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Ocean Literacy to Mainstream Ecosystem Services Concept in Formal and Informal Education: The Example of Coastal Ecosystems of Southern Portugal

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The concept of ecosystem services (ES) emerges as strategic to explain the influences that the ocean, and in particular coastal ecosystems, have on us and how we influence them back. Despite being a term coined several decades ago and being already widespread in the scientific community and among policy-makers, the ES concept still lacks recognition among citizens and educators. There is therefore a need to mainstream this concept in formal education and through Ocean Literacy resources. Although important developments in OL were done in the United States, particularly through the National Marine Educators Association (NMEA), this concept was only recently introduced in Europe. In Portugal, several informal OL education programs were developed in the last years, yet formal education on OL and, in particular, on ES is still very deficient. To address this limitation, the "Environmental Education Network for Ecosystem Services" (REASE), founded in 2017 in the Algarve region by a consortium of educational, environmental and scientific institutions, aims to increase OL through the dissemination of the perspective of how ES provided by coastal vegetation may contribute to the human well-being. The projects and activities implemented by REASE focus mostly on formal-education of school children and include: (1) capacity building for K-12 teachers, (2) educational programs to support and develop ES projects in schools, including a citizen science project to evaluate blue carbon stocks in the Algarve, (3) the publication of a children's book about the ES provided by the local Ria Formosa coastal lagoon, with a community-based participatory design (illustrations made by schoolchildren) and (4) a diverse array of informal education activities to raise awareness on the importance of coastal ecosystems on human well-being. REASE challenges are being successfully addressed by identifying threats to local coastal ecosystems that people worry about, and highlighting solutions to improve and maintain their health.

Keywords: ocean literacy, behavior change, project-based learning, blue carbon, coastal ecosystems, citizen science, environmental education, participatory action research

INTRODUCTION

The oceans, covering 71% of the Earth's surface, have a profound influence on human well-being, by providing services or benefits such as oxygen, food, pharmaceutical compounds, jobs and climate regulation (Dupont and Fauville, 2017). At the same time, human activities, such as overfishing, coastal development, pollution, and those causing the rising of CO_2 concentrations in the atmosphere, are influencing the ocean by, for example, making it warmer and more acidic with consequences to the marine organisms and ecosystems (Fabry et al., 2008; Hoegh-Guldberg and Bruno, 2010; Cheung et al., 2013). Coastal ecosystems, as part of the global ocean, should be a particular target in the global conservation agenda for being under the impacts of an increasing population density along the planet coasts (Lotze et al., 2006) and for providing highly valuable services both at the local and global scale (Barbier et al., 2011). For instance, coastal vegetated ecosystems such as saltmarshes and seagrasses have experienced large losses and degradation in the last decades due to urban development and pollution of coastal areas (Lotze et al., 2006), putting at risk all the ecosystem services (ES) we benefit from and depend upon (Millennium Ecosystem Assessment [MEA], 2005). The high value of these ecosystems relies on their role, for example, in maintaining local fisheries, thus in food provision (Unsworth et al., 2018), controlling pollution and diseases by filtering nutrients and pathogens out of the water (Lamb et al., 2017) and protecting the coasts from flooding and erosion (Duarte et al., 2013; Ondiviela et al., 2014). In addition, these ecosystems rank amongst the most efficient ecosystems in sequestering and storing CO_2, thus contributing to climate change mitigation (Fourqurean et al., 2012; Duarte et al., 2013). The carbon stored in coastal vegetation sediments, commonly called "coastal blue carbon" (Nellemann and Corcoran, 2009), remain trapped for very long periods of time (centuries to millennia) resulting in carbon stocks larger than in terrestrial vegetation (Fourqurean et al., 2012; Chmura, 2013; Duarte et al., 2013). However, the capacity of the coastal vegetated ecosystems to provide blue carbon storage and other benefits is threatened as a consequence of the human impacts (Waycott et al., 2009; Pendleton et al., 2012). There is an urgent, global need to revert their degradation and to secure benefits now and in the future (Cullen-Unsworth and Unsworth, 2018).

