No waves from surface knowledge: diving into the social representations of the deep sea

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Abstract

Recently, new data about deep-sea ecosystems has stirred scientific, economic, and ecological agendas, but little is known about the public's perspectives of the deep sea. Our goal is to explore the public's common sense knowledge of the deep sea, with a view to inform science communication efforts. Based on social representations theory, we investigated the relationship between the public's meanings associated with the deep sea and psychosocial and positional variables, such as attitudes and education level, and reflected on the implications of the findings for science communication. The study was conducted in Portugal, a coastal, sea-connected country. The sample consisted of 315 adults from different age groups and social strata. Participants were asked to elicit and rank their thoughts about the deep sea using a ranked association technique and fill in questions about sociodemographic information, perceptions, and attitudes concerning the deep sea. Results showed that the social representations of the deep sea were structured as emotional versus rational views and as superficial ocean knowledge versus novel or unusual views. Moreover, results evinced a relationship between representations and psychosocial and positional variables. The gap between scientific and common sense knowledge was evident amongst participants with a low education level and low science engagement, whilst highly educated and science- engaged participants' representations seemed to be narrowed by instrumental views on science. This research is significant to better directing science communication to increase well-informed public participation in decision-making related to deep sea management and other socio-scientific issues by responding to audience's background knowledge.

Introduction

Research has consistently shown that people are less aware of and concerned with coastal and deep sea waters than with threats to coastal waters (e.g. Belden, 1999; Hynes et al., 2014). The deep sea still seems to be a remote concept, distant from people's lives, a reality about which they know little (Ankamah-Yeboah et al., 2020), although scientific evidence has long revealed that, below the depth of 200 metres, the ecosystems' biodiversity is as rich as it is vulnerable (O'Leary et al., 2020). In the context of the 'blue economy' (Lee et al., 2020), the deep sea gains momentum as an important socio-scientific issue with further research being urgent to estimate its economic value and sustain- able management (Folkersen et al., 2018). Notably, interest in mining the seabed area – declared humankind's common heritage by the United Nations Convention on the Law of the Sea in 1982 (UNCLOS, 1982) – for polymetallic nodules, polymetallic sulphides, and cobalt-rich ferro-manganese crusts is growing, with the International Seabed Authority (2021) having issued 31 exploration contracts.

In this changing context, science communication becomes important for marine management, as it can have a role in changing people's low levels of concern, awareness, and knowledge of the deep sea (e.g. Belden, 1999; Hynes et al., 2014), enabling them to make more informed decisions. For example, it seems clear that deep sea mining with no net loss is untenable, and detrimental con- sequences will affect humankind's common heritage (Niner et al., 2018). Alternative approaches to mining should be discussed (Miller et al., 2018) and an effective legal framework enabling cooperation and coordination among different organisations defined (O'Leary et al., 2020).

While, recently, some science communication initiatives have brought the deep sea to the attention of broader audiences (e.g. Doherty, 2017), communication initiatives specifically about the deep sea are still scarce, as much of the communications about the ocean focus on shallower areas (Salazar et al., 2019). Further, people's common knowledge about the deep sea as a socio- scientific issue has seldom been investigated (Jobstvogt et al., 2014). In general, research on people's relationship with the environment has been conceptualised in reference to anthropocentric or eco- centric perspectives (Catton & Dunlap, 1980), but such dichotomous approaches might fail to properly explore people's views (McDonald & Patterson, 2007), as each approach is incomplete independently, but conflictual if integrated. We think that approaching the public's common sense knowledge of the deep sea through the lens of social representations theory might capture the issue's nuances and complexity, contribute to more effective management of the deep sea, and refine the target of science communication efforts related to emergent, complex, and less socially visible socio-scientific issues.

This paper aims to explore people's common knowledge about the deep sea and understand how this knowledge relates to variables such as attitudes towards the deep sea. The results of this investigation will contribute to reflection on how science communication efforts might be more effectively targeted. We begin by describing the deep sea as an emergent socio-scientific issue and explaining how social representations, as a communication theory, is well-equipped to explore common sense knowledge about the deep sea. Information about the sample, measures, and procedures will follow. After presenting the results and illustrating the distributed nature of social representations and their relationship with psychosocial and positional variables, we discuss the study's contribution to marine management and science communication.

The unexplored deep sea

The deep sea is Earth's largest ecosystem, yet more than 80% of it remains unobserved and unexplored due to technological limitations and high exploration costs (Da Ros et al., 2019; Kennedy et al., 2019; Santos et al., 2018). Comprising seawater depths below 200 metres and 90% of the world's oceans, some of the deep sea's unique, challenging characteristics include the absence of sunlight, low temperatures, and high pressure levels (Colaço et al., 2017). Deep sea habitats house species with unique bio-ecological adaptations (Colaço et al., 2017; Ramirez-Llodra et al., 2010), many of which are still unknown or understudied (Kennedy et al., 2019; Webb et al., 2010). The deep sea is important to humans because it provides essential services and resources (e.g. food and the regulation of temperature and atmospheric greenhouse gases (Colaço et al., 2017; Jobstvogt et al., 2014)). Valuable resources (e.g. polymetallic massive sulphides, manganese nodules) add to the reasons to search the depths for economic opportunities beyond fishing (Colaço et al., 2017; Santos et al., 2018). Economic interests are pushing towards the exploitation of deep-sea minerals potentially useful to new technologies (e.g. copper, silver, lithium), along with chemical or genetic material with potential pharmaceutical value, due to the unique chemical-biological properties of deep-sea species (Colaço et al., 2017). Although deep sea mining is on the horizon (Wed- ding et al., 2015), scientists advise the need for more studies and precautions to minimise effects upon local deep-sea communities or others (Levin et al., 2016; Santos et al., 2018), as there is much uncertainty and potential larger impacts on the surrounding ecosystems and their services (Da Ros et al., 2019). The mining industry is adopting the aim of exploring the deep sea causing no net loss. However, such aim is impossible, compensatory measures are still to be proved feasible and, even if they work, the recovery of the ecosystems is so slow that detrimental consequences would affect generations to come (Niner et al., 2018).

Deep sea habitats are threatened by anthropogenic activities (Colaço et al., 2017; Ramirez-Llodra et al., 2011). The growing demands for fish, and consequent over-fishing, are leading to the depletion of traditional fishing areas and forcing them to deeper waters. Currently, bottom-trawling is the main threat to the deep sea (Ramirez-Llodra et al., 2011) because it causes immediate severe harm to the deep sea floor and its slow-growing communities, it is economically and ecologically unsustainable (Colaço et al., 2017). Also propelled by increasing demand, oil and gas exploitation have ventured into deeper waters as well, despite the risks of accidental oil spillage and drilling muds affecting fragile and important deep-sea and continental margin habitats (Ramirez-Llodra et al., 2011). Moreover, marine plastic pollution has reached the deep sea, where it causes the death of marine specimens by entanglement and/or intoxication via ingestion, which eventually impacts other consumers, including humans (Chiba et al., 2018).

