Understanding Dimensions of Ocean Literacy in the European Maritime Industry for a Sustainable Blue Economy

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"The ocean is not too big to fail, and it is not too big to fix, but it is so central to our health, prosperity and well-being that it is too big to ignore"

Jane Lubchenco, 2020

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List of Abbreviations

AAEE	Australian Association for Environmental Education
AMEA	Asia Marine Educators Association
BMAP	Biodiversity Monitoring and Assessment Program
CaNOE	Canadian Network for Ocean Education
CI	Collaboration Index
DGMARE	General Direction for Maritime Affairs and Fisheries
EFA	Exploratory Factor Analysis
EMSEA	European Marine Science Educators Association
EQF	European Qualifications Framework
ESCO	European Skills, Competences, and Occupations
EU4Ocean	European Ocean Coalition
FAO	Food and Agriculture Organization
FLORES	Forward Looking at the Offshore Renewables
GDP	Global Gross Domestic Product
GVA	Gross Value Added
IMO	Integrated Ocean Management
IOLS	International Ocean Literacy Survey
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPMEN	International Pacific Marine Educators Network
KMO	Kaiser-Meyer-Olkin measure

kr20	Kuder-Richardson 20 coefficient
LNG	Liquified Natural Gas
MATES	Maritime Alliance for fostering the European Blue Economy through a Marine Technology Skilling Strategy
NMEA	National Marine Educators Association
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
OLWA	Ocean Literacy With All
RELATO	Latin American Marine Education Network for the Ocean
RIGHT	Right Skills for the Right People Project
SDG	Sustainable Development Goals
SOLE	Survey of Ocean Literacy and Engagement
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WLS	Weight Least Squares
WOS	Web of Science
Youth4Ocean	European Youth Forum for the Ocean

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Summary

The ocean plays a crucial role in sustaining life on Earth, offering a wide range of benefits and services. Through its diverse ecosystems, the ocean offers essential resources like food, energy, and minerals, while also regulating the climate and supporting human health and well-being. It significantly contributes to the global economy through industries like offshore renewables, fisheries, tourism and maritime transport, namely blue economy, creating millions of jobs worldwide. However, the rapid expansion of these economic activities poses an increasing risk for the marine environment, that is already facing a growing array of threats, including acidification, overfishing, pollution, habitat degradation and biodiversity loss. As interest in the ocean's economic potential grows, it becomes imperative to adopt sustainable practices and raise awareness among all members of society, particularly those whose livelihoods come directly from the sea, that is the maritime workforce. A thriving blue economy needs a workforce that understands the importance of the ocean, makes informed decisions to manage marine resources and ecosystems, and advocates for sustainable policies. Ocean literacy emerges as a tool to achieve this target, as a way not only to increase awareness, but as an approach to encourage maritime workers to have a more responsible behaviour towards the ocean and its resources. This research aims to expand the understanding on the status of ocean literacy with a focus on the European blue economy and to assess the levels of ocean literacy across maritime workers.

Drawing upon an extensive literature review, the first part of this study presents a comprehensive analysis of key concepts to introduce the reader to the field of ocean literacy. **Chapter 1** provides an overview of the European blue economy sectors describing the features of the maritime workforce. This chapter brings forward the need of integrating ocean literacy research within the maritime sector.

Given the emergence of numerous ocean literacy initiatives, it became essential to obtain a comprehensive understanding of this topic to effectively involve the wider community. In **chapter 2**, we assessed the development of global research on ocean literacy applying bibliometric analysis and science mapping of the available scientific publications on ocean literacy (2005-2019). These techniques enabled us to represent the development of the ocean literacy field, to analyze the level of collaborations and to uncover its thematic areas. Our approach further identified the gaps in research related to the blue economy. Bibliometric analyses were used to describe the field's main features, including indicators of growth and research collaboration. We then used science mapping techniques to build collaboration networks among countries and institutions, and to identify research communities. The findings of this study suggest that ocean literacy is an emerging field of research with promising trends in research collaboration. Our results also suggest disparities in the scientific production and collaborations between the Global North and South. This study allowed us to verify the presence of a gap in the existing research, given that only a small proportion of the global ocean literacy research was focused on the blue economy (7.2%).

Having set the scene for the need of studies on the coupling of ocean literacy and the blue economy, we needed a tool to measure ocean literacy targeted to professionally active people. In **chapter 3**, we developed and tested the Blue Survey, an online instrument meant to measure ocean literacy in adult

populations. Factor analysis was used to explore the validity and internal consistency of the Blue Survey in a purposive online sample of 251 adults. We found ocean literacy to consist of six dimensions captured by 34 survey items, *viz.* knowledge, personal interest, ocean stewardship, ocean as an economic resource, ocean-friendly behaviour, and willingness to act responsibly towards the ocean. The Blue Survey is proposed as a new instrument to measure ocean literacy in an adult population. This multilingual validated tool combines aspects such as knowledge, attitudes, and behaviours, in the same construct and provides a more integrated perspective on ocean literacy as a means of producing change, which has not been done before for this stakeholder group.

Based on the results from chapter 3, and in order to assess the validity of the Blue Survey across populations closely related to the sea, particularly maritime professionals, we designed the Blue Survey 2.0. In **chapter 4**, we conducted the Blue Survey 2.0 to assess the levels of ocean literacy of 536 maritime workers across Europe, using exploratory factor analysis, univariate and cluster analyses. Our findings suggest that the way maritime workers connect to the ocean is complex, but it can be simplified by considering the integration of five pillars including knowledge, attitudes towards ocean sustainability, attitudes towards the use of the ocean, behaviour and personal interest. In addition, we found that factors related to the industry such as the blue economy sector, region and occupation; as well as sociodemographics like age and gender, influenced the levels of ocean literacy in European maritime workers. In the second part of chapter 4, we showcased the application of the Blue Survey 2.0 among maritime workers in Peru. These results constitute a benchmark for measuring ocean literacy in the blue economy sector. Finally, a comprehensive discussion of the main findings presented in the previous chapters is showcased in **chapter 5**. This chapter highlights the implications of our findings for marine science and broaden goals of sustainability, such as the UN Sustainable Development

Goals, the Ocean Decade and the European Strategy for a sustainable blue economy.

In conclusion, this study has deepened our understanding in the topic of ocean literacy in the context of the blue economy and has highlighted the importance of ocean literacy to ensure a sustainable future. Through an in-depth assessment of the current state of ocean literacy research, our findings support the inclusion of ocean literacy as one of the priority areas of research of the Ocean Decade. By conducting empirical research on the dimensions and levels of ocean literacy using the Blue Survey, this study provides two validated multilingual tools to measure the various dimensions of ocean literacy. The findings of this study underscore the need to integrate ocean literacy content into the trainings of maritime workers, especially for young workers, which seem to be the least engaged. Our results might help companies to understand that for certain groups of maritime workers enhancing knowledge on the ocean alone is not enough to achieve ocean-friendly behaviour and that other approaches for engagement with ocean sustainability seem appropriate. Moving forward, further research in this field should continue building on the foundations laid here to obtain an ocean literacy baseline in maritime communities over time and to assess the mechanisms through which ocean literacy initiatives effectively lead to an increase of knowledge, positive attitudes and behaviours towards the ocean.

Samenvatting

De oceaan speelt een cruciale rol in het in stand houden van het leven op aarde en biedt een breed scala aan voordelen en diensten. Via zijn diverse ecosystemen biedt de oceaan essentiële hulpbronnen zoals voedsel, energie en mineralen, terwijl de oceaan ook het klimaat reguleert en de gezondheid en het welzijn van de mens ondersteunt. De oceaan levert een belangrijke bijdrage aan de wereldeconomie door industrieën als offshore hernieuwbare energie, visserij, toerisme en zeetransport, de blauwe economie, en creëert zo wereldwijd miljoenen banen. De snelle uitbreiding van deze economische activiteiten vormt echter een toenemend risico voor het mariene milieu dat reeds wordt geconfronteerd met een groeiend aantal bedreigingen, waaronder verzuring, overbevissing, vervuiling, aantasting van habitats en verlies van biodiversiteit. Naarmate de belangstelling voor het economische potentieel van de oceaan toeneemt, wordt het noodzakelijk om duurzame praktijken toe te passen en het bewustzijn onder alle leden van de samenleving te vergroten, met name onder degenen waarvan hun levensonderhoud rechtstreeks uit de zee komt, de maritieme beroepsbevolking. Een welvarende blauwe economie heeft een beroepsbevolking nodig die het belang van de oceaan begrijpt, weloverwogen beslissingen neemt om mariene hulpbronnen en ecosystemen te beheren en pleit voor duurzaam beleid. *Ocean literacy* komt naar voren als een middel om dit doel te bereiken, als een manier om niet alleen het bewustzijn te vergroten, maar ook als een benadering om maritieme werknemers aan te moedigen tot een meer

verantwoordelijk gedrag ten opzichte van de oceaan en haar hulpbronnen. Dit onderzoek heeft als doel meer inzicht krijgen in de status van *Ocean literacy* met een focus op de Europese blauwe economie en om de niveaus van *Ocean literacy* onder maritieme werknemers te beoordelen.

Op basis van een uitgebreid literatuuronderzoek presenteert het eerste deel van deze studie een uitgebreide analyse van de belangrijkste concepten om de lezer wegwijs te maken op het gebied van *Ocean literacy*. **Hoofdstuk 1** geeft een overzicht van de Europese blauwe economie sectoren en beschrijft de kenmerken van de maritieme beroepsbevolking. Dit hoofdstuk vestigt de aandacht op de noodzaak om onderzoek naar *Ocean literacy* te integreren in de maritieme sector.

Gezien de opkomst van talloze initiatieven op het gebied van *Ocean literacy*, is het essentieel om een uitgebreid inzicht te krijgen in dit onderwerp om de bredere gemeenschap er effectief bij te betrekken. In **hoofdstuk 2** hebben we de ontwikkeling van wereldwijd onderzoek naar *Ocean literacy* beoordeeld aan de hand van een bibliometrische analyse en het in kaart brengen van de beschikbare wetenschappelijke publicaties over *Ocean literacy* (2005-2019). Deze technieken stelden ons in staat om de ontwikkeling van het gebied van *Ocean literacy* weer te geven, het niveau van de samenwerkingsverbanden te analyseren en de thematische gebieden ervan bloot te leggen. Onze aanpak identificeerde verder de hiaten in het onderzoek naar de blauwe economie. Bibliometrische analyses werden gebruikt om de belangrijkste kenmerken van het domein te beschrijven, waaronder indicatoren van groei en onderzoekssamenwerking. Vervolgens gebruikten we technieken voor het in kaart brengen van de wetenschap om samenwerkingsnetwerken tussen landen en instellingen op te bouwen en onderzoeksgemeenschappen te identificeren. De bevindingen van dit onderzoek suggereren dat *Ocean literacy* een opkomend onderzoeksgebied is met veelbelovende trends in onderzoekssamenwerking. Onze resultaten wijzen ook op ongelijkheden in de wetenschappelijke productie en samenwerking tussen het Noorden en het Zuiden. Deze studie stelde ons in

staat om de aanwezigheid van een hiaat in het bestaande onderzoek te verifiëren, gezien het feit dat slechts een klein deel van het wereldwijde onderzoek naar *Ocean literacy* gericht was op de blauwe economie (7,2%).

Nadat de basis gelegd was voor de behoefte aan studies over de koppeling van *Ocean literacy* en de blauwe economie, hadden we een instrument nodig om *Ocean literacy* te meten gericht op professioneel actieve mensen. In **hoofdstuk 3** ontwikkelden en testten we de *Blue Survey*, een online instrument om *Ocean literacy* bij volwassenen te meten. Factoranalyse werd gebruikt om de validiteit en interne consistentie van de *Blue Survey*, te onderzoeken in een doelgerichte online steekproef van 251 volwassenen. We ontdekten dat *Ocean literacy* bestaat uit zes dimensies die zijn vastgelegd in 34 enquête-items, namelijk kennis, persoonlijke interesse, rentmeesterschap over de oceaan, de oceaan als economische hulpbron, oceaanvriendelijk gedrag en de bereidheid om verantwoordelijk te handelen tegenover de oceaan. De *Blue Survey*, wordt voorgesteld als een nieuw instrument om *Ocean literacy* te meten bij een volwassen populatie. Dit meertalige gevalideerde instrument combineert aspecten als kennis, houding en gedrag in dezelfde constructie en biedt een meer geïntegreerd perspectief op *Ocean literacy* als middel om verandering teweeg te brengen, wat nog niet eerder is gedaan voor deze groep belanghebbenden.

Op basis van de resultaten uit hoofdstuk 3 en om de geldigheid van de *Blue Survey* te beoordelen bij bevolkingsgroepen die nauw verbonden zijn met de zee, met name maritieme werknemers, hebben we de *Blue Survey 2.0* ontworpen. In **hoofdstuk 4** voerden we de *Blue Survey 2.0* uit om de niveaus van *Ocean literacy* van 536 maritieme werknemers in heel Europa te beoordelen, met behulp van verkennende factoranalyse, univariate en clusteranalyses. Onze bevindingen suggereren dat de manier waarop maritieme werknemers zich verbinden met de oceaan complex is, maar vereenvoudigd kan worden door de integratie van vijf pijlers te overwegen, waaronder kennis, houding ten opzichte van duurzaamheid van de oceaan, houding ten opzichte van het gebruik van de oceaan, gedrag en persoonlijke

interesse. Daarnaast ontdekten we dat factoren die verband houden met de industrie, zoals de blauwe economie sector, regio en beroep, evenals socio-demografische factoren zoals leeftijd en geslacht, van invloed zijn op de niveaus van *Ocean literacy* bij Europese maritieme werknemers. In het tweede deel van hoofdstuk 4 werd de toepassing van de *Blue Survey 2.0* onder maritieme werknemers in Peru voorgesteld. Deze resultaten vormen een maatstaaf voor het meten van *Ocean literacy* in de blauwe economie. Tot slot wordt in **hoofdstuk 5** een uitgebreide bespreking gegeven van de belangrijkste bevindingen uit de voorgaande hoofdstukken. Dit hoofdstuk belicht de implicaties van onze bevindingen voor de mariene wetenschap en bredere duurzaamheidsdoelen, zoals de Duurzame Ontwikkelingsdoelstellingen van de Verenigde Naties, het de Ocean Decade en de Europese Strategie voor een duurzame blauwe economie.

Concluderend kan worden gesteld dat deze studie ons inzicht in het onderwerp *Ocean literacy* in de context van de blauwe economie heeft verdiept en het belang van *Ocean literacy* voor een duurzame toekomst heeft benadrukt. Door een grondige beoordeling van de huidige stand van zaken van het onderzoek naar *Ocean literacy,* ondersteunen onze bevindingen de opname van *Ocean literacy* als een van de prioritaire onderzoeksgebieden van de Ocean Decade. Door empirisch onderzoek uit te voeren naar de dimensies en niveaus van *Ocean literacy* met behulp van de *Blue Survey*, biedt deze studie twee gevalideerde meertalige instrumenten om de verschillende dimensies van *Ocean literacy* te meten. De bevindingen van dit onderzoek onderstrepen de noodzaak om *Ocean literacy* te integreren in de opleiding van maritieme werknemers, met name voor jonge werknemers, die het minst betrokken lijken te zijn. Onze resultaten kunnen bedrijven helpen te begrijpen dat voor bepaalde groepen maritieme werknemers het vergroten van kennis over de oceaan alleen niet genoeg is om oceaanvriendelijk gedrag te bereiken en dat andere benaderingen voor betrokkenheid bij duurzaamheid van de oceaan geschikt lijken. Verder onderzoek op dit gebied moet voortbouwen op de hier gelegde fundamenten

om een basisniveau van *Ocean literacy* in maritieme gemeenschappen te verkrijgen en om de mechanismen te beoordelen waarmee initiatieven op het gebied van *Ocean literacy* effectief leiden tot een toename van kennis, positieve houdingen en gedrag ten opzichte van de oceaan.

Resumen

El océano desempeña un papel crucial manteniendo la vida en la Tierra, ofreciendo una amplia gama de beneficios y servicios. A través de sus diversos ecosistemas, el océano ofrece recursos esenciales como alimentos, energía y minerales, mientras que regula el clima y favorece la salud y el bienestar humano. El océano contribuye significativamente a la economía mundial a través de industrias como las energías renovables en alta mar, la pesca, el turismo y el transporte marítimo, conocidos como la economía azul, que crea millones de puestos de trabajo en todo el mundo. Sin embargo, la rápida expansión de estas actividades económicas supone un riesgo cada vez mayor para el medio marino, que ya viene enfrentando una creciente serie de amenazas, como la acidificación, la sobrepesca, la contaminación, la degradación de los hábitats y la pérdida de biodiversidad. A medida que el interés por el potencial económico del océano crece, se hace imperativo adoptar prácticas sostenibles y aumentar la sensibilización en todos los miembros de la sociedad, particularmente, en aquellos cuyo medio de vida procede directamente del mar, es decir, la fuerza de trabajo marítima. Una economía azul próspera necesita una mano de obra que comprenda la importancia del océano, tome decisiones con conocimiento de causa para gestionar los recursos y ecosistemas marinos, y abogue por políticas sostenibles. La cultura oceánica surge como una herramienta para alcanzar este objetivo, no sólo como una forma de aumentar la concientización, sino como un enfoque para fomentar un comportamiento más responsable hacia

el océano y sus recursos en los trabajadores marítimos. Esta investigación pretende ampliar los conocimientos sobre el estado de la cultura oceánica centrándose en la economía azul europea y evaluar los niveles de cultura oceánica de los trabajadores marítimos.

Basándose en una amplia revisión bibliográfica, la primera parte de este estudio presenta un análisis exhaustivo de los conceptos clave para introducir al lector en el campo de la cultura oceánica. El **capítulo 1** ofrece una visión general de los sectores de la economía azul europea y describe las características de la fuerza laboral marítima. Este capítulo plantea la necesidad de integrar la investigación sobre la cultura oceánica en el sector marítimo.

Dada la aparición de numerosas iniciativas sobre cultura oceánica, se hizo esencial obtener una comprensión exhaustiva de este tema para involucrar eficazmente a la comunidad en general. En el **capítulo 2**, evaluamos el desarrollo de la investigación global sobre cultura oceánica aplicando análisis bibliométrico y mapeo científico de las publicaciones científicas disponibles sobre cultura oceánica (2005-2019). Estas técnicas nos permitieron representar el desarrollo del campo de la cultura oceánica, analizar el nivel de colaboraciones y descubrir sus áreas temáticas. Además, nuestro enfoque identificó las brechas en la investigación relacionada con la economía azul. Se utilizaron análisis bibliométricos para describir las principales características del campo de investigación, incluidos los indicadores de crecimiento y colaboración en la investigación. A continuación, utilizamos técnicas de mapeo científico para crear redes de colaboración entre países e instituciones e identificar comunidades de investigación. Las conclusiones de este estudio sugieren que la cultura oceánica es un campo de investigación emergente con tendencias prometedoras en materia de colaboración en la investigación. Nuestros resultados también sugieren disparidades en la producción científica y las colaboraciones entre el Norte y el Sur Global. Este estudio nos permitió comprobar la presencia de una brecha en la investigación existente, dado que sólo una pequeña proporción de la

investigación mundial sobre cultura oceánica se centraba en la economía azul (7,2%).

Habiendo preparado la escena sobre la necesidad de estudios acerca del acoplamiento de la cultura oceánica y la economía azul, necesitábamos una herramienta para medir la cultura oceánica dirigida a personas profesionalmente activas. En el **capítulo 3**, desarrollamos y probamos el *Blue Survey*, un instrumento en línea destinado a medir la cultura oceánica en poblaciones adultas. Se utilizó un análisis factorial para explorar la validez y la consistencia interna del *Blue Survey* en una muestra intencionada de 251 adultos. Se constató que la cultura oceánica consta de seis dimensiones recogidas en 34 ítems de la encuesta, a saber: conocimiento, interés personal, gestión del océano, el océano como recurso económico, comportamiento respetuoso hacia el océano y voluntad de actuar de forma responsable hacia el océano. El *Blue Survey* se propone como un nuevo instrumento para medir la cultura oceánica en una población profesionalmente activa. Esta herramienta multilingüe validada combina aspectos como los conocimientos, las actitudes y los comportamientos en un mismo constructo y ofrece una perspectiva más integrada de la cultura oceánica como medio para producir cambios, algo que no se había hecho antes para este grupo de interés.

Basándonos en los resultados del capítulo 3, y con el fin de evaluar la validez del *Blue Survey* en poblaciones estrechamente relacionadas con el mar, en particular los profesionales marítimos, diseñamos el *Blue Survey 2.0*. En el **capítulo 4**, llevamos a cabo el *Blue Survey 2.0* para evaluar los niveles de cultura oceánica de 536 trabajadores marítimos de toda Europa, utilizando análisis factoriales exploratorios, análisis univariantes y análisis de conglomerados. Nuestros resultados sugieren que la forma en que los trabajadores marítimos se relacionan con el océano es compleja, pero puede simplificarse si se considera la integración de cinco pilares: conocimientos, actitudes hacia la sostenibilidad del océano, actitudes hacia el uso del océano, comportamiento e interés personal. Además, descubrimos que los factores relacionados con la industria, como el sector de la economía azul, la

región y la profesión, así como los factores sociodemográficos, como la edad y el sexo, influían en los niveles de cultura oceánica de los trabajadores marítimos europeos. En la segunda parte del capítulo 4 se muestra la aplicación del *Blue Survey 2.0* en trabajadores marítimos en Perú. Estos resultados constituyen un punto de referencia para medir la cultura oceánica en el sector de la economía azul. Por último, en el **capítulo 5** se presenta un análisis exhaustivo de los principales resultados presentados en los capítulos anteriores. En este capítulo se destacan las implicaciones de nuestros hallazgos para la ciencia marina y objetivos globales y regionales de sostenibilidad, como los Objetivos de Desarrollo Sostenible de las Naciones Unidas, la Década de los Océanos y la Estrategia Europea para una economía azul sostenible.

En conclusión, este estudio ha profundizado nuestra comprensión sobre la cultura oceánica en el contexto de la economía azul y ha puesto de relieve la importancia de la cultura oceánica para garantizar un futuro sostenible. A través de una evaluación en profundidad del estado actual de la investigación sobre la cultura oceánica, nuestros resultados apoyan su inclusión como una de las áreas prioritarias de investigación de la Década Oceánica. Al llevar a cabo una investigación empírica sobre las dimensiones y los niveles de la cultura oceánica utilizando el *Blue Survey*, este estudio proporciona dos herramientas multilingües validadas para medir las diversas dimensiones de la cultura oceánica. Las conclusiones de este estudio subrayan la necesidad de integrar contenidos de cultura oceánica en la formación de los trabajadores marítimos, especialmente para los trabajadores jóvenes, que parecen ser los menos comprometidos. Nuestros resultados podrían ayudar a las empresas a comprender que, para determinados grupos de trabajadores marítimos, no basta con incrementar los conocimientos sobre el océano para lograr un comportamiento respetuoso, y que otros enfoques para comprometerse con la sostenibilidad del océano parecen apropiados. De cara al futuro, la investigación en este campo debería seguir construyendo sobre los cimientos presentados en este estudio para obtener una línea de base de la cultura

oceánica en las comunidades marítimas a lo largo del tiempo y evaluar los mecanismos a través de los cuales las iniciativas de cultura oceánica conducen a un aumento efectivo de los conocimientos, las actitudes y los comportamientos positivos hacia el océano.

