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Contribution to the Special Issue: “Ocean Literacy across the Mediterranean Sea region”

The Blue Survey: Validation of an instrument to measure ocean literacy among adults

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Abstract

Human activities have put the ocean under unprecedented pressure. Nevertheless, levels of public awareness of ocean issues remain low. Ocean literacy is a global movement that aims to improve the understanding of the ocean and provide an incentive for positive change in people's behaviour. To date, there is no validated scale targeted to adults to measure ocean literacy that includes measuring people's knowledge about the ocean, as well as surveying their attitudes and willingness to act. The Blue Survey, an online instrument meant to measure ocean literacy in adult populations, was developed by a multidisciplinary team of experts. Using factor analysis, the present study explores the validity and internal consistency of the Blue Survey in a purposive online sample of 251 adults. We found ocean literacy to consist of six sub-dimensions captured by 34 survey items, viz. knowledge of ocean-related topics, personal interest in ocean-related aspects, ocean stewardship, ocean as an economic resource, ocean-friendly behaviour, and willingness to act responsibly towards the ocean. Our analysis resulted in the development of a new validated instrument to measure the various dimensions of ocean literacy. These results may help researchers and practitioners to better understand the factors which contribute to shaping an ocean-literate person. Further research should be carried out to assess the validity of the Blue Survey across different populations, including those closely related to the sea, such as maritime professionals.

Keywords: Ocean literacy; blue survey; survey validation; exploratory factor analysis.

Introduction

Reconciling the need for a healthy ocean while at the same time using its resources sustainably is one of the main challenges of the current decade (Ryabinin *et al.*, 2019). While safeguarding ocean sustainability lies partly in the hands of individuals and their communities (McKinley & Fletcher, 2010), public understanding of basic concepts related to the marine environment and the threats associated with human activities remains at low levels, as reported.

Ocean literacy is a global movement that intends to bridge this gap by improving the understanding of the ocean's influence on us and our influence on the ocean. Initially, the concept of ocean literacy was based on three pillars or dimensions that described an ocean-literate person as someone who i) understands the importance of the ocean to humankind; ii) can communicate about the ocean in a meaningful way; iii) is able to make informed and responsible decisions regarding the ocean and its resources (Cava *et al.*, 2005). More recently, there has been

a shift in this practical definition: ocean literacy is not only about increasing public understanding of the issues involved but is also about providing tools and approaches to transform ocean knowledge into behaviours and actions promoting the sustainable use of the ocean. Six dimensions have been suggested: these include knowledge, awareness, attitude, communication, behaviour and activism (Brennan *et al.*, 2019). The present study focuses on four dimensions that will be measured independently:

- I. Knowledge: the understanding of the seven essential principles and fundamental concepts of ocean literacy as described by Cava *et al.* (2005) (Table 1).
- II. Interest: such as what attracts attention so that individuals want to learn or hear more about the ocean.
- III. Attitudes: the level of agreement with or concern for a particular position related to the sustainable use of the ocean.
- IV. Willingness to act: future behavioural and lifestyle choices that individuals are willing to make for the ocean within a reasonably short time span.

Yet there is still no instrument by which we can mea-

Table 1. The seven essential principles of Ocean literacy.

1.	Earth has one big ocean with many features.
2.	The ocean and life in the ocean shape the features of Earth.
3.	The ocean is a major influence on weather and climate.
4.	The ocean makes Earth habitable.
5.	The ocean supports a great diversity of life and ecosystems.
6.	The ocean and humans are inextricably interconnected.
7.	The ocean is largely unexplored.

Source: Cava *et al.*, 2005

sure those dimensions. While several initiatives have been taken worldwide to increase ocean literacy, little is known about the levels or potential improvements of participants. Without a reliable and valid measurement instrument as a benchmark, it is impossible to evaluate the effectiveness of these initiatives; in other words, “if you can’t measure it, you can’t improve it” (Thomson, 1883).

Nonetheless, a few instruments to measure ocean literacy have been designed and validated in the last decades. The Survey of Ocean Literacy and Experience (SOLE) is the first reported study that measured the knowledge on ocean topics of 13-14 years old American girls (Greely, 2008). The Greek version of the SOLE was tested and validated among pre-service teachers (Markos *et al.*, 2017; Mogias *et al.*, 2015). Fauville *et al.* (2019) designed, tested and validated the International Ocean Literacy Survey (IOLS), a multilingual scale to measure the knowledge dimension of ocean literacy among pupils (16-18 years old) across several countries. While these studies provide valuable insights, their contribution is restricted to capturing the knowledge dimension only, leaving other important components out of the picture, such as people’s attitudes towards the ocean or their willingness to act.