The deep sea also absorbs heat and carbon dioxide, exposing its ecosystems to increased warming, acidification, deoxygenation, and reductions of their already low food supply levels (Levin & Bris, 2015). Consequently, biodiversity is threatened, negatively affecting key ocean functions that sustain Earth and compromising the health of its inhabitants' health, including the human species (Colaço et al., 2017; Levin & Bris, 2015). Even scientific research affects deep-sea communities by creating disturbance (Glowka, 2003), which requires a constant weighing of pros and cons of each human intervention on the deep sea.

Public participation in decision making processes is seen to be critical to deep sea management. Jaeckel et al. (2017) claim that public participation is necessary to define environmental measures to regulate the sharing of benefits and conservation of the seabed area in line with the common heritage of humankind principle (UNCLOS, 1982). Niner et al. (2018) claim that well-informed and public participation is needed to define the level of acceptable loss in deep-sea mining, given that the goal of no net loss is untenable. However, mass media coverage (e.g. Doherty, 2017) or participatory projects involving scientists, students, and science communicators (e.g. 'My deep sea, my backyard'; Ocean Exploration Trust, n.d) are few. In short, public communication about the deep sea is scarce (Salazar et al., 2019) and there is a need to increase the public's 'ocean literacy'; that is, our understanding of the ocean's influence on us and our influence on it (Cava et al., 2005). In fact, misconceptions about it are common, for example, tides are caused by the wind, the bottom of the ocean is sandy rock (Ballantyne, 2004; Fauville et al., 2019). There is a lack of awareness about the marine environment and many people do not consider the ocean to be relevant or influential in their lives (Arnold, 2004; Nepote & Medina-Rosas, 2021). A recent study showed that people's self-perceived knowledge about the deep sea is low and, although caring a lot about the impact of human activity in the deep sea, people cared less when compared with other remote environments (Kaikkonen & van Putten, 2021). The findings of this study contradicted pervasive ideas in the field suggesting that people do not care about the deep sea for a number of reasons, including fear and loathing (Jamieson et al., 2020).

However, ocean literacy is not achievable solely by understanding of how oceans influence humans and vice versa (Cava et al., 2005); as Fauville et al. (2019) have stressed, it also calls for an investigation of public awareness and the application of positive attitudes, and decision-making and participation skills to ocean-related actions. The ecological paradigms we review next help us to understand people's relationship with the environment.

Ecological paradigms and people's connection the (deep)sea

In the 1970s, several global environmental problems culminated in a paradigm shift from the *human exemptionalist paradigm* (HEP), an anthropocentric, optimistic, and unecological view, to the *new ecological paradigm* (NEP), an ecocentric, realistic, and ecological perspective (Catton & Dunlap, 1980; Dunlap & Catton, 1991). Validation of the NEP scale supports a single construct of an ecological worldview (Dunlap et al., 2000), suggesting that people's worldview is either eco- centric or anthropocentric but not both (Manoli et al., 2019). However, replications using the NEP scale are not consensual about whether the scale measures a single construct or it is multidimensional, nor is there agreement on the number of dimensions (Dunlap et al., 2000). For instance, a Portuguese study on the public's environmental concerns found four configurations combining the two belief systems. Although the ecocentric view seemed to predominate, the study found that some groups attempted to harmonise the apparently incompatible ecocentric and anthropo- centric perspectives (Castro, 2003). In the southwestern United States, similar results were found (Manoli et al., 2019). Some relied on the insufficiency of the HEP or NEP alone to explain human attitudes toward nature, thus defending a perspective of integration and/or dialogue between the HEP and NEP (McDonald & Patterson, 2007). Nevertheless, studies using the NEP scale (Dunlap & Van Liere, 1978) and its revised version (Dunlap et al., 2000) have suggested that stronger NEP beliefs are associated with younger age, less income, more education, and less conservative political views. Although findings regarding gender are unclear, women tend to be more supportive of NEP views (Castro, 2005).

As for the deep sea, Belden (1999) have shown that young Americans are more preoccupied with damage to the deep ocean than older Americans. In general, among those most concerned about threats to the oceans, the authors identified women, African-Americans and Hispanics, less educated people, and citizens with a low income. As for engagement with science, the authors emphasised that individuals were more likely to engage with science by visiting aquariums and science museums, and although they recognised the oceans' vulnerability, they attached only moderate personal importance to ocean protection. Proximity to the sea is another factor impacting the public's opinion on topics related with the marine environment (Hynes et al., 2014); however, it seems to affect only concerns with beaches and not coastal or deep waters (Arnold, 2004; Belden, 1999). More recently, Ankamah- Yeboah et al. (2020) have shown that age, gender, and education level are associated with 'awareness of [the effects of] deep-sea changes on human well-being, perceptions of deep-sea condition and management as well as general pro-environmental attitudes and values' (pp. 12-13).

Despite the literature on ecological paradigms and people's connection to the (deep)sea, to our knowledge, there is no research on social representations of the deep sea. Hence, an introduction to the theory and its relevance to science communication is needed.

Social representations as a communication theory

Social representations constitute a theory of common knowledge that seeks to describe and explain how people make sense of scientific and technological novelties, as well as how they make the strange familiar, and regulate their behaviour (Kronberger, 2015; Moscovici, 1976). According to the theory, common sense knowledge is not a set of individual representations, perceptions, or ideas, but rather a distributed, socially negotiated process that urges us to look beyond individuals (Harré, 1984). Resulting from and enabling social interaction rather than arising exclusively from individual reflections (Sammut, 2015), social representations constitute their very own field of communication (Doise, 2003). In science communication, Farr (1993) has long argued in favour of a social representations approach to studying scientific topics, as it offers insights into the public's (mis)understanding to inform the design and implementation of effective initiatives.

The psychological construct of *attitude* is one component of social representations theory (de Rosa, 1993; Doise, 2003; Sammut, 2015). Although its definition depends on the models into which the attitudes are integrated (de Rosa, 1993), there is consensus that they express an individual evaluation of a given subject with a certain degree of (un)favourability (Eagly & Chaiken, 1998).

Integrating attitudes – an intraindividual concept – into social representations – a psychosocial theory – seems to be a question of articulating the levels of analysis (Doise, 1982; Doise & Valentim, 2015). Integration involves placing and understanding individuals' attitudes into communicational fields constructed and shared by social groups. In this context, attitudes are best conceived as argumentative elements of social representations (Billig, 1993) through which individuals express their support for or opposition to any given social topic.

