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Ocean literacy in Brazilian school curricula: An opportunity to improve coastal management and address coastal risks?

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ABSTRACT

Ocean literacy (OL) is defined as the understanding of the ocean's influence on human beings and vice versa. It aims to improve knowledge on marine environments, enabling citizens to make responsible decisions concerning marine-related issues. To this purpose, formal education mediated by curricula plays an important hole. Therefore, the goal of this study was to investigate both the presence (if the principle or concept were identified) and frequency of occurrence (number of times each principle or concept was found) of OL principles and concepts in Brazilian curricular documents at federal [Common National Curriculum Base (*Base Nacional Curricular Comum*–BNCC)] and regional [Brazilian Federative Curricular Guidelines (*Referenciais Curriculares das Unidades Federativas*–RCs)] levels. OL topics were mostly found in RCs than in the BNCC, especially concerning principle 1 (The Earth has one big ocean with many features). However, most of the concepts from principles 2 (The ocean and life in the ocean shape the features of the Earth), 4 (The ocean makes Earth habitable), and 5 (The ocean supports a great diversity of life and ecosystems) were poorly addressed, and there was no mention of principle 7 (The ocean is largely unexplored). Non-parametric statistics was performed and showed significant differences in the frequency of occurrence of OL principles and concepts among the RCs from the five Brazilian geographical regions (Kruskal-Wallis test, $p = 0.034$), as well as those from coastal and non-coastal areas (U-Mann-Whitney test, $p = 0.021$). Principal component analysis discriminated the Brazilian curricula from different geographical regions into two different groups. These clusters were formed by South-Southeast-Midwest regions and North-Northeast (Principal component 1 explained 99.33% of the total variation, with a 0.95 correlation with the frequency of OL principles and concepts in the RCs), showing certain heterogeneity among the RCs of the different Brazilian Federative Units. The results indicated that Brazilian curricula address more OL contents than do other countries. However, the representativeness of OL in Brazilian documents is below the recommended for a person to be considered ocean literate, especially for topics dealing with environmental risks in coastal zones. Furthermore, the inclusion of OL in classrooms will depend on the teacher's approach to the curricula, which, therefore, depends on their professional training to deal with the subject. An effort to improve curricula in terms of OL contents can be a helpful strategy to overcome one of the main challenges for social participation in a bottom-up management, the lack of information.

1. Introduction

Coastal zones (CZs) are located between terrestrial and marine environments and have some of the most valuable ecosystems on Earth in terms of biodiversity, productivity, and provision of ecosystem services to ensure human development and well-being (Kuijper, 2003; UNEP, 2006). Such services include recycling of nutrients and pollutants; protection against storms, floods, seawater intrusion, and coastal erosion; and provision of mineral and biological resources (deReynier et al., 2010; Golden et al., 2017; Suarez et al., 2014). The Brazilian coastal zone is a national heritage area (Brasil, 1988, 2004) with a length of 7500 km and area of about 514,000 km^2, besides being one of the largest CZs in the world (Marroni and Asmus, 2013). This region has unique ecosystems, including mangroves, coral reefs, dunes, sandy beaches, rocky shores, lagoons, estuaries, bays, marshes, and endemic species (Diegues, 1999; Miloslavich et al., 2011).

In Brazil, CZs concentrate about 40% of the Brazilian population, with a density of 105 inhabitants per km^2, which is near five times the

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national average of 20 inhabitants per km^2 (Marroni and Asmus, 2013). Despite its importance, this region undergoes many threats such as unplanned sprawl and industrialization; dumping of untreated domestic sewage and industrial waste into lagoons, bays, and beaches; destruction of mangroves, dunes, and beaches for construction of roads and touristic complexes; and intensification of oil and gas extraction (Diegues, 1999; Buruaem et al., 2013; Roth et al., 2016; Pinheiro and Silva, 2021). Besides the impact of land occupation, the environmental risk in CZs has been aggravated by climate changes (Adger et al., 2005; Roca et al., 2018; Suarez et al., 2014), of which effects include changes in ocean temperature, elevation of mean sea level, and acidification (IPCC, 2013).

In short, uncontrolled development, population growth, and climate change reduce the ability of CZs to provide ecosystem services and increase human exposure to environmental risk factors. Studies have shown that such conditions will worsen in the coming decades (Adger et al., 2005; Suarez et al., 2014), highlighting the need for governance systems that consider the interdependence between humans and nature to manage environmental risks in CZs (Crowder et al., 2006; Young et al., 2007). Governance forms vary with its goals and motivations, including top-down and bottom-up models. The first suggests a descending guidance of information flow and presupposes a disconnection between elaboration and implementation of public policies such as state government actions. The latter model assumes that stakeholders are active and decisive in establishing public policies.

