

## Navigating through ocean literacy gaps: an analysis of elementary school textbooks in Croatian education

Daria EZGETA-BALIĆ<sup>1</sup> and Nikola BALIĆ<sup>2</sup>

<sup>1</sup> Institute of Oceanography and Fisheries, Split, Croatia

<sup>2</sup> University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia

Corresponding author: Daria EZGETA-BALIĆ; [ezgeta@izor.hr](mailto:ezgeta@izor.hr)

Contributing Editor: Panayota KOULOURI

Received: 11 September 2023; Accepted: 01 December 2023; Published online: 02 February 2024

### Abstract

Ocean literacy (OL), defined as understanding the ocean's influence on us and our influence on the ocean, is crucial for protecting marine ecosystems and resources. This study analysed the integration of ocean literacy principles (OLP) and concepts in Croatian elementary education. The content of textbooks for grades 1-8 across subjects like Nature, Biology, Geography, Chemistry, and Physics was examined. In total, 7,520 pages across 55 textbooks were analysed. The results revealed that, although all seven OLPs were present, numerous concepts were absent or only partially addressed. Discrepancies with the recommended Ocean Literacy Scope and Sequence were identified, particularly in lower grades. The findings highlight gaps in incorporating ocean sciences topics into formal education. Enhanced inclusion of OL principles and concepts across subjects and grades would provide students with comprehensive knowledge about the ocean, empowering future generations to make informed decisions and take responsible actions regarding ocean sustainability and conservation. The findings highlight the necessity for collaboration among ocean scientists, educational specialists, and policymakers to incorporate OL into curricula and textbooks, thereby enhancing students' understanding of ocean sciences.

**Keywords:** science curriculum; marine education; textbooks; ocean literacy principles; content analysis; primary school; formal education; Adriatic Sea.

### Introduction

The importance of the ocean for life on Earth is well understood today. Notably, it is responsible for generating 50% of the planet's oxygen (Grégoire *et al.*, 2023). Still, concerns are also raised when we consider the various threats it faces, such as pollution, acidification, overfishing, and more (Amelia *et al.*, 2021; Coll *et al.*, 2008; Hönnisch *et al.*, 2012; Landrigan *et al.*, 2020). Consequently, preserving the ocean is vital for maintaining life on Earth (Costanza, 1999). The importance of the ocean is also emphasised by the United Nations General Assembly, which declared the Decade of Ocean Science for Sustainable Development (2021–2030) that is coordinated by IOC-UNESCO. In addition, the United Nations' Sustainable Development Goal 14 emphasises "Life Below Water", which focuses on the sustainable development of oceans, seas, and marine resources (United Nations, 2015). Increasing ocean literacy (OL) represents a key point for achieving those goals and objectives. Therefore, it is essential to educate future generations about the ocean and its processes. Each nation

and educational system is obligated to educate and raise generations who will know and understand the ocean and contribute to its future protection through their decisions. This process begins with formal education in schools, as the knowledge acquired during this time shapes students' perceptions and understanding of the environment (Palmer & Suggate, 2004), including the ocean.

To increase knowledge about the ocean, the concept of OL was developed around 20 years ago in the United States (Costa & Caldeira, 2018; Schoedinger *et al.*, 2005). OL has been defined as "an understanding of the ocean's influence on you, and your influence on the ocean" (Cava *et al.*, 2005). In the United States, educators and scientists have observed that formal education does not adequately include marine topics. As a result, the Ocean Literacy Framework (OLF) was developed, consisting of seven principles and numerous concepts to enhance students' understanding of the ocean's role by the time they graduate from high school (Table 1) (Halversen *et al.*, 2021). Although, OL topics have gained significant attention worldwide over the past two decades, and more recently in Croatia (Cheimonopoulou *et al.*,

**Table 1.** Overview of main ocean literacy principles and concepts used in this analysis, adopted and modified from Mogias *et al.* (2022).

Principles	Concepts
1. The Earth has one big ocean with many features	1a. one ocean, seven basins, 70% of planet 1b. geological features of the seafloor 1c. ocean circulation 1d. sea level changes caused by tides, plate tectonics, temperature of water 1e. properties of water 1f. water cycle 1g. connection of the ocean to all watersheds 1h. large and finite ocean, limited resources
2. The ocean and life in the ocean shape the features of Earth	2a. Earth materials originate in ocean 2b. sea level changes shape the land surface 2c. erosion in coastal areas 2d. carbon cycle, dissolved carbon used by sea organisms 2e. tectonic activity, sea level changes, force of waves influence the coast
3. The ocean is a major influence on weather and climate	3a. interaction of oceanic and atmospheric processes controls weather and climate 3b. absorbs most of solar radiation 3c. heat exchange between ocean and atmosphere, El Nino, La Nina 3d. most rain from tropical ocean, evaporated water from warm seas, energy for hurricanes and cyclones 3e. carbon cycle, primary productivity in ocean 3f. ocean absorbs, stores and moves heat, carbon, waste 3g. changes in ocean-atmosphere system result in climate change
4. The ocean made Earth habitable	4a. most oxygen on earth from photosynthesis in ocean 4b. ocean is the cradle of life 4c. provides water, oxygen, nutrients
5. The ocean supports a great diversity of life and ecosystems	5a. ocean life ranges in size 5b. microbes the most important primary producers 5c. most major groups of organisms in ocean 5d. important relationships among organisms 5e. most of the living space in ocean, unique ecosystems 5f. ocean life not evenly distributed due to abiotic factors 5g. deep ecosystems independent of sunlight 5h. vertical zonation pattern along coast and in open ocean 5i. estuaries
6. The ocean and humans are inextricably interconnected	6a. affects every human life, freshwater, most oxygen, moderates climate 6b. provides food, medicine, mineral and energy resources, transportation, jobs, national security 6c. inspiration, recreation, discovery 6d. humans affect ocean, laws, resource management, pollution, physical modifications, removed most large invertebrates from ocean 6e. changes in ocean temperature and pH due to human activities 6f. most human population in coastal areas, susceptible to natural hazards from ocean 6g. individual and collective actions for ocean protection
7. The ocean is largely unexplored	7a. less than 5% of ocean explored 7b. exploration, experimentation to better understand ocean systems 7c. should understand ocean resources' potential 7d. new technologies to explore ocean 7e. develop models to understand ocean complexity 7f. interdisciplinary scientific approach in ocean exploration

2022; Koulouri *et al.*, 2022; Mokos *et al.*, 2020), it is still unknown to what extent these topics are represented in formal education in many countries, including Croatia. In the context of Croatia, where the Adriatic Sea forms an integral part of the country's identity and economy (European Commission, 2023), OL education becomes even more important. Therefore, integrating the main Ocean Literacy Principles (OLPs) into educational practices and textbooks is crucial for fostering an ocean-literate society (Tran *et al.*, 2010).

In Croatia, education is recognised as a fundamental constitutional right. Elementary education is mandatory for children aged 6 to 14 and provided at no cost to students (Official Gazette, 2008). The elementary schooling process spans a duration of eight years and is structured into two distinct levels. In grades 1-4, instruction is typically provided by a single teacher for most subjects, which include mandatory subjects such as Mathematics, Croatian language, Nature and Society, Visual art, Music education, and Physical education. Additionally, there are separate teachers for foreign language instruction (English) and two optional subjects: Informatics and Religious Studies. Grades 5 to 8 encompass a range of subjects that are taught by specialized teachers. The mandatory subjects include Nature, Biology, Chemistry, Geography, Physics, Informatics, History, English language, Mathematics, Croatian language, Visual arts, Music education, and Physical education. Various optional subjects, such as Religious studies and foreign languages, are available for students.

