frontiers in Marine Science

ORIGINAL RESEARCH
published: 10 July 2019
doi: 10.3389/fmars.2019.00396

Evaluating Ocean Literacy of Elementary School Students: Preliminary Results of a Cross-Cultural Study in the Mediterranean Region

Athanasios Mogias[1], Theodora Boubonari[1], Giulia Realdon[2], Monica Previati[3], Melita Mokos[4], Panayota Koulouri[5] and Maria Th. Cheimonopoulou[6]*

[1] Department of Elementary Education, Laboratory of Environmental Research and Education, Democritus University of Thrace, Alexandroupolis, Greece, [2] UNICAMearth Group, University of Camerino, Camerino, Italy, [3] UBICA srl (Underwater Bio-Cartography), Genoa, Italy, [4] Department of Ecology, Agronomy and Aquaculture, University of Zadar, Zadar, Croatia, [5] Institute of Marine Biology, Biotechnology and Aquaculture, Hellenic Centre for Marine Research, Heraklion, Greece, [6] Hydrobiological Station of Pella, Hellenic Ministry of Rural Development and Food, Edessa, Greece

OPEN ACCESS

Edited by:
Angel Borja, Centro Tecnológico Experto en Innovación Marina y Alimentaria (AZTI), Spain

Reviewed by:
Francesco Tiralongo, Ente Fauna Marina Mediterranea (EFMM), Italy
Donata Melaku Canu, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Italy

***Correspondence:**
Athanasios Mogias
amogias@eled.duth.gr

Specialty section:
This article was submitted to Marine Ecosystem Ecology, a section of the journal Frontiers in Marine Science

Received: *13 December 2018*
Accepted: *26 June 2019*
Published: *10 July 2019*

Citation:
Mogias A, Boubonari T, Realdon G, Previati M, Mokos M, Koulouri P and Cheimonopoulou MT (2019) Evaluating Ocean Literacy of Elementary School Students: Preliminary Results of a Cross-Cultural Study in the Mediterranean Region. Front. Mar. Sci. 6:396. doi: 10.3389/fmars.2019.00396

A good understanding of the role and function of the ocean seems to be of paramount importance in recent years, constituting the basic tool for the promotion of healthy and sustainable marine environment, and a target area of the 2030 Agenda for Sustainable Development. In this study, the content knowledge of elementary school students (grades 3–6) in regards to ocean sciences issues was examined. A structured questionnaire was administered to 1004 students participating in a cross-cultural study from three Mediterranean countries (Italy, Croatia, and Greece). The results of the study indicated a rather moderate level of knowledge in the total sample, while slight differences were recorded among the three countries revealing common knowledge gains and misconceptions. Rasch analysis was applied to further evaluate the validity of the results, while the influence of certain demographics on students' knowledge level was also investigated. This study concludes with a discussion of the implications on national curriculum development in elementary education level, in order to promote ocean literacy and to ensure protection and conservation of the Mediterranean Sea.

Keywords: ocean literacy, marine science education, elementary school students, content knowledge, cross-cultural study, Mediterranean region

INTRODUCTION

The ocean is the main physical characteristic that defines our planet making the Earth habitable. It covers over 70% of the Earth's surface, produces more than 50% of the oxygen in the atmosphere, regulates weather and climate, supports a great diversity of life and provides food available for people all over our planet (Cava et al., 2005). Despite its role as a part of the Earth's system and its value for human society, the ocean has shown severe signs of change as a result of human activities. Decades of intensive exploitation of marine resources, pollution, coastal urbanization and climate change have led to degradation and even destruction of marine ecosystems, resulting in the deterioration of ocean health and, subsequently, of human health (UNEP, 2001; Giorgi and Lionello, 2008; UNEP/MAP, 2012, 2015). Last WWF Living Blue Planet Report indicates the critical state of the ocean, showing a decrease of 49% in populations of marine organisms between 1970 and 2012 (WWF, 2015). Thus, understanding the ocean is essential to understanding the planet on which we live and, thereby, is essential to its sustainability (Cava et al., 2005).

The Mediterranean Sea, in particular, the largest and deepest enclosed sea on Earth, is one of the most important global biodiversity hotspots since it hosts 7% of the world's marine biodiversity with a high percentage of endemic species (Coll et al., 2010, 2012), though it holds only 0.82% of the global ocean surface (Blondel et al., 2010). This particular ecosystem has been strongly affected by human activities for millennia (Lotze et al., 2011), and therefore it has been suffering from overexploitation and habitat loss long before the Industrial Revolution (Coll et al., 2010). At present, the Mediterranean Sea is characterized as "under siege" (Coll et al., 2012), due to the impacts of multiple human-induced pressures such as urbanization and mass touristic development (30% of world tourism occurs in the Mediterranean Sea per year), overfishing of more than 90% of fish stocks, different types of pollution, and climate change, which crucially altered the Mediterranean Sea environment (UNEP/MAP, 2012; Volosciuk et al., 2016; Fernandes et al., 2017; Garcia-Nieto et al., 2018). Cumulative and synergetic effects of these pressures have led to severe loss of biodiversity along with impacts on biological communities, ecosystem functioning and its capacity to provide essential goods and services to human society (Guidetti et al., 2014).

International initiatives and instruments, such as the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78), the United Nations Convention on the Law of the Sea (UNCLOS, 1982), Rio Declaration on Environment and Development (1992), Jakarta Mandate on Marine and Coastal Biological Diversity (1995), Code of Conduct for Responsible Fisheries (1995), the London Protocol (1996), the Kyoto Protocol (1997), World Summit on Sustainable Development (2002), Earth Summit (2012), the UNESCO Roadmap for Implementing the Global Action Program on Education for Sustainable Development (2014), all reflect humans' attitudes and awareness toward the ocean environment. Similar initiatives and policies have focused particularly on the Mediterranean region. In 1975, the Mediterranean Action Plan (MAP) was adopted and this was the first-ever Regional Seas Program under the United Nations Environment umbrella, followed by the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention, 1976). Furthermore, all Mediterranean countries are members of the International Maritime Organization (IMO), which is the United Nations body with primary responsibility for international shipping. Several key EU policies are also important for the protection and sustainability of the Mediterranean region, such as the Common Fisheries Policy (EC/170/83), the Habitats Directive (92/43/EEC), the Water Framework Directive (2000/60/EC), the Marine Strategy Framework Directive (2008/56/EC), the Blue Growth Strategy (COM (2012) 494), and the Maritime Spatial Planning Directive (2014/89/EU).

To protect, conserve and sustainably use marine resources, citizens of all ages need to know and understand the connection between man and sea, i.e., to be ocean-literate citizens. Ocean literacy has been defined as "*an understanding of the ocean's influence on you and your influence on the ocean*" (Cava et al., 2005). Beyond understanding, an ocean literate citizen uses ocean knowledge and awareness of ocean issues to communicate about the ocean in a meaningful way and make informed and responsible decisions. To this aim, United Nations has declared a Decade of Ocean Science for Sustainable Development 2021–2030, and Agenda 2030 for Sustainable Development including 17 goals (SDGs) (United Nations, 2017), among which the approval of a stand-alone goal on the ocean (i.e., SDG 14) has been a major achievement for the global ocean community (Santoro et al., 2017b). In 2017, the United Nations convened a high level "Our Ocean" conference to support the implementation of SDG 14. One outcome of this conference was an inter-governmentally agreed declaration "Call for action" of whose Article 13a reads as follows: "*Support plans to foster ocean-related education, for example as part of education curricula, to promote ocean literacy and a culture of conservation, restoration and sustainable use of our ocean*", hence emphasizing the importance of ocean literacy. To successfully achieve SDG14, ocean-literate and therefore engaged citizens, from the general public to scientists and decision-makers, are needed. Consequently, promotion of ocean literacy in elementary and secondary education is vital (Visbeck, 2018), as children represent the future citizens and consumers, who will develop attitudes and make decisions that will inevitably affect the environment. Children are also important agents of social change in society, because apart from performing responsible environmental behaviors themselves directly, they also have the potential to bring about change by influencing the environmental knowledge, attitudes and behaviors of peers, family and of the wider community (Hartley et al., 2015).

Unfortunately, national school curricula worldwide lack ocean literacy-related issues (Visbeck, 2018), and in some cases, as in New Zealand, they do not even include the word "ocean" (Gough, 2017). Furthermore, coastal and marine topics are almost absent in Science and Geography curricula in different countries such as United Kingdom and Canada, while limited reference to related issues is also evident in Brazilian, Chinese, and Australian curricula (Gough, 2017). Lately, an Ocean Education Curriculum was also created in Japan (Ocean Policy Research Foundation, 2011) in order to promote ocean education in elementary and secondary education. Universities also lack ocean literacy-oriented training programs (Visbeck, 2018), while the absence of ocean topics, particularly in teacher preparation programs, is evident (Payne and Zimmerman, 2010).