From the perspective of social representations theory, making sense of new ideas is not simply about abandoning old ones. If the continuous flow of new information challenges common sense knowledge, people will struggle to find a balance between old and new perspectives, often resulting in their coexistence (Castro, 2003). Social change typically unfolds through conflictual processes that are either intrapersonal, occurring when individuals search for internal coherence among different representations, or intergroup, which involves discussion among different groups (Castro, 2015). Social representations theory and, as we will see, its methodological apparatus are well-suited to deal with novel socio-scientific issues such as the deep sea (Da Ros et al., 2019; Jobstvogt et al., 2014).

The lack of studies on how laypeople make sense of scientific information about the deep sea stresses the deep sea's relevance as a case study for reflecting on how science communication efforts might be better targeted with regard to socio-scientific issues. The relationship between the public's common sense knowledge of the deep sea and the variables revised to this point (i.e. age, gender, educational level, proximity to the sea, engagement with science, attitudes, and perceptions) have not yet been explored. Because the deep sea is a remote, complex, and less socially visible socio-scientific issue, we reasoned that people might be struggling to make sense of the scarce information available to them. In this study, we aim to investigate the relationship between social representations and the variables mentioned before and identify the implications for science communication.

Methods

Research questions

The study is guided by two main research questions. The first one is:

- What is the relationship between social representations of the deep sea and relevant illustrative variables?

After charting associations between social representations and participants' characteristics, we ask the second main question:

- What are the implications of the findings for science communication?

We expect that the findings will be significant in terms of better directing science communication actions to increase well-informed public participation in decision-making processes related to deep sea management issues.

Participants

The sample consisted of 315 participants (Female = 217; Male = 95, Missing = 3), distributed across four age groups: 18–29 years old = 22.2%, 30–39 years old = 28.5%, 40–49 years old = 23.8%, over 50 years old = 24.5% (Missing = 3). As for education level, 18.3% of the participants held a high school diploma or less, 32.4% held a bachelor's degree, 34,6% held a master's degree, and 14,0% earned a doctoral degree (Missing = 2). All but ten participants were Portuguese (305, 96.8%). Most participants were born, had previously lived, or were living near the coast (69.8%); few were born, had previously lived, or were living on an island (7.3%).

Our objective was to survey different groups within the general population in order to explore the relationship between social representation and illustrative variables. Due to time and budget constraints, participants were recruited using a snowball method: the researchers sent an invitation to acquaintances older than 18 years who were not involved in the research (e.g. students, col- leagues, friends) and asked them to forward it to other potential participants. In addition, the survey was advertised on social networks. We intended to secure at least 300 positive answers, as this would be an adequate sample size for factor analysis (Comrey & Lee, 2013), and would be larger than those typically used in social representations studies (e.g. Capozza et al., 2003). We recognised that the results might be affected by volunteer bias (Rosenthal & Rosnow, 2009). However, we tried to over- come the limitations of not using a random sample by following Rosenthal and Rosnow's (2009) recommendations. Specifically, the invitations shared via email and social networking were designed to (i) make the prospect of participation interesting through the use of enthusiastic language and thematic novelty, (ii) emphasise participants' contribution to research, and (iii) make participation sound non-threatening by guaranteeing anonymity and confidentiality, and refraining from any expertise or background prerequisites. In many cases, invitations were shared by high-status persons (i.e. researchers and professors from prestigious, well-known academic institutions).

Measures and procedures

As partially reported elsewhere (Morais et al., 2019), the survey was preceded by a qualitative research phase that involved individual and group interviews with deep sea experts and science centre staff. Different improved versions of the survey were piloted among volunteers, who discussed their views in a focus group after completing the survey. This procedure helped identify important themes (e.g. threats to and importance of the deep sea) and assess the readability of survey items.

The survey was created and administered using Lime Survey version 2.00+ (LimeSurvey, 2020), hosted by the authors' university. Informed consent was obtained from participants.

The form authorised data collection (that occurred between June and August 2019) and provided assurance that the respondents' answers would be anonymous and confidential. The survey comprised five sections:

(1) *Sociodemographic/Positional Variables* (age, gender, education, proximity to the sea) were measured using close-ended questions.
(2) *Representations of the Deep Sea* were measured using ranked association questions (Abric, 2003a). Participants were asked to evoke words or ideas they associated with the deep sea and then rank them by importance by assigning 1 to the most important word or idea in such a way that the lower the score, the greater the importance.
(3) *Engagement With Science* was measured using a 3-item rating scale (visiting science museums, watching science communication programmes, and reading text or news about science; (Morais et al., 2019; Paiva et al., 2020), with five answer options: 1 – *never*, 2 – *seldom*, 3 – *sometimes*, 4 – *frequently*, and 5 – *very often*.
(4) *Perceptions of the Deep Sea* were measured via the following rating scale questions adapted from surveys concerning ocean/marine environmental themes (Belden, 1999; Hynes et al., 2014; Potts et al., 2011):
(4a) *Perceived Importance of the Threat to the Deep Sea* consisted of seven items (e.g. pollution, garbage, climate change) with possible answers reported on a 5-point scale (ranging from 1 = *not a threat* to 5 = *great threat*).
(4b) *Perceived Importance of the Deep Sea to Society* consisted of nine items (e.g. relating to education and science, climate and meteorology, food), with possible answers reported on a 5-point scale (ranging from 1 = *unimportant* to 5 = *very important*).
(4c) *Attitudes Towards the Deep Sea* were measured using an original scale, with possible answers reported on a 5-point scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = *agree*, and 5 = *strongly agree*).

The corpus of data yielded by the ranked association questions was analysed using Iramuteq 0.7 (Ratinaud, 2020) for prototypical and similitude analysis and DtmVic 6.0 (Lebart, n.d.) for lexical correspondence analysis. For these analyses, some variable data were aggregated into comparable and crescent groups. For simplicity's sake, psychosocial and positional variables will be referred to as illustrative variables.

The remaining data were analysed using IBM SPSS Statistics 25 and 26 (IBM, 2020). Whenever constructs were measured by more than one variable (e.g. attitudes scale, engagement with science), factorial and internal consistency analyses (Cronbach's α) were performed.