Chapter 1

General Introduction

1.1 Introduction

The ocean is our life support system. No matter where we live, the ocean plays a significant role in our lives, by influencing cultural, social, historical, biological, and economic aspects. It offers numerous benefits to human societies, from providing food, energy and minerals, regulating the climate, and hosting the greatest diversity of life and ecosystems (Cooley et al., 2022), to contributing to human health and well-being (Fleming et al., 2019). The ocean covers almost 71% of the Earth's surface (equivalent to 361 million km^2) and yet we call it planet Earth (Stel, 2021).

The ocean is a source of food, with fisheries and aquaculture supporting the livelihoods of millions of people around the world (Tigchelaar et al., 2022). It is also a source of non-food resources, including oil, gas, minerals, and renewable energy sources such as wind, wave and tidal power (OECD, 2016). In addition to its economic importance, the ocean is also crucial for regulating the Earth's climate, acting as a carbon sink and absorbing heat from the atmosphere (Gruber et al., 2023) providing half of the planet's oxygen (NOAA, 2023a). Not least, the ocean is a source of inspiration and recreation, offering opportunities for activities such as swimming, diving, surfing, and sailing (Allison et al., 2020).

Despite these benefits, the ocean itself faces a growing array of threats, including acidification, overfishing, pollution, habitat degradation and the loss of biodiversity (Cooley et al., 2022; Halpern et al., 2015). To address these issues, it is crucial to increase awareness across all actors of society including the general public, policy makers, youngsters and people working at ocean-based industries. However, despite its significance, many people lack awareness about the ocean and its importance (Fletcher et al., 2009; Gelcich et al., 2014; Potts et al., 2016; Steel et al., 2005a).

1.1.1 Importance of the Ocean to the Global Economy and Society

The global economy is heavily dependent on the ocean and its resources. In 2010 it was estimated that the ocean provides US$1.5 trillion annually to the world economy, or around 2.5% of global gross domestic product (GDP), and it is expected to increase over US$3 trillion in 2030 (OECD, 2016) (**Figure 1.1**). The ocean contributes to the economy in several different ways, including, but not limited, economic activities such as offshore renewables, shipbuilding, fisheries, maritime transport, oil and gas, and tourism. These industries offer employment to millions of individuals and sustain the livelihoods for millions of people around the world (OECD, 2016).

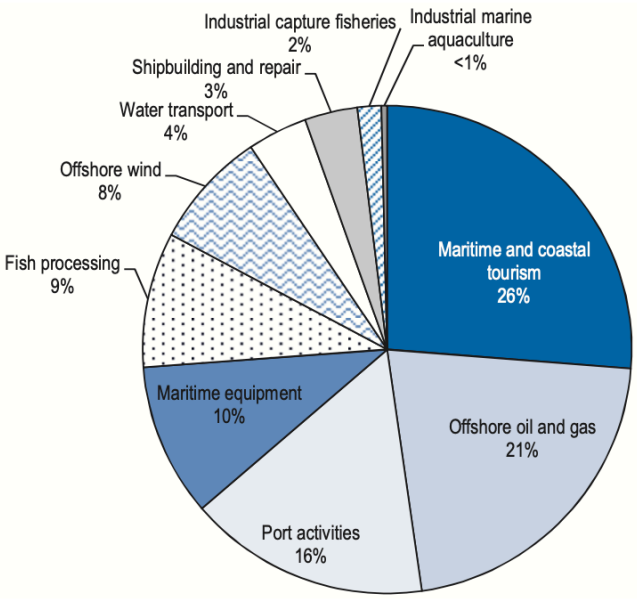

Figure 1.1 Value added of the ocean economy "business-as-usual scenario" in 2030. Source OECD (2016).

The ocean also plays a crucial role in global trade, with approximately 90% of global trade being carried by sea (Sirimanne et al., 2019). Shipping is one of the most cost-effective methods of transporting goods, and the ocean provides the infrastructure for global trade, connecting countries and markets around the world. Coastal areas also provide the space for the development of the shipbuilding industry, port activities, and tourism activities. Tourism is today the second largest employer in the ocean economy and maritime tourism is one of the fastest-growing segments of the global tourism industry (Jouffray et al., 2020). The ocean also contributes to global food and nutrition security and provides around 58.5 million jobs (FAO, 2022). Seafood production and aquaculture currently accounts for 17% of the global edible protein, and despite being recently affected by COVID-19, it is expected to increase by a further 36-74% by 2050 (Costello et al., 2020) (**Table 1.1**).

The recognition of the ocean as a new economic frontier has led to considerable investments that are driving growth in sectors that are currently in early stages of development, also called emerging sectors, such as offshore renewable energy (wind and ocean energy, floating solar energy and offshore hydrogen generation), blue biotechnology, desalination, maritime defence, security and surveillance, submarine cables and marine robotics (European Commission, 2023a; Jouffray et al., 2020).

Beyond its economic significance, the ocean also plays a critical role for society by supporting human well-being and culture. The ocean is a source of recreation and leisure, it represents a space for swimming, sailing, and practicing surfing. Additionally, the ocean has a cultural significance as a space related to cultural symbolism and spiritual beliefs (Allison et al., 2020). For example, many coastal regions around the world are also inhabited by indigenous people that display spiritual practices and rituals involving the ocean (ocean spirituality) (Minguzzi, 2021). Other cultures attribute philosophical and religious interpretations of the ocean and see it

as a source of transcendence, while for others it is a source of inspiration in arts, literature and popular culture (Ebbin, 2020; Rock et al., 2020) (**Table 1.1**).

Table 1.1 List of ocean services evaluated based on available scientific knowledge. Source: European Commission (2022).

Functions & services evaluated	
Ecological functions	Food web maintenance
	Reproduction and nursery
Goods produced by ecosystems	Production of goods from fishing
	Production of goods from shellfish farming
	Exploitation of macroalgae
	Exploitation of molecules
Regulation and maintenance services	Nutrient regulation
	Coastal protection
	Climate regulation
	Pathogen regulation
Cultural services	Recreational services
	Landscape amenities
	Knowledge production
	Institutionalised heritage
	Other forms of heritage

Unfortunately, the continued exploitation of ocean resources without proper management has led to various forms of environmental degradation. Overfishing, habitat destruction, pollution, and climate change-induced impacts, such as ocean acidification and rising sea levels, pose substantial threats to both marine ecosystems and the economic sectors that rely upon them (Halpern et al., 2015). If left uncontrolled, these unsustainable practices jeopardize the long-term viability of ocean-based industries, disrupt coastal communities, and ultimately undermine the global economy.

1.1.2 The Need for Sustainable Management of the Ocean

A healthy ocean is crucial for a healthy planet and consequently for healthy people (Damanaki et al., 2020; Ekins and Gupta, 2019; Redford et al., 2022). The ocean, its ecosystems, and the life therein are critical to an optimal functioning of the planet, absorbing around 26% of human-produced carbon dioxide and generating almost half of the oxygen production on Earth (NOAA, 2023a; Stuchtey et al., 2023). Marine biodiversity also plays a substantial role supporting a healthy planet (Pasca Palmer, 2017); for instance, coral reefs supply essential food, refuge, and breeding habitats for fish and other organisms. They serve as protective barriers for coastlines against storms and erosion, offer food and employment opportunities for nearby communities, and stand as primary attractions for coastal tourists. If coral reefs were to disappear, marine-food webs would be altered and over half billion people that depend on reefs would be affected (Woodhead et al., 2019).

Mangrove ecosystems provide a natural habitat for more than 300 threatened species around the world, protect coastal areas from erosion and extreme weather events, provide jobs and food, and have a critical role in mitigating climate change. They act as powerful carbon sinks, absorbing large quantities of carbon and stopping it from entering the atmosphere (Murdiyarso et al., 2015). Mangrove loss will have as consequence impoverish livelihoods, decline in human security to extreme weather events and sea-level rise and release of carbon into the atmosphere (Lee et al., 2014). Deep-sea ecosystems provide crucial services to the planet capturing and transforming a large part of the carbon dioxide produced by human activities preventing greenhouse gases from resurfacing and accelerating climate change (Thurber et al., 2014). These ecosystems also yield great chemical compounds diversity with pharmaceutical potential (Haefner, 2003); however, the expansion of ocean-based economic activities, pollution

and climate change are threatening the health of these fragile ecosystems (Vanreusel et al., 2016).

Sustaining the health and productivity of the ocean is crucial for ensuring the well-being of society and the prosperity of the global economy. By recognizing the vast economic contributions of the ocean and valuing the essential ecosystem services that it provides, we can foster a more sustainable blue economy (Pace et al., 2023). Embracing responsible ocean management practices and promoting ocean awareness are crucial steps towards achieving this goal, to ensure that future generations can continue to benefit from the vast potential of the ocean (Nunes et al., 2017; Zielinski et al., 2022).

Yet, achieving a healthy, productive and resilient ocean demands adopting a holistic approach towards ocean utilization, while efficiently executing appropriate management strategies at both national and regional levels. In line with this, the Ocean Panel[1] arise as a high-level initiative comprised of world leaders, dedicated to driving transformative action for a sustainable ocean economy. It aims to promote ocean health, conservation, and the responsible use of marine resources to ensure a prosperous future. The Ocean Panel has proposed the concept of Integrated Ocean Management (IOM) as a holistic, ecosystem-based and knowledge-based approach for organizing and managing ocean space utilization. The primary objective of IOM is to balance various ocean uses and needs, aiming to achieve both a sustainable ocean economy and the preservation of healthy ecosystems (Winther et al., 2020) (**Figure 1.2**).

The UN Sustainable Development Goals (SDGs) are a collection of 17 interlinked objectives designed to serve as a call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The SDGs recognize that development must balance social,

[1] The Ocean Panel - https://oceanpanel.org

economic and environmental sustainability. They provide a comprehensive framework that recognizes the importance of sustainable ocean management as an integral part of achieving a sustainable and prosperous future for both people and the planet. Particularly, SDG 14 "Life below water" focuses on the conservation and sustainable use of the ocean, seas, and marine resources. This goal addresses various aspects of sustainable ocean management, including the protection of marine ecosystems, the reduction of marine pollution, the regulation of fishing activities, the promotion of sustainable aquaculture, and the preservation of coastal and marine habitats (United Nations, 2015).

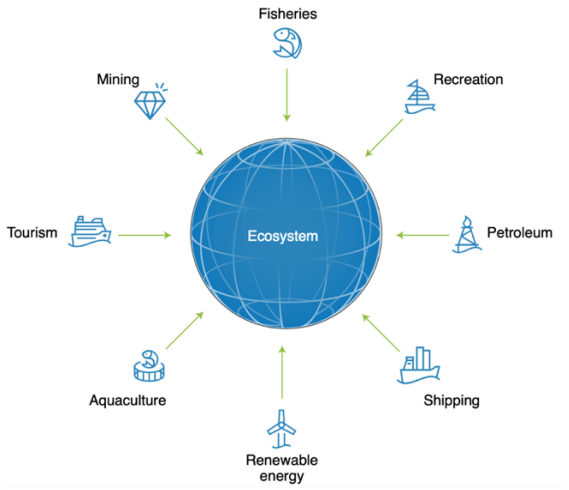

Figure 1.2. The marine ecosystem is at the core of the Integrated Ocean Management (IOM). Source: Winther et al (2020).

Achieving SDG 14 helps to achieve the other SDGs. Among others, it has clear links with food security through fisheries and aquaculture (SDG 2 "Zero hunger"). The ocean is a major regulator for our climate and has an important function as carbon sink (SDG 13 "Climate action"). Moreover, SDG 9 "Industry, innovation and infrastructure" helps to achieve SDG 14

in such a way that green technologies in the maritime industry contribute to both economic development and sustainability criteria (low carbon ports, low emission vessels, offshore renewable energy, etc). In addition, it contributes to SDG 17 “Partnerships for the goals”, as the ocean provides excellent platforms for (scientific) collaboration (Stuchtey et al., 2023; United Nations, 2015).

In 2017, the UN General Assembly declared the Decade of Ocean Science for Sustainable Development (2021-2030). The objective of the Ocean Decade is to support initiatives aimed at reversing the deteriorating health of the ocean and gathering stakeholders worldwide around a shared framework. This framework aims to ensure ocean science can fully support countries in creating improved conditions for sustainable development of the ocean, while achieving the UN 2030 Agenda (UNESCO, 2017).

Efforts to enhance ocean literacy can contribute to the Ocean Decade by fostering a well-informed society that recognizes the importance of the ocean and proactively engages in actions to protect it. This includes but is not limited to encouraging governments and the private sector to invest in ocean science, advocating for evidence-based policies, and fostering collaborations and alliances (UNESCO-IOC, 2021a). **Figure 1.3** visualizes the interactions between the Decade objectives, challenges and outcomes and identifies the contribution of ocean literacy to overcome the Decade challenges to ultimately achieve the Decade Objectives.

Improving individual and collective knowledge and understanding the ocean importance will be essential to accomplish the SDGs (specially SDG 14), the Ocean Decade's objectives, and to achieve effective management of the ocean. This will imply that all sectors of society understand how the ocean supports life on Earth, how society depends on the ocean for the provision of services and its well-being, and how human-induced impacts are affecting the ocean.

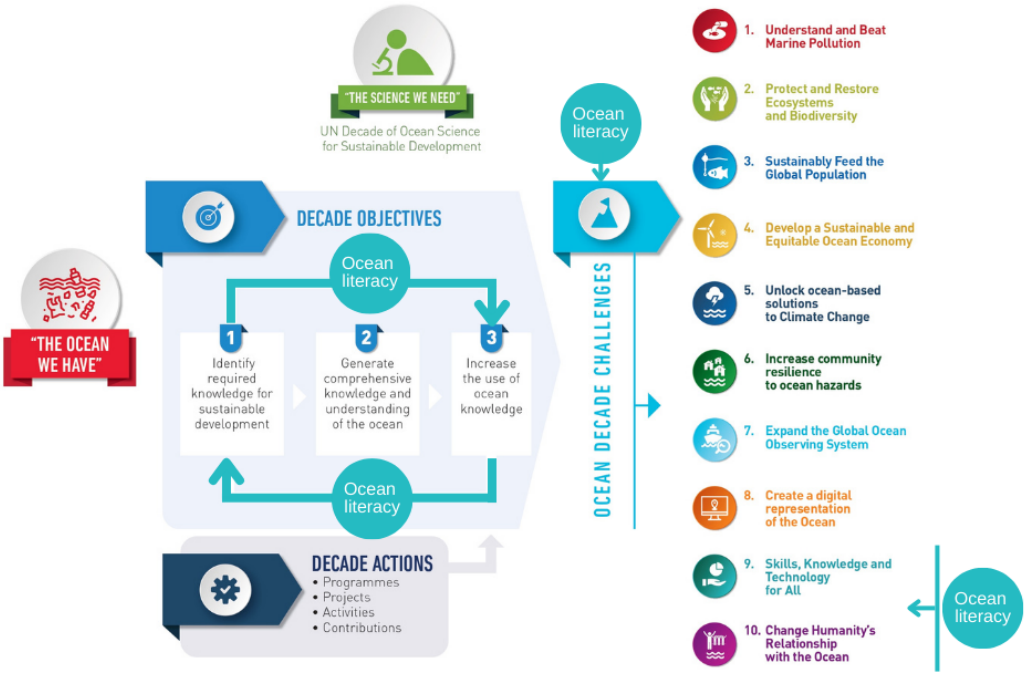

Figure 1.3. Contribution of ocean literacy to the Ocean Decade objectives, actions, challenges and outcomes. Adapted from UNESCO-IOC (2021a).

1.1.3 The Role of Ocean Awareness in Promoting Sustainable Practices

"Knowing is the key to caring, and with caring there is hope that people will be motivated to take positive actions. They might not care even if they know, but they can't care if they are unaware." Sylvia A. Earle

While the health of the ocean is increasingly threatened by human activities such as overfishing, pollution, loss of biodiversity and habitat destruction, there is a growing recognition of the need for ocean awareness to promote public engagement (Gelcich et al., 2014). A significant outcome resulting from successful engagement will be a shift towards more sustainable

practices, both at the individual and collective levels (Lubchenco and Haugan, 2023).

Ocean awareness aims to increase the appreciation on the importance of the ocean, its interconnectedness with other ecosystems, and the impact of human activities on the health of the ocean. By fostering ocean awareness, individuals, communities, and policy makers can make informed decisions to mitigate the negative impacts of human activities on the ocean (Zielinski et al., 2022).

Promoting sustainable practices in the marine environment is crucial to ensure the replenishment of fish stocks, waste management from ships, the reduction of greenhouse gas emissions and pollution from coastal-based and maritime activities (European Commission, 2021b). Furthermore, ocean awareness plays a crucial role in fostering a sense of responsibility and stewardship towards the ocean. By raising awareness, individuals are encouraged to adopt behaviours that minimize harm and contribute to its preservation. This can range from reducing single-use plastic consumption to supporting sustainable seafood choices and participating in beach clean-up initiatives (Santoro et al., 2017).

Despite being a crucial tool in promoting sustainable practices, raising ocean awareness represents a significant challenge mostly because many ocean features are difficult to experience due to perceived remoteness, complexity and vastness leading to public misconceptions (Mokos et al., 2020b).

1.2 Ocean Literacy: An Evolving Concept

1.2.1 Definition of Ocean Literacy

Ocean literacy is a relatively new term that refers to the connection between humans and the ocean, and that intends to be an incentive for positive change in people's behaviour. It is defined as the understanding of the ocean's influence on us and our influence on the ocean. According to this definition, an ocean-literate person understands the importance of the ocean to humankind, can communicate about the ocean in a meaningful way, and, is able to make informed and responsible decisions regarding the ocean and its resources (Cava et al., 2005). As an ocean-literate person, one should understand fundamental ideas and principles about the ocean that are described in detail in the following subsections.

1.2.1.1 Ocean Literacy Essential Principles and Fundamental Concepts

The seven essential principles of ocean literacy constitute the cornerstones of the knowledge about the ocean as they reveal the importance of the human-ocean connection. The content of these principles does not fall neatly within traditional science disciplines, but rather supports a focus on integrated science. The 45 fundamental concepts support and add detail to the essential principles. Despite being included under a specific essential principle, many fundamental concepts illustrate more than one essential principle (**Table 1.2** adapted from NOAA, 2020). It is important to note that the latest version with the seven essential principles and their fundamental concepts was published in 2020, so some fundamental concepts need to be updated according to the latest scientific developments. For example, principle 7A states that less than 5% of the ocean has been explored, however, recent studies revealed that about 20% of the ocean has been explored (NOAA, 2023b).

Table 1.2. Ocean literacy essential principles (in bold) and fundamental concepts. Source: NOAA, 2020

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. Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys and flattest plains are all in the ocean.
C. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth's rotation (Coriolis effect), the Sun and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. This "global ocean conveyor belt" moves waterthroughout all of the ocean basins, transporting energy (heat), matter, and organisms around the ocean. Changes in ocean circulation have a large impact on the climate and cause changes in ecosystems.
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 salty, 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. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.
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.
G. The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to coastal estuaries and to the ocean.
H. Although the ocean is large, it is finite, and resources are limited.
2. The ocean and life in the ocean shape the features of Earth
A. Many earth materials and biogeochemical 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. 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, and the processes associated with plate tectonics move sediments. Most beach sand (tiny bits of animals, plants, rocks, and minerals) is eroded from land sources and carried to the coast by rivers; sand is also eroded from coastal sources by surf. Sand is redistributed seasonally by waves and coastal currents.
D. The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.
E. Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.

Table 1.2. Ocean literacy essential principles (in bold) and fundamental concepts. Source: NOAA, 2020 *(continued)*

3. The ocean is a major influence on weather and climate
A. The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth's energy, water, and carbon systems.
B. The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth. Heat exchange between the ocean and atmosphere drives the water cycle and oceanic and atmospheric circulation.
C. Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought. Significant examples include the El Niño Southern Oscillation and La Niña, which cause important changes in global weather patterns because they alter the sea surface temperature patterns in the Pacific.
D. Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones. Most rain that falls on land originally evaporated from the tropical ocean.
E. The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are 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. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
G. Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical,chemical, biological, economic, and social consequences.
4. The ocean made Earth habitable
A. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. This accumulation of oxygen in Earth's atmosphere was necessary for life to develop and be sustained on land.
B. The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.
C. The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth (Principles 1, 3, and 5).
5. The ocean supports a great diversity of life and ecosystems
A. Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.
B. Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles, and produce a huge amount of the carbon and oxygen on Earth.
C. Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.
D. Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.

Table 1.2. Ocean literacy essential principles (in bold) and fundamental concepts. Source: NOAA, 2020 *(continued)*

E. The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.
F. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.
G. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.
H. Tides, waves, predation, substrate, and/or other factors cause vertical zonation patterns along the coast; density, pressure, and light levels cause vertical zonation patterns in the open ocean. Zonation patterns influence organisms' distribution and diversity.
I. Estuaries provide important and productive nursery areas for many marine and aquatic species.
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. The ocean moderates the Earth's climate, influences our weather, and affects human health.
B. The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, 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. 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 leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
E. Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).
F. Much of the world's population lives in coastal areas. 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.

Table 1.2. Ocean literacy essential principles (in bold) and fundamental concepts. Source: NOAA, 2020 *(continued)*

7. The ocean is largely unexplored
A. The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.
B. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.
C. Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.
D. New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.
E. Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.
F. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

Over the years, ocean literacy has been translated into several languages with the aim to reach and engage a bigger audience (**Table 1.3**). However, some authors stressed the need of a more inclusive approach in the ocean literacy definition, including diverse perspectives from indigenous knowledge, spiritual beliefs, and arts tailored to regional cultural contexts (Worm et al., 2021).

An example of a region-specific definition of ocean literacy is the Mediterranean Sea Literacy guide, that adapted the essential principles and fundamental concepts of ocean literacy to the needs of the Mediterranean region (Mokos et al., 2020a). Similar efforts have been done in other topics such as Great Lakes literacy[2] and Climate literacy[3].

Despite ocean literacy emerged as a knowledge concept closely linked to ocean sciences, over the years it evolved to a multi-perspective approach that not only aims to increase the understanding on ocean-related topics but also promotes interdisciplinary and intercultural skills which contributes to ocean conservation, management, governance and sustainability. The multi-perspective approach includes scientific, historical, geographic, gender equality, value, cultural and sustainability aspects (Santoro et al., 2017).

Shifting from the knowledge-centered notion of ocean literacy primarily used within the educational sphere, has resulted in the emergence of modern frameworks. In these newer models, ocean literacy serves as both a tool and an approach applicable to the entire society, aimed at triggering actions towards ocean sustainability (UNESCO-IOC, 2021a).