Although the ocean practically defines our planet, relative knowledge still appears inadequate (The Ocean Project, 2009; Gelcich et al., 2014; Chen and Tsai, 2015; Guest et al., 2015;

Mogias et al., 2015). This lack has been evidenced since the birth of marine education in mid 1970s, with the definition itself of "Marine and Aquatic Education" (Goodwin and Schaadt, 1978), a forbearer of ocean literacy, and of the first academic studies in this field (e.g., Fortner and Wildman, 1980; Fortner, 1985; Fortner and Lyon, 1985). After these pioneering investigations, marine education and related topics have been addressed by numerous surveys carried out among different target groups, and spanning from the general public to students as well as their teachers. Analysing the literature, some large surveys have addressed the knowledge of the general public mostly in the United States and Europe; most of these studies have shown people to be concerned about pollution, industrial toxic waste, and overfishing, but to have poor knowledge of other ocean issues (e.g., ocean acidification), and little trust in individual action, despite the positive attitudes toward behavioral changes for the sake of ocean environment (e.g., Belden Russonello and Stuart, 1999; Steel et al., 2005; Fletcher et al., 2009; The Ocean Project, 2009; Gelcich et al., 2014; Perry et al., 2014; Capstick et al., 2016). A few published surveys on pre- and in-service teachers have revealed a rather moderate knowledge of ocean science (e.g., Boubonari et al., 2013; Mogias et al., 2015; Dromgool-Regan et al., 2017; Hartley et al., 2018). Published research on the knowledge of ocean issues among college and university students from different countries (e.g., United States, Taiwan, China, Australia) is also scarce, revealing moderate knowledge (Ballantyne et al., 2005; Cudaback, 2006; Chen and Tsai, 2015; Danielson and Tanner, 2015; Umuhire and Fang, 2016). On the contrary, most of the studies focusing on the knowledge of the ocean environment have been performed on elementary and secondary school students, mostly in the United States (e.g., Brody and Koch, 1986; Fortner and Mayer, 1989; Brody, 1996; Rodriguez-Martinez and Ortiz, 1999; Ballantyne, 2004; Lambert, 2006; Plankis and Marrero, 2010; Guest et al., 2015). Further to the above, learning activities and school programs have also been investigated through interventional studies, revealing students' knowledge improvement, especially after first-hand experiences on ocean-related topics (e.g., Fortner and Teates, 1980; Fortner, 1985; Cummins and Snivelly, 2000; Lambert, 2005, 2006; Stepath, 2007; Plankis and Marrero, 2010; Hartley et al., 2015, 2018).

The aim of the present study, which constitutes the first cross-cultural attempt at the elementary school level, is two-fold: (a) to evaluate and compare students' knowledge about ocean sciences issues according to the ocean literacy framework, and (b) to examine for possible common misconceptions among three Mediterranean countries. The present study illustrates the level of students' ocean literacy on a sub-regional level, and provides guidance for a more focused and sound design, development, and implementation of marine-friendly curricula in terms of elementary school courses and textbooks, in-service teacher training, and pre-service teacher preparation programs.

The Ocean Literacy Framework

Ocean literacy has received increased attention in recent years (e.g., Steel et al., 2005; Buckley et al., 2017), while the interest on issues related to marine education and the aquatic environment has its roots in the environmental movement of the 1960s and 1970s (Marrero and Moore Mensah, 2010). Consequently, the need for marine and aquatic education had already been underlined and studied since the early 1970s (e.g., Charlier and Charlier, 1971; Schweitzer, 1973; McFadden, 1973; Goodwin and Schaadt, 1978; Fortner and Wildman, 1980; Madrazo, Jr., and Hounshell, 1980; Picker, 1980; Dresser and Butzow, 1981; Rakow, 1983/1984; Picker et al., 1984; Fortner, 1985; Fortner and Lyon, 1985). However, it was marginalized and reborn as an official ocean literacy movement in 2004 in the United States. After an extensive process of continuous meetings and constructive discussions, ocean literacy was defined as "an understanding of the ocean's influence on you, and your influence on the ocean," (Cava et al., 2005), and two documents comprising the Ocean Literacy Framework, were developed: a) the Essential Principles and Fundamental Concepts of Ocean Sciences (National Oceanic and Atmospheric Administration [NOAA], 2013), which represent the major ideas that high school graduates should know and understand about the ocean and its significance in the earth system, and b) The Ocean Literacy Scope and Sequence (National Marine Educators Association, 2010), which provides information and guidance as to what students need to comprehend in different grade bands in order to achieve a full understanding of the seven ocean literacy principles and their concepts.

These guidelines, developed to help implement an ocean-dedicated curriculum in the United States, are now largely accepted and have been an inspiration for several initiatives worldwide (Fauville et al., 2018). The U.S. National Science Foundation has invested more than $40M for a 12 year period in a network of Centers for Ocean Sciences Education Excellence, and the European Union (EU) invested more than €7 M in two large international ocean literacy-dedicated projects, SeaChange and ResponSEAble (Fauville et al., 2018). Furthermore, the EU, United States, and Canada signed a transatlantic ocean research alliance that identifies ocean literacy as one of the key areas for cooperation among marine scientists (Costa and Caldeira, 2018). New professional organizations and networks, similar to the U.S. National Marine Educators Association (NMEA), have emerged, including the International Pacific Marine Educators Network (IPMEN), the European Marine Science Educators Association (EMSEA), the Canadian Network for Ocean Education (CaNOE), and the Asia Marine Educators Association (AMEA).

In 2015, a group of researchers and educators from the Mediterranean region (forming the EMSEA Med working group) started an effort to adapt them to the specificities of the Mediterranean Sea. As a result of this procedure, the Mediterranean Sea Literacy (MSL) guide was developed consisting of 7 principles and 46 concepts which describes different aspects of the Mediterranean Sea and its connection to people and society (Santoro et al., 2017a; Realdon et al., 2018). The goal of the MSL guide is to provide basic fundamental knowledge about the Mediterranean Sea to educators, teachers, scientists, Non-Governmental Organizations, blue business sector and policymakers, thus help to achieve awareness, and therefore a blue and sustainable Mediterranean region at all levels of society.

MATERIALS AND METHODS

Participants

A cross-cultural study was conducted to a group of elementary school students from three European countries located on the coasts of the Mediterranean Sea, namely Italy, Croatia, and Greece (**Figure 1**). Our research employed a convenience sampling method with the constraint that participants fit into groups stratified by grade level. Third to 6th-grade students from 20 schools and 17 cities, located in north-western and north-eastern Italy, central coastal Croatia, and northern and southern Greece, comprised the final sample (**Figure 1**), while special attention was paid to obtain similar percentages of gender representation. As a result, the final sample was comprised of 1004 students; forty-eight percent of the participants were females.

Instrument

For the needs of the present study a structured questionnaire to investigate knowledge related to ocean sciences issues was developed taking into consideration previous research (Greely, 2008; Mogias et al., 2015; Fauville et al., 2018), and following the guidelines of the seven essential principles of the Ocean Literacy Framework (National Oceanic and Atmospheric Administration [NOAA], 2013) and the Ocean Literacy Scope and Sequence (NMEA, 2010), which actually provides the guidelines for what it should be taught in certain grade bands. More specifically, the questionnaire contained a set of demographic and sixteen multiple choice questions targeted in certain principles of the framework (**Table 1**). Demographics highly supported anonymity of the participants, and the non-sensitive collected data from the three EU countries (Italy, Croatia, and Greece) cannot be rated as "personal data," according to EU General Data Protection Regulation (EU 679/2016, article 4, paragraph 1); therefore an ethics approval was not required as per applicable institutional and national guidelines and regulations. The items of the knowledge scale were close-ended, making the instrument easy to use, code, and score for statistical purposes. Each correct answer received a value of 1 and incorrect a value of 0; therefore, the score could vary between 0 and 16 (mean value 8.5 portrays the balance point of the scale). Lower scale scores indicated lower student knowledge and *vice versa*. All items consisted of three well distinct distractors, considering the young age of students, and common for all countries except for items 5 and 7 which used region-specific wording; in the former case, the name of each country was referred and in the latter, the Tyrrhenian and the Adriatic Seas were used for the Italian sample, the Adriatic alone for the Croatian, and the Aegean Sea for the Greek sample, respectively.

TABLE 1 | Alignment of the survey questions with the seven essential principles of the Ocean Literacy Framework.

Ocean literacy essential principles	Questions
1. Earth has one big ocean with many features	1, 7, 13
2. The ocean and life in the ocean shape the features of Earth	2, 10
3. The ocean is a major influence on weather and climate	5, 11
4. The ocean makes earth habitable	3, 8
5. The ocean supports a great diversity of life and ecosystems	4, 9
6. The ocean and humans are inextricably linked	12, 14, 16
7. The ocean is largely unexplored	6, 15

FIGURE 1 | Sampling locations of the three Mediterranean countries participating in the study.