Representations of the deep sea

Participants were asked to report at least five words or ideas they associate with the deep sea and rank them by importance. As in similar studies, the corpus was subjected to dictionary organisation (Brondi & Neresini, 2018). This procedure consisted of (1) lemmatisation (e.g. *whales* = *whale*), (2) synonym aggregation (e.g. *animals* = *fauna*), and (3) the association of antonyms with single representations (e.g. *silence* = *sound and* *murmur*). Whenever participants mentioned terms that were more scientifically related to the deep sea (e.g. *submarines*) than generic terms (e.g. *boats*), the more scientifically accurate responses were privileged (*boats include ships*, whereas *submarines include bathyscaphe*). Composed expressions were deconstructed (e.g. *unknown_mystery* = *unknown* and *mystery*). In expressions featuring nouns plus adjectives, adjectives prevailed as meaning changers because these were considered to be more important for understanding the meaning of the deep sea (e.g. *strangeness* = *strange_animals*). When doubts arose, all each participant's stimulus associations (Bardin, 2011) were consulted (e.g. one participant evoked *water, submarines, apnoea,* and *assisted_diving*; therefore, *apnoea* was added to *diving* and not to *oxygen*). The category name adopted in each case was based on the most representative word or expression.

Engagement with science

Participants were asked to state the frequency with which they engaged in specific science communication activities. The internal consistency score (Cronbach's α) was satisfactory (α = .81). We used an aggregate measure for the construct consisting of the mean of the item scores.

Attitudes towards the deep sea

Attitudinal sentences were structured to include cognitive, affective, and behavioural components (Rosenberg & Hovland, 1960). The phrasing of the items were assessed for readability, ambiguity, and abstraction (Angleitner et al., 1986), and these were discussed amongst the researchers. To further validate the survey's content and structural organisation, three focus groups, each with three to four participants, were convened. This exercise led to iterative modifications. Changes included removing excessively similar items, reformulating misinterpreted items, and modifying instructions. After conducting a preliminary principal component analysis (PCA) with varimax rotation, 37 items were produced and given to the participants, which allowed for the identification of three important components. A new PCA was conducted using those items only.

The Kaiser-Meyer-Olkin measure of sampling adequacy indicated that the sample size was suit- able (KMO = .85) (Kaiser, 1974). The Bartlett's test of sphericity was statistically significant ($\chi2(171) = 2166.31$; $p < .001$) and revealed correlations large enough to conduct a PCA. The correlation matrix showed many values above .30 and only one above .80. As Cattell suggested (as cited in Field, 2017), the analysis of the scree plot supported a three-factor solution. The combination of the three components explained 55.70% of the variance. Loading values were between -.66 and .87 for the Economic Exploration component, between .57 and .75 for the Preservation component, and between -.80 and .73 for the Scientific Exploration component (Table 1).

Table 1. Results from a Factor Analysis of Attitudes Towards the Deep Sea Scale

Items	Factors		
	Economic exploration	Preservation	Scientific exploration
I agree with deep-sea mining exploration.	.87		
I would vote for deep-sea economic exploration.	.85		
I would vote for deep-sea mining exploration.	.85		
I am in favor of deep-sea economic exploration.	.78		
I don't believe that deep-sea mining exploration has negative effects.	.71		
I disagree with deep-sea economic exploration.	-.66		
I think humans have the right to explore the deep sea.	.64		
Deep-sea preservation is something that concerns me.		.75	
I am in favor of allocating economic funds for deep-sea protection.		.75	
I think that implementing deep-sea protection measures should be mandatory.		.74	
I think that if we don't preserve the deep sea, we are endangering humans.		.62	
I consider the designation of marine protected areas urgent.		.61	
I agree that the deep sea must be protected.		.57	
I think that I can take measures to prevent deep-sea pollution.		.57	
I disagree with the scientific exploration of the deep sea.			-.80
I think that scientific exploration of the deep sea is beneficial for humans.			.73
I would vote against scientific exploration of the deep sea.			-.72
I am in favor of deep-sea scientific exploration.			.70
I believe science is favorable to the deep sea.			.67

Note. $N = 315$. The extraction method was principal component analysis with a varimax (Kaiser rotation normalisation) rotation.

We reverse scored negatively worded items (e.g. 'I disagree with deep-sea economic exploration') and calculated the means of the item scores for each factor. Internal consistency analysis (Cronbach's α) revealed satisfactory values for Economic Exploration (.89) and Preservation (.79), and an acceptable value (.77) for Scientific Exploration.

Results

First, we present results related to engagement with science, attitudes, the perceived importance of the deep sea, and threats to the deep sea (psychosocial variables). We then present the prototypical (social representation structure of ideas about the deep sea) and lexical correspondence analyses results. Given that this paper's goal is to understand the relationship between the social representation structure and psychosocial and positional variables, we will end this section projecting these variables into the semantic field of the representation in order to provide an understanding of people's views, so that science communication efforts might be more specifically targeted.

Illustrative variables

Engagement with science

Participants occasionally engaged in science communication activities ($M = 3.42$, $SD = 0.87$), mostly by reading science-related material ($M = 3.70$, $SD = 1.07$), watching science programmes ($M = 3.47$, $SD = 1.03$), and visiting science-related venues ($M = 3.10$, $SD = 0.96$). Engagement with science was divided into approximate quarters, using quartiles as cut-off scores (3.00, 3.33, 4.00). We grouped the results into approximate quarters because doing so made it easy to sensibly combine them with the social representations data.

Attitudes towards the deep sea

Participants showed less favourable attitudes towards the Economic Exploration of the deep sea ($M= 2.39$, $SD = 0.80$), high favourability towards its preservation ($M = 4.34$, $SD = 0.50$), and moderate favourability towards scientific exploration ($M = 3.80$, $SD = 0.68$). A Pearson correlation analysis revealed a weak negative correlation between Preservation and Economic Exploration ($r = -.32$, $p < .001$) and a weaker but positive correlation between Scientific Exploration and Preservation ($r = .16$, $p = .004$). The correlation between Economic Exploration and Scientific Exploration was not statistically significant ($r = .11$, $p = .053$).

Answers regarding attitudes were again divided into approximate quarters, using quartiles as cut-off scores (Economic Exploration: 1.86, 2.29, 3.00; Preservation: 4.00, 4.43, 4.71; Scientific Exploration: 3.20, 4.00, 4.20).

Perceived Importance of the deep sea

Participants perceived the deep sea as important to education and science as well as to climate and meteorology (see Table 2). However, the deep sea was perceived as only moderately important to food, technology, energy production, creativity, and culture and identity. Employment, leisure, and tourism were less consensual topics and were considered to be the least important.

Table 2. Means, Standards Deviation, and Percentage responses to Items about the Perceived Importance of the Deep Sea to Societal and Economic aspects.