The Croatian school system supports textbook-led instruction. According to Croatian legislation, all textbooks and workbooks must be approved by the Ministry of Science and Education. Textbooks must be evaluated by an expert panel that assesses their alignment with the subject curriculum. This evaluation process involves a thorough examination of the textbooks to ensure their compatibility with the educational objectives and requirements set forth in the curriculum. The expert panel reviews the content of the textbooks, structure, and pedagogical approach, considering the specific learning outcomes outlined in the curriculum (e.g., Official Gazette, 2019a; b). The evaluation process determines whether the textbooks adequately cover the required topics, provide accurate and up-to-date information, and present the content clearly and coherently. Only textbooks and workbooks that have passed this strict procedure can be used for teaching as they meet all curriculum standards.

In Croatian schools, OL topics are taught in subjects like Nature and Society, Nature, Biology, Chemistry, Geography, and Physics. In addition to being incorporated into formal educational curricula, OL initiatives for school-aged children encompass a wide range of stakeholders, including universities, research institutes, associations, Non-Governmental Organisations (NGOs), aquaria, marine national parks, and enthusiastic individuals. Unlike the analysis of the presence of ocean-related topics in formal education, it is more challenging to track activities related to other organisations, and their availability is not evenly distributed geographically. A recent

survey (Seys *et al.*, 2022) revealed that students are more likely to encounter news about the ocean through social media platforms than through school-based channels. Although, in their survey, high school students were engaged with higher accessibility to social media, this could still also be due to the lack of the OL topic in formal education. When testing OL knowledge in the elementary schools of three Mediterranean countries, Italy, Greece, and Croatia, students showed moderate knowledge of ocean sciences topics, albeit accompanied by several misconceptions (Mogias *et al.*, 2019).

In observing the integration of OL in educational materials and curricula, studies worldwide have indicated a disparity in OL presentation across various educational systems (e.g., Chang *et al.*, 2021; Freitas *et al.*, 2022; Mogias *et al.*, 2021). Research in Greece has revealed a considerable emphasis on the anthropocentric views of the ocean, while other principles are less represented (Mogias *et al.*, 2021). In Canada, formal education has shown an insufficient incorporation of OL (McPherson *et al.*, 2018). India's educational curriculum has also demonstrated gaps, with particular OL principles not being covered (Chang *et al.*, 2021), while in the United States variations exist in which OLPs are emphasised within textbooks (Chang *et al.*, 2021). These findings point to a broader pattern where OL education is patchy at best – reinforcing the need for a dedicated approach towards a more comprehensive inclusion of marine themes within global educational frameworks.

Considering that the early education phase, including elementary school, lays the foundation for children's understanding of the world around them, this study aimed to examine the occurrence of OL topics in the textbooks used at this educational level. By evaluating the content of these textbooks, we aim to analyse how comprehensively ocean-related concepts and knowledge are presented and explore potential gaps. The assessment of the representation of OL subjects in elementary school textbooks aims to offer insights into OL education's present condition and highlights potential improvement areas. This study seeks to identify the gaps in the OL coverage within educational materials. By doing so, we intend to inspire improvements that will provide students with the necessary ocean knowledge. This knowledge is critical for tackling sustainability challenges, safeguarding marine ecosystems, and fostering informed, responsible behaviours that contribute to the conservation of our interconnected ocean through formal education.

## Material and Methods

In Croatia, elementary school education is served by three leading textbook publishers. Additionally, certain publishers offer two different lines of textbooks for the same subject. Each teacher has autonomy in choosing the textbooks for their respective subjects, and textbooks for the same subject may not necessarily be from the same publisher across different years of schooling. The presence of multiple textbook publishers offers teachers the

flexibility to choose materials that suit their teaching style, preferences, and students' needs. However, this variety among publishers may result in differences in how content is organised and the depth with which topics are covered. As a result, this could lead to inconsistencies in the coherence of knowledge across different classrooms. Therefore, when presenting the results in this study, we distinguished between a) the presence of specific OL principles or concepts, regardless of the chosen textbook, and b) those that depend on the selected textbook. If one principle or concept was present in each textbook for the same subject, we consider that pupils will become familiar with it, regardless of the chosen publisher. In other cases, when a principle or concept is not present in all books for a particular subject, the pupils' familiarisation with a specific topic depends on the textbook chosen. This approach provides insights into the possibility of all students receiving a foundational understanding of key ocean-related topics, versus the potential disparities created by varied textbook selections.

For this study, all the published textbooks from three main publishers for the following subjects were analysed: i) Nature and Society, ii) Nature, iii) Biology, iv) Geography, v) Chemistry, and vi) Physics (Table 2). To reduce the burden of heavy school bags in lower grades, certain textbooks are structured into two distinct sections, with

one portion designated for the initial half of the academic year and another for the latter half. During the process of analysis, the books were examined collectively as they constitute a cohesive entity.

A total of 7,520 pages from 55 textbooks were analysed. Analysis was focused only on the OL topics in the textbook's content, in both the text and accompanying illustrations. However, the analysis did not consider the potential additional input provided by teachers, as this input could vary among teachers. Furthermore, only textbook material was analysed, while links to external resources were not considered, as accessibility to external material could differ among students. The content analysis performed in this study adopted the approach previously utilised by Mogias *et al.* (2022). The first part of the analysis was focused on the pages containing OL topics in the text and/or graphic illustrations in the textbook. Afterwards, the textbooks were analysed for the presence of 7 essential OLPs and 45 fundamental concepts, according to National Oceanic and Atmospheric Administration (NOAA) (2013). At the beginning of the content analysis, both authors were trained to recognise and analyse the presence of OL principles and concepts. Furthermore, after the authors' training, 300 pages from different textbooks were analysed by both authors. To assess the level of agreement between the two readers,

**Table 2.** Elementary education textbooks (grades 1-8) analysed in this study.

Grade	Students' age	Subject	Number of analysed textbooks
1	6/7	Nature and Society	5
2	7/8	Nature and Society	5
3	8/9	Nature and Society	5
4	9/10	Nature and Society	5
5	10/11	Nature	3
		Geography	3
6	11/12	Nature	3
		Geography	2
7	12/13	Biology	3
		Chemistry	3
		Physics	4
		Geography	2
8	13/14	Biology	3
		Chemistry	3
		Physics	4
		Geography	2