Existing instruments have mostly focused on youngsters (Fauville, 2019) and less attention has been paid to other groups in society (Fernández Otero *et al.*, 2019). This is particularly problematic when considering that it is the adults who have the most potential to engage in decisions that impact the ocean (Kelly *et al.*, 2021). The Blue Survey, presented in this paper, is an international comparative online instrument meant to measure ocean literacy in adult populations which has been developed by a multidisciplinary team of experts. In contrast to other comparative instruments, the Blue Survey assesses the influence of different cognitive, attitudinal, and behavioural factors to better orientate and improve ocean literacy initiatives.

When developing measurement instruments, one has to be aware that they are only appropriate for use once researchers have documented their validity (Knekta *et al.*, 2019). One way to achieve this is by testing the construct validity using Exploratory Factor Analysis (EFA), a statistical technique that analyzes the way responses on dif-

ferent subsets of survey items (e.g., questions) are related and have a higher chance of co-occurring, hence revealing the dimensionality in our data (Fabrigar & Wegener, 2011).

To date, there is no validated instrument to measure ocean literacy targeted to adults that not only measures knowledge, but also measures attitudes and willingness to act. In this study we evaluated the quality, both in terms of reliability and content validity, of the Blue Survey. Using EFA, we explored the relationships between the survey items and the dimensionality. This study reports the validation procedure of the Blue Survey and discusses its suitability for application among adult populations.

Materials and Methods

Development of the Blue Survey

Various sources were used to draft the survey on ocean literacy. We based the development of the new instrument on (1) re-using existing items from validated surveys (Cudaback, 2006; Greely, 2008; Chen *et al.*, 2020) and (2) creating new items in line with ideas and insights from three rounds of expert consultations. These expert panels included ocean literacy practitioners, marine and social scientists as well as maritime stakeholders. This resulted in a total of 51 items, which included 20 test questions and 31 five-point Likert-items. Additionally, questions to collect background information on participant gender, age, country of residence and job sector were included. Test questions included multiple-choice items with single- and multiple-answers. Multiple-answer questions were scored as correct only when all the correct alternatives were checked; otherwise, they were scored as incorrect. The items were grouped into four sections to measure (I) knowledge, (II) interests, (III) attitudes and (IV) willingness to act. Section I comprised 20 test-items and sections II, III and IV comprised 6, 19 and 6 Likert-items respectively. We based the draft knowledge section on the seven essential ocean literacy principles with a special focus on principle 6 that highlights the connection between humans and the ocean as well as the impact of human activities on the ocean. Table S1 includes a summary of the number of questions in section I and their alignment with the seven essential principles and specific fundamental concepts. The survey was designed in English and translated into Spanish, Portuguese, Dutch, Italian, German, Croatian, French, and Greek.

Pilot testing

Responses were obtained from March to May 2020 using the online tool SurveyMonkey Inc (2021). The Blue Survey aimed to reach professionals linked to marine and maritime careers working for the industry. Using convenience sampling, the survey link was sent by email and shared through social media networks such as Twitter and Facebook. Prior to data analysis, a listwise deletion procedure was applied to handle missing data.

Construct Validation

Given the explorative rationale, we chose to perform EFA. Data were analyzed using the psych R package (version 2.0.12) (Revelle, 2020). The Kaiser-Meyer-Olkin measure (KMO) was calculated to test sampling adequacy (Kaiser & Rice, 1974). Internal correlations were verified before performing EFA. Based on the different nature of the answering categories, we ran four EFAs for each section separately (I up to IV). We used tetrachoric correlation for section (I) before running an EFA (Starkweather, 2014). Considering the ordinal and non-normal nature of the data, Weight Least Squares (WLS) was used as an estimator. Oblimin rotation was chosen for section (III) (Reise *et al.*, 2000). Visual inspection of the scree plot and parallel analysis based on eigenvalues were used to decide on the appropriate number of factors to retain. Items with factor loadings <0.40 were removed and EFA was re-run. Kuder-Richardson 20 (kr20) and Cronbach's alpha (α) coefficients were calculated for the test- and Likert-items respectively to assess internal consistency.

Results

From a total of 453 participants, 251 complete responses were used in the analysis (50.2% female, 49.8% male). Overall, the survey population was composed of adults, of whom 51.8% were between 19-39 years old, followed by 37.1% whose age ranged between 40-59 years old and the remaining 11.2% were between 60-80 years old. Survey participants were distributed across 33 countries, mostly from Europe (72.5%), followed by the Americas (22.7%), Asia (2.4%), Africa (2%) and Australia (0.4%). Most respondents were workers ($n = 181$; 72.1%), of which 24.7% belonged to the marine and maritime sectors. Those sectors directly linked to the ocean included offshore renewable energy, oil & gas, fisheries & fish processing, coastal tourism, marine biotechnology, shipping & logistics, aquaculture, research development & innovation, education and the public sector.