The concept of ES, i.e., the benefits that humans get from nature (Millennium Ecosystem Assessment [MEA], 2005), emerges as strategic to explain the influences that the ocean, and in particular coastal ecosystems, have on us and how we influence them back, which is the essence of the Ocean Literacy (OL, Ocean Literacy Campaign, 2013). Educating people on marine ES, so they get a better understanding of the tight bond between natural habitats and human well-being, constitutes a powerful strategy to advance toward a more ocean-literate society, i.e., a society that "understands the Essential Principles and Fundamental concepts about the ocean," that "is able to make informed and responsible decisions regarding the ocean and its resources," and that "can communicate about the ocean in a meaningful way" (Ocean Literacy Campaign, 2013). Despite being a term coined several decades ago, in the 1980s (Millennium Ecosystem Assessment [MEA], 2005), and being already wide-spread in the scientific community and among policy-makers, the ES concept still lacks popularity among citizens and educators. There is therefore a need to mainstream this concept in formal education and through Ocean Literacy resources.

The "Ocean Literacy Essential Principles and Fundamental Concepts" (Ocean Literacy Campaign, 2013) is a cornerstone document to guide educators on the seven most important concepts that citizens should know about the oceans. Some of these principles indirectly refer to the ES delivered by the ocean and its ecosystems. For instance, principle 3.f. mentions that the ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water, principle 4.c. "The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth," principle 5, "The ocean supports a great diversity of life and ecosystems," includes a specific mention (5.i.) to coastal ecosystems, in particular estuaries, in providing "important and productive nursery areas for many marine and aquatic species," and in principle 6 "The ocean and humans are inextricably interconnected," there are many references to marine ES such as food, medicines, jobs, navigation and culture (6.a. to 6.c). These ES-related principles are, however, built on a global scale, so tailoring them to local necessities and problems is needed so that they will have a more efficient impact.

Although important developments in OL have been done in United States, particularly through the achievements of the National Marine Educators Association (NMEA), this concept was only recently introduced in Europe. The first Conference on Ocean Literacy in Europe was only held in 2012. Despite the fact that OL is a political priority to the EU, little has been done to improve it, as recognized by the European Marine Science Educators Association [EMSEA], 2013. OL concepts are not present in most European school's curricula (Water World Adventure Learning Approach, 2016), although Portugal was among the first countries to implement informal OL education projects (**Table 1**), in particular through the project "Knowing the Ocean" that aimed to stimulate the citizens' involvement with the ocean based on the North American Ocean Literacy initiative. In fact, due to the Portuguese geographic location and its long maritime tradition, many education programs that included sea-related activities were developed before OL became the hallmark for sea-related environmental education, for example the centers for monitoring and environmental interpretation, CMIA, in northern Portugal[1,2,3]. In terms of OL targeting specifically the Portuguese coastal ecosystems there are two programs running at present (**Table 1**), Ocean Alive[4], focused on the seagrasses of the

[1]www.cmia-viana-castelo.pt/servicos-educativos/atividades-grupos

[2]www.cmia-viladoconde.net/eventoseatividades.php

[3]www.cmia-matosinhos.net/eventoseatividades.php?page=2&ipp=10&t=2

[4]https://www.ocean-alive.org

TABLE 1 | Past and present ocean literacy education projects developed in Portugal.

Name of project	Website	Promotor	Year of implementation	Still running (yes/no)	Target audience
Sea for Society – Mar para a Sociedade.	http://www.cienciaviva.pt/peixes/home	Ciência Viva Agency	2007–2013	No (web page of resources still available)	General public (on line resources)
KIT DO MAR	https://www.dgpm.mm.gov.pt/kit-do-mar	DGPM	2008–2013	No (web page of resources still available)	Formal education (K12)
ADOPTE	Not available	CCMAR – Center of Marine Sciences, University of Algarve	2010	No	Formal education (Elementary school)
Oceanário Shuttle	https://www.oceanario.pt/educacao/vaivem-oceanario/	Oceanário de Lisboa/Fundação Oceano Azul	2011	Yes	General public
O MARE VAI Á ESCOLA	https://ciencias.ulisboa.pt/pt/o-mare-vai-%C3%A0-escola	MARE	2015	Yes	Formal education (K12)
OceanLab	http://www.ciimar.up.pt/oCIIMARnaEscola/OCEANLAB.php	CIIMAR, CMIA Vila do Conde e CMIA Matosinhos	2015	Yes	Formal education (K12)
Oceanaction	http://oceanaction.pt/projeto	CIIMAR	2015	Yes	Formal education (K12)
Chef Fish Challenge	https://decojovem.pt/alimentacao/concurso-chef-fish/	DECO – consumers defense association	2015–2016	No	Formal education (K12)
Sea Change	http://www.seachangeproject.eu/	Ciência Viva Agency	2015–2018	No (web page of resources still available)	General public (on line resources)
EduCO2cean	http://www.educo2cean.org	ASPEA – Portuguese Association of Environmental Education	2016–2018	No	Formal education (from 15 to 17 years old)
Blue School-Escola Azul	https://escolaazul.pt	Ciência Viva Agency	2017	Yes	Formal education (K12)
Do CO2 ao O2	https://abae.pt/do-co2-ao-o2/	ABAE, European Blue Flag Association	2017	No	General public and formal education (K12)
REASE	http://rease.ccmar.ualg.pt/#home	CCMAR – Center of Marine Sciences, University of Algarve	2017	Yes	General public and formal education (K12)
Ocean alive	https://www.ocean-alive.org/	Ocean alive Coop	2017	Yes	General public and formal education (K12)
SERMARE-PRO – Formação para Professores	https://laboratoriomarefoz.wixsite.com/laboratoriomarefoz/nacionais-1	MARE	2017	Yes	Teacher trainning
Programa Geração azul	https://www.oceanoazulfoundation.org/pt-pt/o-que-fazemos/literacia/	Oceanário de Lisboa/Fundação Oceano Azul	2018	Yes	Formal education (from 5 to 9 years old)
Young People's Parliament (2018/19 THEME: Climate Change Save the Oceans	http://www.jovens.parlamento.pt	Portuguese Parliament	2018–2019	No	Formal education (K12)
Knowing the Ocean	http://www.cienciaviva.pt/oceano/home	Ciência Viva Agency	Not available	Yes	Formal education (K12)