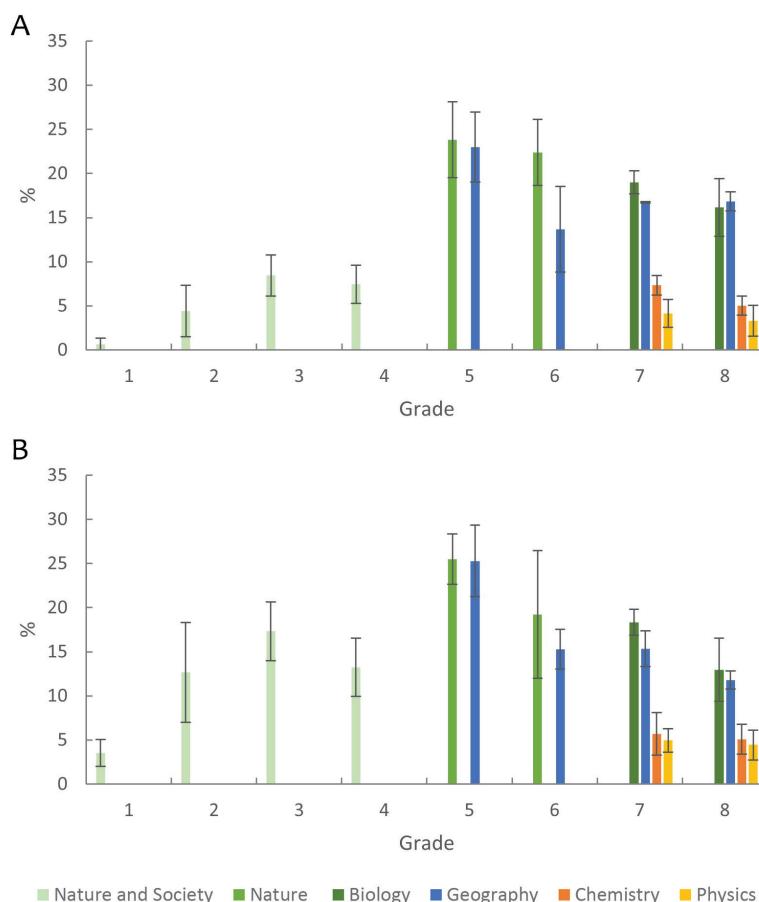
Krippendorff's alpha index (Hayes & Krippendorff, 2007) was calculated using the R package 'irr' (Version 0.84.1). The high Krippendorff's alpha index value ( $\alpha=0.995$ ) confirmed a high level of agreement between the two authors. Therefore, the first author completed the analysis. All the analyses performed were descriptive only, with frequency tables and graphs to present the occurrence of OL principles and concepts in the elementary school textbooks. To quantify the representation of OL topics within the textbooks analysed, we applied mean values and standard deviations to our results. The mean value, or average, was used to encapsulate the central tendency of the occurrence of OL topics within textbooks, providing a single figure that represents the typical extent of coverage. Standard deviation accompanied these mean values to convey the degree of variability, or spread, observed in the presence of OL topics across different textbooks. This information is important as it illustrates not only the average level of OL content inclusion but also the consistency of that inclusion, hence providing information on whether certain principles and concepts are universally emphasised or subject to significant variation depending on the textbook chosen.

## Results

Out of the 7,520 pages analysed, OL topics in the text

were present on 758 pages (10.1%). In total, 6967 pages had images or graphic content, of which 968 (13.9%) had ocean-related illustrations (Fig. 1). In the lower grades (1-4) in the Nature and Society textbooks, ocean-related topics were present on from  $0.7\pm0.7\%$  to  $8.4\pm2.3\%$  text pages and from  $3.5\pm1.5\%$  to  $17.3\pm3.3\%$  pages with ocean-related illustration. Among the higher-grade textbooks analysed, Nature/Biology and Geography had more pages where ocean-related topics were addressed, in both text and illustrations, than Chemistry and Physics (Fig. 1).

Content analysis showed that OLPs and concepts are not equally represented among different publishers or even among different textbook lines from the same publisher (Table 3). Although all OLPs were present in the analysed textbooks, differences in the occurrence of OL principles were evident (Figs 2 and 3). OLP 6 and 1 were the best represented mainly in Geography in higher grades, and Nature and Society, the only subject analysed in the lower grades. In OLP 6, the best-represented concepts were 6b and 6d, while in OLP 1 the best-represented concepts were 1b, 1c and 1d. OLP 5 was the third best represented in the analysed textbooks, mostly Nature and Biology, with OL concept 5d being the best-represented concept overall. OLP 7 was the most underrepresented in all the analysed textbooks. In summary, 27 OL concepts were covered regardless of the chosen textbook; coverage of an additional 15 OL concepts de-



**Fig. 1:** Mean contribution of pages with ocean-related topics in the text (A) and illustration (B) in the Croatian elementary school textbooks. Error bars represent the standard deviation among different publishers or textbook lines.

**Table 3.** Number of OL principles and concepts mentioned in text in the Croatian elementary science textbooks.

Grade	Subject	Covered regardless of the chosen textbook		Coverage depends on the selected textbook		Not mentioned in any textbook	
		OL principles	OL concepts	OL principles	OL concepts	OL principles	OL concepts
1	Nature and Society	0	0	1	2	6	43
2	Nature and Society	1	1	3	9	4	35
3	Nature and Society	2	4	4	13	3	28
4	Nature and Society	3	5	5	20	2	20
	Nature	2	5	6	17	1	23
5	Geography	6	17	4	8	0	20
	<b>Total</b>	<b>6</b>	<b>19</b>	<b>5</b>	<b>12</b>	<b>0</b>	<b>14</b>
	Nature	4	10	6	7	1	28
6	Geography	3	8	1	2	4	35
	<b>Total</b>	<b>4</b>	<b>12</b>	<b>6</b>	<b>7</b>	<b>1</b>	<b>26</b>
	Biology	1	1	5	9	2	35
	Geography	5	12	7	12	0	11
7	Chemistry	2	4	5	9	2	32
	Physics	1	1	4	6	2	38
	<b>Total</b>	<b>5</b>	<b>15</b>	<b>7</b>	<b>17</b>	<b>0</b>	<b>13</b>
	Biology	3	4	5	14	2	27
	Geography	5	13	6	10	1	22
8	Chemistry	1	1	5	11	2	33
	Physics	1	1	4	7	3	37
	<b>Total</b>	<b>6</b>	<b>18</b>	<b>7</b>	<b>15</b>	<b>0</b>	<b>12</b>

pended on the selected textbook, while 3 OL concepts were not mentioned (5i, 7e, and 7f).

Considering that selecting specific textbooks can lead to different representations of certain concepts and principles, a detailed alignment with the Ocean Literacy Scope and Sequence (National Marine Educators Association (NMEA), 2010) was not possible. Still, the data obtained pointed toward a low representation of certain concepts (Table 4). The highest discrepancy in alignment was recorded in the first two grades where, according to NMEA (2010), 27 concepts need to be at least mentioned. The Nature and Society textbooks analysed from the first two grades revealed that only one concept was mentioned, regardless of the chosen textbook; nine more depended on the selected textbook, while the other concepts were not introduced in any textbook from the first two grades.

In total, 35 OL concepts need to be covered from grade 3 to grade 5 according to NMEA (2010). In Croatian textbooks, 20 OL concepts were present regardless of the chosen textbook, out of which 17 aligned with the Scope and Sequence, while three concepts (1d, 2b, and 2e) were not mentioned in the Scope and Sequence for those grades. Two concepts, namely 1d and 2b, were not in the Scope and Sequence for grades 1 and 2, while concept 2e was in the Scope and Sequence for those grades but not represented in the textbooks for those grades. Additionally, the representation of 17 more concepts

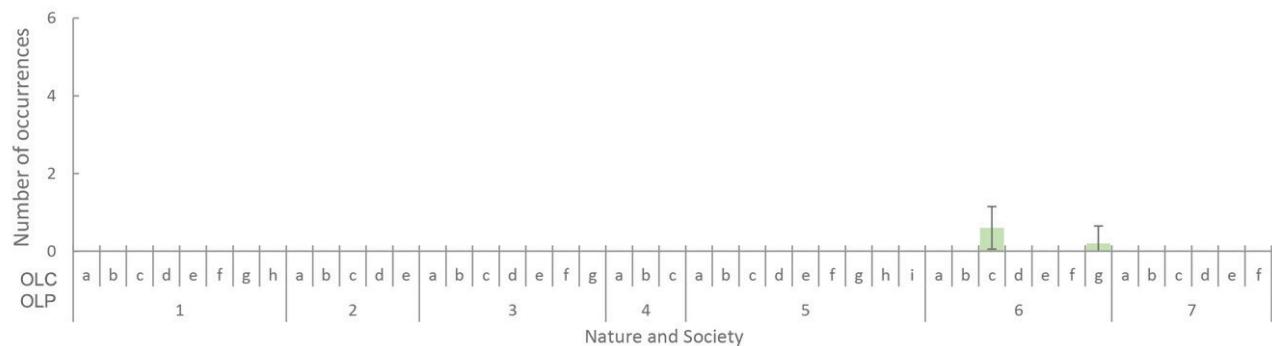
depends on the selected textbook and could potentially result in the representation of 37 concepts. Although the number of concepts exceeds the recommendations outlined in the Scope and Sequence, there are five topics (1h, 3c, 3f, 4c, and 5h) that are not included in the suggested Scope and Sequence for those specific grades.

