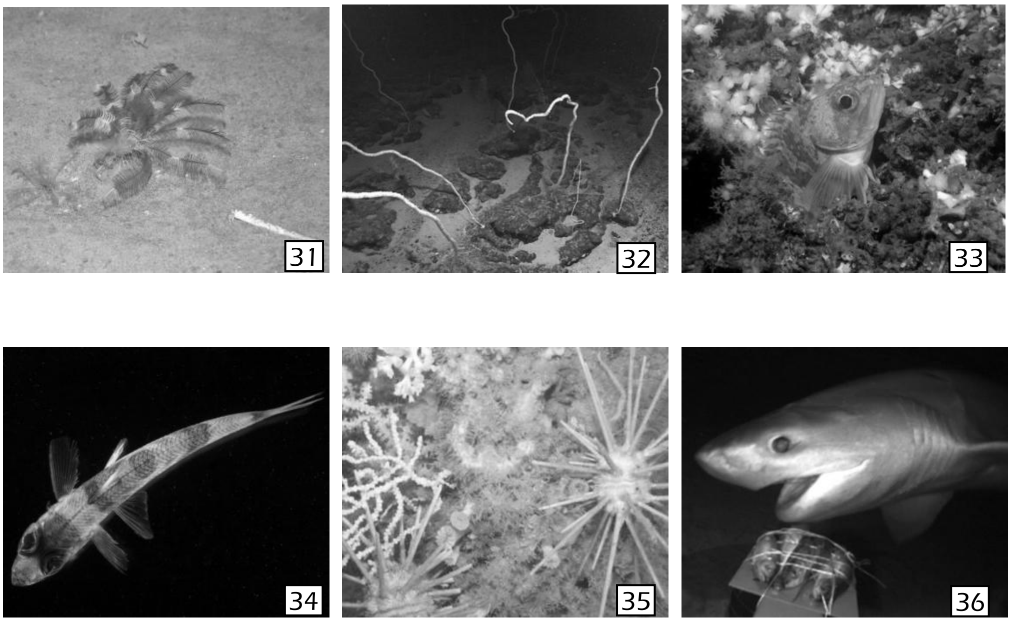


Figure 1 Q sample: Mediterranean deep-sea images

-4	-3	-2	-1	0	+1	+2	+3	+4
-4	-3	-2	-1	0	+1	+2	+3	+4
-4	-3	-2	-1	0	+1	+2	+3	+4
-4	-3	-2	-1	0	+1	+2	+3	+4

Figure 2 Q sorting Distribution

Table 1 Eigenvalues and explained variance for each factor

	Factors		
	Noah's Ark Fans	Ecosystem Functions Supporters	Deep Coral Lovers
Eigenvalues	12.5859	1.3503	1.3102
N° Q sorts	18	4	2
% expl. Var.	47	11	5