Sado estuary and the network REASE[5], which is presented and discussed below.

Even though some informal OL education programs have been developed in Portugal, there is a need for formal education in the classroom arena, tailored to local ecosystems. Based on this principle, the "Environmental Education Network for Ecosystem Services" of the Algarve region (REASE, from its abbreviation in Portuguese) aims at planning and implementing environmental education projects on coastal ecosystem services with a special focus on the formal-education of school children. The network was founded in 2017 and includes institutions in the Algarve region interested in disseminating the perspective of the ES, namely the Center of Marine Sciences (CCMAR) of the University of Algarve, schools and associations of schools, science outreach centers, teachers training centers and non-governmental organizations.

[5]http://rease.ccmar.ualg.pt/#home

OCEAN LITERACY EDUCATION IN PORTUGUESE SCHOOLS

The main target for ocean literacy dissemination is the primary and secondary students (K-12) because school is mandatory for all and not everyone has access to informal educational contexts. However, ocean literacy and environmental education continues to be disregarded in the formal K-12 curricular programs in Portugal as well as in other European and American countries (Fauville et al., 2012), resulting in a citizenry that is not equipped to deal capably with many environmental problems. Teachers and schools need scientific support to understand ocean problems and to take on the challenges of disseminating OL. Thus, contemporary projects involving scientists, school teachers and students are needed to explore ocean problems in innovative ways. The current REASE project and the MARE and OCEANLAB training programs for teachers (**Table 1**) are good examples of this.

The main obstacles to the inclusion of OL in the Portuguese school is the overly fragmented curricular program by many disciplines, the length of the ordinary curricular program that does not encourage extra-curricular activities, the weak tradition of interdisciplinary project development as well as the lack of conditions for collaborative work among teachers (Santiago et al., 2012; OECD, 2018a). This is particularly relevant because ocean problems are complex and require transdisciplinary approaches. In addition, the Portuguese educational system based on national exams to access higher education at Universities exerts a pressure on teachers, students and families, for whom the main objective is to prepare the students for the exams, promoting a general standardization of school education. However, important reforms have been recently introduced, which may provide an opportunity for the inclusion of OL in the standard curriculum. In July 2018, Portugal officially adopted the Legislative Orders no. 55/2018, which obligates Portuguese schools (1st, 5th, 7th and 10th grades) to join the "Project for Autonomy and Curriculum Flexibility" (PACF). PACF provides schools with the necessary conditions to adjust the national curricular program with local contents. Schools may thus integrate innovative methodologies and practices to promote better learning. This project includes the National Education Strategy for Citizenship to introduce citizenship education in the schools. This strategy has created mandatory teaching areas, such as environmental education, sustainability, human rights and health. In addition, it promotes partnerships with NGOs and other institutions. PACF recommends to develop curricula according to the local contexts, associated with active methodologies such as project-based learning methodologies.