In Brazil, policies, plans, and management programs in coastal areas of states and municipalities are framed by the National Coastal Management Plan (*Plano Nacional de Gerenciamento Costeiro*-PNGC). It establishes legal basis for integrated, decentralized, and participatory management of CZs and their resources (Wever et al., 2012). Decentralization of public policies allows increasing participation and active involvement of communities and other stakeholders outside the government in decision-making, planning, and management (Larson and Ribot, 2004). However, citizen participation in these processes is limited. Wever et al. (2012) highlighted that the greatest challenge in coastal management is promoting public participation, which can only be achieved by training citizens on problems and solutions to serve as active agents. In this respect, ocean literacy (OL) can stimulate social participation in governance processes and, therefore, contribute to implement bottom-up approaches (Barracosa et al., 2019; deReynier et al., 2010; Gerhardinger et al., 2009; McKinley and Fletcher, 2010; Rodriguez-Martínez and Ortiz, 1999).

The OL campaign emerged in the United States in the early 2000s from a movement organized by scientists, educators, and other groups interested in including topics related to marine environments into school curriculum. OL was defined as “understanding the ocean’s influence on humans and vice versa” (Ocean Literacy Network, 2020). It is expected that a person knowledgeable about the ocean should (1) understand fundamental concepts about ocean functioning, (2) speak meaningfully about marine environment-related issues, and (3) make informed and responsible decisions about the ocean and its resources (Ocean Literacy Network, 2020). Studies and intergovernmental reports have recommended including OL into school curricula to increase public awareness (Dupont and Fauville, 2017; Visbeck, 2018; Ryabinin et al., 2019; United Nations, 2018). However, only five studies have evaluated the presence of OL in school curricula. Castle et al. (2010) and Gough (2017) searched for words and themes related to ocean and marine environments in English and Australian school curricula, respectively. Hoffman and Barstow (2007) identified OL in Earth Science Education Standards in all 50 US states. McPherson et al. (2018a) noted OL in High School Science Courses in Nova Scotia, Canada. Finally, Chang et al. (2021) observed OL in the Indian National Standards. The results of these studies demonstrated the low presence of OL in school curricula.

Studies about OL in BRICS countries (Brazil, Russia, India, China, and South Africa) are rare, only a recent study by Chang et al. (2021) has assessed the inclusion of such topic in Indian school curricula. Few studies have measured the level of knowledge about ocean and marine environments in BRICS countries. In this sense, Ballantyne (2004) observed a limited knowledge about such content by primary school students in South Africa, and Umuhire and Fang (2016) observed the same in university students from China. A survey conducted by the Center of Excellence for the Brazilian Sea (Cembra) in 2011 has shown that Brazilian knowledge on the importance of marine ecosystems is limited (CEMBRA, 2012). Moreover, Stefanelli-Silva et al. (2019) observed that the inclusion of contents related to marine ecosystems into school curriculum increased student involvement in ocean-related discussions.

Considering the large coastal area of BRICS countries, and the fact that developing countries will be strongly affected by climate change (Munang et al., 2013; Suarez et al., 2014), many authors (Guest et al., 2015; Uyarra and Borja, 2016; United Nations, 2018; Visbeck, 2018) have been recommending the inclusion of OL into school curricula to increase public awareness on ocean health. This study aimed to investigate the inclusion of contents related to OL principles and concepts into school curricula in the Brazilian formal education system (especially regarding coastal risks such as erosion, global warming, human activity action, and urban occupation on coastal zones etc.). This is the first study to evaluate it in tropical Atlantic Ocean marine environments with a high potential for economic growth (Miloslavich et al., 2011; Turra et al., 2013). Qualitative and quantitative approaches were proposed based on exploratory statistics methods, which can provide relevant information on patterns and trends to improve coastal management and address coastal risks.

2. Material and methods

2.1. Documents

The document “Ocean Literacy - The Essential Principles of Ocean Sciences K-12” addresses the definition and fundamentals of OL and discusses seven principles and 44 fundamental concepts (Ocean Literacy Network, 2020). These were included in this study to define what information to provide to the public and add to school curricula to stimulate learning about oceans and marine environments (Schoedinger et al., 2010). Herein, we used the Portuguese version of the original document, which contained 43 concepts and was translated by Ciência Viva de Portugal.[1] Table 1 shows the essential principles and fundamental concepts of OL. Some of them are directly related to coastal risks such as those which (1) make explicit the role of natural phenomena in shaping the physical characteristics of CZs (concepts 2C and 6F); (2) describe erosion (concept 2D); (3) approach the ocean’s influence on carbon cycle and respective link with global warming (concepts 3E, 3F, and 3G); and (4) connect human activity and urban occupation to the impacts on coastal zone (concepts 6D, 6E, and 6G).