Societal and economic aspects	*N*	*M* (*SD*)	Level of importance (Percentage of answers)				
			1 Unimportant	2	3	4	5 Very important
Education and science	306	4.44 (*0.74*)	0	1	11.8	29.1	58.2
Climate and meteorology	304	4.24 (*0.99*)	2	4.9	12.5	28	52.6
Food	299	3.94 (*1.00*)	2.3	5	24.1	33.1	35.5
Technology	295	3.90 (*1.00*)	2.4	5.4	26.4	31.5	34.2
Energy production	295	3.84 (*1.07*)	3.4	6.8	25.1	31.5	33.2
Creativity	295	3.70 (*1.04*)	3.7	7.8	28.1	35.6	24.7
Culture and identity	300	3.54 (*1.12*)	5.3	11.7	29	31.3	22.7
Employment	295	3.44 (*1.02*)	3.7	11.5	38	30.2	16.6
Leisure and tourism	306	3.34 (*1.30*)	13.7	10.1	26.5	27.8	21.9

Perceived threats to the deep sea

As we can observe in Table 3, participants perceived pollution, garbage, and climate change as major threats to the deep sea. Answers were more moderate and distributed for mining, fishing, and tourism. Scientific research was considered to be a lesser threat to the deep sea.

Table 3. Means, Standards Deviation, and Percentage responses to Items about Perceived Threats to the Deep Sea.

Threats	*M* (*SD*)	Level of threat (Percentage of answers)				
		1 Not a threat	2	3	4	5 Great threat
Pollution	4.83 (*0.50*)	.3	.3	2.3	10.6	86.5
Garbage	4.83 (*0.50*)	.3	.6	1.6	10.5	86.9
Climate change	4.52 (0.80)	1	1.6	8.8	21.2	67.4
Mining	4.13 (*1.03*)	2	4.4	22.1	21.8	49.7
Fishing	3.82 (*1.05*)	4.9	4.2	23.7	38	29.2
Tourism	3.38 (*1.14*)	7.3	13.2	32	29.7	17.8
Scientific research	2.34 (*1.26*)	32.4	27.1	23.5	8.2	8.8

Social representations of the deep sea

The corpus related to *deep sea* (collected via the ranked association task) consisted of 1,708 words; the thirteen most frequent terms (Table 4) covered 50.8%. Among these were generic (e.g. *darkness, life*) and concrete nouns (e.g. *fish, water*) as well as adjectives (e.g. *unknown, blue*).

Table 4. Frequency, Mean Rank of Importance, and Percentage for the 13 Most Frequent Themes Associated to the Deep Sea.

Word/expression	Frequency	Mean Rank of Importance	Percentage of Corpus
Darkness	160	3.0	9.4
Unknown	109	3.4	6.4
Fish	90	3.7	5.3
Life	80	4.1	4.7
Tranquility	67	3.2	3.9
Blue	63	2.8	3.7
Deep-sea threats	52	4.2	3.0
Water	44	2.9	2.6
Immensity	42	2.8	2.5
Coral	41	3.0	2.4
Cold	40	2.9	2.3
Silence	39	3.2	2.3
Depth	39	3.0	2.3
Total	866	-	50.8

Note. N = 312. The lower the mean rank score the higher the importance of the theme.

To explore the social representation structure, we conducted a prototypical analysis (for an over- view of this approach, see Wachelke & Wolter, 2011). This approach's objective is to identify likable themes as core of the representation, that is, the elements without which the representation does not exist. In Figure 1, we can observe four quadrants that result from the combination of (high or low) frequency and each theme's/word's ranking by importance (e.g. Abric, 2003b). The core quadrant refers to frequent and important words, which are the best candidates for the representation's core elements. The first periphery includes words that are high in frequency but low in importance, whereas the second periphery contains elements that are neither frequent nor important. The peripheral elements' function is to protect core elements from sudden and radical change. Peripheral areas are more open, flexible, and adaptable to new ideas, which they absorb without immediately affecting essential understanding of the subject. Finally, the contrasting zone includes words that are ranked as important but are not frequently used. It is therefore a kind of repository of new ideas, usually associated with minority thinking.

We limited the upper quadrants to words with more than 16 occurrences to represent the minimal frequency of one quarter of all distinct words (123 occurrences). *Darkness*, *tranquility*, and *blue* were the best potential candidates for the core of the representation of the deep sea, comprising 16.9% of all mentions. The first periphery was mostly characterised by *unknown*, *fish*, and *life* (16.3%), and the second periphery included *plants*, *investigation*, *geology*, *danger*, *fishing*, *protection*, and *undulation* (5.1%). The contrasting elements were *imaginary*, *oxygen*, *boats*, *Marianas Trench*, *purity*, *sharks*, *sunken ships*, and *whales* (6%); these included many scientific but also imaginary elements.

The prototypical analysis revealed a lack of definition of core elements. No single representative potential core element stood out as undoubtedly important because the ranks of all quadrants' most representative elements varied only marginally between 2.4 (contrasting element *oxygen* and core element candidate *rocks*) and 4.5 (second periphery element *investigation*). Most of the candidates for the representation's core were close to the cut-off point (≤ 3.33), and many of the first periphery elements were only slightly above the cut-off.

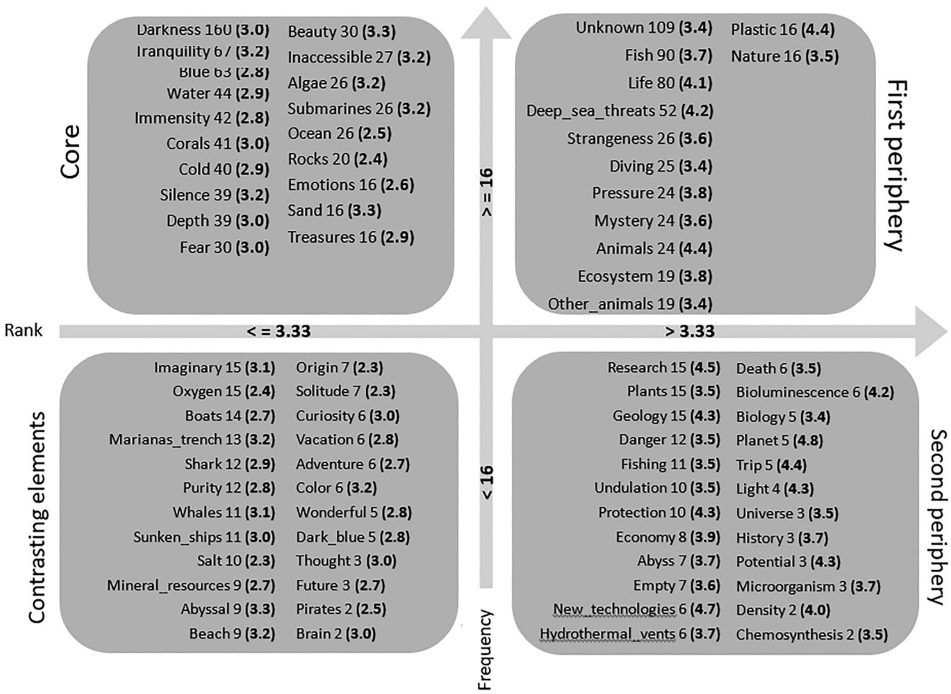

Figure 1. Prototypical Analysis of Themes Mentioned for the Deep Sea.