Furthermore, NMEA (2010) suggests that 41 OL concepts need to be covered in the last grades of elementary school. In Croatian textbooks, from grade 6 to grade 8, 22 concepts were covered regardless of the chosen textbook, out of which 21 aligned with the Scope and Sequence, while one concept (4b) was not mentioned in the Scope and Sequence for those grades but for lower grades. Additionally, the representation of 16 more concepts depends on the selected textbook and could potentially result in the representation of 38 concepts. Again, concepts 1h and 4c mentioned in those grades are not suggested in the Scope and Sequence for those or lower grades. The overall best-case scenario of OL concepts occurring in the analysed textbook is presented in Figure 4.

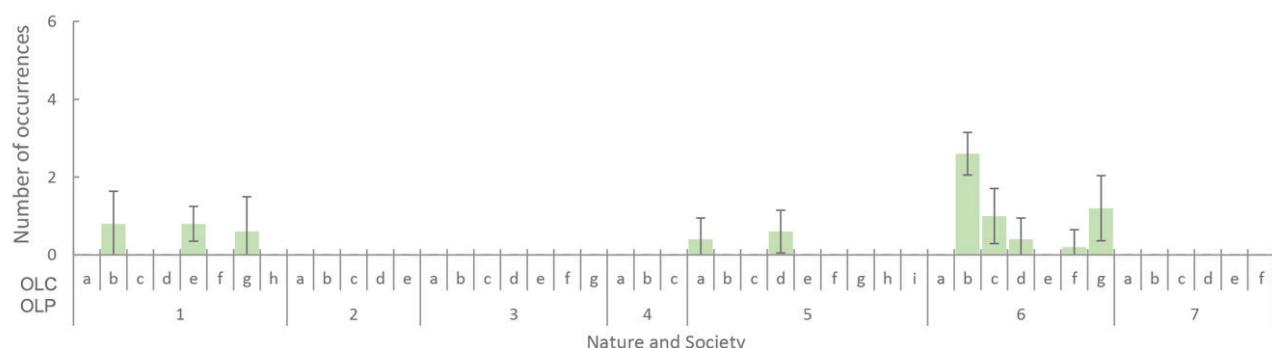
Besides the discrepancy in the Ocean Literacy Scope and Sequence, unbalanced representative examples from terrestrial and marine ecosystems were noticed. Students might understand that marine ecosystems are less important and have lower biodiversity than terrestrial ecosystems. Furthermore, students will become more familiar with terrestrial plants and animals, including their life

**A**

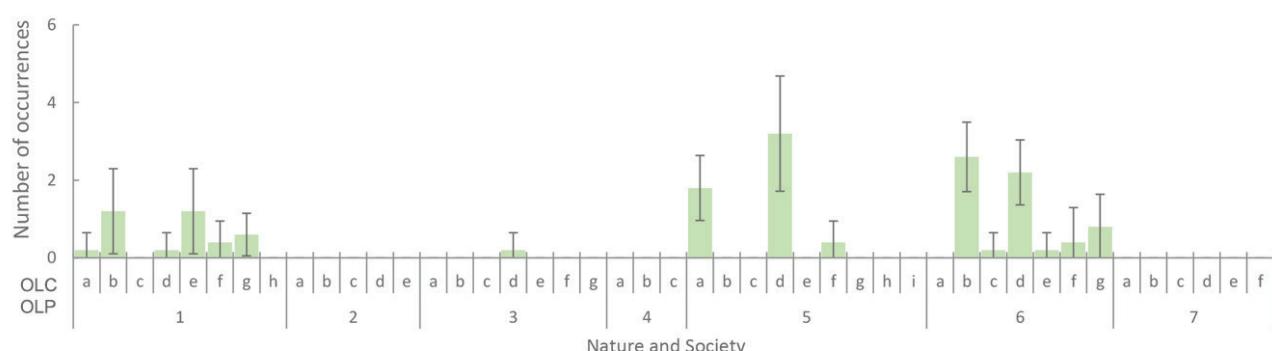
Grade 1

**B**

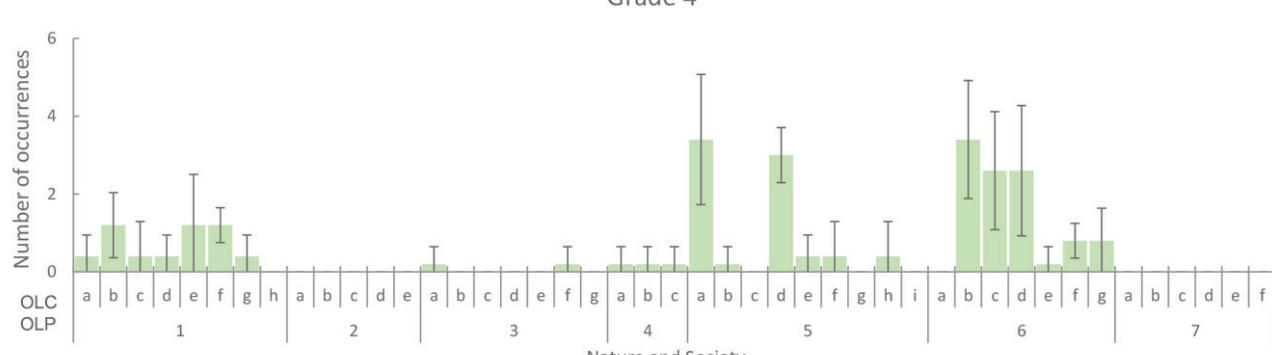
Grade 2

**C**

Grade 3

**D**

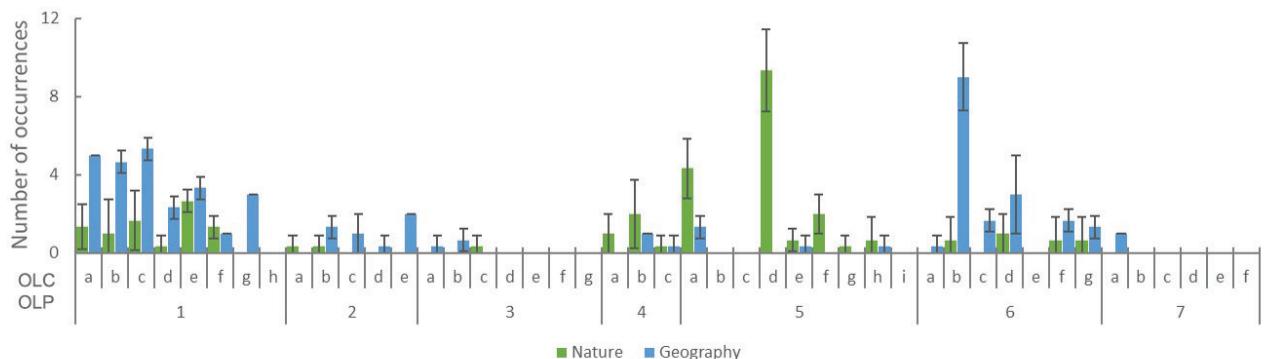
Grade 4



**Fig. 2:** Presence of ocean literacy principles (OLP) and concepts (OLC) in lower grades of the elementary school science textbooks in Croatia (grades 1-4). Results are presented as average occurrence and standard deviation of books analysed for each grade.