In Brazil, school curricula are guided by the Common National Curriculum Base (*Base Nacional Curricular Comum*–BNCC). This public education policy document establishes a minimum content to be taught to Brazilian students (Brasil, 2017). The Brazilian Federative Curricular Guidelines (*Referenciais Curriculares das Unidades Federativas*–RCs) are developed by the Federative Units. These RCs contain BNCC guidelines and may also have contents based on each region characteristics, allowing to address Federative Units-specific issues (e.g., cultural background, economic activities, and unique ecosystems). This study analyzes the BNCC and RCs for Brazilian elementary education and covers nine years of schooling (ages from 6 to 14 years) which is the longest schooling time in the Brazilian educational system. Eventually, data extracted from (1) “Ocean Literacy - The Essential Principles of

[1] Conhecer o Oceano- Princípios Essenciais e Conceitos Fundamentais, available at https://img.circuitoscienciaviva.pt/img/recursos/files/principiosematriz_postera2_6935785215dd3c.pdf.

Table 1
Essential principles and fundamental concepts of OL based on the Portuguese version of the document. The Portuguese version was used to facilitate the search procedure. In the original version, principle 1 has eight concepts (1A to 1H); however, in the Portuguese version, the concepts 1F and 1G were merged. Also, the order of some concepts is different for principles 2, 3, and 5. *Fundamental concepts of OL related to coastal risks.

Principle	Concept
1: The Earth has one big ocean with many features.	A: The ocean is the defining physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic.
	B: An ocean basin's size, shape, and features (islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates.
	C: Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation, the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation.
	D: Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.
	E: Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition.
	F: The ocean is an integral part of the water cycle and is connected to all of Earth's water reservoirs via evaporation and precipitation processes. The hydrographic basins transport nutrients, salts, sediments, and pollutants to the ocean.
	G: Although the ocean is large, it is finite, and resources are limited.
2: The ocean and life in the ocean shape the features of the Earth.	A: Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
	B: Sea level changes over time have expanded and contracted continental shelves, created, and destroyed inland seas, and shaped the surface of land.
	*C: Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.
	*D: Erosion—the wearing away of rock, soil, and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.
	E: Sand consists of tiny bits of animals, plants, rocks, and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. Sand is redistributed by waves and coastal currents seasonally.
3: The ocean is a major influence on weather and climate.	A: The ocean controls weather and climate by dominating the Earth's energy, water, and carbon systems.
	B: The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
	C: Most rain that falls on land originally evaporated from the tropical ocean.
	D: The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.
	*E: The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.
	*F: The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water.
	*G: Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
4: The ocean makes Earth habitable.	A: The first life is thought to have started in the ocean, in the absence of oxygen.
	B: Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.
5: The ocean supports a great diversity of life and ecosystems.	A: The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
	B: Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.
	C: Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
	D: Most life in the ocean exists as microbes, they have extremely fast growth rates and life cycles. The most important primary producers in the ocean are microbes.
	E: Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially. Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
	F: Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.
	G: Estuaries provide important and productive nursery areas for many marine and aquatic species.
	H: Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer).
	I: There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.
6: The ocean and humans are inextricably interconnected.	A: The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It

(continued on next page)

Table 1 (*continued*)

Principle	Concept
	moderates the Earth's climate, influences our weather, and affects human health. B: From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security. C: The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures. *D: Much of the world's population lives in coastal areas. *E: Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity lead to pollution and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean. *F: Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges). *G: Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.
7: The ocean is largely unexplored.	A: The ocean is the last and largest unexplored place on Earth — less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation. B: Understanding the ocean is more than a matter of curiosity. Exploration, inquiry, and study are required to better understand ocean systems and processes. C: Over the last 50 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations. D: New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles. E: Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems. F: Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Ocean Sciences K-12", (2) BNCC, and (3) RCs of elementary schools in 27 Federative Units, corresponding to 29 documents, were analyzed. The RCs[2] and BNCC[3] can be accessed on the website of the Ministry of Education of Brazil.

2.2. Qualitative and quantitative analyses

To analyze the presence of OL principles and concepts in school curricula, we used the content analysis proposed by Bardin (2011), which allows extracting data from the original source by locating, identifying, and organizing the contents in written documents. For that purpose, the principles and concepts of OL were regarded as *a priori* search categories and guided the reading of documents (Silva and Fossá, 2015). First, one of the authors of this article (CEP) read the entire corpus of documents to get acquainted with it. Afterwards, excerpts from each document were identified and categorized. When identified, the presence and frequency of occurrence (number of times it was found) of each principle and concept were determined for both the BNCC and each RC. Only excerpts explicitly related to OL principles and concepts were retained, ruling out those transversely related to the subject so that ambiguous results could be avoided. Reading and recording were performed twice by the researcher, and a third time using the word search tool provided by Adobe Reader/Acrobat to confirm records. Results of the three word searches in documents were consistent. Then, descriptive statistics were performed.