This recent legislation represents an opportunity to introduce and explore the theme of coastal ES and OL in the Portuguese school curriculum. Ocean literacy provides a way for students and teachers to work with their communities, and to change behaviors to reduce negative impacts on the ocean and its resources, ensuring that a healthy ocean will be available for future generations. Furthermore, the OECD (Organization for Economic Co-operation and Development) Learning Framework 2030 (OECD, 2018b) acknowledges that the concept of "competency" implies more than just the acquisition of knowledge and skills; it involves the mobilization of knowledge, skills, attitudes and values to meet complex demands (like the concept of ES). One of the recommendations of OECD's Skills Strategy Diagnosis for Portugal is "adjusting decision-making power to meet local needs."

ENVIRONMENTAL EDUCATION NETWORK FOR ECOSYSTEM SERVICES IN SOUTHERN PORTUGAL (REASE): MISSION AND VISION

The eastern coast of Algarve in southern Portugal is dominated by the Ria Formosa lagoon and the Guadiana river estuary with its Castro Marim saltmarshes. These are coastal protected areas recognized for their ecological and socio-economic importance where the preservation of ecosystems cohabits with their long-term, historical economic exploitation. Ria Formosa lagoon is probably the main employer of Algarve, where touristic usufruct shares this territory with artisanal fishing activities, salt extraction and mostly important, bivalve production. This anthropogenic pressure is increasing and diversifying, producing important disturbances in the landscape, habitats and species. These estuarine-lagoon ecosystems are dominated by seagrasses and saltmarshes, which support high biodiversity including iconic, endangered species such as seahorses, the provision of food resources, the purification of the water and the regulation of nutrient biogeochemical cycles, including globally relevant ES of carbon sequestration, ocean acidification mitigation, enable cultural and recreational practices and goods that relate people with the natural system and many dimensions of well-being that result on high touristic demand. This is the background that motivated the recent creation of the REASE network, whose aim is to increase coastal OL through the dissemination of the perspective of the ES provided by coastal vegetation, and in particular, how saltmarshes and seagrasses contribute to the well-being of the local population. The ultimate goal is to increase awareness of ES to promote the preservation and conservation of coastal ecosystems and the public pressure to manage them for sustainability.

The REASE strategy is not only to focus on primary and secondary schools, which are the key institutions with higher potential to deliver scientific knowledge on ES and OL to students through formal education, but also to deliver informal education of the general public by institutions such as environmental education centers, science centers, museums and aquaria. The specific objectives of REASE are (1) to train primary and secondary teachers on coastal ES and OL, (2) to create an incubator of innovative ES and OL projects that may be developed in schools under the PACF and in environmental education institutions, endowed with the scientific, technical (laboratory and field) equipment for the design, implementation and replication throughout schools, and (3) to promote informal activities for all types of public to improve the awareness on ES and OL. **Table 2** summarizes the activities conducted by REASE,

TABLE 2 | Activities conducted by the REASE network to mainstream the concept of ecosystem services (ES) in the western Algarve region (Portugal), including the target public, objective, and results obtained in the first year.

Activity	Target public	Objective	Results
Continuing teacher training (F)	K-12 teachers	Create capacity building in the education community through theoretical and field training on ES.	82 teachers from 20 schools
Incubator of ES projects (F)	K-12 teachers and students	Develop small scientific projects on ES though scientific support and resource provision.	9 field trips with over 200 students; 6 talks/student conference participations reaching over 250 students Total of 15 events reaching over 380 students
"Being a researcher for one day" program (F)	K-12 students	Student immersion in real ES research activities	3 students
Publication of a children booklet on ES (F/IF)	K-12 students	Involve the local schoolchildren community in the creation of OL resources on ES. Create a free resource on the ES provided by local ecosystems.	20 book presentations (4 of them including fieldtrips); 464 students, 950 booklets distributed
Exhibition stands on coastal ES by coastal ecosystems (IF)	General public	General dissemination of ES concepts	2 science centers
Roll ups on ES of Ria Formosa lagoon (F/IF)	General public	General dissemination of ES concepts	1 shopping mall, 2 nautical fairs and 3 schools

Each activity is categorized in formal (F) and informal (IF) education.

which will be developed below. The number of participating teachers was 82 from 20 schools, which represents 3% of the total number of K-12 teachers in municipalities of eastern Algarve (Loulé, Faro, Olhão, Tavira and Vila Real de Santo António).