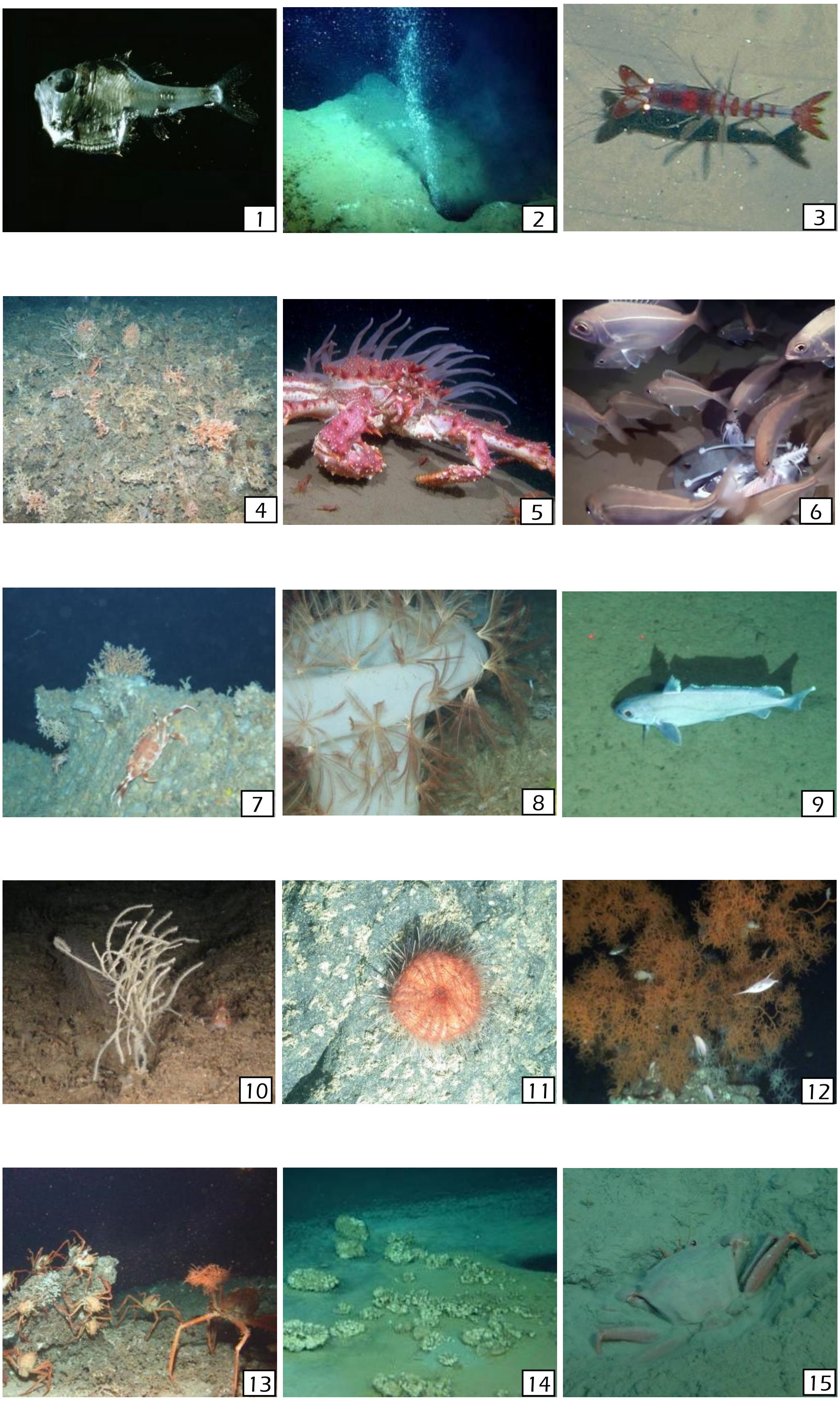
Table 2 Distinguishing images and their factor scores

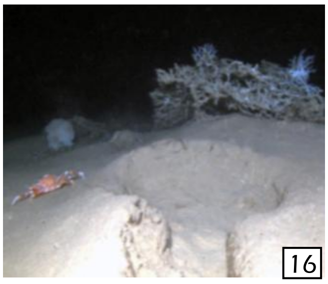
	Positive		Negative	
	ID Images	Factor scores	ID Images	Factor scores
F.1 Noah's Ark Fans	28	4	18	-4
	33	4	2	-3
	9	4	4	-2
	26	3	30	-2
	5	3	22	0
	15	3		
	34	2		
	24	1		
	21	1		
	12	0		
F.2 Ecosystem Functions Supporters	2	4	17	-4
	24	4	27	-3
	30	4	18	-2
	25	3	9	-2
	22	2		
	28	1		
	5	1		
	26	1		
	4	0		
F.3 Deep Coral Lovers	4	4	28	-4
	22	4	16	-4
	32	4	30	-3
	10	3	1	-3
	29	3	24	-3
	20	2	26	-3
	2	2	5	-2
	18	2	7	-1
	9	1	14	-1
			6	-1

Table 3 Consensus images and their factor scores

	Factor scores		
ID Image	F.1 Noah's Ark Fans	F.2 Ecosystem Functions Supporters	F.3 Deep Coral Lovers
3	3	3	3
8	-1	-1	1
11	1	2	1
13	1	1	2
19	-4	-4	-4
23	2	1	0
31	-1	-1	-2
35	-1	0	0
36	2	3	3

Supplementary File: Fig. 1 in colour

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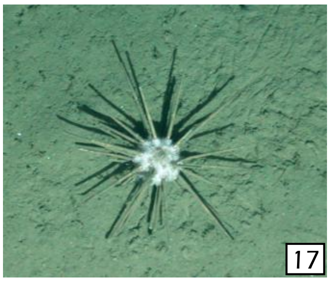
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18