The data were analyzed by principal component analysis (PCA). This technique linearly converts a set of correlated variables into a smaller number of uncorrelated variables, which is used to explain information from the original set. The new variables, known as Principal Components (PCs), are graphically represented by the x and y axes (PC1 and PC2, respectively). The former provides the highest explanation of the original data variation, and the latter has the second-highest, and so on until the total variance in original data is accounted for. These axes (PCs) comprise a synthetic way of reducing several redundant variables into super-variables (PCs), which are easily visualized but not necessarily easily interpreted. This exploratory multivariate analysis is used to identify patterns and trends, as well as generate knowledge on the importance of the studied variables (Hair et al., 2009). A total of 44 variables were analyzed, including frequency of occurrence of each fundamental concept (number of times each of the 43 concepts was found) and total frequency of occurrence (number of times that all 43 concepts were found in the document).

Statistical differences were determined in a hierarchical analysis, including: (1) 27 Federative Units, (2) five geographic regions (Midwest, North, Northeast, Southeast, and South), and (3) coastal and non-coastal regions (Fig. 1). We also tested the PCA pattern identified for the five geographic regions. The variance between two datasets (Federative Units two by two, Brazilian geographic regions two by two, coastal and non-coastal regions, and PCA pattern) was determined using Mann-Whitney *U* test, whereas the Kruskal–Wallis test was used to compare more than two datasets (all Federative Units and all Brazilian geographic regions). To reject the null hypothesis, we considered a significance level of 5%. Bonferroni correction was also performed to avoid errors from multiple comparisons. Non-parametric tests were chosen because of the non-normal distribution and heteroscedasticity of data variance, which were evaluated using Shapiro-Wilk and Levene tests, respectively. All analyses were performed using the PAST software version 2.08 (Hammer et al., 2001).

[2] Available at http://basenacionalcomum.mec.gov.br/index.php?option=com_content&view=article& layout = edit&id = 207.

[3] Available at http://basenacionalcomum.mec.gov.br/images/BNCC_EI_EF_110518_versaofinal_site.pdf.

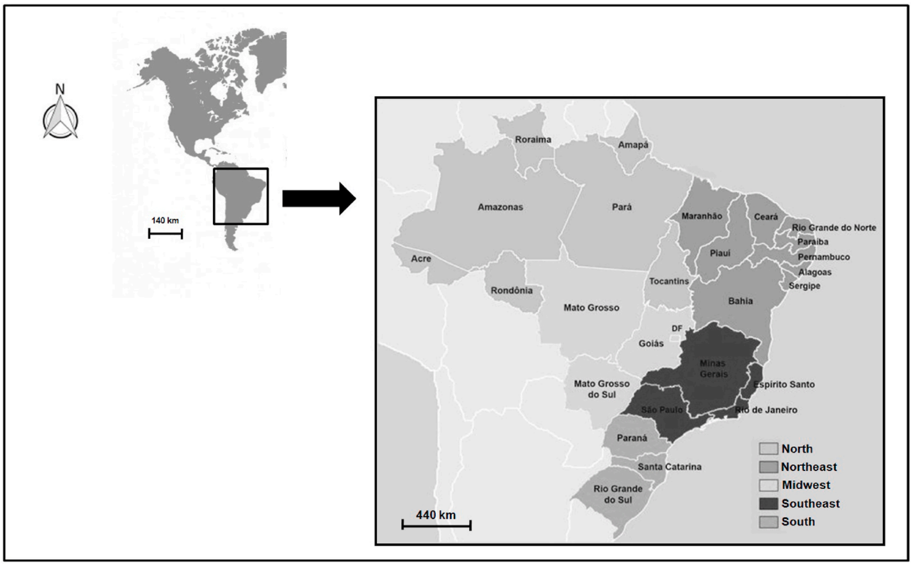

Fig. 1. Map of Brazil showing its Federative Units [Acre (AC), Amazonas (AM), Amapá (AP), Pará (PA), Rondônia (RO), Roraima (RR), Tocantins (TO), Distrito Federal (DF), Goiás (GO), Mato Grosso do Sul (MS), Mato Grosso (MT), Alagoas (AL), Bahia (BA), Ceará (CE), Maranhão (MA), Paraíba (PB), Pernambuco (PE), Piauí (PI), Rio Grande do Norte (RN), Sergipe (SE), Espírito Santo (ES), Minas Gerais (MG), Rio de Janeiro (RJ), São Paulo (SP), Paraná (PR), Rio Grande do Sul (RS), and Santa Catarina (SC)], and highlighting its five geographic regions.