Continuing Teacher Training

The training of teachers is central in the REASE attempts to increase the knowledge on ES in the region. This is particularly relevant in Portugal as the ES concept is relatively new (the concept was disseminated by the United Nations Millennium Ecosystem Assessments, publishied in 2005) and the Portuguese teacher's population is old, so that at the time they graduated the ES concept was not known. Data from 2015 to 2016 indicate that in 104,386 school primary and secondary teachers in public schools, there were only 383 under the age of 30. In fact, the age of teachers has increased drastically in the last decade revealing a worrisome lack of renovation. In the 1990's the number of teachers above 50 and below 35 years old was similar (aging index about 100), whereas in 2017 the number of teachers above 50 was 33 times higher than the number of teachers below 35 years old (**Figure 1**).

Given the increasing aging of the teaching class, continuing training of K-12 teachers is fundamental, especially in emerging areas such as ES and OL. Continuing teacher training in southwestern Portugal is formally provided by the Teacher Training Centers of "Levante Algarvio" in Vila Real de Santo António, "Ria Formosa" in Faro and "Litoral à Serra" in Loulé, being all of them involved in the foundation of REASE and in its activities. From the start of REASE in November 2017, to November 2018, a total of 7 training actions for teachers (**Figure 2A**) were delivered on coastal ES by researchers from the Center of Marine Sciences of University of Algarve, CCMAR. Eighty-two teachers from 20 schools were trained in the first year, 60 of which have implemented related activities to approximately 1200 K-12 students.

Incubator of ES Projects

The REASE network includes an "incubator of ES projects" (**Figure 2B**) that provides scientific support to K-12 education centers to develop small scientific projects with their students as an opportunity to learn about current scientific research related to ES. The learning process in science is more effective when the students are introduced and directly immersed into the scientific work throughout an "inquiry" learning process, instead of just learning about the "products" of science. They should have a question to investigate as a background of the learning process (Dewey, 1938). The ES projects launched within this framework were therefore based on experimentation, so students follow the scientific process of formulating problems, testing hypotheses, analyzing data, finding answers and presenting and communicating the results. This approach aims to reinforce the principle that an ocean-literate person may be able to communicate about the ocean in a meaningful way, a skill that the students put in practice through participation in various school events (conferences, competitions, meetings) where they present the results of their investigations. Finally, the incubator of ES projects is also based on the principle that field visits and experimentation are unique opportunities to learn about the coastal ecosystems and their services since, during such activities, students interact with the ecosystems through observations of natural processes and learn how they are connected to their well-being.