The original survey was first developed in English as a common language among the researchers, and then the national versions were written in Italian, Croatian, and Greek languages using translation and back translation (Brislin, 1970). It was examined for content validity in terms of content clarity, language, and difficulty, and also the extent to which the items truly represented basic concepts of ocean literacy principles, by a panel of marine scientists and marine educators. Furthermore, a team of four in-service teachers assigned the corresponding grades 3–6 from each country with a minimum of 5 years of classroom experience was asked to point out the items they did not fully understand; thus their comments were taken into consideration and led to modifications, mainly of the wording. In an effort to further validate the instrument, students' responses were evaluated using the Rasch model for dichotomous items. The family of Rasch models, based on the original ideas and theory of Rasch (1960), has been widely employed for the psychometric evaluation of assessment instruments in science education (Boone and Scantlebury, 2006; Boone et al., 2011, 2014). The main outcome of a Rasch analysis is a unidimensional line or continuum along which test items and persons are located according to their difficulty and ability measures, respectively. Ability is used here as a generic term to indicate the level of achievement of a person on a particular test in a particular area. The response patterns observed on the test items are examined against the model requirements, which include latent monotonicity, local independence, unidimensionality and specific objectivity (e.g., see Wilson, 2004; Bond and Fox, 2007, for an introduction to Rasch analysis). Rasch models are compatible with fundamental measurement (Boone et al., 2011) and offer certain advantages as construct validation tools (Baghaei, 2008). In particular, the dichotomous Rasch model, is one of the dominant models for analyzing binary items (e.g., success/failure) in psychometrics. Rasch analysis was conducted separately on the data of each country, using the R-package eRm (Mair and Hatzinger, 2007; see **Figures 2–4**). The person-item-map displays the distribution of person parameters across the latent construct (questionnaire) in association with item difficulty parameters. This shows whether the distribution of person parameters is approximately normally distributed and it allows investigating whether the items are distributed across the whole spectrum of the latent construct. **Figures 2–4** display the person – item maps for the three countries (Italy, Croatia, and Greece, respectively). The distribution of person

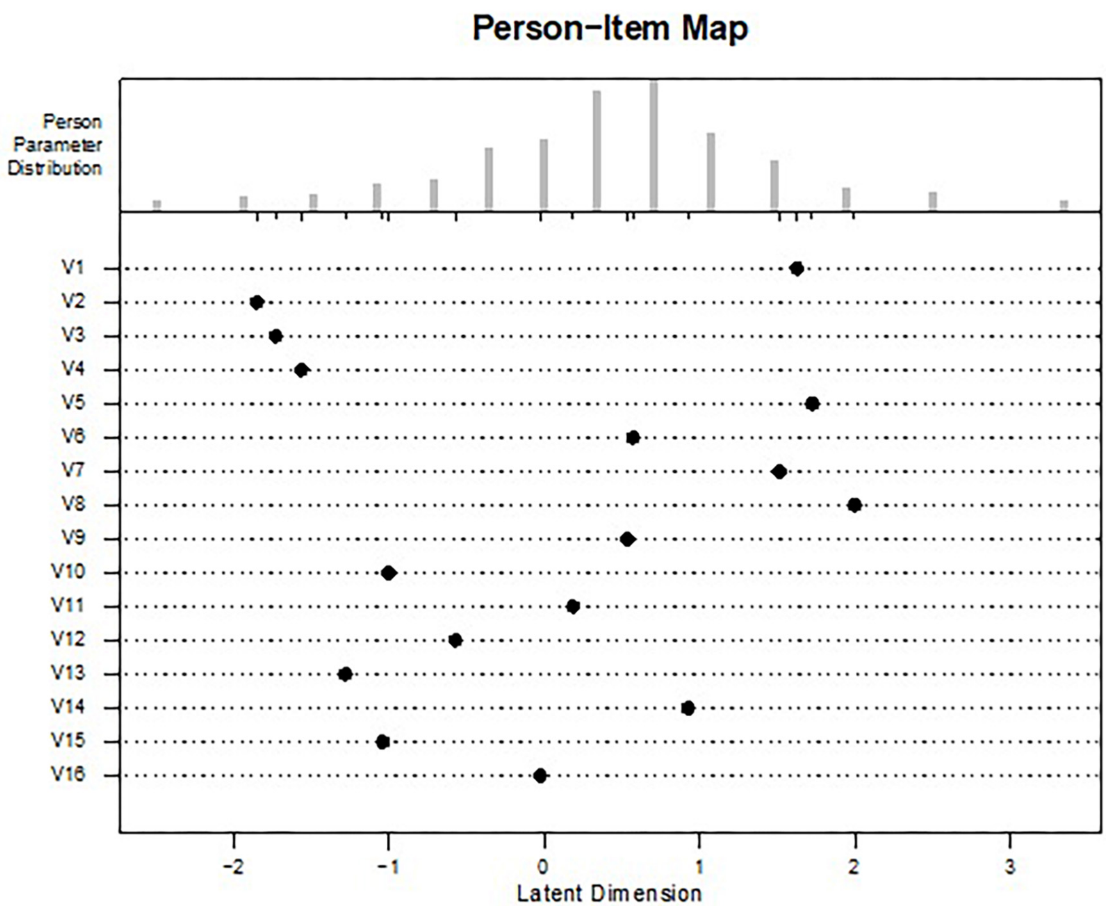

FIGURE 2 | Person-Item map for Italy.

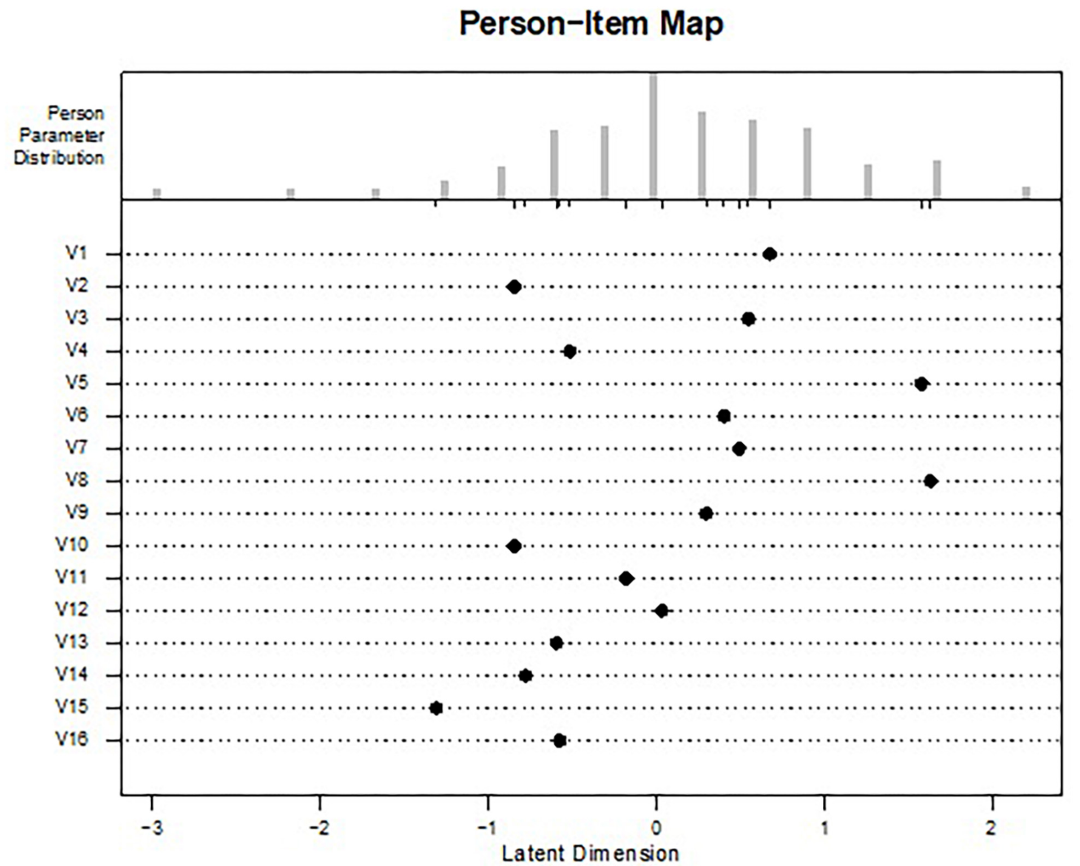

FIGURE 3 | Person-Item map for Croatia.

parameters is approximately normal for all three countries. In the case of Italy items are distributed across the whole spectrum of the construct indicating that the questionnaire is well suited for the specific student population, while in the case of Croatia and Greece the instrument appears to be not that well suited for students of lower ability levels. The analysis revealed that item separation reliability for each subscale was rather low (0.4638, 0.4202, and 0.5292 for Italy, Croatia, and Greece, respectively), and therefore the item estimates are to be interpreted conservatively. Even though the item separation reliability was proved to be lower than expected, there are points of great interest in terms of the relative difficulties among the response categories, which constitutes the actual scope of the paper.

Background Factors

The questionnaire also included questions about students' gender, grade level, participation in any kind of nature-related activities, and use of television documentaries as the main information source about general environmental issues.

Data Collection and Analysis

Prior to the administration of the survey instrument, participants were informed about the purpose of the study and the voluntary basis of participation from their classroom teachers. Moreover, the researchers from all three countries ensured the official approval of the participating schools' principals to administer the questionnaire, while written and informed consent was obtained from the parents of all participants in Italian and Croatian schools, and oral and informed consent was obtained from the parents of all participants in Greek schools for participation in this study; both consent procedures followed were in accordance with applicable institutional and national guidelines and regulations. Questionnaires were administered in the classroom in February–June and September–October 2018. Completion time ranged between 20 and 30 min.