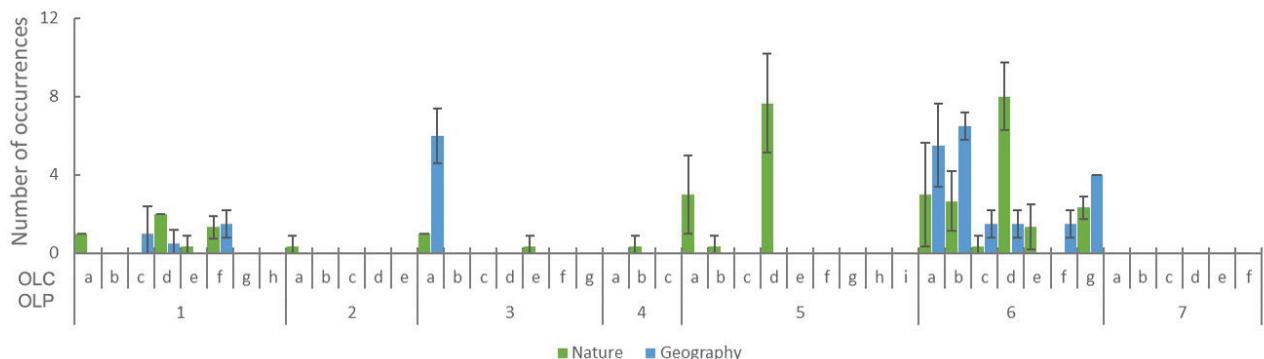
A

Grade 5



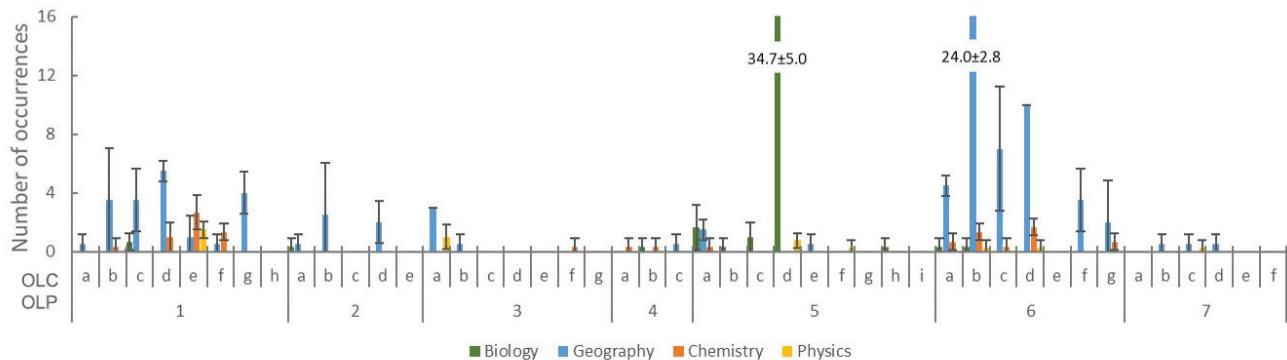
B

Grade 6



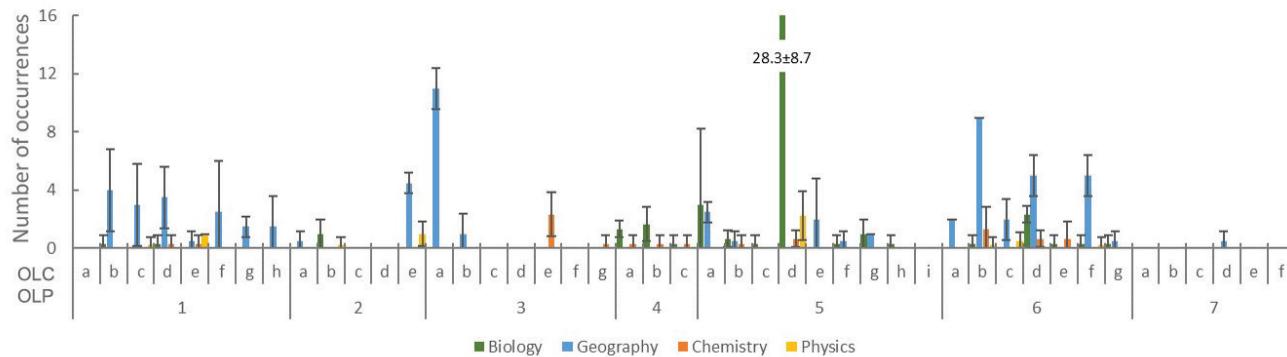
C

Grade 7



D

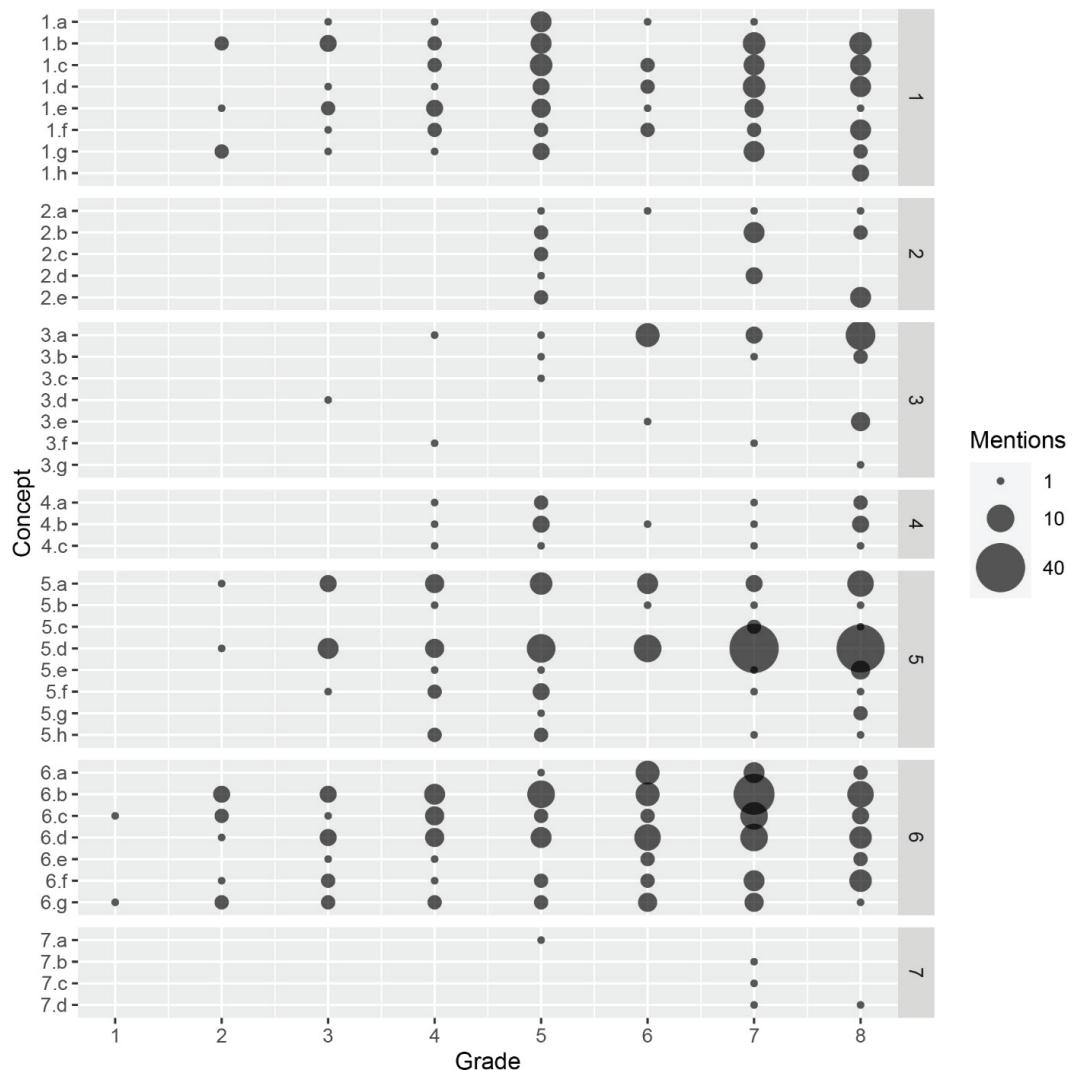
Grade 8



**Fig. 3:** Presence of ocean literacy principles (OLP) and concepts (OLC) in higher grades of the elementary school science textbooks in Croatia (grades 5-8). Results are presented as average occurrence and standard deviation of books analysed for each grade.

**Table 4.** Comparison of OL principles and concepts suggested by NMEA (2010) for elementary education and those present in the Croatian science textbooks for the elementary school (P – principle, C – concept, Yes – indicates concept covered regardless of the chosen textbook, Partially – indicates that coverage of certain concepts depends on the chosen textbook).

			Grades 1 – 2			Grades 3 – 5			Grades 6 – 8		
P	C	Scope & Sequence	Yes	Partially	Scope & Sequence	Yes	Partially	Scope & Sequence	Yes	Partially	
OL1	1a	+			+	+		+	+		
	1b	+		+	+	+		+	+		
	1c	+			+	+		+	+		
	1d					+		+	+		
	1e	+		+	+	+		+	+		
	1f	+			+	+		+	+		
	1g	+		+	+	+		+	+		
	1h						+			+	
OL2	2a				+		+	+		+	
	2b					+		+		+	
	2c	+			+		+	+			
	2d	+			+		+	+		+	
OL3	2e	+				+		+		+	
	3a	+			+		+	+		+	
	3b	+			+		+	+			
	3c						+	+			
	3d	+			+		+	+			
	3e							+		+	
	3f						+	+		+	
OL4	3g				+		+	+		+	
	4a				+		+	+		+	
	4b				+	+				+	
	4c					+				+	
OL5	5a	+		+	+	+		+	+		
	5b				+		+	+		+	
	5c	+			+	+		+		+	
	5d	+		+	+	+		+	+		
	5e				+		+	+		+	
	5f	+			+	+		+		+	
	5g	+			+		+	+		+	
	5h						+	+		+	
	5i				+		+				
	6a	+			+		+	+		+	
OL6	6b	+	+		+	+		+		+	
	6c	+		+	+	+		+		+	
	6d	+		+	+	+		+		+	
	6e	+			+		+	+			
	6f	+		+	+	+		+		+	
	6g	+		+	+	+		+		+	
	7a				+	+		+			
OL7	7b	+			+			+		+	
	7c	+			+			+		+	
	7d				+			+		+	
	7e										
	7f	+			+			+			
Total	27	1	9	35	20	17	41	22	16		



**Fig. 4:** Best-case scenario of presence of ocean sciences topics according to OL principles and concepts in the elementary school textbooks in Croatia.

cycle and their importance for ecosystem functioning and balance. For example, the importance of phytoplankton for life on Earth needs to be adequately emphasised, as most of the content regarding photosynthesis is explained through terrestrial examples.

## Discussion

While all the OLPs are present in the elementary school textbooks in Croatia, there is a notable lack of coverage for many OL concepts. Some of these concepts are either completely absent or addressed only partially; therefore, they do not cover the full range of ocean-related topics suggested by NOAA (2013). This situation is not unique to Croatia, as similar gaps were observed in school textbooks and educational curricula in other countries such as Greece (Mogias *et al.*, 2021, 2022), Canada (McPherson *et al.*, 2018), Fiji (Lal, 2017), India, and the United States (Chang *et al.*, 2021). These countries also face challenges in integrating all ocean concepts into formal education.

The most prevalent OLP in Croatian textbooks is