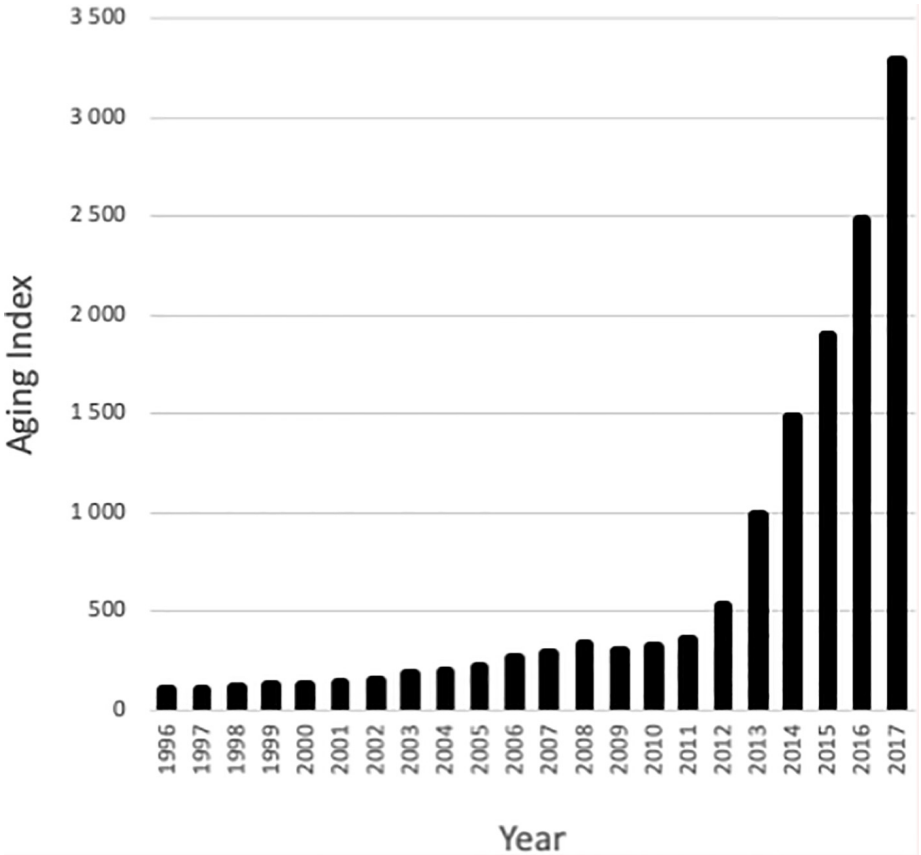

FIGURE 1 | Aging index (no. of teachers with more than 50 years/no. teachers with less than 35 years × 100). Source: Pordata (https://www.pordata.pt/DB/Portugal/Ambiente+de+Consulta/Tabela, assessed in 13-12-2018).

The flag pioneering project of REASE incubator is the "Carbono Azul" (Blue Carbon). This scientific project aims at mapping the blue carbon stocks of coastal vegetated ecosystems in the Algarve region[6]. Mapping the blue carbon stored in saltmarshes and seagrasses requires some training on the scientific protocols to quantify the organic carbon stored in the sediment and vegetation, as well as specific laboratory and field resources that may not be available in every school. For that reason, the first step was the implementation of training actions for teachers (see previous sub-section "training"). Secondly, the schools were provided with a field kit containing the materials needed to collect and analyze vegetation and sediment samples, including among other items, a handheld GPS, sampling cores, thermometer and zip lock bags (**Figure 2B**). In addition, one of the schools of the REASE network (AEJD Faro) was assigned as the "Incubator of ES project" headquarters and it was provided with laboratory equipment needed for the analysis of samples (laboratory oven and muffle furnace), to be shared with all other schools, teachers and students included in the REASE network, reinforcing in this way the inter-school cooperation and sharing of resources. Apart from the laboratory equipment needed for the "Blue Carbon" project, the "Incubator of ES project" headquarters was provided as well with microscopes and binocular magnifiers to develop other scientific projects. The Blue Carbon project is supported by a digital platform where the blue carbon data may be deposited and shared. The Internet and geographic information system (GIS) web applications developed by REASE allow participants to collect large volumes of location-based ecological data and submit them electronically to a centralized database. An *app* is also being developed[7] to directly upload field measurements, photos and blue carbon data into the website of the project, where data are scientifically validated and analyzed by CCMAR researchers. The ubiquity of smartphones, the potential for digital photo and the development of an infrastructure for creating simple online data-entry provide added potential for democratizing the project development, allowing the creation of data-entry systems for community-based projects of ecological research as Dickinson et al. (2012) recommended. Such empowerment means that data that may drive resource management decisions, are more likely to be in the hands of the people who will be affected by the outcomes, which reinforces the degree of participation and implication and guarantees its own sustainability.

[6]http://rease.ccmar.ualg.pt/#map

[7]http://rease.ccmar.ualg.pt/#app

FIGURE 2 | REASE activities for formal education includes **(A)** continuing training for K-12 teachers on ecosystem services (ES); **(B)** an incubator of innovative projects on ES, such as mapping the blue carbon in the Algarve that includes the delivery of a field kit; **(C)** field trips with schoolchildren; **(D)** using storytelling to educate on ES using local examples; **(E)** researcher for one day program; and **(F)** public presentations. All identifiable individuals have delivered a written consent for the publication of the images.

In the framework of the "Incubator of ES projects," the REASE network has co-organized field trips with schools to the Ria Formosa Natural Park and the Castro Marim saltmarsh Natural Reserve in which about 500 K-12 students have participated in the last year (**Figure 2C**). During the field trips, the "Blue Carbon" and other projects (e.g., assessment of the ES of biodiversity support by seagrass meadows, in particular commercial bivalves) have been implemented, in which students actively participated in the collection of plants and sediment samples from different locations and measured environmental parameters.

The "Formosa" Story: A Booklet for Children on ES

The use of appropriate stories may enhance the Ocean Literacy of children and also educate them toward a more sustainable attitude in relation to the environment. When a child listens to a story narrated by a person who has a deep knowledge on environmental issues, it has the chance to experience a new field of sensations by becoming a part of the story (Barton and Booth, 1990). REASE followed this approach by publishing a children booklet entitled ("Formosa")[8] that is being used as an educational tool for teaching the ES provided by seagrass meadows in the Ria Formosa lagoon. The creation of the booklet was, at the same time, an educational and participatory project, in which local schoolchildren prepared drawings to illustrate the booklet after hearing the story from the author at their school and after participating in a field trip to visit the ecosystem that is the booklet's protagonist, the seagrass meadows of Ria Formosa. The published booklet was then presented to the local community in a public event where children, parents and scholars were invited. After its publication, about 20 presentations (**Figures 2D,F**, 4 of

[8]http://rease.ccmar.ualg.pt/downloads/attachments/FORMOSA%20Maquete%20210x148mm_4c.pdf

them including a field trip to visit seagrass meadows, **Figure 2C**) of the booklet story were given by its author to more than 400 children at schools and *Ciência Viva* centers. A total of 950 paper copies were distributed in the first year in schools and in several fairs and other ocean-related meetings and events.