3. Results

Four of the seven principles were included in the BNCC (1- The Earth has one big ocean with many features; 3- The ocean is a major influence on weather and climate; 5- The ocean supports a great diversity of life and ecosystems; and 6- The ocean and humans are inextricably interconnected). From three to five principles were present in the RCs (in addition to those previously found in the BNCC, principle 5 was absent in the RC of Bahia and São Paulo, and principle 4 was found in the RCs of Amazonas and Santa Catarina; see Table 2 and supplementary material). The principle 7 (exploration of the marine environment and the interdisciplinarity of this field of research) was not present in the analyzed documents.

Only 11 out of the 43 OL fundamental concepts were present in the BNCC (Table 2). An average of 13.9 (10–23) concepts was found in the RCs. Only 10 fundamental concepts were found in all documents (1F: is related to the ocean's importance to water cycle; 3A, B, C, D, and F: approach the ocean's influences on climate regulation and control; 6B and C: describe the ocean's importance to human welfare; 6E: is related to how humans affect the ocean; and 6F: approaches the susceptibility of coastal regions to natural disasters). The concepts mostly found in the documents belonged to principle 3 (on the relationship between ocean and climate) and principle 6 (on the relationship between ocean and humans). Nine fundamental concepts were absent from these documents (2A: addresses the ocean relationship with geochemical cycles; 2B: addresses sea level changes over time; 3G: addresses ocean circulation changes over time; and 7A, B, C, D, E, and F: address the exploration of marine environments).

Nine concepts addressed coastal risks (2C and 6F: the role of natural phenomena in shaping the physical characteristics of CZs; 2D: describes erosion; 3E, F, and G: approach the ocean's influence on carbon cycle and respective link with global warming; and 6D, E, and G: connect the human activity and urban occupation to impacts on CZs), with frequencies varying between the BNCC and RCs. The concepts 3F, 6E, and 6F were present in all documents, and the concept 3G was absent from them. The other concepts related to coastal risks were present in at least one and at most eight of the RCs, showing its rarity in school curricula.

On average, the RCs of non-coastal Federative Units addressed 14.7 fundamental OL concepts, while coastal Federative Units 13.5. Statistically significant differences ($p = 0.032$) were found among the average of the five regions (Southeast = 11.7; North = 14.8; Northeast = 14.0; Midwest = 13.7 and South = 14.6).

The results of Kruskal-Wallis test showed no significant differences in frequency among the 27 Federative Units, but significant results ($p = 0.034$) among the five geographic regions. Moreover, the U-Mann-Whitney test indicated significant differences in frequency between coastal and non-coastal regions ($p = 0.021$). Table 3 shows pairwise comparison of geographical regions by the U-Mann-Whitney test. After Bonferroni's correction, significant differences were found only between North and Southeast regions.

In the Principal Component Analysis (PCA), 44 original variables from the five samples were reduced into four orthogonal components, which could explain the entire data variation. Each of the four components represent the relative contribution of each of the 220 variables (44 variables x five samples) to the total data variation. Principal component 1 (PC1) and 2 (PC2) explained 99.71% of the total variation and recovered 99.33% and 0.39% of the total variation, respectively. Therefore, only PC1 was needed to explain almost all data variation. PC1 was highly correlated (correlation index = 0.95) with the frequency of OL principles and concepts in RCs (i.e., this is the variable whose vector is closer to the principal axis). Thus, it is the most important variable to interpret the PC1. Scatter plots allowed discriminating two groups, one formed by South, Southeast, and Midwest regions, and another by North and Northeast (Fig. 2). Both groups showed significant differences between each other by the U Mann-Whitney test ($p = 0.04$). The former group had the lowest frequency of OL principles and concepts in documents.

4. Discussion

Public knowledge is essential to implementing ocean and coastal management based on a bottom-up approach; formal education is useful to improve decision-making by the population (Castle et al., 2010; Kuijper, 2003; Smith, 2002; United Nations, 2018; Visbeck, 2018). In this respect, the inclusion of OL into school curricula should be considered by teachers and educational managers to raise awareness on ocean issues. Such an outreach can help professionals engaged in environmental management and social mobilization for coastal risk prevention (Guest et al., 2015; Jefferson et al., 2014; Steel et al., 2005b). This study provides the first diagnosis of the presence of OL in Brazilian school curricula, we believe these findings can subsidize public awareness of ocean issues, thereby helping to promote a bottom-up management under the current global warming scenario.

Qualitative analysis showed that contents directly related to OL principles and concepts were more common in the Brazilian curricula than were in the United States (Hoffman and Barstow, 2007), England

Table 2
The presence of ocean literacy principles and concepts in the BNCC and RCs of each Brazilian Federative Unit (North, Midwest, Northeast, Southeast, and South respectively) and their frequency of occurrence is shown in each cell.
N1: number of concepts covered in each document; N2: absolute frequency of occurrence of concepts approached in each document; N3: number of RCs containing the concepts; N4: frequency of occurrence of a concept in the RCs.