Data analysis involved the following two steps. As this was the main focus of our study, in the first step descriptive statistics were applied to portray frequencies and knowledge scores of the participants as a whole and for each country separately, with regard to certain grade levels. The second step referred to the use of *t*-tests and one-way analyses of variance (ANOVA) to assess the effects of background variables on students' knowledge as well as possible differences among the three sample sub-groups. Statistical analyses were performed with the use of the Statistical Package for Social Sciences (SPSS v. 21); for all statistical tests, the

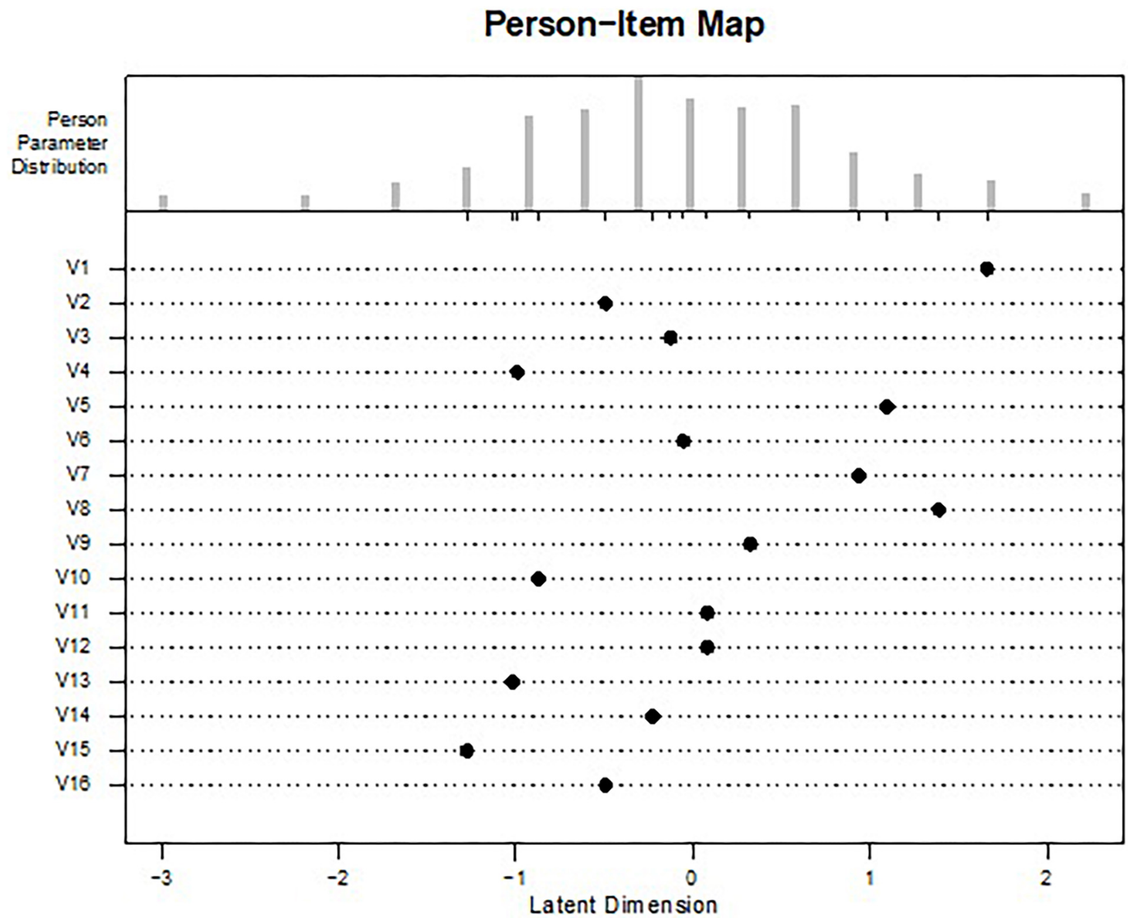

FIGURE 4 | Person-Item map for Greece.

significance level was predetermined at a probability value of 0.05 or less.

RESULTS

Background Data

From the 1004 students comprising the total sample in the present study, 41.2% resulted from Greece, 35.1% from Italy, and 23.7% from Croatia. The percentages of participation recorded for each grade level were 12.4% for grade 3, 31.8% for grade 4, 30.2% for grade 5, and 25.7% for grade 6, respectively. Detailed sample characteristics per country and grade level are given in **Table 2**. The majority of the students grew up in a coastal hometown environment, as their schools seem to be in an immediate vicinity to the sea, few were located at a slightly bigger distance (between 5 and 25 km), while students of two Greek cities and one Italian, consisting 25.1% of the total student sample, were located in a distance larger than 30 km far away from the nearest coast; moreover, only 7.6% of the participants, coming exclusively from a Greek city, had a direct access to a marine institute and an aquarium. Furthermore, 75.5% of the students argued that they had already taken part in some kind of nature activities in their schools,

TABLE 2 | Sample characteristics of the participating countries per grade; y.o. stands for years-old.

Country	Gender		Grade 3 (8–9 y.o.) (*n* = 124)	Grade 4 (9–10 y.o.) (*n* = 319)	Grade 5 (10–11 y.o.) (*n* = 303)	Grade 6 (11–12 y.o.) (*n* = 258)	Total (*n* = 1004)	Schools (n)	Cities (n)
	Males (*n* = 522)	Females (*n* = 482)							
Italy	189 (53.7%)	163 (46.3%)		152 (43.2%)	136 (38.6%)	64 (18.2%)	352 (35.1%)	12	11
Croatia	127 (53.4%)	111 (46.6%)	91 (38.2%)	48 (20.2%)	5 (18.9%)	54 (22.7%)	238 (23.7%)	2	1
Greece	206 (49.8%)	208 (50.2%)	33 (8.0%)	119 (28.7%)	122 (29.5%)	140 (33.8%)	414 (41.2%)	6	5

while almost 60.0% of them claimed to have made use of television documentaries as the main information source for general environmental issues.

Ocean Content Knowledge

Elementary school students were found to possess a rather moderate level of ocean sciences content knowledge exhibiting scores slightly above the balance point (8.53/16), ranging between 7.78 (±2.557) for the Greek sub-sample and 9.18 (±2.223) for the Italian one. **Table 3** shows the frequencies of correct answers per country and question. More specifically, the mean correct values were 57.4, 54.0, and 48.6% for Italy, Croatia, and Greece, respectively; identifying a cut-off limit of 70% of correct answering, 7 out of 16 questions for the Italian students were met, four for the Croatian, and three for the Greek students; while no significant difference was detected among the three sub-samples in six out of the total 16 questions (items 5, 6, 8, 9, 15, and 16), *post hoc* analysis revealed a statistically significant difference among all three countries only in four questions (items 1,2,3, and 14), indicating in some extent similarities in both knowledge gains and misconceptions (**Table 3**).

TABLE 3 | Relative frequencies of correct answers, and *p*-values per question among the three countries (bold letters indicate high similarities).

Question	Italy (*N* = 352)	Croatia (*N* = 238)	Greece (*N* = 414)	*p*-value
1	24.1	38.2	16.2	0.000
2	89.5	72.7	59.4	0.000
3	88.4	41.2	51.0	0.000
4	86.6	66.0	70.0	0.000
5	**22.4**	**20.6**	**24.9**	0.435
6	**46.6**	**44.5**	**49.3**	0.486
7	**26.1**	42.4	**27.8**	0.000
8	**18.2**	**19.7**	**20.0**	0.795
9	**47.4**	**47.1**	40.6	0.109
10	79.3	72.7	67.6	0.001
11	**55.7**	**58.4**	46.1	0.003
12	71.9	53.4	46.1	0.000
13	83.2	**67.6**	**70.5**	0.000
14	38.4	71.4	53.4	0.000
15	**79.8**	**80.7**	**75.4**	0.187
16	**60.5**	67.2	**59.4**	0.123
mean	57.4	54.0	48.6	

Furthermore, the ordering of the knowledge items from Rasch Analysis demonstrated in **Table 4** showed an interesting pattern of responses among the three countries. Items at the base of the scale implied the most difficult ones, while those at the top of the scale indicated the easiest ones to correctly answer. This item placement in the scale clearly revealed that students presented, with some variations among the three countries, greater difficulty in identifying that oxygen originates mainly from the ocean (question 8); all sub-samples managed to give correct answers in very low percentages, hardly ranging between 18 and 20%, while almost two thirds of them clearly chose woods and meadows as the main source of oxygen. Question 5 concerned knowledge about the global water cycle and the origin of evaporated water; all students misplaced the correct answer, namely the warmer seas far away from the participants' temperate countries, in the last position with frequencies varying between 20 and 25%, as they presented the nearest seas as their first choice and the land after a rain as their second one. Another very difficult item was proven to be the first one, pertained to the connectedness of the global ocean; students commonly disregarded the ability for a boat to hypothetically reach every oceanic basin, by presenting high preference for the nearest Atlantic Ocean. Question 7 was very close to that item, as the majority of students confirmed their ignorance of the one and only interconnected ocean by responding that the Aegean Sea for the Greeks, the

TABLE 4 | Item difficulty (in logits) obtained via Rasch Analysis on the data of each country.