[2] Center for Great Lakes literacy - https://www.cgll.org/principles/

[3] Climate literacy - https://www.climate.gov/teaching/climate

Table 1.3. Ocean literacy concepts in different languages. Sources: Worm et al., (2021); https://www.marine-ed.org/ocean-literacy/translations

Name	Language	Direct translation into English	Used in country	Defined by
Ocean literacy	English	Ocean literacy	USA	National Marine Science Association
Cultura oceânica	Portuguese	Ocean culture	Brazil	UNESCO-IOC
Connaissance de l'océan	French	Ocean knowledge	Canada	Canadian Coalition on Ocean Literacy
Cultura oceánica	Spanish	Ocean culture	Spain	UNESCO-IOC
Educazione all'oceano	Italian	Ocean education	Italy	UNESCO-IOC
海洋リテラシー	Japanese	Ocean literacy	Japan	Centre for Ocean Literacy and Education
Świadomość morska	Polish	Sea awareness	Poland	European Marine Science Educators Association
সমুদ্র সাক্ষরতা / বঙ্গোপসাগর-সাক্ষরতার	Bengali	Sea literacy/Bay of Bengal literacy	Bangladesh and India	Bay of Bengal Literacy Network
znanje o moru	Croatian	Knowledge about the sea	Croatia	European Marine Science Educators Association and social media
Γραμματισμό ως προς το Ωκεάνιο Περιβάλλον	Greek	Ocean environment literacy	Greece	International Ocean Literacy Survey
Cultura oceànica	Catalan	Ocean culture	Catalonia	International Ocean Literacy Survey
Elimu ya bahari Ujuzi wa bahari	Swahili	Marine education/ marine skills	Tanzania	European Marine Science Educators Association and social media

1.2.1.2 Ocean Literacy Dimensions

Since its conception, ocean literacy evolved from a grassroots initiative to a research field and as such, has been a topic of study for different domains ranging from marine and social sciences, educational and behavioural sciences, and systems thinking (Brennan et al., 2019; Cheimonopoulou et al., 2022; Fauville, 2017; Koulouri et al., 2022a; McKinley et al., 2022; McKinley and Burdon, 2020; Mogias et al., 2019; Mokos et al., 2020b; Paredes-Coral et al., 2022). Based on the definitions of literacy, a framework of six dimensions was proposed to better understand the multidimensionality of ocean literacy, including knowledge, attitudes, awareness, communication, behaviour and activism (Brennan et al., 2019) (**Figure 1.4**). These dimensions were meant to be measured independently, and an individual could score different levels in different dimensions.

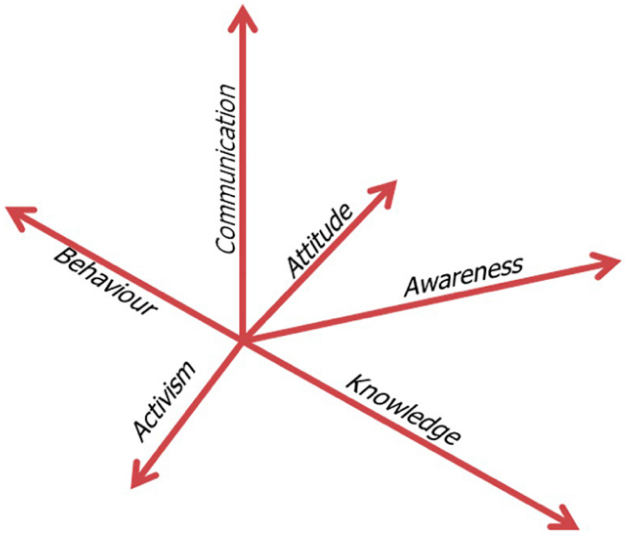

Figure 1.4. Ocean literacy framework including six dimensions proposed by Brennan et al. (2019). The length of the arrows indicates dimensionality only.

Recently, McKinley et al., (2023) revised the scheme suggested by Brennan et al., (2019) and proposed an updated framework containing 10 ocean literacy dimensions. These dimensions included knowledge, awareness, attitudes, communication, activism, behaviour, emotions (emoceans), access and experience, adaptive capacity, trust and transparency (**Figure 1.5**). This framework recognised the complexity of the ocean literacy concept, identified the factors that have an impact and influence on the ocean literacy levels, and that might vary with different audiences.

These frameworks intended to translate the complexity of the ocean literacy concept and serve as a reference for designing and assessing ocean literacy initiatives but also are used to monitor ocean literacy levels over time and across communities in ocean literacy surveys.

Figure 1.5. An updated ocean literacy framework including ten dimensions. Source: McKinley et al. (2023).

The concept of ocean literacy is continuously evolving, and further studies should assess how terminology and translations of the term can be recognised by all actors of society in different geographical and sociocultural settings from both public and private sectors (Worm et al., 2021).

1.2.2 Evolution and Development of the Ocean Literacy Movement

Ocean literacy emerged in the United States (US) as a response to the need for a clear understanding and structure of ocean-related content within the American school curricula. This initiative aimed to identify crucial ocean-related concepts that were lacking in educational programs. Starting in 2002,

a series of meetings and workshops involving experts from ocean science, education communities, and policy makers took place, leading to a consensus on the definition of ocean literacy in 2004 (Cava et al., 2005). Consequently, a roadmap outlining the essential principles and fundamental concepts of ocean literacy was published in 2010 (Schoedinger et al., 2010) (**Table 1.2**).

Although ocean literacy originated as a grassroots movement in the US and was eventually integrated into the American educational system, its trajectory in Europe took a distinct path. After the publication of the ocean literacy roadmap, more precisely, at the NMEA 2011 conference, the dissemination of the ocean literacy concept gained traction in Europe. It was during this conference that the College of Exploration organised an international workshop, in which numerous European marine educators participated. Consequently, many educators were inspired to establish a comparable network within Europe. As a result, the European Marine Science Educators Association (EMSEA) was created along with the First European Conference on Ocean Literacy in 2012 (Copejans and Seys, 2012; Fauville et al., 2013; Mokos et al., 2022).

In its early days in Europe, ocean literacy did not receive legal validation or official recognition as a fundamental component for the effective governance and conservation of the ocean and its resources. However, in a collaborative effort to promote ocean literacy initiatives and advocate for its integration in policy communication, the European Union (EU), Canada, and the US signed the Galway Statement on Atlantic Ocean Cooperation in 2013 (European Commission, 2013a). The Galway Statement serves as an example of how the principles and concepts of ocean literacy have become integral to European marine strategies and policies, including the Marine Strategy Framework Directive, the Marine Spatial Planning Directive, the Common Fisheries Policy, the Birds Directive, the Habitats Directive, and more recently, the European Green Deal and the Sustainable Blue Economy

Strategy (European Commission, 1992, 2008, 2009, 2014b, 2019, 2021, 2023b).

As part of its commitment to fostering ocean literacy among EU citizens, the European Commission funded the SeaChange and ReponSEAble projects in 2015. These initiatives sought to bring about a significant transformation in how people perceive the ocean, empowering them to make ecologically conscious choices and enhancing their understanding of the interconnection between humans and the ocean (European Commission, 2015a, 2015b).

Meanwhile, other national and regional networks were created, namely, the Canadian Network for Ocean Education (CaNOE), the Asia Marine Educators Association (AMEA), the International Pacific Marine Educators Network (IPMEN), and the Australian Association for Environmental Education (AAEE) (Marrero et al., 2019).

In 2018, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) launched the Ocean Literacy Portal[4] as part of their efforts to advance the Sustainable Development Goal 14. The portal provides a comprehensive collection of ocean literacy resources accessible to students, educators, scientists, policymakers, and stakeholders worldwide (UNESCO, 2018). Two years later, in 2020, the European Commission established the European Ocean Coalition (EU4Ocean)[5], an initiative made up of three components that included a Platform for organisations and individuals engaged in ocean literacy initiatives, a European Youth Forum for the Ocean (Youth4Ocean) and a Network of European Blue Schools. By that time, Latin America made progress in fostering an ocean literate society

[4] Ocean Literacy Portal - https://oceanliteracy.unesco.org

[5] European Ocean Coalition - https://maritime-forum.ec.europa.eu/en/frontpage/1482

by creating the Latin American Marine Education Network for the Ocean (RELATO)[6].

With the start of the Ocean Decade in 2021, a framework to promote the development of global, regional, national and local Ocean Literacy Actions around the world was published (UNESCO-IOC, 2021a). The same year, Canada launched its National Ocean Literacy Strategy (Canadian Ocean Literacy Coalition, 2021). Following the wave of ocean literacy initiatives, UNESCO launched the Ocean Literacy Dialogues with its first edition taken place during the UN Ocean Conference in Lisbon in 2022, followed by editions in Brazil and Canada. **Figure 1.6** shows the evolution of the ocean literacy movement since the conception of the term in 2002 until 2023.

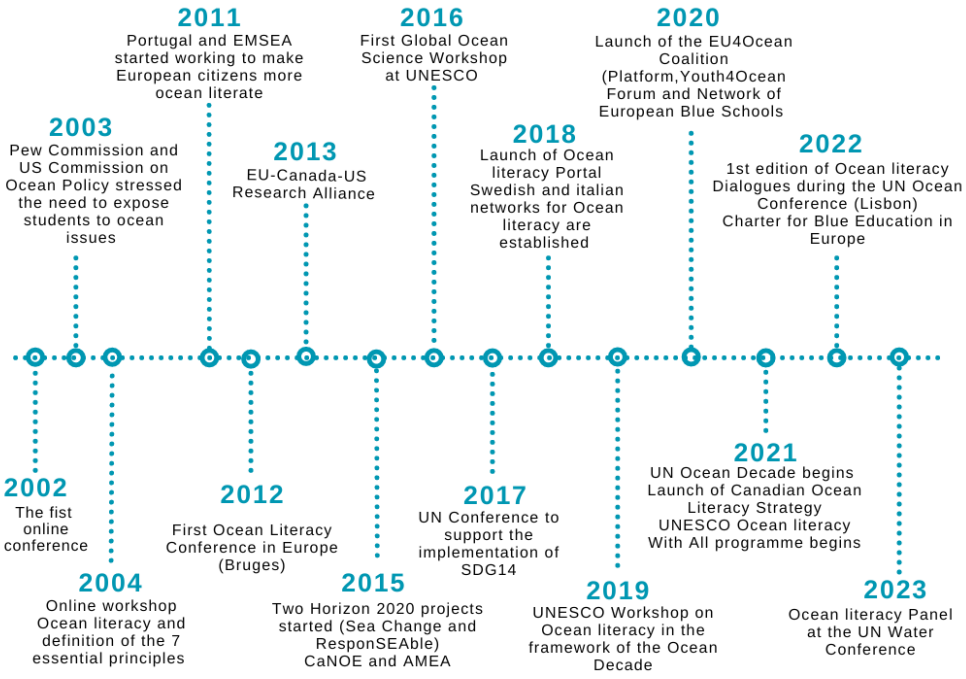

Figure 1.6. Ocean literacy timeline from 2002 to 2023. Adapted from UNESCO and Mokos et al. (2022).

[6] Latin American Marine Education Network for the Ocean - https://relatoceano.org

1.3 The Importance of Ocean Literacy in Building a Sustainable Blue Economy

Ocean literacy is considered as one of the key steps towards achieving the sustainability of the ocean (UNESCO-IOC, 2021a). Given the central role of the ocean in shaping a sustainable future, it becomes essential to assign it a central position in the policy agendas, research, economy, and ultimately in our lives (Claudet et al., 2020; Sumaila et al., 2021; UNESCO-IOC, 2021a). Enhancing public awareness and fostering motivation for behavioural changes towards actions that mitigate and prevent human-induced impacts on the marine environment and its resources becomes imperative (Kelly et al., 2021).

1.3.1 Overview of the Blue Economy Concept

The future of the global ocean economy is currently envisioned as advancing towards a 'blue economy', that consists of ocean industries that are socially equitable, environmentally sustainable and economically viable (Cisneros-Montemayor et al., 2021). The blue economy concept gained prominence during the 2012 Rio+20 Conference, and since then, the term 'blue economy' has become increasingly common (Smith-Godfrey, 2016; United Nations, 2014). However, there is no consensus on a definition and the narratives surrounding the blue economy diverge considerably across different actors (Voyer et al., 2018). According to the World Bank, the blue economy refers to the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of marine ecosystems (World Bank and United Nations Department of Economic and Social Affairs, 2017). The European Commission defines the blue economy as all sectoral and cross-sectoral economic activities related to the oceans, seas and coasts (European Commission, 2020a).

If we were to compare the global blue economy to a national economy, it would rank as the world's seventh-largest economy. Additionally, considering the ocean as an economic entity would position it as a member of the G7 group (European Commission, 2021). The approaches to operationalize the blue economy exhibit significant diversity among geographical regions and organizational contexts. Nevertheless, these approaches frequently center around fostering private sector development of the ocean by means of innovation and investment strategies. These efforts are supported by thorough assessments and forecasts of the present and future economic value of maritime industries in global markets (European Commission, 2023c).

At the European level, there is a set of policy tools including Directives, Action Plans, Strategies and Protocols for regulating relevant blue economy sectors. These documents include but are not limited to the Offshore Renewable Energy Strategy, European Green Deal, Farm to Fork Strategy, Circular Economy Action Plan, Marine Strategy Framework Directive, Habitats Directive, Marine Spatial Planning Directive, Climate and Energy Framework, Biodiversity Strategy for 2030, Energy Efficiency Directive, among others (European Commission, 2008, 2014a, 2014b, 2018, 2020b, 2020c, 2020d, 2020e). Recently, a new approach for a sustainable blue economy was published as an agenda for a maritime policy for this decade, to transform the ocean economy according to the vision outlined in the European Green Deal (European Commission, 2021).

There is relatively little consensus on the sectors that conforms the global blue economy, however, for the purposes of this PhD thesis, we will use the classification provided by the European Commission as stated in the latest EU blue economy report (European Commission, 2023a). According to this classification, the EU blue economy encompasses a series of established and emergent sectors that will be described in the following sections.

1.3.1.1 Established Sectors of the EU Blue Economy

In accordance with the latest EU blue economy report (European Commission, 2023a), the established sectors comprise those industries that traditionally contributed to the blue economy. These sectors include activities related to the exploitation of marine living and non-living resources, offshore wind energy, port activities, shipbuilding and repair, maritime transport and coastal tourism (**Table 1.4**).

The established sectors of the EU blue economy generated a gross value added (GVA) of €129 billion (30% less than in 2019), a gross operating surplus (profit) of €43.6 billion and a total turnover of €523 billion in 2020 (European Commission, 2023a). COVID-19 measures affected all blue industries specially the coastal tourism sector (van Tatenhove, 2021).

Based on the information provided by the European Blue Economy Observatory[7] and the latest EU Blue Economy Report (European Commission, 2023a), established sectors are defined and categorized as follows:

Marine Living Resources

This sector comprises fisheries (small-scale coastal, large-scale and industrial fleets) and aquaculture (marine, freshwater and shellfish); processing of fish products (preservation of fish, crustaceans and molluscs; meal preparation, manufacture of oils, fats and other food products); and their distribution along the supply chain (European Commission, 2023a). This sector was affected by COVID-19, generating about €19.4 billion in GVA in 2020, 0.2% less than 2019 (van Tatenhove, 2021). In 2020, the sector contributed to 15% of the EU blue economy GVA and directly employed about 540

[7] EU Blue Economy Observatory - https://blue-economy-observatory.ec.europa.eu/index_en

thousand individuals (representing 16.1% of the employment). The aggregate expenses for staff amounted to €11.8 billion, with an approximate annual average wage standing at €21.9 thousand (European Commission, 2023a).

Table 1.4. The EU establish blue economy sectors. Source: European Commission (2023a).

Sector	Sub-sector
Marine living resources	Primary production
	Processing of fish products
	Distribution of fish products
Marine non-living resources	Oil and gas
	Other minerals
	Support activities
Marine renewable energy	Offshore wind energy
Port activities	Cargo and warehousing
	Port and water projects
Shipbuilding and repair	Shipbuilding
	Equipment and machinery
Maritime transport	Passenger transport
	Freight transport
	Services for transport
Coastal tourism	Accommodation
	Transport
	Other expenditure

Marine Non-Living Resources

This sector comprises economic activities such as the extraction of oil and gas and other minerals (including gravel, sandpits, clays, kaolin, and salt), and their support activities (European Commission, 2022). For many years, this industry has played a critical role in ensuring access to energy and raw materials for the EU (Craig et al., 2018). However, the offshore oil and gas sector has been in decline since the last decade, in line with the EU targets

for net-zero emission and decarbonization (European Commission, 2019). Over 80% of the present oil and gas production in Europe occurs in offshore waters, primarily concentrated in the North Sea (Murray et al., 2018), with limited operations in the Atlantic and East Mediterranean regions (Legorburu et al., 2018). In 2020, this industry contributed €2.8 billion to the GVA. However, there has been a noticeable decline in performance since 2019, as turnover experienced a reduction of 28% (amounting to €9.4 billion), while the GVA witnessed an even more significant decrease of 40%. According to official sources, this sector employed 9490 people in 2020 and since personnel costs dropped by 40% in total, the annual average gross wage reached €92 375 (European Commission, 2023a).

Offshore Wind Energy

This industry harvests the energy taken from the force of the winds out at sea, transforms it into electricity and supplies it into the electricity network onshore (Soukissian et al., 2023). Despite being considered as part of the emergent sectors in 2020 (European Commission, 2020a), it is currently the only commercial deployment of a marine renewable energy source with wide-scale adoption. It is foreseen that by 2030, the sector aims to have at least 60 GW of offshore wind energy and 300 GW by 2050 (accounting for around 30% of future EU electricity) (Soukissian et al., 2023). Undoubtedly, offshore wind energy plays a crucial role in achieving Europe's carbon-neutral goals and has the potential to sustainably generate economic development and jobs, enhance energy access and boost industry competitiveness through technological innovation (European Commission, 2020d; QBIS, 2020). The EU holds a prominent global position in the field of offshore wind manufacturing. As of the end of 2022, the cumulative installed capacity of this sector has reached 17.5 GW, with an increase of 1.2 GW in the last year. Key contributors to offshore wind energy production within the EU includes Germany, the Netherlands, Belgium, and Denmark. The sector's economic impact is substantial, yielding over €2.15 billion in GVA in 2020 and directly employing nearly 12.3 thousand persons. Personnel costs

amounted to €630 million, with an estimated average annual wage of €55.1 thousand (European Commission, 2023a).

Shipbuilding and Repair

Around 300 shipyards, responsible for producing civilian and naval ships, alongside platforms and other equipment for maritime usage, constitute this industry (European Commission, 2023a). The EU holds a prominent position as the foremost global manufacturer of cruise ships, excelling particularly in the creation of sophisticated and hi-tech vessel types (ASIME, 2019). Furthermore, the EU stands as a major supplier of marine equipment encompassing diesel engines, turbines, propellers, and blades. In 2020, this sector contributed significantly to the economy, generating a €14.5 billion GVA and providing employment for approximately 305 500 individuals. Total wages and salaries reached €12.1 billion, with an estimated annual average wage of €39 000 (European Commission, 2023a).

Maritime Transport

The EU stands as the largest global trading bloc, with a predominant reliance on maritime transport for the transportation of goods to and from its borders (European Commission, 2022). The EU's maritime fleet is extensive and diverse in nature. Ships registered under the flags of EU Member States constitute 16.2% of the global fleet. Within this, nearly 40% of the world's vessels that can carry cars and passengers, 33% of cruise vessels, 29% of passenger ships, and 20% of container ships are part of the EU Member State-flagged fleet (European Commission, 2023a). Despite being an energy-efficient mode of transportation, maritime transport contributes approximately 2 to 3% of the global energy-related CO_2 emissions. Considering the sector's projected growth, it remains imperative for the maritime transport industry to further mitigate its environmental impact (Adamowicz, 2022). In terms of economic contribution, the sector generated a GVA of €29.5 billion and provided employment to

approximately 371 000 individuals in 2020. Total wages and salaries reached €14.9 billion, with an estimated average annual wage of €40 000 (European Commission, 2023a).

Coastal Tourism

Coastal and maritime tourism stands as the most rapidly expanding domain within the EU Blue Economy concerning both GVA and employment (European Commission, 2023a). This sector encompasses leisure activities occurring in close proximity to the sea, such as beach-based tourism, coastal walks, wildlife watching, as well as those taking place in the maritime area, encompassing nautical sports like sailing, scuba diving, and cruising. Despite its seasonal nature, numerous coastal EU Member States, particularly in Southern Europe, rely substantially on tourism to contribute a notable share of their overall national revenue (European Commission, 2022). The COVID-19 pandemic significantly impacted this sector (van Tatenhove, 2021), evident by the decline in GVA from €81.5 billion in 2019 to €33.9 billion in 2020. Within the accommodation sector, approximately 863 000 individuals (comprising 50% of jobs) were directly employed, while less than 618 000 individuals (36%) found employment in other services like restaurants. Additionally, around 237 000 persons (14%) secured employment within the realm of tourist transport (European Commission, 2023a).

Port Activities

Ports represent critical infrastructures with both commercial and strategic significance. They serve as pivotal entry points for EU trade, facilitating the free movement of goods and individuals across the continent. Moreover, ports play a vital role in fostering economic and trade development, encompassing traditional activities such as cargo handling, logistics, and service provisions (Trujillo and Tovar, 2007). Besides, they provide a multifaceted environment that supports a diverse range of industries, acting

as hubs for energy and industrial companies. This diverse industrial clustering includes sectors such as shipbuilding, chemical, food, construction, petroleum, electrical power, steel, fish processing, and automotive industries. Notably, the sector's contribution to the economy, measured by the GVA, reached €26.9 billion in 2020 (European Commission, 2023a). The industry's investments are being boosted by the ambitious sustainability goals outlined in the European Green Deal, coupled with the increasing integration of carbon-neutral technologies within energy-intensive sectors gravitating around European ports (Puig et al., 2022). While the COVID-19 pandemic did impact the sector, it has embarked on a recovery path. In terms of employment, approximately 214 950 individuals were engaged in port and water projects in 2020, constituting 56% of the total employment within the sector. The remaining 44% of the workforce (around 170 680 individuals) were employed in cargo handling and warehousing activities (European Commission, 2023a).

1.3.1.2 Emerging Sectors in the EU Blue Economy

Emerging and innovative sectors encompass those activities where accurate information is still in the process of being developed. These sectors offer new investment prospects and hold considerable potential for the future development of coastal communities (European Commission, 2023c). They include domains like marine renewable energy (i.e., ocean energy, floating solar energy and offshore hydrogen generation), blue biotechnology, desalination, maritime defense, security and surveillance, as well as research and infrastructure (such as submarine cables and robotics) (European Commission, 2023a). Economic indicators of development and employment on emerging sectors are not entirely available for the public domain. Emerging industries are developing quickly and will play an important role in the EU's transition towards a sustainable, carbon-neutral, circular and

biodiverse economy. For example, floating solar energy represents a pivotal advancement in clean energy, ready to lead the way in the next era of environmentally friendly power generation (BBC, 2023). Furthermore, hydrogen is set to play a key role in the process of decarbonizing the energy system across Europe (Durakovic et al., 2023). Moreover, blue biotechnology holds significant potential in providing viable substitutions derived from plants for plastics and other petrochemical applications (Doussineau et al., 2020). Various domains such as maritime security and surveillance as well as research and infrastructure are producing changes across the maritime industry. These transformations encompass a wide spectrum of operations, spanning from underwater to aerial equipment utilization (Bueger et al., 2022). Notably, there is an increasing usage of robotics across diverse operations such as surveys, scientific surveys, oil and gas prospecting, border surveillance, infrastructure inspection, and farming (Pastra et al., 2023; Stenius et al., 2022).