Note. Figure based on IRAMUTEQ output. Frequency refers to the number of times a given theme was referred by the participants; rank – reported between parenthesis - refers to the mean rank of the importance assigned by the participants to a given theme (the lower the mean rank the higher the importance).

Positioning illustrative variables in the structure of the representation

A lexical correspondence analysis was conducted (ASPAR procedure). The goal was to explore associations among the words that participants reported. As in factorial analysis, the idea is to reduce data to common factors. A threshold of four occurrences was used as the criterion to explore the structure of the representational field and position illustrative variables. The first two factors explained 7.13% of the variance, in line with other studies that have used this technique (e.g. Contarello & Sarrica, 2007). Each word's absolute contribution (≥ 2.00) was considered in interpretation (Contarello & Sarrica, 2007). The illustrative variables (Figure 2) were projected onto the representational field. Only variables that revealed higher significances (test-values ≥ 2.00) were retained (Lebart et al., 1995).

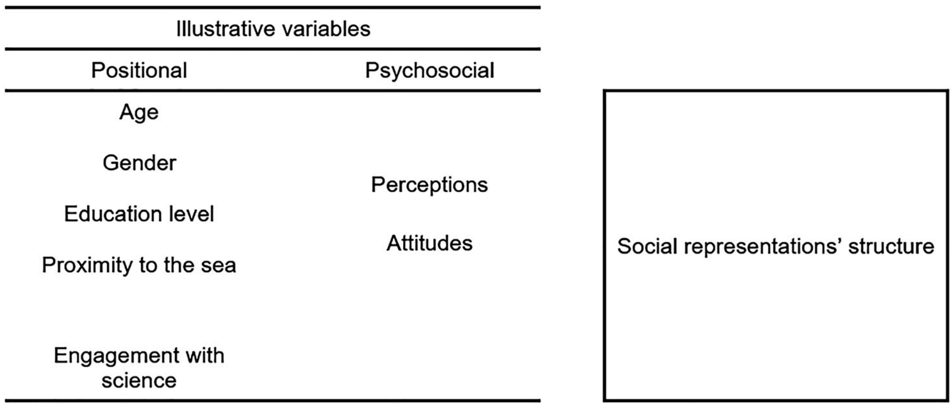

Figure 2. Illustrative Variables Selected for the Study Based on the Literature Review.

Figure 3 represents a Cartesian space resulting from the first two factors of the lexical com- ponent analysis onto which the words were projected according to their coordinates. The figure facilitates the visualisation and exploration of the deep sea representational field. The first task is to make sense of the extracted factors by considering the words that significantly contributed to each one or to both. The first factor (x-axis) opposes words like *water, waves,* and *fish* to *dark- ness, unknown,* and *strangeness*. We labelled this factor *known-unknown*. The second factor (y- axis) opposes words like *abyssal* and *submarines* to *tranquility* and *emotions*. We labelled this factor *emotions-reason*.

The second task is to make sense of the information in each quadrant. The upper left quadrant relates to *leisure* (and includes mentions such as *tranquility, beach, holidays*). The respondents that evoked leisure terms were mostly women, people born or living far from the coast, persons who consider the deep sea to be important to leisure and tourism and also to culture and identity, those with a moderate position regarding the deep sea's value to technology, those who were the least engaged in science communication activities, and those with the least favourable attitudes towards scientific exploration.

The lower left quadrant is related to the *surface* of the sea (e.g. *whales, sand, boats*). Participants were characterised as having up to a secondary education level, considering mining to be somewhat of a threat to the deep sea, and moderately supporting with deep sea scientific exploration.

The upper right quadrant relates to *fear* of the unknown (e.g. *immensity, fear, emotions*). In this quadrant, we found participants with graduate degrees, those highly engaged in science communication activities, and persons who support the scientific exploration of the deep sea. They also recognised the deep sea's importance to technology and considered tourism to be somewhat of a threat to the deep sea.

The lower right quadrant includes terms related to *science and technology* (e.g. *geology, investigation, economy*). Respondents were mainly men in the 18–29 age group, born or living near the coast, and those with favourable attitudes towards scientific exploration. This group undervalued the deep sea's importance to culture and identity and also to leisure and tourism, and they do not consider the latter to be a threat to the deep sea.

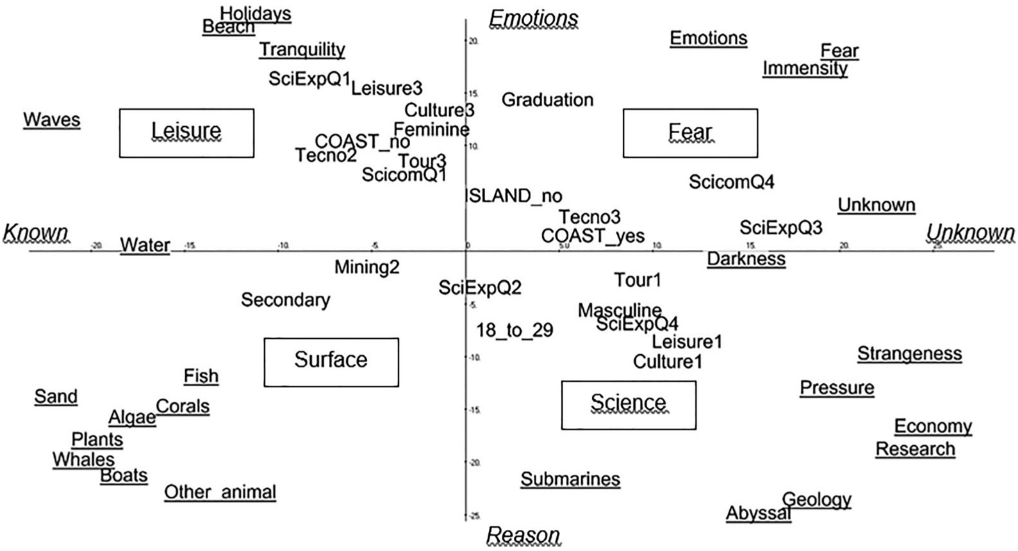

Figure 3. Representational Field of the Deep Sea.