	Italy	Difficulty (logits)	Croatia	Difficulty (logits)	Greece	Difficulty (logits)
Easy Items ↑	Q2	−1.851	Q15	−1.310	Q15	−1.276
	Q3	−1.73	Q2	−0.845	Q13	−1.017
	Q4	−1.565	Q10	−0.845	Q4	−0.992
	Q13	−1.282	Q14	−0.780	Q10	−0.873
	Q15	−1.040	Q13	−0.595	Q2	−0.494
	Q10	−1.003	Q16	−0.575	Q16	−0.494
	Q12	−0.573	Q4	−0.516	Q14	−0.231
	Q16	−0.027	Q11	−0.181	Q3	−0.127
	Q11	0.184	Q12	0.033	Q6	−0.055
	Q9	0.533	Q9	0.296	Q11	0.080
	Q6	0.570	Q6	0.402	Q12	0.080
	Q14	0.925	Q1	0.674	Q9	0.323
	Q7	1.515	Q7	0.491	Q7	0.935
	Q1	1.625	Q3	0.545	Q5	1.094
	Q5	1.724	Q5	1.576	Q8	1.387
↓ Difficult items	Q8	1.997	Q8	1.630	Q1	1.661

Tyrrhenian and the Adriatic for the Italians, and in lower extent the Adriatic Sea for the Croatians are all connected solely to the Mediterranean Sea and not the rest of the seas worldwide (**Tables 3**, **4**).

Contrary to these difficult to answer items, questions 2, 4, 10, 13, and 15 were generally easy for the students to answer. More specifically, the majority of the participants were able to easily identify that ocean research is a basic prerequisite for its protection, that fish fossils, wherever met on land, were formed sometime during the past in the sea, that the ocean hosts a great diversity of life in different parts of its vast volume, that the coastlines are continually been shaped by sea water motions, and that most of the earth's water occurs in the seas and the oceans (**Tables 3**, **4**).

On a grade level basis, although the values slightly varied among the three countries, a rather similar progression pattern in the knowledge level was detected for Croatia and Greece, while this was not the case for Italy (**Figure 5**). More specifically, in the former case a small decrease in grade 4 and a progressive increase in scores during grades 5 and 6 was illustrated; for the Greek sub-sample, this score progression appeared to be more intensive. On the other hand, the Italian sample revealed a slight gradual decrease in scores with progressing in grades. The mean score values among grade levels are also given in **Figure 5**.

Relationships Between Knowledge and Background Factors

In the total sample, male students demonstrated slightly higher knowledge level (mean score: 8.56 ± 2.540) than female students (8.38 ± 2.377) but no statistically significant difference was observed [$t(1002) = -1.193$, $p = 0.233$]; while the Italian and Greek sub-samples showed similar trends regarding gender, Croatian female students revealed higher knowledge scores, but with no statistically significant difference as well. Students who had participated in some kind of nature-related activities within their formal school settings revealed significantly higher mean scores (8.66 ± 2.453) in comparison to students with no such experience (7.91 ± 2.414) [$t(1002) = 4.163$, $p = 0.000$]; this was exactly the case for each country separately. Moreover, students who used to make use of TV documentaries for obtaining environmental information also demonstrated significantly higher knowledge scores in the total sample (8.84 ± 2.401) compared to the others (7.96 ± 2.462) [$t(1002) = 5.619$, $p = 0.000$]; no statistically significant difference was recorded in the Croatian sub-sample in particular.

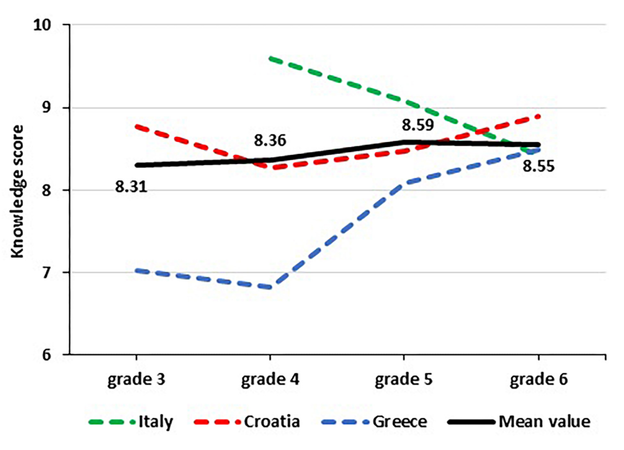

FIGURE 5 | Knowledge scores for each country, and mean values per grade level.

On a country basis, it appears that there was a significant difference among Italy, Croatia and Greece (9.18 ± 2.223, 8.64 ± 2.314, and 7.78 ± 2.557, respectively) [$F(2, 1001) = 33.656$, $p = 0.000$], while *post hoc* analysis revealed three distinct groups, corresponding to the three countries under study. One-way analysis of variance was also applied on a grade basis, where no significant difference was found among the grade levels [$F(3, 1000) = 0.722$, $p = 0.539$]. Possible relationships between coastal and non-coastal hometown participants' knowledge within each country separately were investigated; Croatia was not included in this analysis as the participating schools were all from the same coastal city. For the Italian case, results revealed that there was a significant difference among students' locations [$F(17, 334) = 2.910$, $p = 0.000$], showing a trend that schools closer to the coast seem to demonstrate rather higher scores; no such pattern was observed in Greece since some inland cities presented higher knowledge scores than some coastal ones. Finally, mean score differences were examined between schools with direct access to a marine institute and an aquarium and schools with not such access; with mean values 9.84 (±2.281) for the former case and 8.36 (±2.445) for the latter, a statistically significant difference [$t(1002) = 5.098$, $p = 0.000$] is apparent in favor of the students who have accessibility to these non-formal educational settings.

DISCUSSION

In the present study, elementary school students (grades 3–6) of three Mediterranean countries, i.e., Italy, Croatia, and Greece which together cover almost 65% of the total Mediterranean coastline, were found to possess rather moderate knowledge of ocean sciences issues, holding also some misconceptions. The majority of the participants was located in coastal areas and drew on their ocean content knowledge mainly from school environmental activities and TV documentaries. More specifically, the Italian students turned up to have a relatively higher ocean-related knowledge level than the rest of their counterparts, but with a slightly decreasing trend in higher grades. This was not the case for the Greek students who although appeared less knowledgeable among the three countries, their ocean-related knowledge increased progressively with higher grades; Croatian students followed a rather similar to the Greek's pattern. Our findings, in terms of students' knowledge level seems to be in line with studies from other countries (e.g., United States, United Kingdom, Mexico, Canada, South Africa, and Korea) focusing on similar school grades (Brody and Koch, 1986; Fortner and Mayer, 1989; Brody, 1996; Rodriguez-Martinez and Ortiz, 1999; Cummins and Snivelly, 2000; Ballantyne, 2004;

Kim et al., 2013; Hartley et al., 2015, 2018). To the best of our knowledge, only a study from Taiwan evidenced a high level of correct answers concerning knowledge of the marine environment (Wen and Lu, 2013). It should be noted though that most of these studies investigated students' knowledge only as a part of assessments addressing also attitudes and often behaviors. Moreover, and probably due to the relative novelty of the ocean literacy framework, only a few studies have investigated specifically the knowledge concerning ocean literacy principles; Wen and Lu (2013) addressed only some of them, while Fauville et al. (2018) investigated students aged 16 and older.

Participants' rather moderate knowledge could be attributed to the fact that ocean sciences do not constitute a basic part of the educational system in Italian, Croatian, and Greek national curricula, as well as in most European Countries. More specifically, although there is no official reference to the sea in Italian elementary school science curricula, revealing a gap which is covered in some extent by the geography curriculum, sea-related topics are present in elementary school textbooks and therefore probably addressed by most teachers. The Croatian elementary school science curriculum seems to be much more sea-oriented as it foresees an environmental education approach to water and sea, with specifications about water and life, water cycle, coastal landscape, and the Adriatic Sea. According to the Greek curriculum, among the topics addressed in primary school textbooks, marine ecosystems and human influence on the sea can be found along with a superficial and fragmented mention of ocean and regional seas characteristics. In any case, initiatives, originating from Environmental Education Centers and from teachers with remarkable enthusiasm in running environmental education programs, are present in all three countries under study, but they cannot actually meet the needs for a meaningful ocean education.

A rather interesting finding is the fact that the majority of students seemed to share the same difficulty in answering certain questions, and at the same time they showed the same efficacy in correctly answering others, indicating cross-cultural similarities in both knowledge gains and the existence of common misconceptions. Some of the wrong perceptions emerged from this study can be described as true misconceptions for being shared by a large percentage of the students under the present study, but also emerged in others researches and academic catalogs. Misconceptions, or "*ideas that are at variance with accepted views*" (Fisher, 1983), are not simple mistakes due to ignorance; they are extremely widespread within science (and non-science) subjects so that to be considered a universal trait among children, teenagers and, to some extent, adults. Ocean sciences and ocean literacy are no exceptions.

The most difficult question concerned the origin of atmospheric oxygen, in which less than 20% of students answered correctly, which was the ocean and not the widely chosen woods, meadows or the tropical forests. Brody and Koch (1986) evidenced a similar difficulty in a sample of students from Maine (United States). This topic, including the primordial origin of O_2 in earth's history, also resulted very hard to answer for students older than 16 years (Fauville et al., 2018). The misconception about the origin of atmospheric oxygen also emerged in a highly cited list of Earth science misconceptions compiled by Phillips (1991) and is quoted among the "Ten Forest Myths" by Cook (2018).