The established sectors of the EU blue economy contribute to 1.8% of the national employment, directly employing almost 3.34 million people in 2020 (26% less than 2019). Table 1.5 presents the reduction in employment numbers resulting from the effects of the COVID-19 pandemic on the EU blue economy. Notably, coastal tourism experienced the most substantial decline, witnessing a 40% reduction in employment, followed by maritime transport and non-living resources. The only sector to display a rise in employment in the year 2020 was offshore wind energy (European Commission, 2023a).

The gross remuneration received by each employee in the established sectors of the EU Blue Economy has demonstrated a consistent positive trend since 2009. Coastal tourism and living resources sectors showed the lowest average gross remuneration per employee; while non-living resources and marine

renewable energy sectors showed the highest percentages (European Commission, 2023a).

Table 1.5. Overview of the Employment numbers in the EU Blue economy, by sector, from 2009 to 2020. National employment and Blue economy contribution (%) is also included as a reference. Source: European Commission (2023a).

Persons employed (thousands)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Living resources	556.5	555.1	536.1	536.7	520.7	518.5	521.7	529.9	525.2	539.9	550.7	539.4
Non-living resources	34.4	31.6	29.8	30.4	27.7	28.1	27.5	17.9	12.5	11.1	10.1	9.5
Marine energy	0.4	0.6	0.9	1.0	1.2	1.7	4.0	5.1	7.0	8.3	10.6	12.3
Port activities	381.5	372.4	359.4	367.3	363.5	403.3	413.9	418.1	415.6	385.2	382.6	385.6
Shipbuilding and repair	306.8	274.7	263.4	255.5	256.6	258.8	264.1	269.2	274.8	292.8	299.1	305.5
Maritime transport	357.4	354.5	363.1	356.2	356.3	375.8	383.1	367.6	384.6	398.1	403.1	371.6
Coastal tourism	2,816.0	2,595.5	2,285.3	1,939.0	2,033.7	2,029.7	1,960.1	2,187.8	2,366.6	2,839.0	2,846.7	1,717.4
Blue economy jobs	4,453.0	4,184.4	3,838.1	3,486.1	3,559.9	3,616.0	3,574.4	3,795.6	3,986.3	4,474.3	4,502.8	3,341.3
National employment	184,570	182,166	182,277	181,282	180,464	181,981	184,044	186,964	189,678	191,831	193,604	190,062
Blue economy contribution (%)	2.4%	2.3%	2.1%	1.9%	2.0%	2.0%	1.9%	2.0%	2.1%	2.3%	2.3%	1.8%

Regarding employment trends, sectors such as non-living resources and marine renewable energy exhibited notable distinctions. While marine renewable energy experienced the most significant expansion, the non-living resources sector, conversely, witnessed a decline primarily attributed to the implementation of EU policies aimed at diminishing dependence on fossil fuels. Among the key contributors to the EU blue economy are Germany, Spain, Italy and France, that collectively account for 55% and 57% on employment and GVA respectively (European Commission, 2023a).

1.3.2 Present and Future Skill Needs in the Blue Economy

The World Economic Forum projected that 60% of all employees worldwide would need reskilling before 2027 (World Economic Forum, 2023). This estimation refers to all the industrial sectors, including the blue economy. Prior to the COVID-19 pandemic, the rise of automation and new technologies brought about significant changes in the world of work, thereby creating a pressing demand for extensive upskilling and reskilling initiatives. Presently, this demand has gained importance and urgency. Highly qualified and skilled individuals are required for a competitive, resilient, socially equitable and sustainable blue economy. Nonetheless, many blue economy sectors are having difficulties recruiting qualified candidates (Edler and Infante, 2019; Harris et al., 2021; MATES Project, 2022).

The energy transition is already generating job vacancies. For instance, up to 30% of offshore renewable energy companies are facing a shortage of skilled workforce. The offshore wind energy sector alone could see a threefold increase in job numbers by 2030. Additionally, it is foreseen that 750,000 seafarers would require additional training to handle alternative fuels and technologies by 2050 (Kaspersen et al., 2022).

With regards to the digital transformation, increased IT, maritime data systems analysis, management and interpretation of digital data are skills that will be needed in the future to meet the demands of shipping companies and port operations and business services (Harris et al., 2021). Besides, as 'smart' ships are coming into service, competent and highly skilled maritime professionals are needed in the fields of robotics and digital twins, programming and handling of computer numerical control (CNC) machines and robots; data management and data quality assurance; and IoT (Internet of Things) (Oksavik et al., 2020; Sdoukopoulos et al., 2021).

Environmental sustainability has been identified as one of the main drivers of change in the maritime sector (Carpenter et al.; 2021; European Commission, 2021; European Environmental Agency, 2020; Papandreou et al., 2021). Maritime industries need workers that possess skills such as knowledge for the exploitation of alternative fuels and renewable energy sources; and knowledge on energy and environmental performance (environmental impact, waste management processes, compliance with environmental legislation) (Vidican Auktor, 2020).

Besides, there is an increasing need for workers with the ability to manage daily environmentally friendly operations and work with new technologies. Most of all, there is a need to integrate these sustainable skills into the trainings and to equip maritime workers with sustainable transferable skills to perform across maritime sectors (Oksavik et al., 2020; Sdoukopoulos et al., 2021).

One of the main challenges of the blue economy is attracting and retaining employees (MATES Project, 2022). Young people and early-career workers are not familiar about the career opportunities that the blue economy has to offer. This sector has suffered with the stigma of only being associated to technical careers (blue collars and 'dirty work'), due to the lack of awareness of the career paths and the innovative potential in the sector.

Some EU initiatives that tackle the blue economy skill needs and promote blue careers are the European Skills Agenda, the Blue Careers program, EU4Ocean, the European Maritime, Aquaculture and Fisheries Fund and other EU funds, such as the European Social Fund+ and Technical Support Instrument (European Commission, 2021).

1.3.3 The Role of Ocean Literacy in Promoting Sustainable Practices

The relationship between maritime workers and the ocean is diverse and complex, still, a sustainable blue economy must be built on these diverse relationships (Paredes-Coral et al., submitted for publication). Ocean literacy emerged as a tool to increase knowledge on the ocean but rapidly evolved to become a tool for behaviour change promoting good practices towards the marine environment and contributing to a more sustainable future. Gaining awareness on the importance of the ocean and its impact on our personal well-being, as well as recognizing how individual actions affect the ocean, holds great significance. Empowering individuals with the knowledge, competences, and skills required to participate in and benefit from ocean opportunities is essential. This empowerment ensures that people can actively take part in and reap advantages from various opportunities linked to the ocean (Lubchenco and Haugan, 2023).

Governments, the private sector, and international organizations are recognizing the relevance of ocean literacy and public engagement in promoting informed decision-making and translating decisions into good practices in everyday life (Canadian Ocean Literacy Coalition, 2021; UNESCO-IOC, 2021a; United Nations Global Compact, 2019).

Ocean-literate maritime workers can have a substantial impact on the blue industries, for instance, by boosting sustainability, innovation, and competitiveness, as well as promoting cooperation and public engagement (Fernández Otero et al., 2019). Such workers should have a greater awareness of the ocean's value as well as the effects of economic activities on the ocean and its ecosystems (Papathanasiou et al., 2018; Paredes-Coral et al., submitted for publication).

Consequently, they will make informed decisions at work that prioritize sustainability and the long-term health of the ocean. This improved

behaviour could encourage innovation by discovering new potential for sustainable ocean resource harnessing such as new materials and carbon-storage solutions or the creation of new technology, medicines, animal feed, fuel and services that are more aligned with sustainability criteria. Such workforce can even predict regulatory changes and identify new opportunities for blue enterprises (Hussein and Song, 2023; Kaspersen et al., 2022; Oksavik et al., 2020). In addition, ocean-literate workers could promote the visibility of blue careers and encourage youngsters to pursue blue careers, shortening the existing need for skilled maritime workers (Sdoukopoulos et al., 2021).

1.4 Objectives and Thesis Outline

The future of the ocean is currently envisioned as environmentally sustainable, coupled with economically viable and socially equitable industries. To achieve this target, marine scientists together with educators and policymakers have recognized the need to include ocean science as key component in formal and non-formal education for all sectors of society. It is expected that fundamental knowledge is present among different stakeholders to support evidence-informed policies to manage ocean resources. Ocean literacy emerges in response to this need, as a way not only to increase the awareness about the ocean and the current threats it is facing, but as an approach to encourage citizens to have a more responsible behaviour towards the ocean and its resources.

Now, more than ever before, we need better insights on how ocean literacy relates to sustainable actions, particularly for people whose livelihoods come directly from the sea, like the blue economy workforce. The aim of this PhD thesis is to expand the understanding on the status of ocean literacy with a focus on the European blue economy and to assess the levels of ocean literacy among maritime workers. Furthermore, this PhD intended at developing an

international validated tool that can be used to effectively measure ocean literacy among the maritime workforce. Ultimately, this thesis aims to contribute to the global efforts to build a more informed and responsible maritime workforce, by providing a scientific basis and validated tools to support education and training initiatives for the blue economy.

In order to fill the identified knowledge gaps and gaps in available data, this thesis focused on the following main research questions:

- What is the status of ocean literacy research in terms of its main features, collaboration structure, major thematic areas; and how is this research linked to the blue economy?
- How can we measure the various dimensions of ocean literacy?
- What are the ocean literacy levels of European maritime workers and how are these levels related to sustainable actions?
- Can we identify groups of maritime workers based on similar ocean literacy levels?
- What are the implications of our findings for marine science, the blue economy and broader goals of sustainability?

As ocean literacy is a relatively new concept and even newer as a field of research, we needed to first set the scene on what is the state-of-the-art. **Chapter 2** therefore presents the assessment of global research on ocean literacy and the identification of research with relevance to the blue economy. In this chapter we analyzed the status of ocean literacy and what was published on this topic from 2005 (the time when the term was first used in a publication) until 2019. The study applied bibliometric techniques to identify the main features of ocean literacy research, to assess the collaborative structure of ocean literacy research at the international and

inter-institutional levels; and to uncover the major thematic areas of research and their progressive evolution. Among our findings, we found that little has been done on ocean literacy research linked to the blue economy.

Based on these results, **chapter 3** focuses on the development, deployment and validation of a scale to measure ocean literacy that goes beyond measuring people's knowledge about the ocean, but also surveying their attitudes and behaviours: the Blue Survey. Using factor analysis, this chapter explores the validity and internal consistency of the Blue Survey and unpacks the various dimensions of ocean literacy.

Having developed a reliable tool to measure ocean literacy, we further focused on those individuals closely related to the sea, such as maritime workers. **Chapter 4** delves into a comprehensive assessment of ocean literacy levels among populations of maritime workers and is structured into two sections. Part I presents the assessment of the levels of ocean literacy among maritime workers across Europe using the Blue Survey 2.0, and different methods including exploratory factor analysis, univariate and cluster analyses. In this chapter we identified the various ocean literacy dimensions relevant for the blue economy as well as industry-related and sociodemographic factors that have a significant effect on the levels of ocean literacy. Furthermore, we performed a segmentation analysis based on the workers' similar sets of ocean literacy skills. In addition, chapter 4 Part II presents the application of the Blue Survey 2.0 among employees of a gas company with maritime activities in Peru.

In the final chapter of this PhD, **chapter 5**, the main results of this dissertation are discussed in a broader context. We discuss the main findings from the previous chapters, and we try to place these results in a European and global context. In this chapter, we discuss about the importance of marine sciences as key component of ocean literacy and how the latest is situated in a general context. Furthermore, this chapter includes an up-to-

date overview of global ocean literacy research, using recent available data up to 2022 and building on the findings introduced in chapter 2. In addition, this chapter elaborates on the implications of the thesis results for education and training initiatives in the maritime sector, and the challenges and opportunities associated with integrating ocean literacy content in the blue economy. Moreover, an analysis of the potential for ocean literacy to contribute to broader goals of sustainability is provided. Finally, remaining challenges and opportunities concerning ocean literacy research are put forward.

Chapter 2

Mapping Global Research on Ocean Literacy: Implications for Science, Policy, and the Blue Economy

Slightly modified from the published article:

Paredes-Coral, E., Mokos, M., Vanreusel, A., & Deprez, T., 2021. Mapping global research on ocean literacy: Implications for science, policy, and the Blue Economy. *Frontiers in Marine Science*, 8, 648492. https://doi.org/10.3389/fmars.2021.648492

Abstract

In recent years, ocean literacy has become a global movement that connects the human dimension to the ocean and intends to be an incentive for positive change in people's behaviour. As multiple initiatives on ocean literacy have arisen, a comprehensive understanding of this topic is required to better engage the broader society. In the present study, we applied a combination of bibliometric analysis and science mapping to a dataset of scientific publications on ocean literacy between 2005 and 2019, obtained from Web of Science and Scopus databases. In order to represent the development of the field, analyze the level of collaborations and uncover its thematic areas, we first used bibliometric analyses to describe the field's main features, including indicators of growth and research collaboration. We then used science mapping techniques to build collaboration networks among countries and institutions, and to identify research communities. Lastly, we performed co-word analysis to reveal the underlying thematic areas and their evolution. Our results reveal a slow-growing number of publications and a promising trend for collaboration among authors, countries and institutions. Education and science were identified as the two major thematic areas on ocean literacy showing that, over time, issues related to these themes have gained more attention among researchers. These findings confirm that ocean literacy is gaining more acknowledgment within the scientific community but still faces considerable limitations to its dissemination in sectors like the blue economy and in regions such as Latin America and Africa. Promoting cross-institutional and cross-disciplinary cooperation among research institutions, marine education networks and the industry is critical to support this purposeful movement and represents an urgent challenge.

Keywords: ocean literacy, science mapping, bibliometrics, blue economy, Sustainable Development Goal 14, Ocean Decade

2.1 Introduction

Maintaining a healthy ocean and moving to a more sustainable use of its resources and services is one of the main challenges of the next decade. The ocean is a critical driver of global climate and maintains life providing many vital functions for our planet. It represents a source of food, raw materials, energy and provides the space for many economic activities (Jouffray et al., 2020; Visbeck, 2018). These rapidly evolving human activities have led to unprecedented pressures such as overfishing, pollution, habitat degradation and ocean acidification. Yet, the level of public understanding of basic concepts related to the ocean and the threats associated to human activities remains low to moderate (Fauville et al., 2019; Gelcich et al., 2014).

Ocean literacy is a relatively new term that connects the human dimension to the ocean and that intends to be an incentive for positive change in people's behaviour. It is defined as the understanding of the ocean's influence on us and our influence on the ocean. An ocean-literate person understands the importance of the ocean to humankind, can communicate about the ocean in a meaningful way, and, is able to make informed and responsible decisions regarding the ocean and its resources (Cava et al., 2005).

The campaign for defining and establishing a framework for ocean literacy began in the United States of America (United States) as an initiative to identify key ocean concepts that were missing in the American school curricula. After a series of meetings and workshops that began in 2002, participants from ocean science and education communities together with policy makers, came to a consensus on the definition of ocean literacy in 2004 (Cava et al., 2005). As a result, a roadmap for marine educators was published, containing the essential principles (**Table 2.1**) and fundamental concepts as well as the scope and sequence for each grade at school (Schoedinger et al., 2010).

Table 2.1. The seven essential principles of ocean literacy

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

Source: Cava *et al*., 2005

Few years later, the ocean literacy concept reached Europe with the establishment of the European Marine Science Education Association (EMSEA) and the First Conference on Ocean literacy in Europe in 2012 (Copejans and Seys, 2012). Similarly, Canada advanced on its efforts to build an ocean-literate society by establishing the Canadian Network for Ocean Education[8] (CaNOE). In a joint effort to promote ocean literacy initiatives and to encourage its use when communicating about policy, the European Union (EU), Canada and the United States signed the Galway Statement on Atlantic Ocean Cooperation in 2013 (European Commission, 2013b). The Galway Statement stands as an example showing that the ocean literacy concept and principles are embedded in the European marine policies. These policies include the Blue Growth Strategy, the Marine Strategy Framework Directive, the Marine Spatial Planning Directive, the Common Fisheries Policy, the Birds Directive, the Habitats Directive and most recently, the European Green Deal (European Commission, 2019; French et al., 2015). In 2015, efforts to promote ocean literacy reached Asia leading to the establishment of the Asia Marine Educators Association[9] (AMEA).

[8] Canadian Network for Ocean Education - http://oceanliteracy.ca

[9] Asia Marine Educators Association - https://sites.google.com/view/asia-marine-ed/home?authuser=0

In 2018, the United Nations Educational, Scientific and Cultural Organization (UNESCO) launched the Ocean Literacy Portal[10] as part of the actions to progress on the Sustainable Development Goal 14. The portal provides a free-access compilation of ocean literacy resources for students, educators, scientists, policy makers and relevant stakeholders from all over the world. Two years later, in 2020, the European Commission launched the European Ocean Coalition[11] (EU4Ocean) as a platform to connect organizations, projects and people that contribute to ocean literacy and the sustainable management of the ocean. The same year, the Global Ocean Literacy Strategy, supported by the United Nations Decade of Ocean Sciences for Sustainable Development (2021–2030; hereafter referred to as the Ocean Decade), was being drafted.

Ocean literacy has evolved from a national (United States initiative) to a global scale movement. This dynamic has caught the attention of researchers from several disciplines. As an interdisciplinary field, ocean literacy integrates knowledge, techniques and tools from marine sciences (e.g., ecology, oceanography, ecosystem modeling), education sciences, social and behavioural sciences (e.g., sociology and psychology), public health, geography, marine policy, science communication, arts and digital technologies (Costa and Caldeira, 2018; Dupont, 2017; European Marine Board, 2020; Fauville, 2017; Kelly et al., 2021). This diversity of research backgrounds has been accompanied by a broad range of approaches and methods that were included in several scientific publications. However, since this information remains sparse, it is necessary to have an updated outlook to investigate how research advancements are developing in structure and what is the relationship between research communities.

Scientific publications are good indicators of the development of a research field. The quantitative study of scientific publications, citations and

[10] Ocean Literacy Portal – https://oceanliteracy.unesco.org

[11] European Ocean Coalition - www.eu-oceanliteracy.eu

journals, is called Bibliometrics (Broadus, 1987; Pritchard, 1969). This technique has been extensively used in a variety of fields ranging from medical sciences (Thompson and Walker, 2015) and cultural evolution (Youngblood and Lahti, 2018) to drug discovery (Agarwal and Searls, 2009) and climate change (Haunschild et al., 2016). In the 1970s and 1980s, bibliometric research was mostly focused on citation analysis to assess the structure of several scientific fields, journal interrelationships, as well as research performance in the humanities and social sciences, citation behaviour and interdisciplinary research. In 1990s, powered by the advancements in information technology, international organizations began systematically collecting data to measure and analyze the development of science and technology by means of bibliometrics. Work in the 1990s was focused on the combination of co-citation and word analysis, journal impact measures and the interface of science and technology (van Raan, 2019).

The first decade of the new century was influenced by technological advancements in computer science and the global availability of large bibliographic databases (e.g., Web of Science, previously known as ISI Web of Knowledge) (Chernyi, 2009). Work on bibliometrics addressed new methods for identifying emerging topics, improvements in the visualization of science maps and measures of journal interdisciplinarity, the triple helix model of government–industry–academy interaction, patent citation analysis and the identification of industrially relevant science and text mining. In the last decade, the bibliometric community focused on new indicators of performance and advanced network methods to improve science mapping, university rankings and the comparison between publication- level and journal-level field classifications (van Raan, 2019).

Bibliometrics has undergone a sharp rise since the late 1960s, evolving from a tool to cover library and information center needs, to a powerful field of science with a set of indicators and analytical methods. Over time, this evolution drew the attention of policymakers. Bibliometric research has

supported strategic decision making and research funding allocation (Waltman and Noyons, 2018) and has helped to identify the connections between scientific growth and policy changes (Machado et al., 2016). Bibliometric techniques are useful to provide a structured analysis of large datasets, to infer trends over time, identify research themes and shifts in the boundaries of the disciplines. It also enables to detect the most prolific authors and institutions, and to present the "big picture" of a given research area (Aria and Cuccurullo, 2017). In bibliometrics, the two main methods for analyzing a research field are performance analysis and science mapping. While the first method is focused on evaluating the production and impact of publications, science mapping intends to display the conceptual, social and intellectual structure of scientific research, as well as its evolution and dynamical aspects (Gutiérrez-Salcedo et al., 2018).

While ocean literacy has captured the attention of diverse research disciplines, previous research has shown that most of the research efforts were focused on educational approaches, particularly at school level (Costa and Caldeira, 2018). Yet, less attention was given to disciplines related to the economic activities happening in the ocean. As the intensity and diversity of these activities continue to grow, the blue economy concept emerges as an approach seeking to promote the sustainable use of ocean resources for economic development, improved livelihoods, and jobs while preserving the health of the ocean (World Bank and United Nations Department of Economic and Social Affairs, 2017). That being said, it becomes essential to understand the implications of ocean literacy as a global movement not only for the scientific community but also in the implementation of sustainable ocean practices and marine policy strategies.

Here, we assess the development of global research on ocean literacy with relevance to science, policy and the blue economy. We provide a detailed analysis of what happened and what was published during the last 15 years of research on ocean literacy from 2005 (the time when the term 'ocean

literacy' was first used in a publication) to 2019. To this end, we applied bibliometric techniques aiming (a) to identify the main features of ocean literacy research, including indicators of growth, most prolific countries, authors, institutions and publishing outlets; (b) to assess the collaborative structure of ocean literacy research at the international and inter-institutional levels; (c) to identify the research coupling ocean literacy and blue economy; and (d) to uncover the major thematic areas of research and their progressive evolution.

2.2 Materials and Methods

2.2.1 Data Collection

Publications related to ocean literacy were obtained from Web of Science (WoS) and Scopus databases during August 2020. With the aim to analyze ocean literacy as a concept, the search criteria was restricted to publications written in English and the keywords used included "ocean literacy," "ocean literate," "ocean and literacy" and "coast* literacy" as search criteria. Publications were retrieved from the databases' custom data from 1950 and 1960 (WoS and Scopus, respectively) to 2019. The documents where search criteria appeared in the title, keywords, and/or abstract were included in the study. Only documents published in peer-reviewed journals such as article, review and conference paper categories were used. Publications retrieved from WoS and Scopus were merged and duplicates were removed. **Tables A.1** and **A.2** (**Appendix A**) include all keywords and steps used to retrieve publications on ocean literacy.

2.2.2 Data Analysis

Bibliometric analysis were carried out using *Bibliometrix* R package (version 3.0.2). *Bibliometrix* is an open-source tool that enables a descriptive and quantitative analysis of the bibliographic data as well as data visualization

(Aria and Cuccurullo, 2017). The analysis included the identification of the main features, including indicators of growth, such as number of publications per year, number of authors, institutions and publishing outlets. The most prolific authors, institutions and publishing outlets were also identified. We used the collaboration index (CI) as an indicator of research collaboration. The CI was calculated as the average number of authors on multi-authored papers per year (Elango and Rajendran, 2012). In order to identify the most productive countries, each publication was assigned to its corresponding author's country. For a better visualization of the international collaboration among countries, a collaboration world map was plotted. Afterward, publications were categorized as Single Country Publications, to designate records with authors from the same country, and Multiple Country Publications for records with authors from multiple countries.