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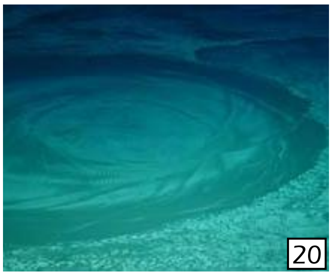
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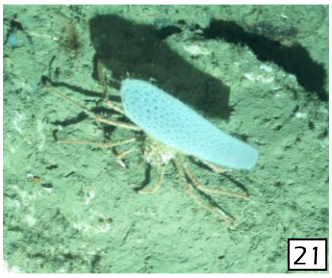
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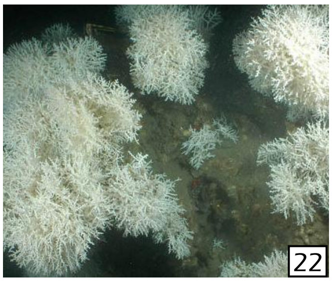
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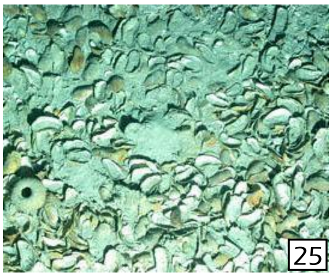
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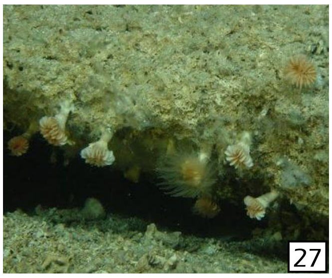
27

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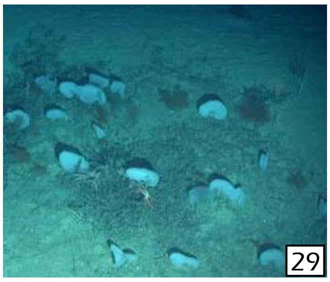
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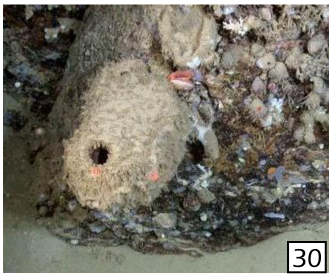
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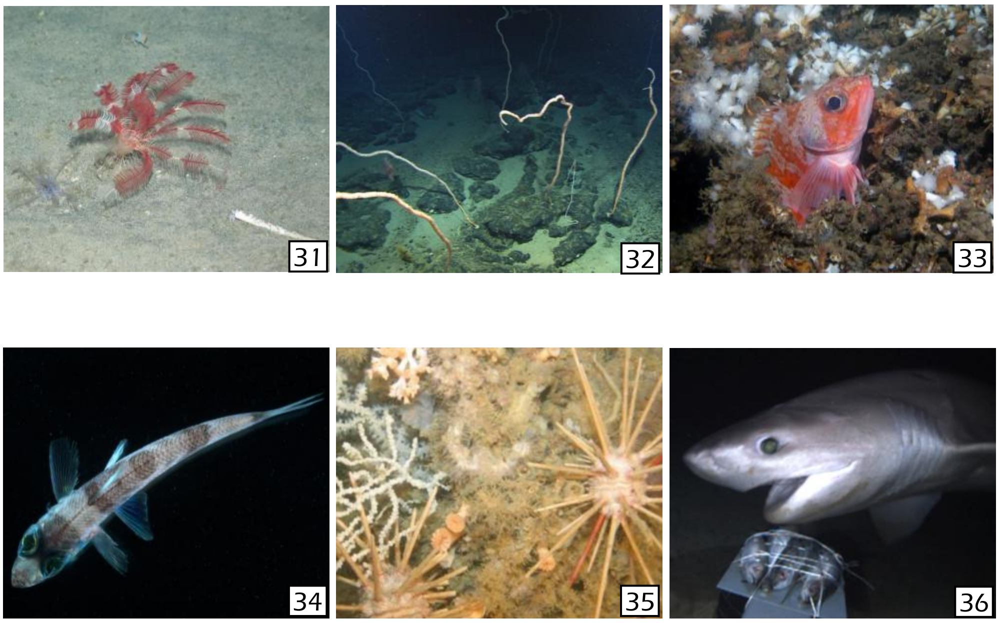

Figure 1 Q sample: Mediterranean deep-sea images