OLP 6, which highlights the interconnection between the ocean and humans. Interestingly, this principle is also strongly represented in the textbooks and curricula of other countries (Chang *et al.*, 2021; McPherson *et al.*, 2018; Mogias *et al.*, 2021). Mogias *et al.* (2021) found that concepts describing how the ocean impacts human life and its benefits were more evident in Greek textbooks under OLP 6, suggesting an anthropocentric perspective. Contrarily, information and principles concerning human impacts on the ocean and the knowledge required for decision-making were less represented. While this trend is also partially evident in Croatian textbooks, this research confirms that textbooks emphasise the negative effects of human activities on the environment and highlight individual and collective actions for marine conservation and environmental conservation in general. The insufficient representation of concepts related to changes in ocean temperature and pH resulting from human activities, together with the low occurrence of OLP 3 concepts in general that emphasise the important role of the ocean on weather and climate in the analysed textbooks, raises concerns, particularly in light of the pressing issues of climate change and global warming (Coma *et al.*, 2009;

Hansen *et al.*, 2006).

Following OLP 6, the next most represented principles in Croatian textbooks are OLP 1, which states that the Earth has one interconnected ocean with various features, and OLP 5, which emphasises the ocean's role in supporting diverse life and ecosystems. Similar patterns of representation can be observed in other countries. In Greece, Canada, and India, OLP 1 also ranks second (Chang *et al.*, 2021; McPherson *et al.*, 2018; Mogias *et al.*, 2021), while in the United States, it is OLP 5 (Chang *et al.*, 2021). OLP 1 is well represented, especially in the Geography textbooks, where it is extensively addressed. However, there is a lack of information that, despite its vastness, the ocean has limited resources. That is an important issue, considering that lots of fish stocks are at risk of overexploitation (Coll *et al.*, 2008; Tsikliras *et al.*, 2015). As for OLP 5, although it is the third most represented principle, not all relevant concepts are adequately covered. The focus tends to lean towards presenting unique examples of life cycles, adaptations, and relationships among organisms in the ocean, which naturally captivates children's interest due to the intriguing nature of these organisms that are less accessible and visible than those on land. Unfortunately, essential information such as the significance of microbes, the ecosystem independent from sunlight, and the significance of equally important estuaries is barely mentioned. A similar situation was observed in Greek textbooks, and Mogias *et al.* (2022) suggested that the observed lack of emphasis may be attributed to the perception that the information is not as relatable or accessible to humans, leading to a prioritisation of other OLP 5 concepts.