PRINCIPLE	1- The Earth has one big ocean with many features							2- The ocean and life in the ocean shape the features of the Earth					3- The ocean is a major influence on weather and climate							4- Ocean makes Earth habitable		5- The ocean supports a great diversity of life and ecosystems									6- The ocean and humans are inextricably interconnected							N1	N2
CONCEPT	A	B	C	D	E	F	G	A	B	C	D	E	A	B	C	D	E	F	G	A	B	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G		
BNCC						1							1	1	1	1		1							1							5	5		1	2		11	20
RC Acre				1	1	4	2			1			2	2	2	2		2				2	2	3	4	2	3	2	2	1		13	9		2	5		23	69
Amazonas		2				2							2	1	1	2	1	1		1				2	3					1	1	8	12		2	5		17	47
Amapá						1							1	1	1	1		1							1							5	5		1	2		11	20
Pará			1			1							2	2	2	2		1							1							5	5		1	2		12	25
Rondônia						2				1			1	1	1	1		1							1							17	12		2	3		12	43
Roraima			1			1							2	2	2	2		1							1							6	5	1	1	2		13	27
Tocantins	1		1	2		4	1						3	2	2	2		1							4							7	6		4	4	1	16	45
Distrito Federal	2		2		2	1							2	2	2	1		1							2							5	6	1	1	3		15	33
Goiás	2			1		1							1	1	1	1		1							1							6	6		1	3		13	26
Mato Grosso do Sul			1			1	1			1	1		2	2	2	2		1							1							19	28		1	3	1	16	67
Mato Grosso						1							1	1	1	1		1							1							5	5		1	2		11	20
Alagoas	1		1			3	2						2	2	2	2		1						1	11							8	12	1	3	2	2	18	48
Bahia						1							1	1	1	1		1														5	6		1	2		10	20
Ceará	2		1		2	5				1	1	1	1	1	1	1		1							1							8	6		4	3	1	18	41
Maranhão				1		2							1	2	1	2		1							1							9	6	2	2	3		13	33
Paraíba						1							1	1	1	1		1							1							5	5		1	3		11	21
Pernambuco					1	3							1	1	1	1		1							2							6	5		3	2	1	13	28
Piauí						1							1	1	1	1		1							1							6	6		1	2		11	22
Rio Grande do Norte					1	3							1	1	1	1		1							1							6	7		3	5		12	31
Sergipe	1			1		2	1				1	1	1	1	1	2		1							4			1	1			8	11	1	2	4	1	20	46
Espírito Santo				1		1	2						2	2	2	2		1							1							10	10		1	2	2	14	39
Minas Gerais						1							1	1	1	1		1							1							6	12		1	2		11	28
Rio de Janeiro			1			1							2	2	2	2		1							1							6	5		1	2		12	26
São Paulo						1							1	1	1	1		1														5	6		1	2		10	20
Paraná						1							1	1	1	1		1							1							5	8		1	2		11	23
Rio Grande do Sul	1				1	1	1			1			1	1	1	1		1							2							9	8		1	3	1	16	34
Santa Catarina	1	1	1		1	4							1	1	1	1		1			1				1							11	14	1	3	4		17	48
N3	8	2	9	7	7	27	7	–	–	5	3	2	27	27	27	27	1	27	–	1	1	1	1	3	25	1	1	2	2	2	1	27	27	6	27	27	8		
N4	11	3	10	9	9	50	10	–	–	5	3	2	38	37	36	38	1	28	–	1	1	2	2	6	39	2	3	3	3	2	1	209	226	7	46	77	10		

Table 3
p-values obtained from pairwise comparisons of the variances of inclusion frequencies of ocean literacy principles and concepts into Brazilian school curricula among geographical regions using the U-Mann-Whitney test. *p*-values obtained before and after Bonferroni's correction are shown above and below the diagonal line, respectively. $^*p < 0.05$.

Geographic Region	Northeast	Southeast	South	Midwest	North
Northeast	–	0.0456*	0.1155	0.2108	0.4563
Southeast	0.4568	–	0.5796	0.4059	0.0041*
South	1.0000	1.0000	–	0.7313	0.0128*
Midwest	1.0000	1.0000	1.0000	–	0.0300*
North	1.0000	0.0411*	0.1289	0.3000	–