In order to complement the macro perspective provided by the collaboration world map, a network analysis was performed using the authors' affiliations (hereafter: institutions) as the units of analysis. The institution collaboration network shows how institutions relate to others in ocean literacy research and enables to uncover relevant institutions in a specific research theme. In its graphical representation, the network is made up of several clusters. In each cluster, the institutions are represented by nodes (which size is proportional to its occurrence) and the links represent the collaborations (Aria and Cuccurullo, 2017). Subsequently, we selected the largest network and identified its clusters. A label was assigned to each cluster based on the content of the collaborative publication, to be used as a conceptual guide only. With the aim to identify the publications coupling research on both, ocean literacy and blue economy, we extracted the publications in which the title, abstract and keywords were related to the blue economy. We then classified them into categories based on the current sectors of the blue economy.

In order to identify and visualize the major themes on ocean literacy research, we performed co-word analysis using the publication's keywords. This technique enables to illustrate associations between keywords by constructing multiple networks based on their similarities (Krsul, 2002). For this specific analysis, we used *KeyWords Plus*, which are the words that frequently appear in the titles of an article's references, but do not appear in the title of the article itself. *KeyWords Plus* is available for WoS publications only. By applying a clustering algorithm on the keywords network, we obtained a two-dimensional diagram, or thematic map, that highlights the different themes present in scientific publications related to ocean literacy. Each theme can be analyzed according to the quadrant in which it is placed. A theme is defined as a recurrent unifying concept or statement about a given subject (Bradley et al., 2007). According to their significance and lifespan, they can be classified as motor themes, basic themes, emerging/disappearing themes, and specialized themes (Aria and Cuccurullo, 2017).

The upper-right quadrant indicates the themes that are well-developed also known as motor themes. Motor themes represent the most overarching concepts that emerge from the data and capture the fundamental aspects or core issues related to ocean literacy research and that served as a starting point for further studies. The lower-right quadrant indicates the basic themes, which are more specific than motor themes and provide a level of detail and nuance beyond the motor themes. The lower-left quadrant indicates the emerging or disappearing themes, those that begin to surface during the analysis process but may not be initially evident and may not last long. The upper-left quadrant indicates the very specialized/niche themes, that are the most specific and detailed level of themes and address specific aspects within the data. They can be used to explore nuances or unique patterns within the basic themes (Aria and Cuccurullo, 2017; Cobo et al., 2011). Each sphere represents a network cluster and the cluster names are the words with the higher occurrence values. The sphere volume is

proportional to the cluster word occurrences and its position is set according to the cluster's centrality and density. The cluster's centrality measures the strength of the links from one research theme to other research themes, and is an indicator of the significance of a theme in the development of an entire field. The cluster's density measures the internal strength of the network that make up a theme and provides a good representation of the cluster's development (Muñoz-Leiva et al., 2012). To better understand the conceptual evolution of the most recurring themes, we divided the study period in three smaller periods (2005–2011, 2012–2016, and 2017–2019) following the methodology proposed by Cobo et al., (2011). We set a first period of 7 years (2005–2011) given that during the first years of ocean literacy research there were few publications and consequently, low number of keywords.

2.3 Results

2.3.1 Development of Global Research on Ocean Literacy

In total, 111 publications were identified suitable for further analysis including 75 articles (67.6%), 30 conference papers (27%) and 6 reviews (5.4%). The development of ocean literacy between 2005 and 2019 is shown in the top panel of **Figure 2.1**. Since 2005, soon after the term ocean literacy was formally adopted in the United States, the number of publications has fluctuated over the years, with an average annual growth of 7.7%. It is important to note that this is an average, and the actual growth in any given year may vary. Some years, the growth may be higher than 7%, while in others, it may be lower or even negative. However, when we look at the overall trend over the entire period 2005 - 2019, the average annual growth rate comes out to be around 7.7%. The overall collaboration index (CI) was 3.8. Generalized additive model (GAM) fitting of the data revealed an increase in the number of publications as from 2012.

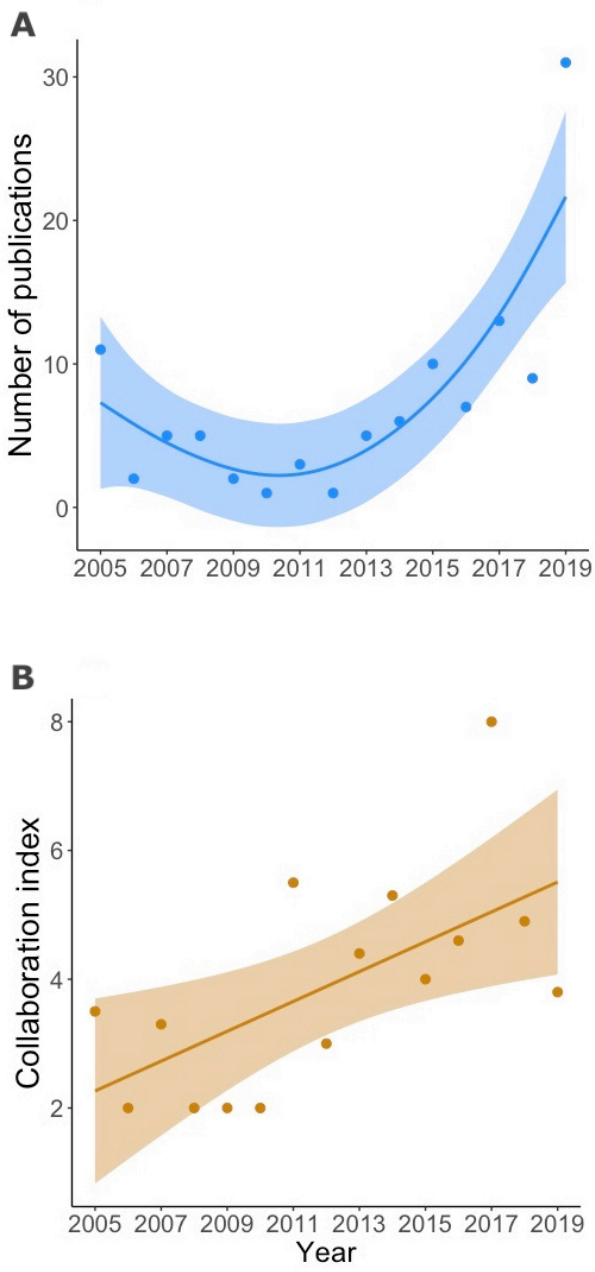

Figure 2.1. **(A)** Scatterplot showing the number of publications on ocean literacy from 2005 to 2019. GAM fitting of the data revealed a positive trend in the number of publications and the appearance of a potential turning point, a rapid increase, for 2019. **(B)** Scatterplot showing the collaboration index per year. Linear fitting of the data revealed an increase in collaboration among authors.

Linear fitting of CI revealed a positive relationship in the collaborations between 2005 and 2019 **(**bottom panel of **Figure 2.1**). In the following years until 2009, publications were dominated by the conference type. The years with less publications were 2010 and 2012 with one article and one conference paper published, respectively. The publication category "review" only appeared in 2017.

A steep noticeable rise in the number of publications was observed in 2019 ($n = 31$). The number of publishing outlets and authors followed a similar pattern. A total of 368 authors affiliated to 188 institutions have published on ocean literacy. Paula Keener-Chavis was identified as the most prolific author with 8 publications (7.2%), other authors included Theodora Boubonari, Mary Carla Curran, Geraldine Fauville and Athanasios Mogias with 4 publications each (3.6%). The majority of authors had an affiliation in the United States (47.7%). The most prolific institutions publishing on ocean literacy were led by the National Oceanographic and Atmospheric Administration (NOAA) (14.4%), followed by University of Gothenburg (6.7%), Democritus University of Thrace (5.6%) and National University of Ireland (5.6%).

In overall, 57 publishing outlets were identified for the article and review categories (68.4%), and 18 for the conference paper category (31.6%). The most popular journal for publishing on ocean literacy was Frontiers in Marine Science (Front. Mar. Sci.) with 15 publications, followed by Marine Policy and Sea Technology with 6 and 5 publications, respectively (**Figure A.1, Appendix A**). Conference papers were published mostly in the Proceedings of OCEANS 05' MTS/IEEE Conference (**Figure A.2, Appendix A**).

2.3.2 Collaboration Networks

2.3.2.1 Country Collaboration

A total of 33 countries from five continents have contributed to publishing on ocean literacy (**Figure 2.2**). From the total publications, 20 (18%) were Single Author Publications (SAP) and 91 (82%) were Multiple Author Publications (MAP). The majority of the publications were Single Country Publications (SCP, n = 81; 73%) and a smaller proportion was made by authors affiliated to institutions from different countries (MCP, n = 30; 27%). The United States was identified as the most active country publishing on ocean literacy leading with the highest proportion of publications (n = 53; 47.7%) followed distantly by the United Kingdom (n = 10; 9%) and Canada (n = 7; 6.3%) (**Figure 2.3**). Detailed information regarding country collaboration is shown in **Table A.3** (**Appendix A**).

2.3.2.2 Institution Collaboration

The network analysis of institutions yielded a total of 46 clusters. As most of the clusters were scattered, we extracted the largest network of institutions linked by research on ocean literacy resulting in the five clusters portrayed in **Figure 2.4**. The first group included institutions from the United States and Europe, such as NOAA, College of Exploration, University of California Berkeley, Centro Tecnológico del Mar (CETMAR) and Indigo Med. Based on the content of the collaborative publications, we have chosen to label this group (1) as "ocean exploration and blue economy." Core institutions from group 2 included only European institutions, represented by University of Gothenburg, Democritus University of Thrace, National University of Ireland and the Hellenic Center for Marine Research.

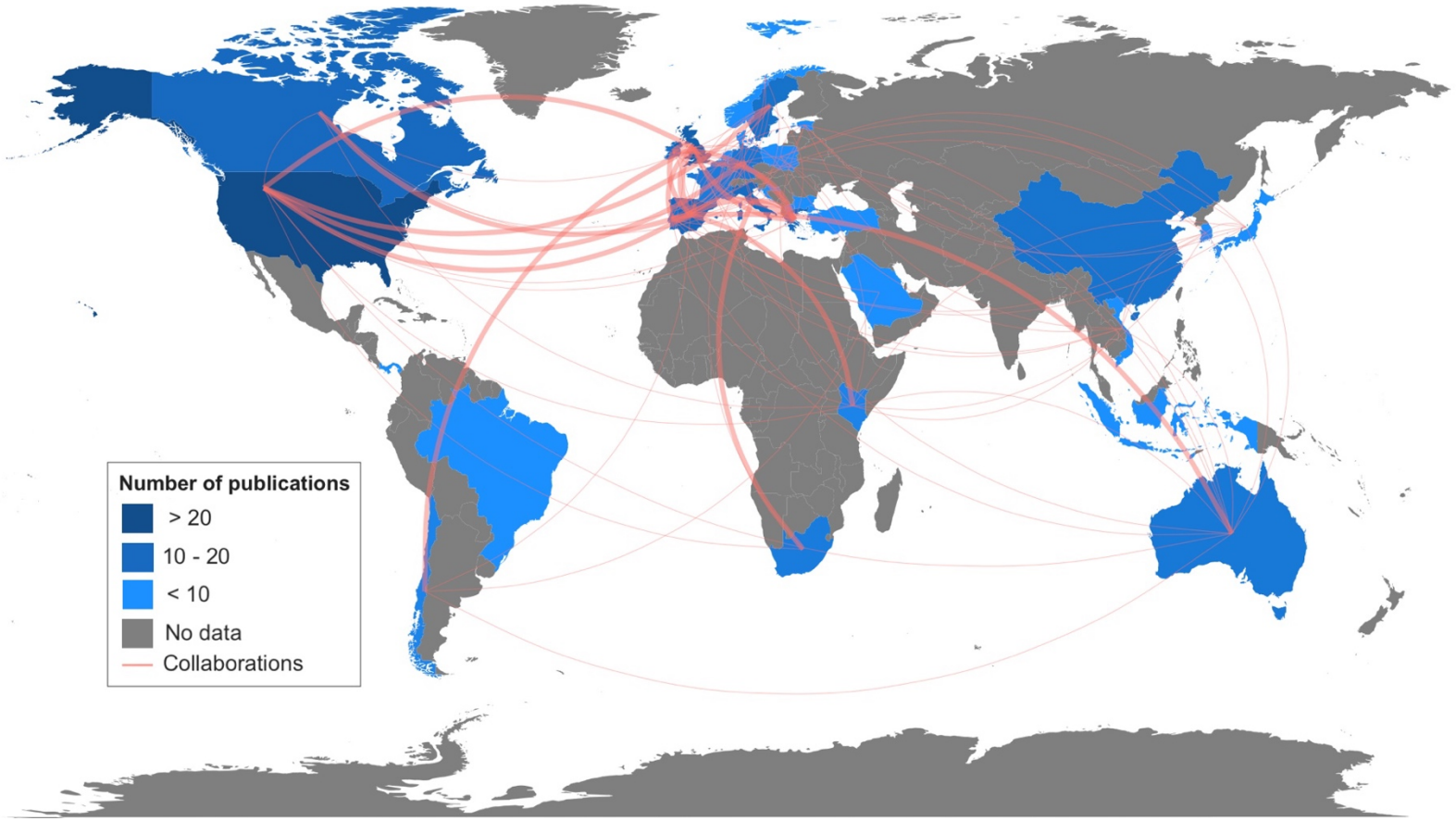

Figure 2.2. Global collaboration on ocean literacy research from 2005 to 2019. The blue gradient is proportional to the number of publications by country. Gray color indicates no data and red lines represent collaborations among countries. Line width is proportional to the number of collaborations. World map was created using Biblioshiny app for Bibliometrix R package (version 3.0.

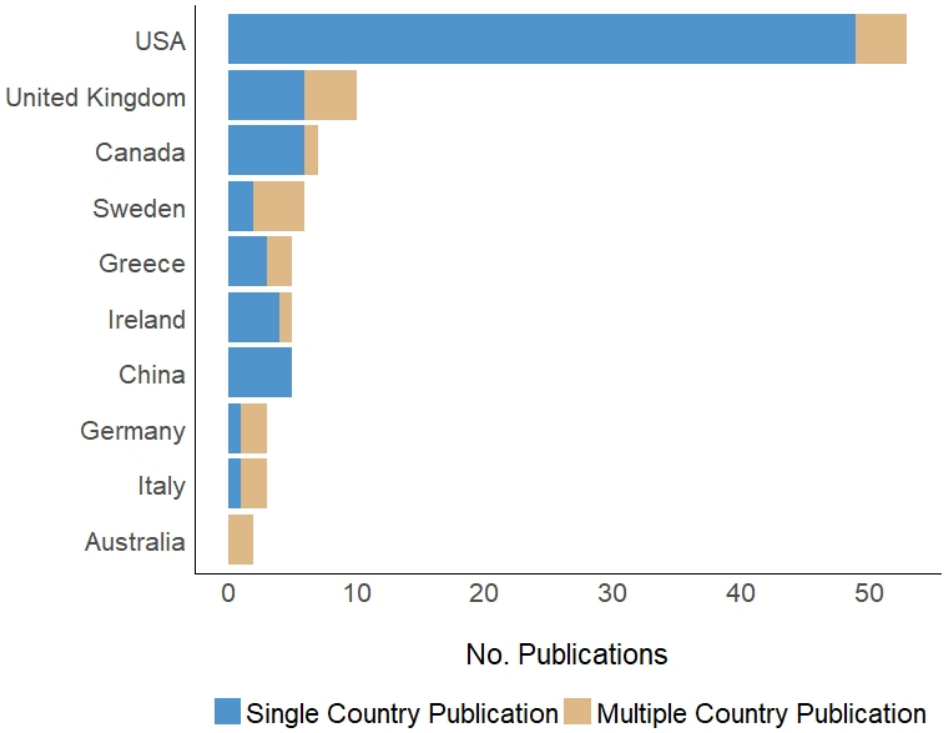

Figure 2.3. Top 10 publishing countries on ocean literacy from 2005 to 2019. Multiple Country Publication indicates the number of publications in which there is at least one co-author from a different country. This classification considered the correspondence author's country as the publication's country.

The label chosen for this group (2) was “marine education and learning technologies.” Core institutions in group 3 where mostly from the United States, including University of Georgia, Woods Hole Oceanography Institute and Monterey Bay Aquarium Research Institute. We have chosen to label this group (3) as “oceanography and geosciences.” Core institutions in group 4 included the European institutions Studio Associate Gaia SNC and University of Plymouth. The label chosen for this group (4) was “conservation.” Core institutions in group 5 belonged to the United States and included the Center for Ocean Sciences Education Excellence (COSEE) and University of Rhode Island. We have chosen to label this group (5) as “public outreach.” The aforementioned group labels should be taken as subjective and only used as indicators of research communities rather than referential thematic definitions.

From the five groups, only group (1) consisted of institutions publishing on blue economy, while only 8 publications (7.2%) from our dataset had a focus on the blue economy. The majority of these publications belonged to the article category (75%), followed by conference papers (25%). A total of 28 authors were identified, belonging to 11 institutions from six countries (United States, United Kingdom, Ireland, Spain, Greece and Turkey).

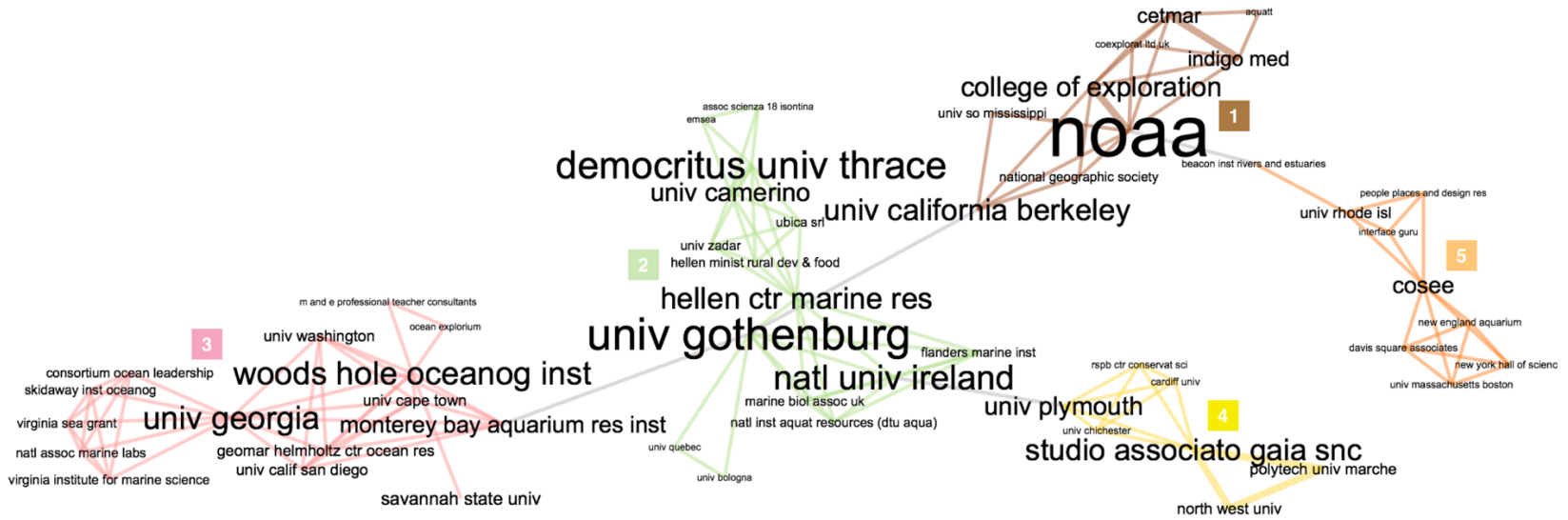

Figure 2.4. The largest connected institution network in ocean literacy research between 2005 and 2019 analyzed using collaboration network techniques. Brown corresponds to group 1 ("ocean exploration and blue economy"), green corresponds to group 2 ("marine education and learning technologies"), pink corresponds to group 3 ("oceanography and geosciences"), yellow corresponds to group 4 ("conservation") and orange corresponds to group 5 ("public outreach"). Name size is proportional to the number of publications.

All publications had more than one author ranging from 2 to 8 authors, with 3.5 authors per publication on average. Overall, the publications focused on topics related to workforce development and training as well as industrial sectors such as shipbuilding, offshore renewables, coastal tourism, desalination, fisheries and seafood production (**Figure 2.5**).

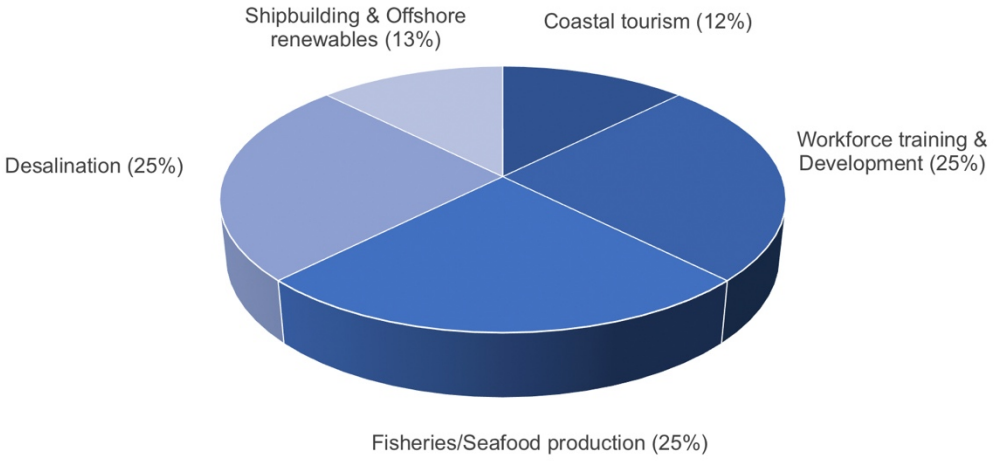

Figure 2.5. Blue economy topics identified from publications on ocean literacy for the period 2005–2019 ($n = 8$).

2.3.3 Research Themes

According to their location in the thematic map (upper-right quadrant), the themes Education and Science were identified as motor themes on ocean literacy research. The themes Management, Attitudes, Knowledge and Climate Change were the most general or basic themes (lower-right quadrant). The themes Hydrothermal Vent, Decision Making and North Atlantic were three very specialized themes and peripheral in character

(upper-left quadrant). The theme System Thinking Skills was presumed to be an emerging theme (lower-left quadrant). The theme Marine Policy was in the transition from motor theme to specialized theme and the theme Risk was in the transition from emerging to specialized theme (**Figure 2.6**).