The remaining three principles, OLP 2, OLP 4, and OLP 7, are the least represented in textbooks, with OLP 7 being barely mentioned. The limited information on OLP 4 could be reflected in the students' knowledge that life originated in the ocean and that primitive single-celled organisms, ancestors of today's single-cell algae and phytoplankton, produced oxygen long before land plants even existed. When considering the oxygen cycle over the geological time scales, the ocean is responsible for 6 of 7 of the breaths that humans take, emphasising the ocean's crucial role in shaping life as we know it today (Grégoire *et al.*, 2023). Considering the United Nations Ocean Decade's motto, "the science we need for the ocean we want", which advocates investing in knowledge and advancing ocean research, it is alarming that OLP 7, which emphasises the largely unexplored nature of the ocean and the need to enhance research methods and collaboration, receives minimal attention in textbooks. The study conducted by Mogias *et al.* (2021) also identified a lack of emphasis on OLP 4 and OLP 7 in Greek textbooks. A similar observation was made in the educational curriculum of Canada, where OLP 4 had the lowest level of representation, and OLP 7 was not mentioned at all (McPherson *et al.*, 2018). OLP 7 was also the least represented in the curriculum of the USA and India, while OLP 4 was not mentioned in the Indian educational curriculum (Chang *et al.*, 2021). Addressing those principles better is of great importance to improve students' understanding

of the ocean's critical contributions to life on Earth and the importance of future scientific research of the ocean.

While there is only limited research on the presence of OL topics in textbooks and educational curricula, recent studies have focused on assessing students' direct knowledge of marine themes using various surveys and instruments (e.g., Cheimonopoulou *et al.*, 2022; Koulouri *et al.*, 2022; Lin *et al.*, 2020; Mogias *et al.*, 2019; Mokos *et al.*, 2020; Realdon *et al.*, 2019). Although the understanding of marine topics varies across studies and countries, it is generally observed that students do possess moderate knowledge about marine themes. The results of a research study conducted among students aged 10 to 16 in different countries throughout the Mediterranean Basin revealed that Croatian and Italian students exhibited the highest frequencies of correct answers and achieved the highest scores in terms of their ocean content knowledge (Koulouri *et al.*, 2022). However, it is important to note that this still represents only moderate knowledge, indicating the need for further improvements within the educational system.

Formal education is not the sole means of increasing OL, as research has shown that students obtain information from various sources such as museums, aquariums, social media platforms, and various media outlets (Seys *et al.*, 2022; Tsai *et al.*, 2023). The quality and accuracy of such information depend on its source, highlighting the importance of considering the reliability and credibility of these sources. Considering the immense importance of the ocean for life on Earth, ensuring that students receive comprehensive OL education throughout their formal education is crucial. In addition to formal education, non-formal educational interventions and activities led by scientists and ocean experts make valuable contributions to enhancing OL, for both students and teachers (e.g., Mokos *et al.*, 2020). In Croatia, initiatives like the Science Festival, the European Researchers' Night ([www.jaistrazujem.hr](http://www.jaistrazujem.hr)), the Future Sea project ([www.futuresea.eu](http://www.futuresea.eu)), and other individual activities engage researchers in schools and present additional sources of ocean-related topics with different hands-on experiences for students. The Future Sea project offered the authors of this study an opportunity to collaborate with numerous teachers and professors in urban and rural areas, including small island schools. All participants recognised the lack of ocean-related themes and resources in formal education. Having identified this need, the authors published "Ocean in Our Hands: A Guide to Ocean Literacy", specifically designed for teachers who wish to enhance their knowledge about the ocean and teach their students about it more efficiently (Ezgeta-Balić *et al.*, 2023). Through interventions like these, educators can bridge the gap in formal education and provide students with a more comprehensive understanding of the ocean.

However, insufficient coverage of ocean-related topics in Croatian textbooks is a concern that needs attention. The absence of certain OLPs and the inconsistency in coverage by different publishers highlight the need for improvement and work towards a broader inclusion of ocean-related themes, regardless of the choice of

textbooks used. This research suggests that the current curriculum needs to be modified to incorporate more ocean-related content into the mandatory curriculum and to optimise the content without overburdening students. Currently, the Croatian Ministry of Science and Education is starting the implementation of the Experimental Program “Elementary school as a full-day school - Balanced, fair, efficient and sustainable system of upbringing and education” (Ministry of Science and Education (MSE), 2023) with a new curriculum, and new books for some subjects will be published. Therefore, it will be interesting to analyse new books for the occurrence of OLP in the future and compare it with this study.

In conclusion, collaboration among educators, curriculum developers, and policymakers is essential to achieve effective integration of OLPs into the curriculum. By including more topics and concepts about the ocean, we can encourage a deep understanding of its importance and empower students to act responsibly towards the ocean and the environment as a whole. By increasing students’ OL, we educate future generations to make informed decisions regarding the management and conservation of ocean resources.

## Acknowledgements

The authors are grateful to two publishers, Školska knjiga and Profil Klett, for granting free access to educational materials. They extend their appreciation to Professor Andreja Dorić, the science subject professor at Elementary school Darda, for her valuable assistance. This work was funded by the Croatian Ministry of Science and Education through the multiannual institutional financing program.

## References

Amelia, T.S.M., Khalik, W.M.A.W.M., Ong, M.C., Shao, Y.T., Pan, H.-J. *et al.*, 2021. Marine microplastics as vectors of major ocean pollutants and its hazards to the marine ecosystem and humans. *Progress in Earth and Planetary Science*, 8 (1), 12.

Cava, F., Schoedinger, S., Strang, C., Tuddenham, P., 2005. *Science content and standards for ocean literacy. A report on ocean literacy*. [https://coexploration.org/oceanliteracy/documents/OLit2004-05\\_Final\\_Report.pdf](https://coexploration.org/oceanliteracy/documents/OLit2004-05_Final_Report.pdf) (Accessed 30 January 2024).

Chang, C.-C., Hirenkumar, T.C., Wu, C.-K., 2021. The concept of ocean sustainability in formal education - comparative ocean literacy coverage analysis of the educational standards of India and the USA. *Sustainability*, 13 (8), 4314.

Cheimonopoulou, M., Koulouri, P., Previati, M., Realdon, G., Mokos, M. *et al.*, 2022. Implementation of a new research tool for evaluating Mediterranean Sea Literacy (MSL) of high school students: A pilot study. *Mediterranean Marine Science*, 23 (2), 302-309.

Coll, M., Libralato, S., Tudela, S., Palomera, I., Pranovi, F., 2008. Ecosystem overfishing in the ocean. *PLOS ONE*, 3 (12), e3881.

Coma, R., Ribes, M., Serrano, E., Jiménez, E., Salat, J. *et al.*, 2009. Global warming-enhanced stratification and mass mortality events in the Mediterranean. *Proceedings of the National Academy of Sciences*, 106 (15), 6176-6181.

Costa, S., Caldeira, R., 2018. Bibliometric analysis of ocean literacy: An underrated term in the scientific literature. *Marine Policy*, 87, 149-157.

Costanza, R., 1999. The ecological, economic, and social importance of the oceans. *Ecological Economics*, 31 (2), 199-213.

European Commission, Directorate-General for Maritime Affairs and Fisheries, Joint Research Centre, Borriello, A., Calvo Santos, A. *et al.*, 2023. *The EU Blue Economy Report 2023*. Publications Office of the European Union. <https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1/language-en> (Accessed 30 January 2024).

Ezgeta-Balić, D., Zorica, B., Balić, N., 2023. *Ocean u našim rukama: Vodič kroz oceansku pismenost*. Institute of Oceanography and Fisheries, Split, Croatia, 55 pp. (in Croatian).

Freitas, C., Bellgrove, A., Venzo, P., Francis, P., 2022. Towards a 2025 National Ocean Literacy Strategy: current status and future needs in primary education. *Frontiers in Marine Science*, 9, 883524.