"Researcher for One Day" Program

While knowledge of the theoretical framework of the ES and OL topics is indispensable, it is not always easy to directly relate it with the real world. In most cases, students have very little knowledge of the coastal marine habitats in the Ria Formosa as a real-world concept, despite living extremely close to them and having studied them in the classroom. The only exceptions are the children of the lagoon's users, such as fisherman and clam cultivators. To promote engagement and active education, REASE developed the "Researcher for one day" program where selected students (by their teachers) participated in the research activities of CCMAR, directly interacting with researchers during a field sampling campaign (**Figure 2E**). This allows a hands-on experience, and interaction with someone who has experience on scientific issues related to ES. This direct contact can be critical to instilling a life-long interest in science. Such arrangements are, however, difficult to organize on a large-scale, due to practical limitations.

Informal Education

The formal education is the main focus of the REASE network to mainstream ES in the eastern Algarve region, but learning is not limited to formal education. To embrace a wider audience, different informal activities were developed, including exhibitions, workshops, "talks with scientists," radio interviews to REASE members, among others. The *Ciência Viva* science centers (of Faro and Tavira), as partners of the REASE network, had an active role in the informal education activities through the presentation of a permanent interactive exhibition on the ES of coastal vegetated ecosystems of Ria Formosa lagoon (**Figure 3A**). As well, roll-ups on the ES services of Ria Formosa lagoon (**Figure 3B**), namely the water purification, the carbon sequestration, biodiversity support and ocean acidification mitigation, were prepared and exhibited in shopping malls, nautical fairs and in schools to commemorate environmental events.

CHALLENGES AND LESSONS LEARNED

The greatest challenge of REASE is to raise the awareness of K-12 students on the benefits that coastal vegetated ecosystems deliver and how they are crucial for the well-being of populations. This challenge was addressed first by training and rising the ES awareness of school teachers who then conveyed it to students. This is probably the best strategy to reach most of families and thus a vast audience, through their children (Uzzell et al., 1994; Ballantyne et al., 1998; Bamberg and Möser, 2007). If the youngest of families learn the benefits of local ecosystems, there is a good possibility that this knowledge will pass on to their parents raising their awareness as well. In order to increase successfully the awareness of teachers and then of students, it is fundamental to make it interesting and exciting. This challenge was successfully addressed by identifying threats to local ecosystems that people worry about, and by discussing solutions to improve and maintain their health.

Then it was necessary to implement exciting projects that involved not only laboratory work but most importantly, field excursions and sampling so that the teachers and their students get in touch with the natural environments and may break the monotony of the day to day work within the school buildings. For this, we developed a close collaboration between researchers and educators. A model project was developed, the Blue Carbon Project (see text footnote 6), whose field and laboratory protocols were tested and improved with teachers. A critical component was the creation of educational materials, including information that allows participants to understand the scientific background, a field kit with everything necessary to collect samples and field information, clear and precise field and laboratory protocols and laboratory conditions to analyze the samples. Potential educational benefits of REASE projects range from acquiring skills needed to collect data accurately to critical scientific

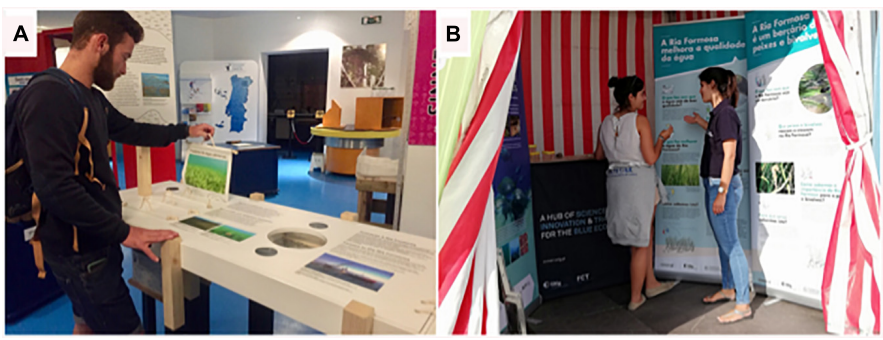

FIGURE 3 | REASE activities for informal education include, among others, **(A)** interactive permanent exhibitions on ES of coastal vegetated ecosystems at science centers, and **(B)** roll-ups exhibitions in shopping malls, nautical fairs and in schools. All identifiable individuals have delivered a written consent for the publication of the images.