The KMO measures for section I, II, III and IV were 0.77, 0.70, 0.76 and 0.75 respectively; indicating that the sample was appropriate for factor analysis. Using four separate EFAs (one per section), a one-factor solution was obtained for sections I, II and IV, and a three-factor solution for section III (II.1, III.2 and III.3), making a total of six factors captured by 34 items (Table 2). Each factor was assigned a descriptive label, as follows:

- I. *Knowledge on ocean-related topics* (11 items; $kr20 = 0.71$): the understanding of ocean-related topics as described in the seven essential principles of ocean literacy.
- II. *Personal interest in ocean-related aspects* (5 items; $\alpha = 0.71$): the feelings or emotions that cause attention to focus on certain aspects of the ocean.
- III.1 *Ocean stewardship* (7 items; $\alpha = 0.74$): the attitudes of individuals towards a healthy and sustainable utilization of the ocean.
- III.2 *Ocean as economic resource* (3 items; $\alpha = 0.68$):

the attitudes towards the utilization of the ocean as a source of economic benefits.

- III.3 *Ocean-friendly behaviour* (4 items; $\alpha = 0.65$): the collective day- to-day behavioural and lifestyle choices made by individuals, in a period of one year prior to the survey, to minimize their negative impact on the ocean (self-reported behaviour).
- IV. *Willingness to act* (4 items; $\alpha = 0.73$): future behavioural and lifestyle choices that individuals are willing to make within a relatively short time span (intentions).

In total, 17 items were removed after the EFAs. The items removed comprised nine items from section I, one from section II, five from section III and two from section IV. A list of the validated questions is presented in Table S2.

Discussion

Using EFA, we developed and validated a new instrument to measure ocean literacy in an adult population. In addition to measuring knowledge about the ocean, the survey instrument also captured a person's attitudes and willingness to act towards the ocean. The six factors presented in Table 2 allowed us to further unpack and refine the various dimensions of ocean literacy. This may help researchers and practitioners to better understand the factors involved when shaping an ocean-literate person. However, because our sample was limited to an online population, we recommend that the instrument should be interpreted with some caution. Thus, generalization to the entire adult population is empirically unwarranted. Furthermore, it is worth mentioning that during the translation process, some questionnaire items may have partly changed from the original version and that this may affect cross-cultural validity (Beaton *et al.*, 2000).

Although six factors were identified, there was a high degree of correspondence between the hypothesized four dimensions and the actual factors. The *knowledge on ocean-related topics* factor is the most well-defined dimension of ocean literacy and has been extensively studied in relation to youngsters (Ballantyne, 2004; Greely, 2008; Fauville *et al.*, 2019; Mogias *et al.*, 2019; Tsai & Chang, 2019; Chen *et al.*, 2020). This youth-centric approach has been identified as one of the main limitations to the development and improvement of ocean literacy (Kelly *et al.*, 2021). Involving adults is critical to effectively improving ocean literacy as is improving their understanding about the ocean. Non-formal learning activities (e.g. experiential learning) have been reported as effective for environmental preservation for this particular group (Eheazu & Akpabio, 2018). Understanding people's *interest in ocean aspects* may provide a pathway for understanding their subsequent engagement (Renninger & Hidi, 2015). Likewise, people are generally more knowledgeable about topics that interest them and, consequently, are likely to hold strong attitudes. Personal interest may motivate those seeking access to a clean and healthy ocean for recreation, or those searching for

Table 2. Pattern matrices of four Exploratory Factor Analyses (N = 251, estimator Weight Least Squares).