Two other questions with low levels of correct answering were those about the connectedness of all seas in one single and united water mass, revealing a misconception in elementary grades, namely the inability to perceive the connectedness of all seas in one single water mass, which appears only marginally to be addressed in published research and therefore needs further investigation. Most of the students seem to have misunderstood this concept, deemed so fundamental to be chosen as the 1st ocean literacy principle. This topic is actually missing or superficially stated in elementary school curricula and textbooks of the countries under study, while geography curricula still insist to focus on different ocean basins and their names, thus hindering the connectedness of the one and only vast ocean. In the literature so far, students' perception of ocean basins was marginally investigated only by Brody (1996), within a research concerning knowledge of Oregon's marine resources in a sample of 4th, 8th, and 11th grade students who viewed nearby ocean as a sort of "bowl" with rocky/sandy bottom. In 2007, a list of 110 Ocean misconceptions quoted "The ocean is basically a bowl, deepest in the middle" and "The three big oceans are not connected; each acts alone"; unfortunately, this datum has a limited value because, according to the author, the list was compiled upon anecdotal basis (Feller, 2007). On the contrary, an international study among a large number of older (>16 years old) students revealed that this concept was quite easy for them to correctly answer (Fauville et al., 2018).

Another difficult question for the students of this study was the one on the knowledge of the global water cycle. Most respondents believed that the origin of rainwater was from their proximal sea, instead of the remote warmer tropical ocean. Even if these students are probably familiar with the water cycle in all three countries from early elementary grades, apparently they do not perceive its global dimension. Gaps in understanding the basic processes, connections, and magnitude involved in the water cycle, have been evidenced in previous research among school students (e.g., Ben-zvi-Assarf and Orion, 2005), university students (e.g., Cardak, 2009) as well as pre-service teachers (e.g., Mogias et al., 2015). Children's misconceptions about the water cycle were also reviewed by Brody (1993) and listed by Henriques (2000) within literature-referenced weather misconceptions. Results about students' knowledge of the connectedness of all seas and of the global water cycle seem to highlight a common element: *"environment" as referred to, is essentially conceived as a space surrounding pupils' life rather than a global milieu* (Squarcina and Pecorelli, 2017).

Although the proximity of the Italian students' residence to the sea seems to have affected their knowledge level, this was not the case for the Greeks, where in some cases "inland" students appeared to be more knowledgeable regarding marine issues than "coastal" ones. Relevant literature reveals that, when people experience coastal environments in their childhood and come closer to certain coastal and ocean problems, they are more likely to practice certain skills important for scientific inquiry, obtain relative content knowledge, and therefore develop an interest in nature and later work for its protection (e.g., Chawla, 1999; Cicin-Sain and Knecht, 2000; Steel et al., 2005; Bennett and Hiebert, 2010).

Additionally, in one of the Greek sub-samples, students who live near or have easy access to non-formal educational settings such as an aquarium and a marine research institute, appeared to possess significantly higher level of marine content knowledge, probably indicating the contribution of such educational environments, as well as the self-confidence and enthusiasm of the teachers who take advantage of these settings. It has been revealed that visits to aquaria and zoos have a measurable impact both on knowledge and attitudes (Falk and Adelman, 2003; Falk et al., 2007). As Ballantyne (2004) argues, such non-formal settings are well placed to address misconceptions by designing exhibits, which accurately demonstrate various phenomena and help children distinguish between them.

Furthermore, students' participation in any kind of nature-related activities within their schools revealed higher knowledge scores in the three countries under study, in comparison to their counterparts with no such experience. The need for ocean literacy activities in the classroom has been pointed out from the very first beginning of the Ocean Literacy Framework launching in the early 2000s (e.g., Schoedinger et al., 2006), while in-school environmental activities promoting inquiry-based and authentic problem-solving learning have shown to increase various aspects of students, such as knowledge among others (e.g., Erdoğan et al., 2009).

Finally, gender differences in marine content knowledge seem to have emerged to some extent from the present study, since in both Italian and Greek sub-samples male students tend to be more knowledgeable than their female classmates, while this was not the case for Croatia. This is not an unexpected finding as a tendency seems to be ascertained with males prevailing in content marine knowledge (e.g., Guest et al., 2015) or general environmental or science knowledge (e.g., Meinhold and Malkus, 2005; Martin et al., 2016); relevant literature also supports opposite results (e.g., McCright, 2010).

Although the present study cannot represent the whole student population of the respective countries and therefore cannot allow for unconditioned generalizations, results have potential implications in different directions within formal education, namely curriculum designers, textbooks authors, in-service teachers, and pre-service training programs. More specifically, having in mind of what Strang (2008) suggests, that we cannot be science literate without being ocean literate, there are implications with regard to the curriculum designers and textbook authors, who are most probably unaware and should be essentially informed of the existence of the Ocean Literacy Framework for the needs of future education reforms on a national level. Accordingly, for in-service teachers who probably miss ocean sciences subject matter knowledge, they should be offered training seminars, especially in subject matters not widely encompassed into the school practice, as the ocean sciences issues, offered by professionals, such as marine scientists and marine educators. Finally, regarding teacher training programs, these should incorporate more intensive opportunities for the prospective teachers to acquire environmental knowledge in general and marine knowledge in particular, aligned with the lately introduced Education 2030 Agenda (UNESCO, 2017).

As elementary school students still maintain their natural curiosity about the world that surrounds them, early capturing their attention by adding ocean literacy-related topics in national curricula, and continually nurturing their inherent curiosity in higher education levels, is fundamental (U. S. Commission On Ocean Policy, 2004). Only ocean-literate future citizens will be able to understand ocean-related issues and will have the ability to take responsible decisions; after all, they will be the ones that will fully comprehend that the vitality of the ocean is inextricably connected to their own survival.

AUTHOR CONTRIBUTIONS

AM designed the research project, administrated the instrument, analyzed the data, and wrote the manuscript. TB, GR, MP, MM, PK, and MC designed the research project, administrated the instrument, and wrote the manuscript.

ACKNOWLEDGMENTS

We would like to cordially thank the elementary school teachers and the hundreds of students from Italy, Croatia, and Greece for their substantial assistance in the participation of the research. Special thanks to the two reviewers for their valuable comments.

REFERENCES

Baghaei, P. (2008). The rasch model as a construct validation tool. *Rasch Meas. Trans.* 22, 1145–1146.

Ballantyne, R. (2004). Young students' conceptions of the marine environment and their role in the development of aquaria exhibits. *Geo J.* 60, 159–163. doi: 10.1023/b:gejo.0000033579.19277.ff

Ballantyne, R., Carr, N., and Hughes, K. (2005). Between the flags: an assessment of domestic and internationaluniversitystudents' knowledge of beach safetyin Australia. *Tour. Manag.* 26, 617–622. doi: 10.1016/j.tourman.2004.02.016

Belden Russonello and Stuart (1999). *Communicating About Oceans: Results of a National Survey*. Washington, DC: Belden Russonello and Stuart.

Bennett, K., and Hiebert, L. (2010). Growing up in the ocean. Complex life cycles of common marine invertebrates. *Sci. Act.* 46, 18–25. doi: 10.3200/sats.46.4.18-26

Ben-zvi-Assarf, O., and Orion, N. (2005). A study of junior high students' perceptions of the water cycle. *J. Geosci. Educ.* 53, 366–373. doi: 10.5408/1089-9995-53.4.366

Blondel, J., Aronson, J., Bodiu, J.-Y., and Boeuf, G. (2010). *The Mediterranean Region. Biological Diversity in Space and Time*. Oxford: Oxford University Press.

Bond, T. G., and Fox, C. M. (2007). *Applying the Rasch Model: Fundamental Measurement in the Human Sciences*. New York, NY: Routledge.

Boone, W. J., and Scantlebury, K. (2006). The role of Rasch analysis when conducting science education research utilizing multiple-choice tests. *Sci. Educ.* 90, 253–269. doi: 10.1002/sce.20106

Boone, W. J., Staver, J. R., and Yale, M. S. (2014). *Rasch Analysis in the Human Sciences*. Dordrecht: Springer.

Boone, W. J., Townsend, J. S., and Staver, J. (2011). Using rasch theory to guide the practice of survey development and survey data analysis in science education and to inform science reform efforts: an exemplar utilizing STEBI self-efficacy data. *Sci. Educ.* 95, 258–280. doi: 10.1002/sce.20413

Boubonari, T., Markos, A., and Kevrekidis, T. (2013). Greek pre-service teachers' knowledge, attitudes, and environmental behavior toward marine pollution. *J. Environ. Educ.* 44, 232–251. doi: 10.1080/00958964.2013.785381

Brislin, R. W. (1970). Back translation for cross-cultural research. *J. Cross. Cult. Psychol.* 1, 185–216. doi: 10.1177/135910457000100301

Brody, M. (1996). An assessment of 4th-, 8th-, and 11th-grade students' environmental science knowledge related to oregon's marine resources. *J. Environ. Educ.* 27, 21–27. doi: 10.1080/00958964.1996.9941463

Brody, M., and Koch, H. (1986). *An Assessment of 4th-, 8th-, and 11th-Grade Students' Knowledge Related to Marine Sciences and Natural Resource Issues*. Orono, ME: University of Maine.

Brody, M. J. (1993). Student understanding of water and water resources: a review of the literature. *Paper Presented at the Annual Meeting of the American Educational Research Association*, Atlanta, GA.