thinking and inquiry, in which participants apply knowledge to generate new questions and then design studies or develop models to answer those questions. Furthermore, the data collected is scientific valuable once is validated by researchers, and has in itself educational value. The experience of collecting data for use by professional scientists is highly motivating, fosters scientific knowledge, and provides opportunities for interacting with members of likeminded communities within local environments (Bonney et al., 2014). The deeper involvement of teachers and students in REASE activities is resulting in increasingly robust learning outcomes. It is gratifying to see that the number of schools and teachers interested in participating is steadily increasing and that researchers have been invited for a number of informal events to discuss on local environmental issues and problems.

One of the lessons learned is that teachers need to understand that not knowing the answer is okay and that science does not have answers to all the questions and problems. Teachers need to overcome the paradigm that they are the holders of all knowledge, to a new paradigm where teachers and students have to co-construct knowledge so that the learning process is focused on the student. Additional training and resources to facilitate this paradigm are needed, for example, methodological training directed to cooperative work, problem-, project- and inquiry-based learning. On what concerns resources, the challenge is how to overcome difficulties related to heavy and fragmented curricula by many disciplines giving limited time to develop projects with students, large numbers of students per class, reduced budgets, lack of transportation to take the students to the field, and many other growing challenges facing schools. However, during the REASE first year, teachers have found ways to overcome those challenges and have shared them within the network so that others may benefit from solutions found, for example developing partnerships with the municipalities and the national agency "Ciência Viva"[9]. Our empirical assessment, based on the feedback received from teachers, shows as well that it is possible to develop interdisciplinary projects integrating various subjects such as biology, geology, physics, chemistry, geography and mathematics. This is particularly relevant because ocean problems are complex and require interdisciplinary approaches.

Environmental and educational impacts of REASE are difficult to measure. However, we are considering three distinct ways of evaluation: the contribution to scientific knowledge through the ES data that is being collected and is being made available at the site (see text footnote 6), the number of blog news published on the activities developed with the students[10] and the impacts on behavior, i.e., if participants become more environmentally responsible individually or collectively, in the present, or in the future. Outdoor educational interventions, including field trips and experiential work, have generally a positive effect (Fiennes et al., 2015), but this effect is attenuated over time. This reinforces the need for continued interventions as it is being done in REASE rather than timely interventions. The long-term effects of REASE may be evaluated by mixed method methodologies including quasi experimental research design (e.g., pretest–posttest), semi-structured interviews and focus groups (Cook and Campbell, 1979; Stern et al., 2014). A relevant immediate impact of REASE was the successful submission of the project Erasmus + 2018-1-PT01-KA229-047540, Human Impacts @ Coastal Ecosystems," by one of the schools of the network, "Francisco Fernandes Lopes." The project involves 6 EU countries to recognize the importance of protecting coastal ecosystems and among other objectives includes the implementation of the Blue Carbon project of REASE in those countries.

With increasingly severe local and global environmental problems, time is running out to develop an ocean literate citizenry that is "capable of understanding, supporting, and demanding the policy changes necessary to protect the ocean" (Schoedinger et al., 2006). Ocean-literate individuals take action, and through active participation in OL experiences, attach emotion and values to the ocean and its resources. However, ocean literacy and environmental education continues to be sub-valorized in the K-12 educational system in Portugal, resulting in a citizenry that is not equipped to deal proficiently with many environmental problems that are considered out of sight and out of mind. PAFC reform could be an opportunity to change this. The PAFC project gives legal space for all schools to spontaneously and progressively adhere to the possibilities for curriculum design, especially project-based learning, where the promotion of OL could conquer a *pool* position.

AUTHOR CONTRIBUTIONS

HB, CS, and RS contributed conception and design of the study. All authors wrote sections of the manuscript, contributed to manuscript revision, and read and approved the submitted version.

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[9]http://www.cienciaviva.pt/home/

[10]http://rease.ccmar.ualg.pt/#news

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