Note. Labels of the axes and quadrants added by the authors to the DTM-Vic output. Only statistically significant data reported. SciExpQ1–Q4: Attitudes towards Scientific Exploration of the Deep Sea (quartiles 1 to 4). SciComQ1–Q4: Engagement with science (quartiles 1 to 4). Leisure1- 3; Culture1-3; Tecno2-3: Perceived Importance of the Deep Sea to Society Leisure, Culture, and Technology (scores in Arabic figures). Tour1 and Tour3, Mining2: Perceived Threat to the Deep Sea of Tourism and Mining (scores in Arabic figures): Coast_yes/no: Being Born/Living near a Coast (yes or no). Island_no: Not Being Born in an Island.

Discussion

In this research, we surveyed 315 adults to explore their common sense knowledge of the deep sea and investigate whether representations were associated with participants' characteristics, such as age, education level, or exposure to science. Moreover, we wanted to reflect on the implications for improving targeted science communication efforts. The results showed that the participants thought of the deep sea according to emotional versus rational views and familiar ocean knowledge versus novel or unusual views. From these, four dimensions emerged, each representing different views on the deep sea. The leisure dimension represents a ludic or tourist view of the deep sea; the surface dimension reduces the deep sea to a familiar understanding of the oceans; the fear dimension conveys an emotionally loaded representation of the deep sea; and the science dimension is structured around scientific and technological lexicon. Notably, we were able to construct different psychosocial profiles for two dimensions. The image of the sea as a source of leisure is associated with female participants, those with low exposure to science, and strongly opposed to scientific exploration. On the contrary, the image of the sea as a space for science is associated with male participants, those who do not recognise the deep sea's importance to leisure or culture and are highly exposed to science.

Diffuse knowledge about the deep sea

The prototypical analysis suggests that participants' representation of the deep sea are fuzzy; that is, it is under development and being disputed by different groups (Abric, 2003a, 2003b). This is expected and consistent with literature that asserts that the topic of the deep sea is rarely brought into the general public sphere (Salazar et al., 2019); rather, it is a remote reality (Ankamah-Yeboah et al., 2020) about which people know little (Kaikkonen & van Putten, 2021), and remains a mystery, even among experts (Da Ros et al., 2019; Kennedy et al., 2019; Santos et al., 2018).

It is reasonable to admit that the participants' diffuse knowledge about the deep sea precluded a tighter representational factor structure. Participants struggled to make the deep sea familiar by using the common sense repository of images and symbols associated with the sea and/or using an often science-based lexicon. Nevertheless, the representation's emotional load (i.e. the degree of affective connotation) varied from rich, intense emotional perspectives to neutral, exempt, or rational views.

Leisure and surface dimensions: gaps and insights

The gap between scientific discourse and common sense is evident in the leisure and surface dimensions. First, although the deep sea harbours lifeforms with unique biological adaptations (Colaço et al., 2017; Doherty, 2017; Ramirez-Llodra et al., 2010), participants with low education levels anchor their representation to well-known, coastal/shallow layers of the ocean, using objectifications such as whales or algae. Second, female participants, those with a low engagement in science, and who are less favourable towards scientific endeavours, anchor their representation to leisure, using objectifications around holidays and natural, paradisiac images (e.g. light, blue, purity), in sharp contrast to the deep-sea scientific representation (e.g. absence of light/dark, high pressure) (Colaço et al., 2017).

However, social representations are less about the loss of information than about the trans- formation of information into useful, practical knowledge (Jodelet, 2003). Although some participants lack a scientific understanding of the deep sea, they perceived the deep sea as only moderately important to leisure, supporting previous associations of the sea with the superficial ocean (Arnold, 2004). Moreover, they insightfully perceive the deep sea as a reserve of untouched nature, associating the deep sea with origins of life (Weiss et al., 2016). Also, according to Kaikkonen and van Putten (2021), the level of knowledge about the deep sea does not seem to be associated with people's declared care. Also noteworthy, participants' positive, yet cautious, attitudes toward science have been noted previously in Portugal (Canavarro, 2000) and globally (Gallup, 2019), revealing medium levels of trust in science and restrained views of its benefits.

Negative perceptions of science are a challenge for the scientific community (Morgan et al., 2018), requiring comprehensive research about how laypeople make sense of scientific knowledge. This study helps to establish a red line hampering scientists and science communicators from sharing an instrumental view of science (Habermas, 1998). Citizens have a right to question science, and it is the scientific community's duty to include them in the making of the scientific agenda, rather than simply imposing it. However, this might be a form of science-related populism (Mede & Schäfer, 2020). As Latour (1989) has shown, scientific endeavour is a social affair, because it depends on a community, alliances, and the mobilisation of the world.

Fear and science dimensions: emotional load and instrumental views

The gap between scientific knowledge and common sense is less evident on the unknown side of the representation, where we find a lexicon related to the deep sea's scientific definition (e.g. *dark, unknown, pressure, submarine*) (Colaço et al., 2017; Ramirez-Llodra et al., 2010). The emotional load intensifies the tension found in the *fear* dimension but not in the *science and technology* dimension. Interestingly, higher exposure to science and advanced education seems to be associated with the perception of the deep sea as the last frontier (Da Ros et al., 2019; Santos et al., 2018). Conversely, *science* jargon is associated primarily with male participants, those strong favourability to the scientific endeavour, and giving less recognition of the deep sea as important for leisure and culture.

The usage of a *scientific* lexicon, together with strong support for science, seems to reduce the deep sea to its scientific layer and evince the prevalence of an instrumental view of science (Habermas, 1998). Undoubtedly, scientific knowledge is important, but we should rightly ask if it should be built at the expense of culture and identity or leisure.

The representation's emotional load is associated with female participants. Solid research on gender stereotypes has asserted that women are portrayed as emotional (Plant et al., 2000; Zhu et al., 2020). Although most of our participants were female, and in the absence of gender triggers in the survey, it seems plausible to infer that gender plays a part in making sense of novelty, supporting the claim that it is important to study the role of positional variables.

Significance for science communication

Negative evidence also deserves our attention. Participants, not even those highly educated and/or with a high degree of exposure to science, were able to identify over-fishing as the most serious threat to the deep sea (Colaço et al., 2017; Ramirez-Llodra et al., 2011). Contrarily, given how participants ranked threats, we recognise echoes of a strongly diffused ecological agenda that stresses marine litter (Völker et al., 2019) and climatic change (Boykoff et al., 2020; Höijer, 2010).