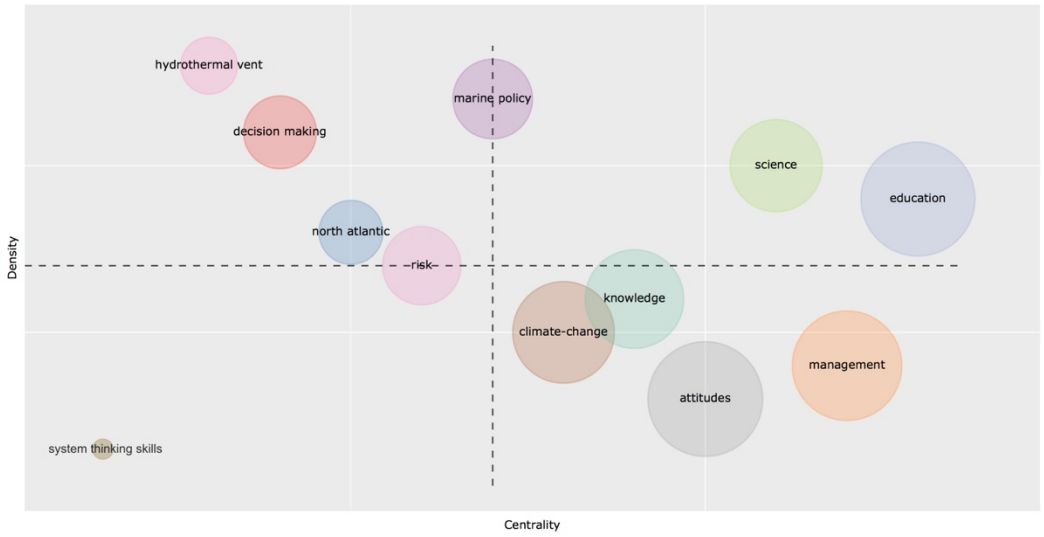

Figure 2.6. Thematic map on ocean literacy research for the period 2005–2019 obtained from co-word analysis. The upper-right quadrant indicates the motor themes, the lower-right quadrant indicates the basic themes; the lower-left quadrant indicates the emerging or disappearing themes and the upper-left quadrant indicates the very specialized/niche themes. The volume of the spheres is proportional to the number of publications corresponding to each keyword.

Figure 2.7 illustrates the evolution of the most recurring themes during the periods 2005–2011, 2012–2016, and 2017–2019. Through the analyzed time span, the basic theme Knowledge has unified with Curricula to later become part of the themes Ecosystems and Attitudes. The theme Curricula has diverged into three themes to later reappear in the period 2017–2019.

The basic theme Management has diverged into three themes and then has reappeared for the period 2017–2019. The motor theme Education has diverged into three themes, namely Attitudes, Curricula and Management. The theme Oceanography has integrated into the theme Education. Over time, the theme Marine Policy has integrated into Research, which was later integrated into Science. The theme Online has emerged in the period 2012–2016 to be later integrated into the theme Perceptions. Notably for the period 2017–2019, the theme Attitudes has integrated the motor and basic themes Knowledge, Science and Education.

2.4 Discussion

When mapping global research on ocean literacy, two main observations regarding its development were identified. First, while the number of publications covering ocean literacy showed a slow-growing pattern especially over the first years, the collaboration among researchers seemed more rapidly growing with more authors, countries and institutions involved in publishing. The second observation refers to the identification of research themes underlying in this multidisciplinary topic. Despite its increasing acceptance, the low number of publications on ocean literacy indicates that this term has not been widely used in scientific publishing. Previous studies have suggested that research on "environmental literacy" has been more successful than ocean literacy research in terms of number of publications (Uyarra and Borja, 2016). Environmental literacy research has produced 292 publications indexed in WoS until 2019, more than twice the amount of publications from ocean literacy research. This difference in productivity is understandable given the fact that the ocean literacy concept emerged 33 years after the first incorporation of environmental literacy in the scientific literature (Anonymous, 1971).

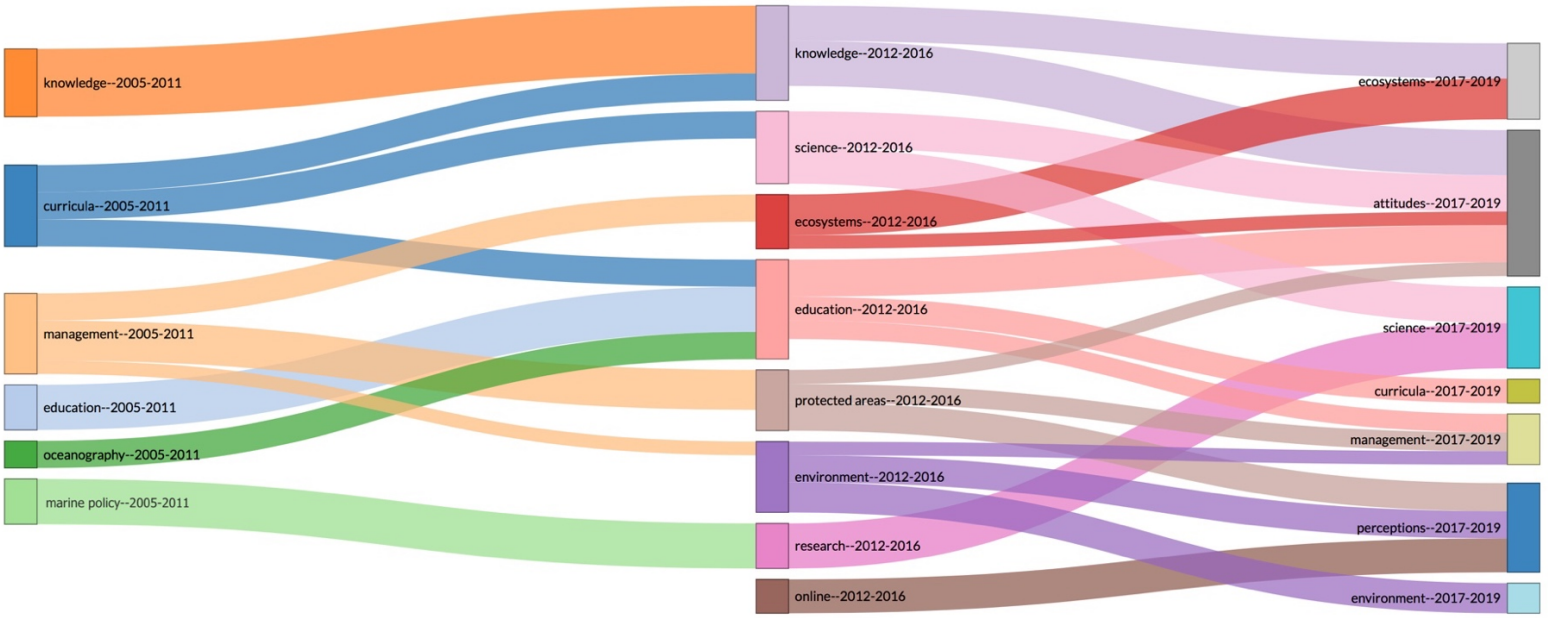

Figure 2.7. Evolution of ocean literacy research themes using keywords from publications in the period 2005-2019. The study period is divided in chronological order from left to right. The first period comprised keywords from 2005-2011 (foundational years), the second period comprised keywords from 2012-2016 (internationalization) and the third period comprised keywords from 2017-2019 (turning point). Ocean literacy themes are represented by rectangles and the size of this rectangles is proportional to the number of keywords. Each color represents a research theme and the width of the streams indicates how strongly a former theme provided foundations for authors when studying a theme in a later period.

Likewise, Uyarra and Borja, (2016) suggested that the interdisciplinary field of "citizen science" was more successful than both ocean literacy and environmental literacy. Since 2006 until 2019, citizen science's output has reached 3962 peer-reviewed publications, exceeding by far the other two fields' production (Bautista-Puig et al., 2019). However, "climate literacy," a concept that was adopted in 2006 and that is analogous in structure to the ocean literacy concept (USGCRP, 2009), seems to be less successful than ocean literacy with only 81 publications indexed in Scopus for the same time span. Additionally, a search of 'ocean literacy' in Google gave 155,000 results, suggesting that the term is mostly used beyond the scientific domain. We suggest that further research should analyze ocean literacy data on websites (web scraping). Web scraping can be employed in addition to bibliometrics studies to study ocean literacy, by collecting real-time data from various online sources, such as social media, news websites, or forums, to analyze and track the development of public discourse and trends.

Notably, the use of two databases enabled to conduct a comprehensive interdisciplinary search and broaden the field of investigation, minimizing the risk of not capturing the full extent of research on ocean literacy. However, the search term "ocean literacy" excludes work by researchers that use different terminology or do not explicitly mention ocean literacy. Whereas including other terms in our query such as "marine education" and "ocean awareness" would have expanded our results, we chose to limit our search to one term to avoid over-representing particular themes.

In particular for 2019, the rapid increase reported, with almost five times the average publication rate, may mark a turning point in the ocean literacy development with a positive trend that may follow. This increment was, in part, a result of *Frontiers in Marine Sciences* special issue on ocean

literacy[12]. Considering the new and ongoing initiatives with focus on ocean literacy, we should expect them to boost ocean literacy publications in the near future. By the time our analysis were done for 2015–2019, there were already 12 publications indexed in WoS and Scopus for 2020, and the Mediterranean Marine Science journal[13] announced a special issue including 13 articles on ocean literacy for 2022.

Ocean literacy research is published in an irregularly distributed manner across publishing outlets. According to our data, the journal with the highest use by ocean literacy researchers (Front. Mar. Sci.) accounts for only 13.5% of the publications. Since this topic brings together researchers and ideas from a broad spectrum of academic fields, the journals' scopes are very diverse ranging from computational intelligence and tourism geographies to education and marine policy. Our results indicate the absence of a dedicated journal for ocean literacy research, which could be mainly due to the recent origin of the term.

Science mapping enables to reveal hidden patterns in the social structure of a given field, that is, how authors, institutions and countries interact with each other (Aria and Cuccurullo, 2017). Our analysis revealed that authorship is collaborative, with most authors publishing in association with other authors. The positive trend for the collaboration index is particularly promising, suggesting the increase of larger teams and interdisciplinary research that may translate into higher scientific impact (Wu et al., 2019) and productivity (Murić et al., 2019; Parish et al., 2018). In our study, the average level of scientific collaboration on ocean literacy research stays

[12] Frontiers in Marine Science Special issue on ocean literacy - https://www.frontiersin.org/research-topics/8508/connecting-people-to-their-oceans-issues-and-options-for-effective-ocean-literacy

[13] Mediterranean Marine Science Special issue on ocean literacy - https://ejournals.epublishing.ekt.gr/index.php/hcmr-med-mar-sc/issue/view/1746

aligned to other topics such as biodiversity (Liu et al., 2011), marine sciences (Elango and Rajendran, 2012) and coastal flooding (Gao and Ruan, 2018).

The large number of clusters obtained from the network analysis of institutions, in relation to the total number of institutions, suggests that a cohesive research team has not yet formed. Our results indicate that the international cooperation teams on ocean literacy research are gathering but the majority of them are still scattered, with limited cooperation among different institutions. The five research groups represented in **Figure 2.4** differ in their activity, topics of study and connectivity. The group 2, labeled as "marine education and learning technologies," has the greatest connectivity to other research groups and closeness to the center of the network, suggesting that it is one of the most influential and central research community. Similarly, members of group 1 "ocean exploration and blue economy" and group 3 "oceanography and geosciences" also have high connectivity. This is unsurprising given the fact that several of these institutions have played crucial roles in setting the basis for the foundation of the field and its further dissemination. Institutions from group 4 "conservation" and group 5 "public outreach" are the only non-adjacent groups identified and the furthest from the center of the network. This approach seems very useful to assess the interactions among research communities and has been applied to other interdisciplinary fields such as circular economy (Alnajem et al., 2020) and cultural evolution (Youngblood and Lahti, 2018). However, this approach raises the challenge of labeling the resulting groups in a subjective manner. Hence, we suggest to use our proposed group labels as indicators of research communities rather than thematic areas.

Publications with focus on the blue economy represent a small proportion of the global research on ocean literacy (7.2%), indicating that the coupling of these two fields is still developing. Ocean literacy research has been predominantly pursued within the educational domain, particularly at

school level (Fauville et al., 2019; Fernández Otero et al., 2019; Mogias et al., 2019; Williams, 2017), despite its potential to reach citizens in their professional careers and industrial activities across different sectors, including the blue economy (Fernández Otero et al., 2019). As an example of an initiative to reach the maritime sector, the EU-funded MATES[14] project capitalizes the synergies between its partnership integrated by the industry, academia and ocean literacy practitioners, to integrate ocean literacy as a transversal component in its overall strategy to foster the European shipbuilding and offshore renewable energy sectors (Fernández Otero et al., 2019). Promoting ocean literacy research with focus on the blue economy is necessary and of special relevance given that maritime stakeholders, decision makers and the workforce in general, are not sufficiently aware of the full extent of the environmental, economic, social and political importance of the ocean for their daily lives (Uyarra and Borja, 2016).

International collaboration on ocean literacy research is promising. This can be partially attributed to the efforts done by the marine education networks such as the US-based National Marine Educators Association (NMEA), the Canadian Network for Ocean Education (CaNOE), the International Pacific Marine Educators Network (IPMEN), the Asia Marine Educators Association (AMEA), the European Marine Science Education Association (EMSEA) and the Australian Association for Environmental Education (AAEE) (Marrero et al., 2019). Particularly, the collaboration among European countries is very dense, reflecting high publication activity in a collaborative basis. An example of this are the EU-funded projects Sea Change and ResponSEAble, which have gathered several EU countries and non-EU external experts into partnerships to collectively work in three main societal groups: the general public, formal educators, and policy makers (European Commission, 2015b, 2018). Likewise, the Marine CoLAboration

[14] MATES Project – https://www.projectmates.eu

initiative (CoLAB) used a multi-sectorial and values-based approach to connect people to the ocean in the United Kingdom (Chambers et al., 2019). Similarly, collaboration among Asian countries was supported by networks such AMEA and the West Asia Blue Waters[15]. Conversely, no research collaborations were found in our dataset within Latin America and Africa. Both regions seem to lack a larger cross-national network to promote ocean literacy initiatives in a consistent and culturally relevant way. Nevertheless, the recently created Latin American Marine Educators Association (RELATO) seeks to promote ocean literacy in Latin America and the Caribbean, by connecting local initiatives, improving practices and sharing educational material. Additionally, there are several local initiatives on marine education in African countries ("Open Ocean Project", 2020; SAAMBR, 2019; University of Namibia, 2019), however, to the best of our knowledge, there is no African network as such. Facilitating the synergies among marine education networks is of particular interest, as this can accelerate the sharing and dissemination of knowledge and attract more attention to ocean literacy research, especially in low and middle income countries. Particularly, programs fostering international collaboration for Latin American and African research communities might help to level the playing field.

Education and Science were identified as the most heavily studied themes on ocean literacy research, being both well-developed and important for the structuring of this field. This is consistent with previous work that highlighted the emphasis placed on educational approaches on ocean literacy research (Costa and Caldeira, 2018). These themes were strategically located in the upper- right quadrant of the thematic map, indicating that they were also related externally to concepts applicable to other themes, such as management and climate change. Our results are well aligned to the current trends in ocean literacy research and are supported by previous work done

[15] West Asia Blue Waters - https://oceandecade.org/actions/the-west-asia-blue-waters/

in education (school and higher education) (Mogias et al., 2019; Schaffner et al., 2016) and marine science (Cava et al., 2005; Schoedinger et al., 2005; Visbeck, 2018). Other important themes were management, climate change, attitudes and knowledge, which notably, include strong social aspects and public perceptions (Ashley et al., 2019; Potts et al., 2016; Stoll-Kleemann, 2019). **Figure 2.7** revealed that most thematic areas evolve in a discontinuous but compact way from their beginning. This suggest that over the time, they attract the interest of the research community, characterized by a progressive growth in the publications on these themes. These findings support the potential advantages of using bibliometric analysis to uncover the intellectual structure and evolution of research themes. Overall, this approach has shown to be effective to analyze the evolution of fields such as climate change (Sharifi et al., 2020), sustainable tourism (Della Corte et al., 2019; Koulouri et al., 2022b) and circular economy (Alnajem et al., 2020). One of the limitations of this analysis is that the use of *KeyWords Plus* excludes the publications indexed by Scopus, which does not provide this metadata. However, *KeyWords Plus* was chosen based on its suitability as the best content field for performing analysis on thematic areas and in order to avoid the lack of standardization reported for author's keywords (Ugolini et al., 2001).

2.5 Implications for Science, Policy, and the Blue Economy

Our results suggesting that ocean literacy is an emerging field of science are not just bibliometric indicators but also powerful evaluation tools for science policymakers, research managers, and individual researchers. It provides a strategic overview that synthesizes 15 years of research and validates the inclusion of ocean literacy as one of the priority areas of research and technology development of the Ocean Decade (R&D 7; Ryabinin et al., 2019). As such, ocean literacy should be recognized as a research field and

should be allocated adequate funding support for long-term projects and placement in organizational work programs (Eparkhina et al., 2021).

Effective strategies to eliminate the reported disparities in ocean literacy research between the Global North and the Global South, are likely to require joint efforts by researchers, practitioners, policy makers and the industry, with a rapid exchange of knowledge among them (Eparkhina et al., 2021). While research capacity on ocean literacy needs to grow globally, particular attention should be given to regions and groups from Small Island Developing States, Least Developed Countries and Landlocked Developing Countries (Ryabinin et al., 2019). In addition, training aimed to improve research capacity should be powered by web-based tools, such as MOOCs and virtual reality, to increase information flow and knowledge exchange (Fauville et al., 2021; Jacobs et al., 2021; Waite et al., 2017). To be most effective, ocean literacy research will need a solid foundation across the science-policy interface and international cooperation within and across ocean basins, as stated in the Ocean Decade's (UNESCO-IOC, 2020a).

Ocean literacy research with focus on the blue economy seems to be scarce and sector-specific, and will increasingly need to follow an interdisciplinary approach across the marine, maritime, education, social and economic sciences (Bavinck and Verrips, 2020; ten Brink et al., 2021). Managing the blue economy requires managing people, which calls for efforts to better understand their knowledge, attitudes, behaviour and needs (Ashley et al., 2019; Cavallo et al., 2020). Such efforts require strategies across multiple sectors, from high-level policy makers to individual-level behavioural changes (Cisneros-Montemayor et al., 2021). Benchmarking and continued monitoring of ocean literacy levels are necessary to evaluate the effectiveness of programs and initiatives (Eparkhina et al., 2021), not only for students but for all actors of society (Kelly et al., 2021), like those directly linked to the ocean, such as maritime workers. This need is well-aligned with the ultimate goal of the Ocean Decade, aiming to connect ocean science with

the needs of society and effectively support sustainable development (Claudet et al., 2020; UNESCO-IOC, 2020b).

Overall, this study provides a global perspective on ocean literacy research. Our findings highlight the development of the field between 2005 and 2019 using the information contained in scientific publications. Based on our findings, we point out the need to foster coordinated and interdisciplinary collaboration by integrating the scientific community, decision- makers, the industry and relevant practitioners, which can result in stronger and more consistent partnerships. We hope that experts and decision makers could use the results provided by this study to gain a better understanding of the current state of the art in ocean literacy research and to orient future research.

Note for the readers:

An updated analysis of the publications, collaboration index and country collaborations on global ocean literacy research is presented in chapter 5. The aim of this analysis is to offer an up-to-date overview of ocean literacy research, building upon the foundational findings presented in this chapter. Through the incorporation of recent data (up to 2022), the updated analysis will provide a current understanding of the global research on ocean literacy. By incorporating the updated analysis in a separate chapter, we seek to enhance the academic coherence of the thesis, facilitating a seamless progression of ideas and substantiating the evolving perspectives on the subject.

Chapter 3

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

Slightly modified from the published article:

Paredes-Coral, E., Deprez, T, Mokos, M., Vanreusel, A., & Roose, H., 2022. The Blue Survey: Validation of an instrument to measure ocean literacy among adults. *Mediterranean Marine Science*, 23(2), 321-326 23(2). https://doi.org/10.12681/mms.26608

Abstract

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

Keywords: ocean literacy; blue survey; survey validation; exploratory factor analysis

3.1 Introduction

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

Ocean literacy is a global movement that intends to bridge this gap by improving the understanding of the ocean's influence on us and our influence on the ocean. Initially, the concept of ocean literacy was based on three pillars or dimensions that described an ocean-literate person as someone who i) understands the importance of the ocean to humankind; ii) can communicate about the ocean in a meaningful way; iii) is able to make informed and responsible decisions regarding the ocean and its resources (Cava et al., 2005). More recently, there has been a shift in this practical definition: ocean literacy is not only about increasing public understanding of the issues involved but is also about providing tools and approaches to transform ocean knowledge into behaviours and actions promoting the sustainable use of the ocean. Six dimensions have been suggested: these include knowledge, awareness, attitude, communication, behaviour and activism (Brennan et al., 2019). While the proposed dimensions provide a framework for empirical research, certain dimensions, namely, communication and activism were not included in the study. This choice was motivated by our commitment to obtaining reliable, complete and interpretable survey responses. We were concerned that including these dimensions would have led to a very long survey, promoting tiredness among survey participants and potentially resulting in inaccurate responses or a high rate of incomplete responses. We acknowledge that by excluding certain dimensions, our analysis may not capture the full complexity of the

construct. However, we believe that the trade-off in terms of data quality and participation is justified in this case. Thus, the present study focuses on four dimensions that will be measured independently:

I. Knowledge: the understanding of the seven essential principles and fundamental concepts of ocean literacy as described by Cava et al., (2005) (**Table 3.1**).
II. Interest: such as what attracts attention so that individuals want to learn or hear more about the ocean.
III. Attitudes: the level of agreement with or concern for a particular position related to the sustainable use of the ocean.
IV. Willingness to act: future behavioural and lifestyle choices that individuals are willing to make for the ocean within a reasonably short time span.

Table 3.1. The seven essential principles of Ocean literacy

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

Source: Cava et al., *(*2005)

Yet there is still no instrument by which we can measure those dimensions. While several initiatives have been taken worldwide to increase ocean literacy, little is known about the levels or potential improvements of

participants. Without a reliable and valid measurement instrument as a benchmark, it is impossible to evaluate the effectiveness of these initiatives; in other words, "if you can't measure it, you can't improve it" (Thomson, 1883).

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

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

When developing measurement instruments, one has to be aware that they are only appropriate for use once researchers have documented their validity (Knekta et al., 2019). One way to achieve this is by testing the construct validity using Exploratory Factor Analysis (EFA), a statistical technique that analyzes the way responses on different subsets of survey items (e.g., questions) are related and have a higher chance of co-occurring, hence revealing the dimensionality in our data (Fabrigar and Wegener, 2011).

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

3.2 Materials and Methods

3.2.1 Development of the Blue Survey

Various sources were used to draft the survey on ocean literacy. We based the development of the new instrument on (1) re-using existing items from validated surveys (Chen et al., 2020; Cudaback, 2006; Greely, 2008) and (2) creating new items in line with ideas and insights from three rounds of expert consultations. Expert consultation was carried out by email and online meetings. Experts were asked to provide their opinion on the adequacy of the survey items. Experts were identified based on their involvement on ocean literacy projects and initiatives as well as through networking activities (mainly within the Erasmus + MATES project). The required expertise consisted of experience in survey design, having a background in marine science (conservation, ocean-based solutions, deep-sea mining, among others) and/or having a background in social sciences. These expert

panels included ocean literacy practitioners, marine and social scientists as well as maritime stakeholders. This resulted in a total of 51 items, which included 20 test questions and 31 five-point Likert items. Additionally, questions to collect background information on participant gender, age, country of residence and job sector were included. Test questions included multiple choice items with single and multiple answers. Multiple answer questions were scored as correct only when all the correct alternatives were checked; otherwise, they were scored as incorrect. The items were grouped into four sections to measure (I) knowledge, (II) interests, (III) attitudes and (IV) willingness to act. Section I comprised 20 test-items and sections II, III and IV comprised 6, 19 and 6 Likert items respectively. We based the draft knowledge section on the seven essential ocean literacy principles with a special focus on principle 6 that highlights the connection between humans and the ocean as well as the impact of human activities on the ocean. **Table B.1** (**Appendix B**) includes a summary of the number of questions in section I and their alignment with the seven essential principles and specific fundamental concepts. The survey was designed in English and translated into Spanish, Portuguese, Dutch, Italian, German, Croatian, French, and Greek.