Items	Factor loadings		
EFA for Section I - Knowledge about ocean-related topics* (11 items)	1		
Which of the following are transported by rivers to the ocean?	0.79		
In the ocean, living spaces and habitats are found	0.75		
The ocean helps to _____ global warming by absorbing human-produced CO ₂ from the atmosphere	0.72		
What produces most of the earth's oxygen?	0.61		
Look at the image. If both cities are at the same elevation, it is likely that	0.60		
What is causing sea level rise	0.50		
The ocean affects your life because it	0.48		
How is the climate change impacting the Arctic?	0.46		
Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are	0.46		
Marine renewable energy industries (e.g., offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as	0.46		
The ocean dynamics (the motion of water within the oceans) is powered by	0.41		
EFA for Section II - Personal interest in ocean-related aspects (5 items)	1		
I am interested in ocean science	0.65		
I am interested in maritime jobs	0.61		
I am interested in aesthetic aspects	0.58		
I am interested in recreational aspects	0.57		
I am interested in marine energy	0.48		
EFA for Section III - Attitudes	1	2	3
Ocean stewardship (7 items)			
The health of the ocean is important to human survival	0.66		
My actions can have a significant effect on the health of oceans and coastal areas	0.62		
I have a personal responsibility to work for the health of oceans and coastal areas	0.59		
Business and industry should be responsible for ocean sustainability	0.57		
I understand the issues facing the global ocean	0.50		
Individual citizens should be responsible for ocean sustainability	0.48		
Ocean sustainability is more important than economic growth	0.41		
Ocean as economic resource (3 items)			
It is all right for humans to use the ocean as a resource for economic purposes		0.79	
We should no longer use the ocean as a resource for economic purposes		-0.72	
Maritime economic activities are compatible with ocean sustainability		0.44	
Ocean-friendly behaviour (4 items)			
I opt for plastic-free alternatives			0.66
I avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms			0.61
I reduce my energy consumption at home			0.50
I take short showers			0.48
EFA for Section IV - Willingness to act (4 items)	1		
I would be willing to reduce my energy consumption at home	0.75		
I would be willing to avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms	0.64		
I would be willing to opt for plastic-free alternatives	0.63		
I would be willing to take short showers	0.57		

*Ocean-related topics were based on the seven essential principles and fundamental concepts of Ocean literacy (Cava *et al.*, 2005).

good water quality for fishing or to develop tourism activities. Ocean-literate individuals must be *willing to act* responsibly towards the ocean. This factor has been used by previous research measuring environmental awareness and environmental responsibility (Stone *et al.*, 1995; Umuhire & Fang, 2016) and has been identified as one of the best predictors of behaviour (Brennan *et al.*, 2019). However, this factor may not perfectly predict observable behaviours, as other factors can impact whether a willingness to act translates into actual action (Stone *et al.*, 1995).

The EFA analysis revealed that the attitudes dimension included three sub-dimensions labelled as ocean stewardship, the ocean as an economic resource and ocean-friendly behaviour. The *ocean stewardship* factor is aligned with previous research reporting that direct experiences have the greatest potential for developing positive attitudes (Greely, 2008). Stewardship activities can engender deeper personal connections to the ocean and stronger place attachments that enhance understanding and appreciation of the marine environment (Ainsworth *et al.*, 2019). As the ocean has been designated the new economic frontier (OECD, 2016), there are more and more communities which depend on the *ocean as economic resource*. Further information on their stances (preservationist, pro-exploitation, pro-sustainable use) might indicate positive or negative behaviour towards the ocean. Self-reports are widely used in academic and commercial research as proxies of behaviour. The self-reported *ocean-friendly behaviour* factor aligns well with previous studies indicating that they represent fairly stable and valid indicators of ecological behaviours, particularly when individuals are asked to report on specific past or present pro-environmental behaviour (Kaiser *et al.*, 2001).

Our results support previous research findings which suggest that ocean literacy is a complex and multi-dimensional concept that, in addition to including factors such as knowledge, ability to communicate and decision-making, also includes attitudes and behaviour (Boubonari *et al.*, 2013; Brennan *et al.*, 2019). We argue that measurement instruments for ocean literacy should go beyond the classic cognitive and awareness approach and should also incorporate attitudinal and behavioural dimensions.

In line with the complexity and multidimensionality of ocean literacy, future research on this field may benefit from the use of a multidisciplinary approach including marine and social scientists, educators and science communicators to design, test and analyze the instruments adapted for different communities. Responses from these communities may have implications as to how public campaigns on ocean literacy should be designed and delivered.

The main contribution of this study is the development of a new instrument to measure ocean literacy among adults. This instrument combines aspects such as knowledge, attitudes, and willingness to act, in the same construct and provides a more integrated perspective on ocean literacy as a means of producing change. Further research should test the Blue Survey across populations

including those closely related to the sea, such as maritime professionals. Additionally, it would be relevant to perform a Confirmatory Factor Analysis and to model the relationships between the six identified factors to attain robust and replicable research.

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Supplementary Data

The following supplementary information is available online for the article:

Table S1. Items from Section I and the specific essential principle that is addressed by each item. The letters next to the essential principles represent the specific fundamental concepts of Ocean Literacy.

Table S2. List of validated questions from The Blue Survey. Items with (*) represent the correct answers.