Marine litter and climate change have prominently entered the mass media and political agendas (Boykoff et al., 2020; Völker et al., 2019). Although research on the impacts of these threats upon the deep sea is relatively recent (Chiba et al., 2018; Levin & Bris, 2015; O'Leary et al., 2020), participants anchored the deep sea to these highly diffused environmental threats, urging us to call for communication strategies related to this subject. The areas beyond national jurisdiction are deteriorating because of fishing/hunting, maritime shipping, climate change, land-based pollution, and mineral exploitation. International legally binding instruments, such as marine protected areas, are urgently needed to enable effective management and the implementation of the precautionary approach (O'Leary et al., 2020). For this to be possible, well-informed public discussion is necessary

(Jaeckel et al., 2017; Niner et al., 2018).

Finally, in this study, except in the youngest group, age did not illustrate the representational field as in previous studies on marine issues (Ankamah-Yeboah et al., 2020; Belden, 1999). While education level was associated with different dimensions of the representation, age was not, except for the younger group. Future studies should clarify whether age is a spurious variable. Neither a solely anthropocentric/pro-economic exploration nor an all-ecological/pro-preservation viewpoint seemed to stand apart in the current system of attitudes and the public's thoughts about nature (Manoli et al., 2019; McDonald & Patterson, 2007), at least not within the context of the deep sea. Results from different measures, including attitudes, corroborate the claim that eco- logical paradigms should not be considered unidimensional (Castro, 2003; Manoli et al., 2019; McDonald & Patterson, 2007), that is, individuals are not either pro-ecological or anti-ecological. This perspective might frame the public discussion around the acceptable level of net loss (Niner et al., 2018), alternatives to deep sea mining (Miller et al., 2018), and the development of inter- national cooperation in the areas beyond national jurisdiction (O'Leary et al., 2020). From a theoretical perspective, this study exemplifies the benefit of the social representations approach, which productively and insightfully nests other constructs, such as attitudes, perceptions, and positional variables (Doise, 2003; Sammut, 2015).

The link between the structure of the social representation of the deep sea and the psychosocial and positional variables reveals that it is increasingly necessary to articulate levels of analysis (Doise, 1982; Doise & Valentim, 2015). This helped us to shape a psychosocial profile that may be useful for designing future science communication messages aimed at promoting positive attitudes, decision- making skills, and a holistic understanding of both the socio-scientific, technological, and economic implications of the deep sea in our lives and our actions upon it.

The results are significant for science communication. The emotion-reason and know-unknown axes of the social representation of the deep sea suggest that when designing science communication projects, one should keep core-peripheral approaches to attitude change in mind. In other words, information processing is generally governed by two subsystems: one that is more peripheral, automatic, and heuristic, and another that is more controlled, core, and systematic (e.g. Chen & Chaiken, 1999; Petty & Cacioppo, 1986). In general, people will use the core subsystem when they are more involved with the subject and rely upon the peripheral system when they are less involved. This seems to be the case of the deep sea (Jamieson et al., 2020). Hence, communication projects pertaining to the deep sea and other contemporary socio-scientific issues topics with reduced social visibility that target an audience comprised of those who are less involved, educated, and science exposed might try to use peripheral approaches to appeal to feelings and the known imaginary in order to create awareness and positive attitudes before putting more time-consuming and cognitively demanding strategies in motion (regarding emotional appeals in science communication, see Taddicken & Reif, 2020). As we have seen, even when participants' approach is more peripheral or emotional and based on what is already known, important aspects are brought to the representation, such as the importance of culture and leisure. They can serve as anchors to build effective communication messages and need to be considered in order to target underserved audiences (Humm et al., 2020). On the other hand, when targeting more exposed, educated and involved participants, the goal might be to make the representation more flexible and open. We have seen that a science-centred representation sets the deep sea's cultural and social significance aside, preventing the establishment of a shared representation that might facilitate dialogue about the issue. To fill the gap between science and society, one needs to equip those who are more engaged and interested in the topic with the tools to sensitise to other socially meaningful visions and concerns in order to reach a common ground of trust in science (Weingart & Guenther, 2016).

Conclusions and limitations

This paper expanded our knowledge about how people make sense of the deep sea using the social representations framework, and it revealed a link between the structure of the social representation of the deep sea and illustrative variables that contributes to more precisely calibrated science communication efforts.

Engagement with science, attitudes towards scientific exploration, perceptions of the deep sea, education, and gender were the variables that were the most frequently associated with different dimensions of the social representation of the deep sea. Moreover, the emergence of scientific exploration as a dimension of attitudes toward the deep sea revealed that popular shared beliefs regarding the relationship between humans and nature might be more complex than a simple matter of either protecting or exploiting the environment.

Our study does not allow for direct inferences about people's ocean literacy level, but it suggests that social groups are building their common knowledge representations about a remote, unnoticed reality using limited superficial information. Low levels of awareness and understanding might affect citizens' support for effective deep sea management initiatives either due to their lack of participation in the discussion or because they do not find it relevant. However, our study convincingly showed that more information alone is not the answer because it might lead to narrow instrumental views of the deep sea. For people to engage in dialogue and open-ended social discussion, from which a shared consensus on how to balance science, economic, and preservation agendas, the deep sea must become emotionally relevant.

This research is also important to science communication for the following epistemological, theoretical, methodological, and practical reasons:

- It stresses the need to recognise that common sense is a complex field that social groups actively build. It is not characterised by naïveté; rather, it is rich and full of insights. By listening to the general audience, the results might help to concretise the participatory turn in science communication.
- It shows that social representations theory is a productive lens through which to study new socio- scientific issues. Specifically, our findings of regarding the deep sea's common knowledge call for a third view on the relationship between humanity and nature. Such a view should be centred on socially constructed knowledge about the core of the sustainability in order to confront increasingly complex challenges that

cannot be neatly compartmentalised into science, economics, or nature.

- Not only does it add new measures (e.g. attitudes towards the deep sea) by virtue of its reliance on non-mainstream data analysis techniques, it also responds to the demands of science communication's complexity.
- It provides scholars and practitioners with insightful empirical data concerning people's perspectives about the deep sea, revealing how social groups struggle to make sense of new data and how their representations are entangled with attitudes and education. These data help to build a road- map leading to more targeted science communication projects capable of reaching specific groups and satisfying their needs.

Lastly, we must note that our representational field results do not express causality, as the variables associated with each quadrant were based on sociological profiles rather than real subjects. Regression analyses using a more significant database would shed additional light on the predictive values of the variables (e.g. engagement in science or attitudes towards scientific exploration) of the public's social representations when confronted with cutting-edge topics like the deep sea. Furthermore, our factorial analysis was performed as a one-time process rather than over various steps. Further research would benefit from including a representative sample and comparing samples from different countries.

For both scientists and the public, the deep sea remains a mystery waiting to be unveiled, as the current paradigm featuring our relationship with the natural environment is still a contemporary issue topic for everyone interested in science communication.

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