3.2.2 Pilot Testing

Responses were obtained from March to May 2020 using the online tool SurveyMonkey Inc, (2021). The Blue Survey aimed to reach professionals linked to marine and maritime careers working for the industry. The selection of the target groups was based on the convenience sampling method, which entails selecting participants who are accessible to the researcher (Wardropper et al., 2021). To initiate contact with the selected target groups, an initial step involved identifying relevant individuals and organizations within the researcher's network and professional affiliations, namely, the network of experts in European initiatives such as MATES, RIGHT, MarineTraining.eu and Marine@UGent. These participants were

considered to be convenient because of their direct accessibility via email communication. Upon identifying the target groups, a formal email communication strategy was employed and the survey link was shared through social media networks such as Twitter and Facebook. Prior to data analysis, a listwise deletion procedure was applied and responses with at least one missing value were removed.

3.2.3 Construct Validation

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

3.3 Results

From a total of 453 participants, 251 complete responses were used in the analysis (50.2% female, 49.8% male). Overall, the survey population was composed of adults, of whom 51.8% were between 19-39 years old, followed by 37.1% whose age ranged between 40-59 years old and the remaining 11.2% were between 60-80 years old. Survey participants were distributed

across 33 countries, mostly from Europe (72.5%), followed by the Americas (22.7%), Asia (2.4%), Africa (2%) and Australia (0.4%). Most respondents were workers (n = 181; 72,1%), of which 24.7% belonged to the marine and maritime sectors. Those sectors directly linked to the ocean included offshore renewable energy, oil & gas, fisheries & fish processing, coastal tourism, marine biotechnology, shipping & logistics, aquaculture, research development & innovation, education and the public sector.

The KMO measures for section I, II, III and IV were 0.77, 0.70, 0.76 and 0.75 respectively; indicating that the sample was appropriate for factor analysis. Using four separate EFAs (one per section), a one-factor solution was obtained for sections I, II and IV, and a three-factor solution for section III (II.1, III.2 and III.3), making a total of six factors (**Table 3.2**). In total, 17 items were removed after the EFAs due to low performance. The items removed comprised nine of 20 items from section I, one of six items from section II, five of 19 items from section III, and two of six items from section IV. A list of the validated questions is presented in **Table B.2** (**Appendix B**). Each factor was assigned a descriptive label, as follows:

I. *Knowledge on ocean-related topics* (11 items; kr20 = 0.71): the understanding of ocean-related topics as described in the seven essential principles of ocean literacy.

II. *Personal interest in ocean-related aspects* (5 items; $\alpha = 0.71$): the feelings or emotions that cause attention to focus on certain aspects of the ocean.

III.1 *Ocean stewardship* (7 items; $\alpha = 0.74$): the attitudes of individuals towards a healthy and sustainable utilization of the ocean.

III.2 *Ocean as economic resource* (3 items; $\alpha = 0.68$): the attitudes towards the utilization of the ocean as a source of economic benefits.

III.3 *Ocean-friendly behaviour* (4 items; $\alpha = 0.65$): the collective day to day behavioural and lifestyle choices made by individuals, in a period of one year prior to the survey, to minimize their negative impact on the ocean (self-reported behaviour).

IV. *Willingness to act* (4 items; $\alpha = 0.73$): future behavioural and lifestyle choices that individuals are willing to make within a relatively short time span (intentions).

3.4 Discussion

Using EFA, we developed and validated a new instrument to measure ocean literacy in an adult population. In addition to measuring knowledge about the ocean, the survey instrument also captured a person's attitudes and willingness to act towards the ocean. The six factors presented in **Table 3.2** allowed us to further unpack and refine the various dimensions of ocean literacy. This may help researchers and practitioners to better understand the factors involved when shaping an ocean-literate person. However, because our sample was limited to an online population, we acknowledge that certain parts of the maritime population were not reached by the survey. Then, we recommend that the instrument should be interpreted with some caution and that generalization to the entire adult population is empirically unwarranted. Furthermore, it is worth mentioning that during the translation process, some questionnaire items may have partly changed from the original version and that this may affect cross-cultural validity (Beaton et al., 2000). Although six factors were identified, there was a high degree of correspondence between the hypothesized four dimensions and the actual factors.

Table 3.2 Pattern matrices of four Exploratory Factor Analyses (N = 251, estimator Weight Least Squares)

Items	Factor loadings		
EFA for Section I - Knowledge about ocean-related topics* (11 items)	1		
Which of the following are transported by rivers to the ocean?	0.79		
In the ocean, living spaces and habitats are found	0.75		
The ocean helps to _____ global warming by absorbing human-produced CO2 from the atmosphere	0.72		
What produces most of the earth's oxygen?	0.61		
Look at the image. If both cities are at the same elevation, it is likely that	0.60		
What is causing sea level rise	0.50		
The ocean affects your life because it	0.48		
How is the climate change impacting the Arctic?	0.46		
Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are	0.46		
Marine renewable energy industries (e.g. offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as	0.46		
The ocean dynamics (the motion of water within the oceans) is powered by	0.41		
EFA for Section II - Personal interest in ocean-related aspects (5 items)	1		
I am interested in ocean science	0.65		
I am interested in maritime jobs	0.61		
I am interested in aesthetic aspects	0.58		
I am interested in recreational aspects	0.57		
I am interested in marine energy	0.48		
EFA for Section III - Attitudes	1	2	3
Ocean stewardship (7 items)			
The health of the ocean is important to human survival	0.66		
My actions can have a significant effect on the health of oceans and coastal areas	0.62		
I have a personal responsibility to work for the health of oceans and coastal areas	0.59		
Business and industry should be responsible for ocean sustainability	0.57		
I understand the issues facing the global ocean	0.50		
Individual citizens should be responsible for ocean sustainability	0.48		
Ocean sustainability is more important than economic growth	0.41		
Ocean as economic resource (3 items)			
It is all right for humans to use the ocean as a resource for economic purposes		0.79	
We should no longer use the ocean as a resource for economic purposes		-0.72	
Maritime economic activities are compatible with ocean sustainability		0.44	
Ocean-friendly behavior (4 items)			
I opt for plastic-free alternatives			0.66
I avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms			0.61
I reduce my energy consumption at home			0.50
I take short showers			0.48
EFA for Section IV - Willingness to act (4 items)	1		
I would be willing to reduce my energy consumption at home	0.75		
I would be willing to avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms	0.64		
I would be willing to opt for plastic-free alternatives	0.63		
I would be willing to take short showers	0.57		

*Ocean-related topics were based on the seven essential principles and fundamental concepts of ocean literacy (Cava et al., 2005; NOAA, 2020).

Knowledge on ocean-related topics is the most well-defined dimension of ocean literacy and has been extensively studied in relation to youngsters (Ballantyne, 2004; Chen et al., 2020; Fauville et al., 2019; Greely, 2008; Mogias et al., 2019; Tsai and Chang, 2019). This youth-centric approach has been identified as one of the main limitations to the development and improvement of ocean literacy (Kelly et al., 2021). Involving adults is critical to effectively improving ocean literacy as is improving their understanding about the ocean. Non-formal learning activities (e.g. experiential learning) have been reported as effective for environmental preservation for this particular group (Eheazu and Akpabio, 2018). Understanding people's *interest in ocean aspects* may provide a pathway for understanding their subsequent engagement (Renninger and Hidi, 2015). Likewise, people are generally more knowledgeable about topics that interest them and, consequently, are likely to hold strong attitudes. Personal interest may motivate those seeking access to a clean and healthy ocean for recreation, or those searching for good water quality for fishing or to develop tourism activities. Ocean-literate individuals must be *willing to act* responsibly towards the ocean. This factor has been used by previous research measuring environmental awareness and environmental responsibility (Stone et al., 1995; Umuhire and Fang, 2016) and has been identified as one of the best predictors of behaviour (Brennan et al., 2019). However, this factor may not perfectly predict observable behaviours, as other factors can impact whether a willingness to act translates into actual action (Stone et al., 1995).

The EFA analysis revealed that the attitudes dimension included three sub-dimensions labelled as ocean stewardship, the ocean as an economic resource and ocean-friendly behaviour. The *ocean stewardship* factor is aligned with previous research reporting that direct experiences have the greatest potential for developing positive attitudes (Greely, 2008). Stewardship activities can engender deeper personal connections to the ocean and stronger place attachments that enhance understanding and appreciation of the marine environment (Ainsworth et al., 2019). As the ocean has been

designated the new economic frontier (OECD, 2016), there are more and more communities which depend on the o*cean as economic resource*. Further information on their stances (preservationist, pro-exploitation, pro-sustainable use) might indicate positive or negative behaviour towards the ocean. Self-reports are widely used in academic and commercial research as proxies of behaviour. The self-reported *ocean-friendly behaviour* factor aligns well with previous studies indicating that they represent fairly stable and valid indicators of ecological behaviours, particularly when individuals are asked to report on specific past or present pro-environmental behaviour (Kaiser et al., 2001).

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

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

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

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

Chapter 4

Measuring Ocean Literacy in the Blue Economy

This chapter delves into a comprehensive assessment of ocean literacy levels among populations of maritime workers and is structured into two distinctive sections. By partitioning the chapter in this manner, a more nuanced understanding of the target public is fostered. Part I encompasses the validation process of the Blue Survey 2.0, a tool to measure ocean literacy among maritime workers. In addition, the first section presents a segmentation analysis conducted among maritime workers in Europe. Part II, on the other hand, presents the application of the Blue Survey 2.0 among employees of a gas company with maritime activities in Peru.

Chapter 4: Part I

Navigating towards a sustainable blue economy: Using maritime workforce segmentation to understand how ocean literacy translates into sustainable practices

Paredes-Coral, E., Mokos, M., Vanreusel, A., & Roose, H. Navigating towards a sustainable blue economy: Using maritime workforce segmentation to understand how ocean literacy translates into sustainable practices. *Submitted for publication.*

Abstract

A sustainable blue economy calls for a workforce that understands the ocean's value, encourages sustainable practices, inspires innovation, and builds support for sustainable policies. Integrating ocean literacy into the blue economy is therefore essential for achieving ocean sustainability. Yet, ocean literacy still faces considerable limitations to its dissemination in the blue economy, while the current levels of ocean literacy in the maritime workforce and how these levels vary with industry-related factors remain unclear until today. Here we assess the levels of ocean literacy of 536 maritime workers across Europe using different methods including exploratory factor analysis, univariate and cluster analyses; and we further discuss the implications for the blue economy. Our results show that industry-related factors such as region, sector and occupation, as well as sociodemographic factors like age and gender, have a significant effect on the levels of ocean literacy. We unpacked five dimensions of ocean literacy relevant to the blue economy (*viz.* knowledge, attitudes towards ocean sustainability, ocean-friendly behaviour, attitudes towards the use of the ocean, and personal interest), which enabled to identify clusters of maritime workers with similar sets of ocean literacy skills. These results constitute a benchmark for measuring ocean literacy in the blue economy sector and may set an example for further initiatives to obtain an ocean literacy baseline in communities over time and compare it across populations and other industries.

Keywords: ocean literacy, blue economy, maritime workforce, segmentation, ocean sustainability

4.1.1 Introduction

A better attitude of humans towards the ocean is required to preserve the ocean while sustainably using its resources (United Nations, 2015). The ocean is facing unprecedent threats caused by human activities and urgent action is needed to restore it to levels that conserves its biodiversity and ecosystem functions. Some of these human activities are closely related to or are happening directly at sea, and despite its positive socioeconomic impacts, they may also exert several pressures on the marine environment and coastal communities (Arbo and Thủy, 2016; Gentry et al., 2017; Halpern et al., 2008).

Ocean literacy is a global movement that intends to improve the human-ocean relationship by increasing the understanding of the ocean's influence on us and the influence of humans on the ocean (Cava et al., 2005); and providing tools and approaches to transform ocean knowledge into actions promoting the sustainable use of the ocean (McKinley and Burdon, 2020). Ocean literacy content is gradually being integrated in professional careers and industrial activities in sectors like the blue economy (Fernández Otero et al., 2019). However, despite all the potential benefits, ocean literacy still faces considerable limitations to its dissemination in this sector (Paredes-Coral et al., 2021).

Integrating ocean literacy into maritime professional careers and industrial activities will improve the understanding of the ocean's value, encourage sustainable practices, inspire innovation, and has the potential to engage workers and build support for sustainable practices and policies. Recently, the European Commission has placed ocean literacy higher on its political agenda by financing different initiatives and projects. Testing the integration of ocean literacy in economic activities by ensuring

accessibility of maritime research knowledge outputs (COLUMBUS[16]), building ocean literacy in professional and industrial environments (MATES[17]), and developing multilingual educational materials to increase the attractiveness of careers and job opportunities in the offshore renewables sector (FLORES[18]) are a few of the objectives implemented in recent EU-funded projects. Still, evaluating the effectiveness of these initiatives is challenging without a reliable and valid measurement instrument for ocean literacy as a benchmark.

Based on existing validated surveys (Fauville et al., 2019; Greely, 2008; Markos et al., 2015) and together with a multidisciplinary team of marine and social scientists, marine educators and practitioners, we created the Blue Survey 2.0. The Blue Survey 2.0 is an international comparative online instrument meant to measure ocean literacy among maritime workers, that assesses the influence of different cognitive, attitudinal, and behavioural factors to better orientate and improve ocean literacy initiatives.

The blue economy in the European Union (EU) represents about 5.4 million jobs and generates a gross added value of almost €500 billion a year (FANBEST Project, 2022). It includes activities that are marine-based or marine-related and comprises established industries such as port activities, offshore wind energy, shipbuilding and repair, maritime transport, coastal tourism, marine living resources and marine non-living resources; and emergent industries such as ocean energy, blue bioeconomy and biotechnology, desalination, maritime defense, security and surveillance, and research and infrastructure (European Commission, 2022).

[16] COLUMBUS project received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no. 652690.
[17] MATES - Maritime Alliance for fostering the European Blue Economy through a Marine Technology Skilling Strategy was co-funded by the Erasmus+ Program of the European Union (Ref. 2017-3114/001-001).
[18] FLORES – Forward Looking at the Offshore Renewables was co-funded by the Erasmus+ Program of the European Union (Ref. 101087224).

To date, most of the research on human-ocean interactions have been done for marine protected areas and the fisheries sector (Barreto et al., 2020; Burgess et al., 2020). Although the increasing need to understand the perspectives and the mechanisms of behaviour change of maritime actors (Bavinck and Verrips, 2020), there is no information on the levels of ocean literacy for any sector of the blue economy and no comparative studies among blue sectors, regions or occupations. These gaps mismatch with the objectives of relevant EU policy instruments such as the European Green Deal, the Sustainable Blue Economy Strategy and the European Skills Agenda[19] (European Commission, 2019, 2021).

Population segmentation using cluster analysis is a widely used analytical approach in marine social science research. This method involves the identification of homogeneous groups or clusters within a larger population based on shared characteristics or attributes (Donovan and Henley, 2010). The process of segmentation enables researchers to gain a deeper understanding of the complex relationships between the variables, such as knowledge, attitudes and behaviours. By performing cluster analysis, one can identify and target specific groups of individuals for intervention, conservation, or management purposes. This approach has been applied in a range of marine social science studies, including those related to marine conservation, fisheries management, and coastal tourism (Carvache-Franco et al., 2021; Kyle et al., 2007; Whatmough et al., 2011).

With this study we contribute to the understanding of the human dimensions in the blue economy, with special focus on ocean literacy. This study is the first of its kind quantifying the levels of ocean literacy among maritime workers, considering the various dimensions of ocean literacy, as well as other factors relevant to the maritime industry. This paper describes how ocean literacy is understood and practised across the maritime domain

[19] European Skills Agenda - https://ec.europa.eu/social/main.jsp?catId=1223&langId=en

in different European regions and sectors. To this, we deployed and validated the Blue Survey (version 2.0) in an online sample of maritime workers to uncover meaningful ocean literacy dimensions. Then, we assessed the linkages of these dimensions with relevant factors (region, occupation and blue economy sector) and sociodemographics, to identify meaningful relationships. We identified maritime worker's clusters with respect to their levels of ocean literacy, identifying which segments of the sampled population were more likely to engage in ocean-friendly behaviours. Finally, based on the newly gained insights, we formulate a series of recommendations and policy implications tailored to the different clusters presented in the study to support future ocean literacy initiatives in the sector and contribute to ocean sustainability.

4.1.2 Materials and Methods

4.1.2.1 Survey Development and Deployment

The Blue Survey 2.0 was specially tailored for maritime professionals and contained modifications to version 1.0 in some item formulations and response categories (Paredes-Coral et al., 2022). Initially, the survey included a total of 44 items, containing 20 test questions and 24 five-point Likert-items. Additionally, questions to collect background information on the participants gender, age, country of residence, hometown location related to the coast, company size, occupation and job sector were included. Test questions included multiple-choice items with single- and multiple-answers. Multiple-answer questions were scored as correct only when all the correct alternatives were checked; otherwise, they were scored as incorrect. Test-type questions intended to measure knowledge on ocean related-topics and were based on the seven essential principles with a special focus on principle 6, that highlights the connection between humans and the ocean as well as the impact of human activities on the ocean. The survey was designed in English and translated by marine scientists into Spanish,

Portuguese, Dutch, Italian, German, Croatian, French, Polish, Finnish and Greek.

We expected to carry on random sampling to obtain a sample representative of the maritime workforce; however, we were unable to do it as the sampling period coincided with the pandemic, so we had to adapt an online version of the survey and we collected data from a convenience sample. This was a compromise that we felt was worthwhile, given the opportunity to collect data even during such an unusual event. Responses were obtained from September 2020 to May 2021 using the online tool SurveyMonkey Inc (2021). The Blue Survey 2.0 was administered online only via social media platform LinkedIn. The survey guaranteed anonymity and the link was sent via direct message to professionals working for marine and maritime industries in Europe.

4.1.2.2 Survey Validation

Given the explorative rationale of this study, we chose to perform Exploratory Factor Analysis (EFA). Listwise deletion method was applied to handle missing data before conducting data analysis. Data were analyzed using the psych R package (version 2.0.12) (Revelle, 2020). In order to test sampling adequacy, the Kaiser-Meyer-Olkin measure (KMO) was obtained (Kaiser and Rice, 1974). Prior to performing EFA, the internal correlations were verified. Due to the distinct characteristics of the answering categories, we conducted two EFA's for test and Likert-type questions separately. We used tetrachoric correlation for test-type questions before running an EFA (Starkweather, 2014). Given the ordinal and non-normal nature of the data, Weight Least Squares (WLS) was employed as a statistical estimator. For the Likert-type questions, the choice of Oblimin rotation was made (Reise et al., 2000). Visual inspection of the scree plot and parallel analysis based on eigenvalues were used to decide on the appropriate number of factors to retain. Items with factor loadings below 0.30 were removed, after which EFA

was re-run. Cronbach's alpha (α) coefficients were calculated for both the test-type items and the Likert-scale items independently in order to evaluate the internal consistency.

4.1.2.3 Assessing Differences in Ocean Literacy Levels Among the European Maritime Workforce

Once the dimensions were identified using two independent EFAs, we calculated the dimension scores as the sum of all the item scores belonging to each dimension. Using t-test and analysis of variance (ANOVA), we assessed significant differences between industry-related factors (occupation, region, job sector, and company size), as well as sociodemographics (gender, age, hometown location) with each ocean literacy dimension. When significant differences were found, Tukey post hoc test was performed to explore the difference between multiple group means. **Table C.1** (**Appendix C**) shows the list of countries constituting each European region.

4.1.2.4 Assessing Similarities Among Maritime Workers

To identify discrete groups of respondents, we used K-means cluster analysis. The K-means cluster analysis was performed using the cluster and Factoextra packages in R (version 2.1.3 and 1.0.7 respectively) (Kassambara et al., 2016; Maechler et al., 2014). K-means cluster analyses were conducted for the most relevant identified dimensions of ocean literacy in the maritime sector. We used the elbow method and the silhouette method to determine the optimal number of clusters.

4.1.3 Results

4.1.3.1 Respondents' Characteristics

From a total of 710 participants, 536 complete responses were used in the analysis. Among the participants, 83 (15.5%) were between 19-29 years old, 161 (30%) were between 30-39 years old, followed by 128 (23.9%) between 40-49 years old, 118 (22%) between 50-59 years old and the lowest proportion (46; 8.6%) represented by workers older than 60 years old. The majority of respondents were male (442; 82.5%) and worked for large companies (369; 68.8%). There was a balance of people growing up close to the coast and those growing up far from the coast (282; 52.4% and 255; 47.6% respectively). Most of the participants lived in Western EU (346; 64.6%); followed by Southern EU (114; 21.3%), Eastern EU (49; 9.1%) and Northern EU (27; 5%). Using the European Skills, Competences, Qualifications and Occupations classification (ESCO) as a reference, respondents were classified as managers (97; 18.1%), professionals (195; 36.4%), technicians (200; 37.3%) and blue collars (44; 8.2%). Additionally, respondents represented mainly four sectors of the blue economy, namely, shipbuilding and repair (185; 34.5%), maritime transport (143; 26.7%), offshore renewables (75; 14%) and emergent sectors such as marine biotechnology, education and research, and military defense (33; 6.2%) (**Table 4.1**).

4.1.3.2 Unpacking the Ocean Literacy Dimensions in the Blue Economy

KMO values for the first and second EFAs proved a sufficient sample size (0.73 and 0.83 respectively). A total of five dimensions were unpacked using two EFAs (**Table 4.2, Figure 4.1**). The first EFA resulted in one dimension that was labelled as "knowledge" and contained 17 items.

Table 4.1. Descriptive variables (N=536): n = subset of the sample; % = subset percentage of the sample. Occupations were based on the European Skills/Competences, Qualifications and Occupations classification (ESCO). Blue economy sectors were based on the categories identified in The EU Blue Economy Report (European Commission, 2022).

Variables	n	%
Age		
19-29	83	15.5
30-39	161	30.0
40-49	128	23.9
50-59	118	22.0
60 and older	46	8.6
Gender		
Male	442	82.5
Female	94	17.5
Company size		
Large (250 or more staff members)	369	68.8
Small & medium (less than 250 staff members)	167	31.2
Hometown location		
Close to the coast (in a range of maximum 15km)	281	52.4
Far from the coast (more than 15km)	255	47.6
EU region		
Western Europe	346	64.6
Southern Europe	114	21.3
Eastern Europe	49	9.1
Northern Europe	27	5.0
Occupation		
Managers	97	18.1
Professionals	195	36.4
Technicians	200	37.3
Blue collars	44	8.2
Blue economy sector		
Shipbuilding & Repair	185	34.5
Maritime Transport	143	26.7
Offshore Renewables	75	14.0
Emergent sectors	33	6.2
Others	100	18.7

The second EFA resulted in four dimensions labelled as "attitudes towards ocean sustainability" (9 items), "ocean-friendly behaviour" (4 items), "attitudes towards the use of the ocean" (3 items), and "personal interest" (5 items) (**Table 4.3**). A total of four items were removed after the two EFAs, three items during the first EFA and one during the second EFA. A list with the validated items of the Blue Survey 2.0 and the Pearson correlations among the five dimensions can be found in **Table C.2** and **C.3** respectively (**Appendix C**).