Buckley, P. J., Pinnegar, J. K., Painting, S. J., Terry, G., Chilvers, J., Lorenzoni, I., et al. (2017). Ten thousand voices on marine climate change in europe: different perceptions among demographic groups and nationalities. *Front. Mar. Sci.* 4:206. doi: 10.3389/fmars.2017.00206

Capstick, S. B., Pidgeon, N. F., Corner, A. J., Spence, E. M., and Pearson, P. N. (2016). Public understanding in great britain of oceanacidification. *Nat. Clim. Chang.* 6, 763–767.

Cardak, O. (2009). Science students' misconceptions of the water cycle according to their drawings. *J. Appl. Sci.* 6, 865–873. doi: 10.3923/jas.2009.865.873

Cava, F., Schoedinger, S., Strang, C., and Tuddenham, P. (2005). *Science Content and Standards for Ocean Literacy: A Report on Ocean Literacy*. Available at: http://coexploration.org/oceanliteracy/documents/OLit200405_Final_Report.pdf (accessed August 10, 2011).

Charlier, P. S., and Charlier, R. H. (1971). A case for oceanography at the inland school. *Sci. Educ.* 55, 15–20. doi: 10.1002/sce.3730550105

Chawla, L. (1999). Life paths into effective environmental action. *J. Environ. Educ.* 31, 15–26. doi: 10.1016/j.scitotenv.2019.01.398

Chen, C. L., and Tsai, C. H. (2015). Marine environmental awareness among university students in Taiwan: a potential signal for sustainability of the oceans. *Environ. Educ. Res.* 22, 958–977. doi: 10.1080/13504622.2015.1054266

Cicin-Sain, B., and Knecht, R. W. (2000). *The Future of US Ocean Policy: Choices for the New Century*. Washington, DC: Island Press, 389.

Coll, M., Piroddi, C., Albouy, C., Rais Lasram, B. F., Cheung, W. W. L., Christensen, V., et al. (2012). The Mediterranean Sea under siege: spatial overlap between marine biodiversity, cumulative threats and marine reserves. *Glob. Ecol. Biogeogr.* 4, 465–480. doi: 10.1111/j.1466-8238.2011.00697.x

Coll, M., Piroddi, J., Steenbeek, K., Kaschner, K., Ben Rais, Lasram, F., et al. (2010). The biodiversity of the mediterranean sea: estimates, patternj s, and threats. *PLoS One* 5:e11842. doi: 10.1371/journal.pone.0011842

Cook, B. (2018). *Ten Forest Myths*. East Lansing, MI: Michigan State University.

Costa, S., and Caldeira, R. (2018). Bibliometric analysis of ocean literacy: an underrated term in the scientific literature. *Mar. Policy* 87, 149–157. doi: 10.1016/j.marpol.2017.10.022

Cudaback, C. (2006). What do college students know about the ocean? *EOS* 87, 418–421.

Cummins, S., and Snivelly, G. (2000). The effect of instruction on children's knowledge of marine ecology, attitudes toward the ocean, and stances toward marine resource issues. *Can. J. Environ. Educ.* 5, 305–324.

Danielson, K. I., and Tanner, K. D. (2015). Investigating undergraduate science students' conceptions and misconceptions of ocean acidification. *CBE Life Sci. Educ.* 14, 1–11.

Dresser, H. H., and Butzow, J. W. (1981). The effects of selected variables on the implementation of a marine education infusion curriculum. *Sch. Sci. Math.* 81, 480–486. doi: 10.1111/j.1949-8594.1981.tb10010.x

Dromgool-Regan, C., Burke, N., and McClouglin, T. J. J. (2017). "Marine deficit disorder: marine literacy in primary student teachers," in *Proceedings of the ESERA 2017 Conference*, Dublini.

Erdoğan, M., Kostova, Z., and Marcinkowski, T. (2009). Components of environmental literacy in elementary science education curriculum in Bulgaria and Turkey. *Eurasia J. Math. Sci. T.* 5, 15–26. doi: 10.12973/ejmste/75253

Falk, J. H., and Adelman, L. M. (2003). Investigating the impact of prior knowledge and interest on aquarium visitor learning. *J. Res. Sci. Teach.* 40, 163–176. doi: 10.1002/tea.10070

Falk, J. H., Reinhard, E. M., Vernon, C. L., Bronnenkant, K., Deans, N. L., and Heimlich, J. E. (2007). *Why Zoos and Aquariums Matter: Assessing the Impact of a Visit*. Silver Spring, MD: Association of Zoos and Aquariums.

Fauville, G., Strang, C., Cannady, M. A., and Chen, Y.-F. (2018). Development of the international ocean literacy survey: measuring knowledge across the world. *Environ. Educ. Res.* 25, 238–263. doi: 10.1080/13504622.2018.1440381

Feller, R. J. (2007). 110 misconceptions about the ocean. *Oceanography* 20, 170–173. doi: 10.5670/oceanog.2007.22

Fernandes, P. G., Ralph, G. M., Nieto, A., Criado, M. G., Vasilakopoulos, P., Maravelias, C. D., et al. (2017). Coherent assessments of Europe's marine fishes show regional divergence and megafauna loss. *Nat. Ecol. Evol.* 1:0170. doi: 10.1038/s41559-017-0170

Fisher, K. M. (1983). "Amino acids and translation: a misconception in biology," in *Proceedings of the International Seminar on Misconceptions in Science and Mathematics*, eds H. Helm and J. D. Novak (Ithaca, NY: Cornell University), 407–419.

Fletcher, S., Potts, J. S., Heeps, C., and Pike, K. (2009). Public awareness of marine environmental issues in the UK. *Mar. Policy* 33, 370–375. doi: 10.1016/j.marpol.2008.08.004

Fortner, R., and Wildman, T. M. (1980). Marine education: progress and promise. *Sci. Educ.* 64, 717–723. doi: 10.1002/sce.3730640517

Fortner, R. W. (1985). Relative effectiveness of classroom and documentary film presentations on marine mammals. *J. Res. Sch. Teach.* 21, 115–126. doi: 10.1002/tea.3660220203

Fortner, R. W., and Lyon, A. E. (1985). Effects of cousteau television special on viewer knowledge and attitudes. *J. Environ. Educ.* 16, 12–20. doi: 10.1080/00958964.1985.9942707

Fortner, R. W., and Mayer, V. J. (1989). Marine and aquatic education - A challenge for science educators. *Sci. Educ.* 73, 135–154. doi: 10.1002/sce.3730730203

Fortner, R. W., and Teates, T. G. (1980). Baseline studies for marine education: experiences related to marine knowledge and attitudes. *J. Environ. Educ.* 11, 11–19. doi: 10.1080/00958964.1980.9941385

Garcia-Nieto, A. P., Geijzendorffer, I. R., Baroì, F., Roche, P. K., Bondeau, A., and Cramer, W. (2018). Impacts of urbanization around mediterranean cities: changes in ecosystem service supply. *Ecol. Indic.* 91, 589–606. doi: 10.1016/j.ecolind.2018.03.082

Gelcich, S., Buckley, P., Pinnegar, J. K., Chilvers, J., Lorenzoni, I., Terry, G., et al. (2014). Public awareness, concerns, and priorities about anthropogenic impacts on marine environments. *PNAS* 111, 15042–15047. doi: 10.1073/pnas.1417344111

Giorgi, F., and Lionello, P. (2008). Climate change projections for the mediterranean region. *Glob. Planet. Change* 63, 90–104. doi: 10.1016/j.gloplacha.2007.09.005

Goodwin, H. L., and Schaadt, J. G. (1978). *A Statement on the Need for Marine and Aquatic Education. To Inform Americans About the World of Water*. Delaware, DE: Delaware Sea Grant College Program.

Gough, A. (2017). Educating for the marine environment: challenges for schools and scientists. *Mar. Pollut. Bull.* 124, 633–638. doi: 10.1016/j.marpolbul.2017.06.069

Greely, T. (2008). *Ocean Literacy and Reasoning About Ocean Issues: The Influence of Content, Experience and Morality*. Ph.D. disserstaion, Tampa, FL: University of South Florida.

Guest, H., Lotze, H. K., and Wallace, D. (2015). Youth and the sea: ocean literacy in Nova Scotia. *Can. Mar. Policy* 58, 98–107. doi: 10.1016/j.marpol.2015.04.007

Guidetti, P., Baiata, P., Ballesteros, E., Di Franco, A., Hereu, B., Macpherson, E., et al. (2014). Large-scale assessment of mediterranean marine protected areas effects on fish assemblages. *PLoS One* 9:e91841. doi: 10.1371/journal.pone.0091841

Hartley, B., Pahl, S., Holland, M., Alampei, I., Veiga, J. M., and Thompson, R. C. (2018). Turning the tide on trash: empowering european educators and school students to tackle marine litter. *Mar. Policy* 96, 227–234. doi: 10.1016/j.marpol.2018.02.002

Hartley, B., Thompson, R. C., and Pahl, S. (2015). Marine litter education boosts children's understanding and self-reportedactions. *Mar. Pollut. Bull.* 90, 209–217. doi: 10.1016/j.marpolbul.2014.10.049

Henriques, L. (2000). "Children's misconceptions about weather: a review of the literature," in *Proceedings of the Annual Meeting of the National Association of Research in Science Teaching*, New Orleans, LA.