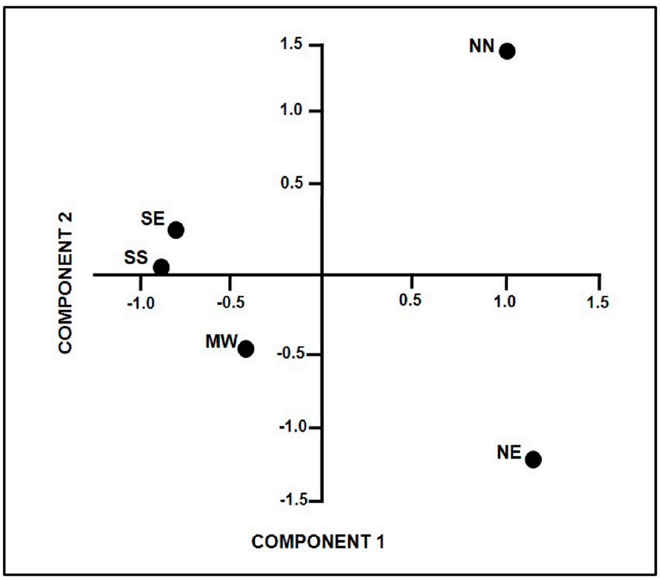

Fig. 2. Principal component analysis for the five Brazilian regions. The first principal component (represented by the x axis) separated the group formed by South, Southeast, and Midwest (to the left of zero point) from that by North and Northeast (to the right of zero point). Acronyms stand for: MW- Midwest; NE- Northeast; NN- North; SE- Southeast; and SS- South.

(Castle et al., 2010), state of Victoria in Australia (Gough, 2017), province of New Scotia in Canada (McPherson et al., 2018a), and Indian (Chang et al., 2021). Still, the representativeness of OL in Brazilian documents is below the recommended for a person to be considered literate in the topic (Ocean Literacy Network, 2020), especially for environmental risks in CZs since all Federative Units in Brazil but Acre have less than 50% of the OL concepts. Furthermore, the inclusion of OL in classes also depends on the teachers' approach and curricula, which will closely be related to their professional training. For instance, Mogias et al. (2015) showed that Greek teachers who were not trained usually do not work with OL principles and concepts in their classes. Likewise, McPherson et al. (2018b) revealed that teachers from Nova Scotia (Canada) felt unprepared to work with OL due to the absence of the subject in their curricula, as well as lack of training.

Still from a qualitative point of view, OL topics were mostly found in the RCs than in the BNCC. This may be due to the inclusion of specific social, cultural, and economic information in school curricula of each Federative Unit. The main difference between BNCC and RCs is that the concepts related to principle 1 (The Earth has one big ocean with many features) are poorly covered by the former and mildly present in the RCs. Although this has no clear explanation, it might be related to each Federation Unit local peculiarity. However, principle 7 (the ocean is largely unexplored) is fully absent from all documents, and others such as 2 (The ocean and life in the ocean shape the features of the Earth), 4 (The ocean makes Earth habitable), and 5 (The ocean supports a great diversity of life and ecosystems) are poorly addressed. Accordingly, although Brazilian school curricula are in a better condition than those of other countries, they are quite heterogeneous and do not cover enough principles and concepts to literate students and raise awareness on ocean problems and risks in CZs. Considering Brazil's geographic extension, curricular heterogeneity is not a problem *per se* and can be even desirable, but the documents still need to be improved, especially regarding principles and concepts that are now absent or poorly covered.

The benefits of formal education on public engagement in coastal management policies have been demonstrated (Lucrezi et al., 2019). However, considering that Brazilian educational public policies have been recently updated (2017–2019), production and distribution of teaching materials for schools and improved access of educators to teaching resources are essential short-term strategies (Ghilardi-Lopes et al., 2019; McManus et al., 2000; Payne and Zimmerman, 2010; Santoro et al., 2017). Fauville et al. (2013) displayed different online resources that could be used as support material to teach marine environments. In Brazil, the Maritime Mentality Program (*Programa de Mentalidade Marítima*–PROMAR) has developed teaching materials for students and teachers (https://www.marinha.mil.br/secirm/promar). Ghilardi-Lopes et al. (2019) showed that different materials, including books, guides, radio programs, and games, have been used in schools to complement the curriculum.

In the present study, PCA was performed to identify patterns and trends in the presence of OL principles and concepts in the RCs and the BNCC. The analysis formed two clusters of different geographic regions regarding the frequency concepts were found in documents. The difference between these groups was statistically significant and corresponded to regions with higher (Midwest, Southeast and South) and lower (North and Northeast) socioeconomic indices (FIRJAN, 2018). Tourism is one of the main economic activities in North and Northeast regions of Brazil, especially in coastal areas of the latter. This activity has been stimulated by federal investments since the 1990s (Diegues, 1999; Jablonski and Filet, 2008). As a result, large tourism developments and highways have been built, which has degraded mangroves, dunes, and sandbanks, leaving the region more susceptible to coastal degradation, especially erosion (Jablonski and Filet, 2008; Martins et al., 2017; Silva et al., 2014). Furthermore, a survey done in 2011 on the perception of people from different Brazilian regions regarding the ocean and its environments revealed that people from Northeast Brazil are the most concerned and interested in these questions (CEMBRA, 2012). The reasons behind these differences are complex and may encompass a network of social, economic, and cultural aspects influencing the local perception on marine environments and their problems. Unfortunately, these issues are beyond the scope of this study.