Grégoire, M., Oschlies, A., Canfield, D., Castro, C., Ciglenečki, I. *et al.*, 2023. *Ocean oxygen: the role of the ocean in the oxygen we breathe and the threat of deoxygenation. Future Science Brief No. 10 of the European Marine Board*. [https://www.marineboard.eu/sites/marineboard.eu/files/public/EMB\\_FSB10\\_Ocean\\_oxygen\\_Web-150DPI\\_V7.pdf](https://www.marineboard.eu/sites/marineboard.eu/files/public/EMB_FSB10_Ocean_oxygen_Web-150DPI_V7.pdf) (Accessed 30 January 2024).

Halversen, C., Schoedinger, S., Payne, D., 2021. *A handbook for increasing ocean literacy: tools for educators and ocean literacy advocates*. National Marine Educators Association, College Park, MD, 96 pp.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D.W. *et al.*, 2006. Global temperature change. *Proceedings of the National Academy of Sciences*, 103 (39), 14288-14293.

Hayes, A.F., Krippendorff, K., 2007. Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures*, 1 (1), 77-89.

Hönisch, B., Ridgwell, A., Schmidt, D.N., Thomas, E., Gibbs, S.J. *et al.*, 2012. The geological record of ocean acidification. *Science*, 335 (6072), 1058-1063.

Koulouri, P., Mogias, A., Mokos, M., Cheimonopoulou, M., Realdon, G. *et al.*, 2022. Ocean literacy across the Mediterranean Sea basin: evaluating middle school students’ knowledge, attitudes, and behaviour towards ocean sciences issues. *Mediterranean Marine Science*, 23 (2), 289-301.

Lal, N., 2017. Oceans and rivers literacy in Fiji’s social science curriculum: an analysis of primary school textbooks. *Pacific Journal of Education*, 1 (1), 47-56.

Landrigan, P.J., Stegeman, J.J., Fleming, L.E., Allemand, D., Anderson, D.M. *et al.*, 2020. Human health and ocean pollution. *Annals of Global Health*, 86 (1), 151.

Lin, Y.-L., Wu, L.-Y., Tsai, L.-T., Chang, C.-C., 2020. The beginning of marine sustainability: preliminary results of measuring students’ marine knowledge and ocean literacy. *Sustainability*, 12 (17), 7115.

McPherson, K.L., Wright, T., Tyedmers, P.H., 2018. Examining

ing the Nova Scotia science curriculum for international Ocean Literacy Principle inclusion. *International Journal of Learning, Teaching and Educational Research*, 17 (11), 1-16.

Mogias, A., Boubonari, T., Realdon, G., Previati, M., Mokos, M. et al., 2019. Evaluating ocean literacy of elementary school students: preliminary results of a cross-cultural study in the Mediterranean Region. *Frontiers in Marine Science*, 6, 396.

Mogias, A., Boubonari, T., Kevrekidis, T., 2021. Examining the presence of ocean literacy principles in Greek primary school textbooks. *International Research in Geographical and Environmental Education*, 30 (4), 314-331.

Mogias, A., Boubonari, T., Kevrekidis, T., 2022. Tracing the occurrence of ocean sciences issues in Greek secondary education textbooks. *Mediterranean Marine Science*, 23 (2), 310-320.

Mokos, M., Realdon, G., Zubak Čižmek, I., 2020. How to increase ocean literacy for future ocean sustainability? The influence of non-formal marine science education. *Sustainability*, 12 (24), 10647.

Ministry of Science and Education (MSE), 2023. *Eksperimentalni program - Osnovna škola kao cjelodnevna škola: Uravnotežen, pravedan, učinkovit i održiv sustav odgoja i obrazovanja*. Ministry of Science and Education, 73 pp. (in Croatian).

National Marine Educators Association (NMEA), 2010. *Ocean Literacy Scope and Sequence for Grades K-12*. <https://www.marine-ed.org/ocean-literacy/scope-and-sequence> (Accessed 30 January 2010).

National Oceanic and Atmospheric Administration (NOAA), 2013. *Ocean Literacy: the essential principles and fundamental concepts of ocean sciences for learners of all ages*. National Oceanic and Atmospheric Administration, College Park, MD, 11 pp.

Official Gazette, 2008. *Zakon o Odgoju i Obrazovanju u Osnovnoj i Srednjoj Školi*, 87/2008. [https://narodne-novine.nn.hr/clanci/sluzbeni/2008\\_07\\_87\\_2789.html](https://narodne-novine.nn.hr/clanci/sluzbeni/2008_07_87_2789.html) (in Croatian) (Accessed 30 January 2024).

Official Gazette, 2019a. *Odluka o Donošenju Kurikuluma Za Nastavni Predmet Geografije Za Osnovne Škole i Gimnazije u Republici Hrvatskoj*, 7/2019. [https://narodne-novine.nn.hr/clanci/sluzbeni/2019\\_01\\_7\\_145.html](https://narodne-novine.nn.hr/clanci/sluzbeni/2019_01_7_145.html) (in Croatian). (Accessed 30 January 2024).

Official Gazette, 2019b. *Odluka o Donošenju Kurikuluma Za Nastavni Predmet Biologije Za Osnovne Škole i Gimnazije u Republici Hrvatskoj*, 7/2019. [https://narodne-novine.nn.hr/clanci/sluzbeni/2019\\_01\\_7\\_149.html](https://narodne-novine.nn.hr/clanci/sluzbeni/2019_01_7_149.html) (in Croatian) (Accessed 30 January 2024).

Palmer, J.A., Suggate, J., 2004. The development of children's understanding of distant places and environmental issues: report of a UK longitudinal study of the development of ideas between the ages of 4 and 10 years. *Research Papers in Education*, 19 (2), 205-237.

Realdon, G., Mogias, A., Fabris, S., Candussio, G., Invernizzi, C. et al., 2019. Assessing ocean literacy in a sample of Italian primary and middle school students. *Rendiconti Online della Società Geologica Italiana*, 49, 107-112.

Schoedinger, S., Cava, F., Strang, C., Tuddenham, P., 2005. *Ocean literacy through science standards*. <https://coexploration.org/oceanliteracy/documents/workshopreport.pdf> (Accessed 30 January 2024).

Seys, J., Cox, L., Şahin Yücel, E., Ezgeta-Balić, D., Faimali, M., Garaventa, F. et al., 2022. *Marine Science Communication in Europe – A way forward. Future Science Brief 8 of the European Marine Board*. [https://www.marineboard.eu/sites/marineboard.eu/files/public/publication/EMB\\_FSB8\\_Marine\\_science\\_communication\\_in\\_Europe\\_Web.pdf](https://www.marineboard.eu/sites/marineboard.eu/files/public/publication/EMB_FSB8_Marine_science_communication_in_Europe_Web.pdf) (Accessed 30 January 2024).

Tran, L.U., Payne, D.L. Whitley, L., 2010. *Research on learning and teaching ocean and aquatic sciences*. National Marine Educators Association. Special Report #3. [https://www.coexploration.org/oceanliteracy/NMEA\\_Report\\_3/NMEA\\_2010-6-Learning.pdf](https://www.coexploration.org/oceanliteracy/NMEA_Report_3/NMEA_2010-6-Learning.pdf) (Accessed 30 January 2024).

Tsai, L.-T., Sasaki, T., Wu, C.-K., Chang, C.-C., 2023. Ocean literacy among Taiwanese and Japanese high school students. *Marine Policy*, 150, 105555.

Tsikliras, A.C., Dinouli, A., Tsirros, V.-Z., Tsalkou, E., 2015. The Mediterranean and Black Sea fisheries at risk from overexploitation. *PLOS ONE*, 10 (3), e0121188.

United Nations, 2015. *Transforming our world: the 2030 agenda for sustainable development*. <https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf> (Accessed 30 January 2024).