Kim, J.-M., Anderson, D., and Scott, S. (2013). Korean elementary school students' perceptions of relationship with marine organisms. *Asia Pac. Forum Sci. Learn. Teach.* 14:1. doi: 10.14333/kjte.2016.32.2.1

Lambert, J. (2005). Students' conceptual understandings of science after participating in a high school marine science course. *J. Geosci. Educ.* 55, 531–539. doi: 10.5408/1089-9995-53.5.531

Lambert, J. (2006). High school marine science and scientific literacy: the promise of an integrated science course. *Int. J. Sci. Educ.* 28, 633–654. doi: 10.1080/09500690500339795

Lotze, H. K., Coll, M., Magera, A. M., Ward-Paige, C., and Airoldi, L. (2011). Recovery of marine animal populations and ecosystems. *Trends Ecol. Evol.* 26, 595–605. doi: 10.1016/j.tree.2011.07.008

Madrazo, G. M. Jr., and Hounshell, P. B. (1980). Marine education in a land-based curriculum. *Sch. Sci. Math.* 80, 363–370. doi: 10.1111/j.1949-8594.1980.tb09673.x

Mair, P., and Hatzinger, R. (2007). Extended rasch modeling: the eRm package for the application of IRT models in R. *J. Stat. Softw.* 20, 1–20. doi: 10.18637/jss.v020.i09

Marrero, M. E., and Moore Mensah, F. M. (2010). Socioscientific decision making and the ocean: a case study of 7th grade life science students. *Electron. J. Sci. Educ.* 14:27.

Martin, M. O., Mullis, I. V. S., Foy, P., and Hooper, M. (2016). *TIMSS 2015 International Results in Science*. Available at: http://timssandpirls.bc.edu/timss2015/international-results/ (accessed November 26, 2018).

McCright, A. M. (2010). The effects of gender on climate change knowledge and concern in the American public. *Popul. Environ.* 32, 66–87. doi: 10.1016/j.puhe.2011.12.015

McFadden, D. L. (1973). Teaching in the tidepools. West coast children study the marine sciences at first hand. *Oceans* 6, 44–49.

Meinhold, J. L., and Malkus, A. J. (2005). Adolescent environmental behaviors. Can knowledge, attitudes, and self-efficacy make a difference? *Environ. Behav.* 37, 511–532. doi: 10.1177/0013916504269665

Mogias, A., Boubonari, T., Markos, A., and Kevrekidis, T. (2015). Greek pre-service teachers' knowledge of ocean sciences issues and attitudes toward ocean stewardship. *J. Environ. Educ.* 46, 251–270. doi: 10.1080/00958964.2015.1050955

National Marine Educators Association (2010). *Ocean Literacy Scope and Sequence for Grades K-12*. College Park, MD: National Marine Educators Association.

National Oceanic and Atmospheric Administration [NOAA] (2013). *Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences for Learners of All Ages Version 2*. College Park, MD: National Oceanic and Atmospheric Administration.

Ocean Policy Research Foundation (2011). *Grand Design for Ocean Education in the 21st Century: Ocean Education Curriculum and Unit Plans*. Tokyo: The Nippon Foundation.

Payne, D. L., and Zimmerman, T. D. (2010). "Beyond terra firma: Bringing ocean and aquatic sciences to environmental and science teacher education," in *The Inclusion of Environmental Education in Science Teacher Education*, eds A. M. Bodzin, B. Shiner Klein, and S. Weaver (Dordrecht: Springer), 81–94. doi: 10.1007/978-90-481-9222-9_6

Perry, E. E., Needham, M. D., Cramer, L. A., and Rosenberger, R. S. (2014). Coastal resident knowledge of new marine reserves in oregon: the impact of proximity and attachment. *Ocean Coast. Manag* 95, 107–116. doi: 10.1016/j.ocecoaman.2014.04.011

Phillips, W. (1991). Earth science misconceptions. *Sci. Teach.* 58, 21–23.

Picker, L. (1980). What is marine education? *Sci. Child* 18, 10–11.

Picker, L., Millman, L., and Aspinwall, K. (1984). A conceptual scheme for aquatic studies: framework for aquatic curriculum development. *Environmentalist* 4, 59–63. doi: 10.1016/s0251-1088(84)91630-9

Plankis, B. J., and Marrero, M. E. (2010). Recent ocean literacy research in United States public schools: results and implications. *Int. Electron. J. Environ. Educ.* 1, 21–51.

Rakow, S. J. (1983/1984). Development of a conceptual structure for aquatic education and its application to existing aquatic curricula and needed curriculum development. *J. Environ. Educ.* 15, 12–16. doi: 10.1080/00958964.1984.9942667

Rasch, G. (1960). *Probabilistic Models for Some Intelligence and Attainment Tests*. Copenhagen: Danmarks Paedagogiske Institut.

Realdon, G., Cheimonopoulou, M., Koulouri, P., Mokos, M., Mogias, A., Boubonari, T., et al. (2018). "EMSEA med: birth and development of an initiative aimed at fostering mediterranean sea literacy," in *Proceedings of the 20th EGU General Assembly Conference*, Vienna.

Rodriguez-Martinez, R., and Ortiz, L. M. (1999). Coral reef education in schools of quintana roo. *Mexico. Ocean Coastl. Manag.* 42, 1061–1068. doi: 10.1016/s0964-5691(99)00061-7

Santoro, F., Mokos, M., Cheimonopoulou, M., Realdon, G., Koulouri, P., Papathanassiou, M., et al. (2017a). "Mediterranean sea literacy: adapting ocean literacy principles to the mediterranean region," in *Proceedings of the EMSEA 2017 Conference Book of Abstracts*, Malta.

Santoro, F., Santin, S., Scowcroft, G., Fauville, G., and Tuddenham, P. (2017b). *Ocean Literacy for all – A Toolkit*. Paris: UNESCO Venice Office.

Schoedinger, S., Cava, F., and Jewell, B. (2006). The need for ocean literacy in the classroom. Part II: ocean literacy classroom activities. *Sci. Teach.* 73, 48–52.

Schweitzer, J. P. (1973). Marine science education in America: its status in precollege programs. *Sci. Teach.* 40, 24–26.

Squarcina, E., and Pecorelli, V. (2017). Ocean citizenship. The time to adopt a useful concept for environmental teaching and citizenship education is now. *J. Res. Didact. Geogr.* 2, 45–53. doi: 10.4458/9446-04

Steel, B. S., Smith, C., Opsommer, L., Curiel, S., and Warner-Steel, R. (2005). Public ocean literacy in the United States. *Ocean Coast. Manag.* 48, 97–114. doi: 10.1016/j.ocecoaman.2005.01.002

Stepath, C. M. (2007). Marine education: learning evaluations. *J. Mar. Educ.* 23, 45–51.

Strang, C. (2008). Education for ocean literacy and sustainability: learning from elders, listening to youth. *Curr. J. Environ. Educ.* 24, 6–10.

The Ocean Project (2009). *America, the Ocean, and Climate Change: New Research Insights for Conservation, Awareness, and Action-key Findings*. Available at: www.theoceanproject.org/resources/environmental.php (accessed December 18, 2018).

U. S. Commission On Ocean Policy (2004). *An Ocean Blueprint for the 21st Century*. Washington, DC: U. S. Commission on Ocean Policy.

Umuhire, M. L., and Fang, Q. (2016). Method and application of ocean environmental awareness measurement: lessons learned from university students of China. *Mar. Poll. Bull.* 102, 289–294. doi: 10.1016/j.marpolbul.2015.07.067

UNEP (2001). *Urbanization in the Mediterranean region from 1950 to 1995. Sophia-Antipolis, Priority Actions Programme, Blue Plan Papers*. Available at:

https://planbleu.org/sites/default/files/publications/cahier1_urbanisation_uk.pdf (accessed June 15, 2018).

UNEP/MAP (2012). *State of the Mediterranean Marine and Coastal Environment*. Athens: Barcelona Convention.

UNEP/MAP (2015). *Marine Litter Assessment in the Mediterranean 2015*. Nairobi: UN Environment.

UNESCO (2017). *Education for Sustainable Development Goals. Learning Objectives*. Paris: United Nations Educational and Cultural Organization.

Visbeck, M. (2018). Ocean science research is key for a sustainable future. *Nat. Commun.* 9:4. doi: 10.1038/s41467-018-03158-3

Volosciuk, C., Maraun, D., Semenov, V. A., Tilinina, N., Gulev, S. K., and Latif, M. (2016). Rising mediterranean sea surface temperatures amplify extreme summer precipitation in central europe. *Sci. Rep.* 6:7. doi: 10.1038/srep32450

Wen, W.-C., and Lu, S.-Y. (2013). Marine environmental protection knowledge, attitudes, behaviors, and curricular involvement of Taiwanese primary school students in senior grades. *Environ. Educ. Res.* 19, 600–619. doi: 10.1080/13504622.2012.717219

Wilson, M. (2004). *Constructing Measures: An Item Response Modeling Approach*. Mahwah, NJ: Lawrence Erlbaum.

WWF (2015). "Living blue planet report," in *Species, Habitats and Human Well-Being*, eds J. Tanzer, C. Phua, A. Lawrence, A. Gonzales, T. Roxburgh, and P. Gamblin (Switzerland: WWF).

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.