Activities in many cities along the Brazilian coast have received financial aids in form of royalties from oil and gas exploration industry (Monteiro, 2015; Reis and Santana, 2015). These royalties are distributed according to law (Brasil, 1997; CNM, 2010), and the Southeast is the most benefited region due to the higher probability of impact on their littoral (CNM, 2010; Monteiro, 2015). For example, oil offshore production in *Bacia de Campos* since the early 2000s has caused intense and disordered urban growth in coastal cities near exploration areas, especially in Espírito Santo and Rio de Janeiro states (Jablonski and Filet, 2008; Neto et al., 2018). According to the law 9.478/1997 (Brasil, 1997) part of the royalties should be invested in education (Reis and Santana, 2015). However, these investments seem not to be focused on including marine environment themes in school curricula. Moreover, non-formal environmental education activities have been developed in the region (Berchez et al., 2016; Pedrini et al., 2019). These initiatives are short-lived and reach a limited audience (Pedrini et al., 2019). In this respect, participatory management needs to rethink school curricula to improve public knowledge.

Unlike Hoffman and Barstow (2007), who found that OL contents were mostly found in school curricula from coastal states of the United

States than were in non-coastal states, this study found that this theme was more represented in non-coastal Federative Units. However, OL should be adopted in all regions, regardless of the proximity to coastline, because everyone benefits from ecosystem services provided by marine environments, and people's attitudes and behaviors impact these ecosystems (Dupont and Fauville, 2017; Fielding et al., 2019; Guest et al., 2015; McKinley and Fletcher, 2010; Steel et al., 2005a). In BRICS countries with extensive territories and large coastal and non-coastal areas, the implementation of OL in school curricula is especially relevant. Notwithstanding, BRICS engagement with OL is still very limited. In South Africa (Ballantyne, 2004) and China (Umuhire and Fang, 2016), student awareness on marine environments is poor, just as in India (Chang et al., 2021) where coverage of OL topics in curricula is low. In Brazil, Stefanelli-Silva et al. (2019) worked in school with activities related to marine environments and noted that such initiatives engage students in discussion on questions about the ocean and the problems related to its use and preservation.

The few studies on OL carried out in BRICS countries have shown that the low levels of information from the public and students do not differ among countries and curricula still have low coverage of OL principles and concepts. This situation is especially delicate in accelerated economic growth countries. As such, they have faced major challenges to manage the effects of their development on CZs and their environments. OL has consistently proven to be a key ally in informed decisions for bottom-up management initiatives and that its effects are positive, structural, and lasting when applied to formal education (Dupont and Fauville, 2017; Barracosa et al., 2019; Lucrezi et al., 2019). In this sense, studies on OL applied to formal education (school, classroom, curricula) are urgent in all countries, but especially for developing countries such as those from BRICS.

5. Conclusions

This study assessed the presence of OL principles and concepts in Brazilian school curricula at regional and national levels. Content analysis showed that such principles and concepts are more represented in regional curricula than are in national documents; however, 7 principles and 43 concepts are still poorly covered. Therefore, actions aimed at expanding the presence of OL principles and concepts in Brazilian school curricula must be taken. If applied to formal education, OL can be a tool for engaging the public in participatory governance practices.

Besides a qualitative content analysis, exploratory multivariate statistics was also carried out, which proved to be successful in multiple areas of research and allowed us to evaluate many variables simultaneously. The Principal Component Analysis indicated that OL-related contents in school curricula were heterogeneous (1) among Brazilian Federative Units but more common among geographic regions with lower social development indexes, and (2) between coastal and non-coastal regions, with a greater amount in the latter. Thus, the pattern identified showed that, especially the Brazilian Midwest, Southeast, and South regions, as well as the Federative Units of the coastal regions, are those that need the most to include OL principles and concepts in their school curriculum.

Coastal management based on bottom-up strategies demands an active participation of different stakeholders; however, social participation is limited because of the lack of information, knowledge, or understanding of technical language. This study was done based on the assumption that OL helps bottom-up strategies by promoting e awareness of people regarding ocean issues. Therefore, increasing the presence of OL principles and concepts in school curricula is a fundamental task, which depends on a proper curriculum analysis like the one performed here. Accordingly, authorities must invest in coordinated attitudes to improve and replicate this study to other countries, as well as include international collaboration. Thus, risks in coastal areas can be faced on a global scale, especially in the current global warming scenario.

Author contributions statement

CEP contributed to data collection, EPS contributed to study concept and design, MRD contributed to data analysis. All contributed equally to interpretation, manuscript preparation, critical revision, and adding intellectual content.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2022.106047.

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