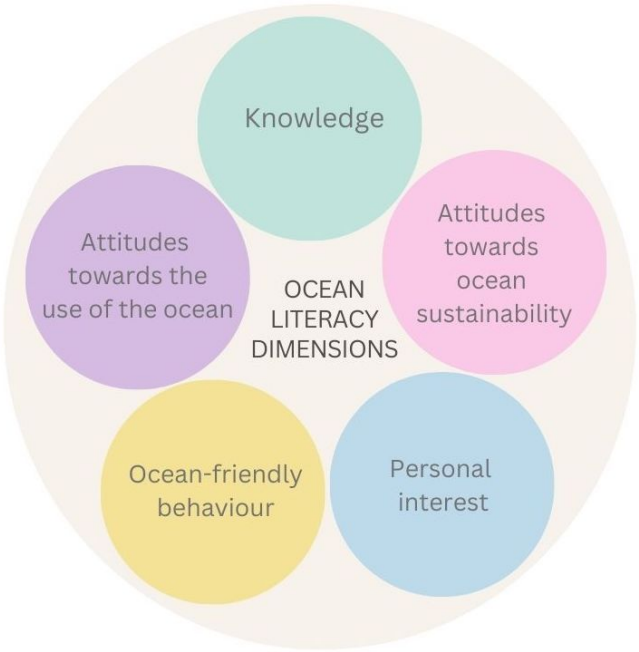

Figure 4.1. Ocean literacy dimensions relevant to the Blue Economy obtained from two independent Exploratory Factor Analyses in a sample of European maritime workers.

Table 4.2. Definition of the five dimensions of ocean literacy identified in the European blue economy using the Blue Survey 2.0

Dimension	Definition	No Survey items	Cronbach's Alpha	Score range
Knowledge	The understanding of ocean-related topics as described in the seven essential principles of ocean literacy.	17	0.62	0 - 17
Attitudes towards ocean sustainability	The attitudes of individuals towards a healthy and sustainable utilization of the ocean.	9	0.81	0 - 45
Ocean-friendly behaviour	The collective day- to-day behavioural and lifestyle choices made by individuals, in a period of one year prior to the survey, to minimize their negative impact on the ocean.	4	0.7	0 - 20
Attitudes towards the use of the ocean	The attitudes towards the utilization of the ocean as a source of economic benefits.	3	0.58	0 - 15
Personal interests	The feelings or emotions that cause attention on certain aspects of the ocean, for example: aesthetics, recreational, etc.	5	0.64	0 - 20

Table 4.3 Pattern matrices of two Exploratory Factor Analyses on a population of European maritime professionals (N = 536, estimator Weight Least Squares)

Items	Factor loadings
EFA I - Knowledge about ocean-related topics* (17 items)	1
Which of the following are transported by rivers to the ocean?	0.66
Fossil evidence shows that life most likely first evolved	0.63
In the ocean, living spaces and habitats are found	0.46
The ocean dynamics (the motion of water within the ocean) is powered by	0.44
How much of the ocean remains unexplored?	0.41
The ocean affects your life because it:	0.41
Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are	0.40
Which of the following most influences the depth at which organisms live in the open ocean (away from the shoreline)?	0.38
What is causing sea level rise?	0.38
Sea level changes have	0.38
Marine renewable energy industries (e.g. offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as	0.36
The ocean helps to _____ global warming by absorbing human-produced CO2 from the atmosphere	0.35
How is the climate change impacting the Arctic?	0.34
Approximately how much of the earth is covered by ocean?	0.33
Most of the marine invasive species are introduced and dispersed to new habitats by	0.33
The use of satellites, buoys, and remotely-operated vehicles improve our understanding of the ocean because the new technologies	0.32
What are the most frequent effects derived from the concentration of industrial activities near the seashore?	0.30

*Ocean-related topics were based on the seven essential principles and fundamental concepts of Ocean literacy (Cava et al., 2005, NOAA, 2020).

Table 4.3 Pattern matrices of two Exploratory Factor Analyses on a population of European maritime professionals (N = 536, estimator Weight Least Squares) (*continued*)

Items	Factor loadings			
EFA II	1	2	3	4
Attitudes towards ocean sustainability (9 items)				
The health of the ocean is important to human survival	0.66			
People have been giving far too little attention to how human progress has been damaging the ocean	0.63			
Business and industry should be responsible for ocean sustainability	0.62			
Ocean sustainability is more important than economic growth	0.60			
I have a personal responsibility to work for the health of oceans and coastal areas	0.60			
My actions can have a significant effect on the health of oceans and coastal areas	0.51			
I understand the issues facing the global ocean	0.50			
Humans do not have the right to damage the ocean just to get greater economic growth	0.47			
Individual citizens should be responsible for ocean sustainability	0.43			
Ocean-friendly behaviour (4 items)				
I reduce my energy consumption at home		0.70		
I avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms		0.60		
I opt for plastic-free alternatives		0.59		
I take short showers		0.53		
Attitudes towards the use of the ocean (3 items)				
It is all right for humans to use the ocean as a resource for economic purposes			0.72	
We should no longer use the ocean as a resource for economic purposes			-0.68	
Maritime economic activities are compatible with ocean sustainability			0.36	
Personal interests (5 items)				
I am interested in recreational aspects of the ocean				0.67
I am interested in aesthetic aspects of the ocean				0.59
I am interested in ocean science				0.41
I am interested in maritime jobs				0.33
I am interested in marine energy				0.30

4.1.3.3 Differences in Ocean Literacy Levels Among the European Maritime Workforce

4.1.3.3.1 Differences in Ocean Literacy Levels According to Occupation, Region and Blue Economy Sector

Our results imply a significant effect of occupation in ocean knowledge ($F_{3,529}$ =8.49; $p < .001$; **Figure 4.2A**), with participants with a professional degree reporting more knowledge on ocean-related topics than technicians ($p < .001$) and blue-collar workers ($p = .001$). Additionally, there was a significant effect of region ($F_{3,529} = 3.91$; $p = .009$), with respondents from Western EU knowing more about the ocean than those working in Southern EU ($p = .01$). Region also had a significant effect on both the worker's attitudes towards ocean sustainability ($F_{3,528} = 6.68$; $p < .001$; **Figure 4.2B**) and their ocean-friendly behaviour ($F_{3,529} = 6.0$; $p = .001$), with workers in Southern EU reporting more positive attitudes towards ocean sustainability than those working in Western EU ($p < .001$) and more ocean-friendly behaviours than workers in Western EU ($p = .002$) and Eastern EU ($p = .004$).

Our findings indicate a significant effect of sector in the worker's knowledge ($F_{4,528} = 3.39$; $p = .009$; **Figure 4.2C**) and the worker's attitudes towards ocean sustainability ($F_{4,527} = 4.05$; $p = .003$), with workers from emergent sectors knowing more about the ocean than those working in maritime transport ($p = .03$). Besides, workers from shipbuilding and repair ($p = .01$) and offshore energy ($p = .006$) reported less positive attitudes towards ocean sustainability compared to other sectors. Moreover, sector influenced the worker's ocean-friendly behaviour ($F_{4,528} = 2.90$; $p = .021$), with workers from maritime transport reporting more ocean-friendly behaviours compared to those working in offshore renewables ($p = .04$). Additionally, sector also had a significant effect on the worker's personal interest ($F_{4,527} = 3.18$; $p = .013$), with workers from shipbuilding and repair reporting less personal

interest for the ocean than those working in other sectors (p = .01). **Table 4.4a** includes the statistics organized by variables and dimensions.

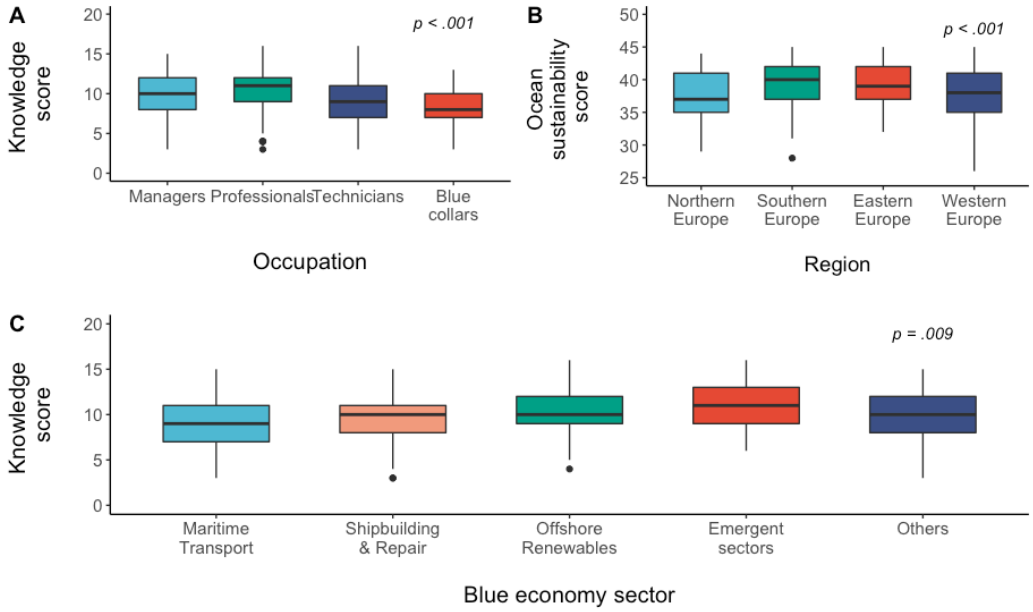

Figure 4.2. Industry-related factors influence the levels of ocean literacy among the maritime workforce **(A)** Differences in ocean knowledge among maritime workers according to ESCO occupations, N=533 **(B)** Differences in attitudes towards ocean sustainability among maritime workers according to region, N=532 **(C)** Differences in ocean knowledge among maritime workers according to blue economy sector, N=533.

Table 4.4a. Industry-related statistics organized by ocean literacy dimensions: n = subset of the sample; % = subset percentage of the sample. Occupations were based on the European Skills/Competences, Qualifications and Occupations classification (ESCO). Blue economy sectors were based on the categories identified in The EU Blue Economy Report (European Commission, 2022).

Variable / Dimension		n	%	Knowledge	Attitudes towards Ocean	Ocean friendly behaviour	Attitudes towards the use of the ocean	Personal interest
EU region				F=3.91; p=0.009	F=6.68; p=0.000	F=6.00; p=0.001	F=1.68; p=0.171	F=1.55; p=0.201
	Western Europe	346	64.6	9.9	37.7	14.6	10.8	15.1
	Southern Europe	114	21.3	8.9	39.5	15.6	10.8	15.5
	Eastern Europe	49	9.1	9.1	39.0	14.1	10.2	15.1
	Northern Europe	27	5.0	10.0	37.3	14.2	10.3	16.0
Occupation				F=8.49; p=0.000	F=0.20; p=0.898	F=0.81; p=0.49	F=1.25; p=0.292	F=0.17; p=0.919
	Managers	97	18.1	9.8	38.0	14.9	10.9	15.4
	Professionals	195	36.4	10.3	38.2	14.6	10.8	15.2
	Technicians	200	37.3	9.1	38.3	14.9	10.6	15.2
	Blue collars	44	8.2	8.6	37.8	14.3	10.3	15.3
Blue economy sector				F=3.39; p=0.009	F=4.05; p=0.003	F=2.90; p=0.021	F=0.43; p=0.786	F=3.18; p=0.013
	Shipbuilding & Repair	185	34.5	9.2	38.2	15.1	10.6	14.6
	Maritime Transport	143	26.7	10.2	36.7	14.0	10.8	15.5
	Offshore Renewables	75	14.0	9.4	37.6	14.4	10.5	15.4
	Emergent sectors	33	6.2	10.2	39.0	15.2	10.6	15.3
	Others	100	18.7	9.8	39.0	14.9	10.9	15.7

4.1.3.3.2 Differences in Ocean Literacy Levels According to Age and Gender

Our results suggest a significant effect of age in the worker's behaviour ($F_{4,528}$ =6.62; p = .000; **Figure 4.3A**), with young workers showing less ocean-friendly behaviour than older workers (p < .001). Likewise, female workers reported more ocean-friendly behaviours than their male counterpart ($F_{1,531}$ =4.40; p = .037). Furthermore, there was a significant effect of gender in the worker's attitudes towards ocean sustainability, with female workers showing more positive attitudes towards ocean sustainability than male workers ($F_{1,530}$ =8.65; p = .003; **Figure 4.3B**). In addition, gender influenced the worker's attitudes towards the use of the ocean, with male workers showing more positive attitudes towards the use of ocean resources than female workers ($F_{1,531}$ =6.64; p = .01). **Table 4.4b** includes the statistics organized by variables and dimensions.

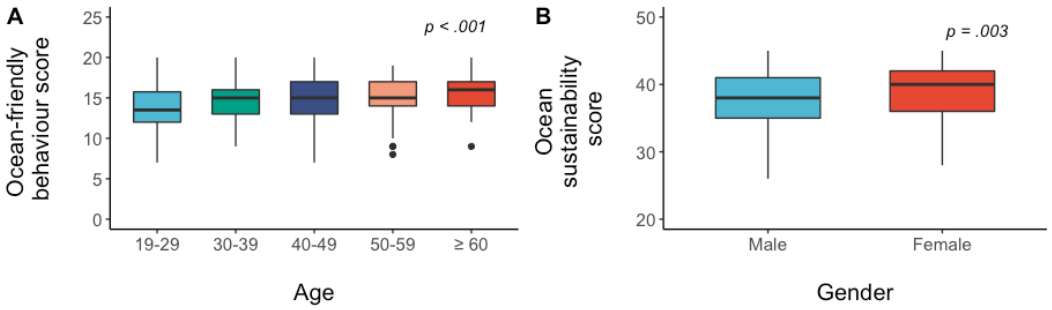

Figure 4.3. Sociodemographic factors influence the levels of ocean literacy among the maritime workforce **(A)** Differences in ocean-friendly behaviour among maritime workers according to age, N=533 **(B)** Differences in attitudes towards ocean sustainability among maritime workers according to gender, N=532.

Table 4.4b. Sociodemographic statistics organized by ocean literacy dimensions: n = subset of the sample; % = subset percentage of the sample. Occupations were based on the European Skills/Competences, Qualifications and Occupations classification (ESCO). Blue economy sectors were based on the categories identified in The EU Blue Economy Report (European Commission, 2022).

Variable / Dimension		n	%	Knowledge	Attitudes towards Ocean	Ocean friendly behaviour	Attitudes towards the use of the ocean	Personal interest
Age				F=0.28; p=0.888	F=1.44; p=0.22	F=6.62; p=0.000	F=1.41; p=0.229	F=0.57; p=0.688
	19-29	83	15.5	9.7	37.8	13.7	10.9	15.5
	30-39	161	30.0	9.7	38.2	14.5	10.9	15.3
	40-49	128	23.9	9.6	38.2	14.9	10.6	15.3
	50-59	118	22.0	9.4	37.8	15.2	10.6	15.0
	60 and older	46	8.6	9.6	39.4	15.7	10.2	15.3
Gender				F=1.12; p=0.291	F=8.65; p=0.003	F=4.40; p=0.037	F=6.64; p=0.010	F=0.32; p=0.574
	Male	442	82.5	9.7	37.9	14.6	10.8	15.2
	Female	94	17.5	9.4	39.3	15.2	10.2	15.4

4.1.3.4 Similarities Among Maritime Workers

The population consisting of maritime workers resulted to be relatively homogeneous. However, it was possible to identify some groups with similar levels of ocean literacy. Considering the scores from the three more relevant dimensions, namely, knowledge, attitudes towards ocean sustainability and ocean-friendly behaviour, a four-cluster solution was obtained (**Figure 4.4**). The first cluster was composed of 165 observations (31.1%) and included individuals with high levels of knowledge, positive attitudes towards ocean sustainability and good behaviour towards the ocean. We labelled this cluster as "*ocean champions*", as this label conveys the idea of individuals who take an active role in preserving the ocean through their knowledge, attitudes, and actions.

The second cluster was composed of 118 observations (22.3%) and included individuals with low levels of knowledge, positive attitudes towards ocean sustainability and good behaviour towards the ocean. We labelled this cluster as "*ocean enthusiasts*" because these individuals care about the ocean but may not have a deep understanding of the topics related to ocean sustainability. It was represented by the higher proportion of workers that grew up close to the coast and that worked in Southern EU.

The third cluster was composed of 145 observations (27.4%) and included individuals with high levels of knowledge, negative attitudes towards ocean sustainability and poor behaviour towards the ocean. We labelled this cluster as "*ocean detractors*" as this label reflect the concept of individuals who exploit the ocean's resources without regard for its well-being, despite their good understanding of ocean-related topics. It had the highest proportion of male workers, from 19-29 years old, working in Western EU, and with a professional degree.

The fourth cluster was composed of 102 observations (19.2%) and included individuals with low levels of knowledge, negative attitudes towards ocean sustainability and poor behaviours towards the ocean. We labelled this

cluster as "*ocean disengaged*" as these words reflect the idea of individuals who may not be aware of ocean-related topics, and who do not prioritize ocean sustainability in their actions or attitudes. It was mainly composed by workers from 50-59 years old, technicians, from the maritime transport sector.

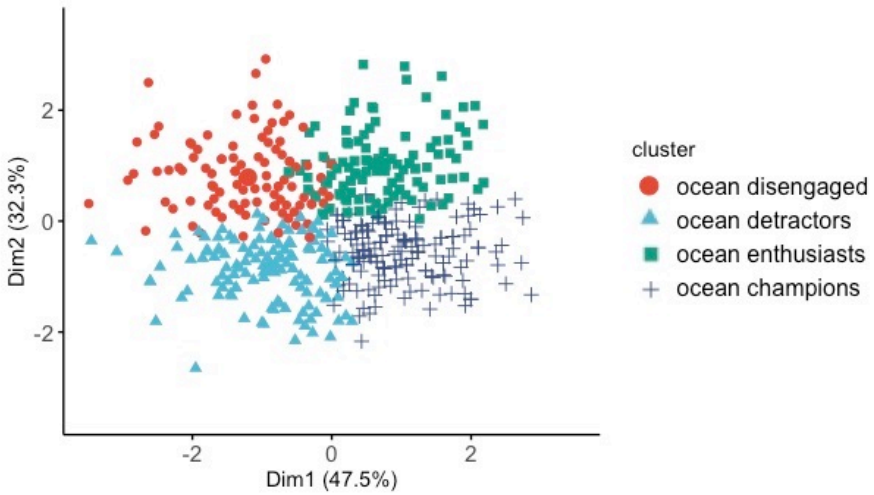

Figure 4.4. Maritime workforce segmentation based on ocean literacy levels obtained from cluster analysis (N = 530). The red dotes represent workers with low ocean awareness and who do not prioritize ocean sustainability. The green squares represent workers that care about the ocean but may not have a deep understanding of ocean sustainability topics. The light blue triangles represent workers who actively exploit the ocean's resources without regard for its well-being, despite their good knowledge. Workers that take an active role in preserving the ocean through their knowledge, attitudes and actions are represented by blue crosses.

4.1.4 Discussion

This study provided a unique opportunity to assess the levels of ocean literacy of maritime workers across several blue economy sectors and regions in Europe, and to explore how different factors influenced the way maritime workers connect to the ocean. In addition to unpacking the most relevant dimensions of ocean literacy in the blue economy, we evaluated the linkages among these dimensions as well as their relationships with industry-related factors. Using the multilingual Blue Survey 2.0 as a scale, we had the opportunity to reach an understudied population, which could help us understand the differences in the choices, perceptions, and actions of maritime workers as well as the similarities among this population.

By unpacking the dimensions of ocean literacy, we identified five underlying factors that play a crucial role in the way maritime workers connect to the ocean, namely, knowledge, attitudes towards ocean sustainability, ocean-friendly behaviour, attitudes towards the use of the ocean and personal interest (**Figure 4.1**). The identification of these dimensions was key to carrying out the segmentation analysis to identify subgroups of maritime workers. We argue that these dimensions are relevant to the blue economy and have an impact on the levels of ocean literacy and the way these levels might vary within different blue economy sectors (McKinley et al., 2023).

Knowledge

Knowledge is by far the most studied dimension of ocean literacy and has been the subject of research among pupils at school, pre-service teachers, university students, and the general public (Fauville et al., 2019; Greely, 2008; Koulouri et al., 2022; Mallick et al., 2023; Markos et al., 2015; Mogias et al., 2015; Paredes-Coral et al., 2022; Steel et al., 2005a, 2005b; Tsai and Chang, 2019). Knowing about the importance of the ocean and the threats it faces is essential for maritime workers as they need to be aware of the

environmental impact of their operations on the ocean. Integrating ocean literacy as action-oriented content into their trainings can help them make informed decisions about how to minimize their impact in marine ecosystems. Besides, this understanding is crucial for complying with local and international regulations related to marine pollution, overfishing, invasive species, antifouling paints, and other activities that affect the ocean (Balaji, 2012; Mineur et al., 2008; Wang et al., 2020).

Attitudes

Both attitudes towards ocean sustainability and attitudes towards the use of the ocean seem to be relevant and timely to the maritime sector (Bavinck and Verrips, 2020). The attitudes of maritime workers can either contribute to the degradation of the marine environment or help to promote its sustainability. Specifically, the attitudes towards ocean sustainability are related to those attitudes that can influence the adoption of sustainable practices in the industry. If workers are aware of the impacts of their activities on the marine environment and are committed to sustainability, they may be more likely to adopt and promote sustainable practices in their workplace (Evans et al., 2013).

The attitudes towards the use of ocean, on the other hand, are more related to the utilitarian views of the ocean as a source of economic benefits. Some workers may see the ocean as a vast resource that can be used to support a range of industries, from fishing and shipping to offshore energy and tourism. They view the ocean as a critical component of the global economy and believe that its harnessing can bring individual benefits. As the maritime workers play a significant role in the use of the ocean's resources, having negative or indifferent attitudes towards ocean sustainability can lead to unsustainable practices and overexploitation of the ocean's resources, which can have severe environmental, social, and economic consequences.

Ocean-Friendly Behaviour

Behaviour change is the ultimate goal of ocean literacy initiatives, and surely, individual behaviour is a crucial component of contemporary models of ocean literacy (Brennan et al., 2019; McKinley et al., 2023; Stoll-Kleemann, 2019). A change in the behaviour of maritime workers can shape the blue economy by adopting sustainable lifestyles and using green technology for processes and operations. However, more and deeper behavioural research on ocean sustainability is required (Belhabib et al., 2022). Although ocean literacy initiatives aim to increase in awareness, which will lead to informed decision making and to trigger behaviour changes, the assessment of their effectiveness will require to monitor if these initiatives actually achieved a positive change in the behaviour of the participants (Ashley et al., 2019).

Personal Interest

This dimension refers to a personal orientation, predisposition or tendency to engage with something that may guide one's behaviour and decision-making (Ainley and Ainley, 2011). Gaining insight into worker's interest in ocean-related aspects could serve as a pathway to understand their subsequent involvement and to identify the diverse motivations that drive individuals to exhibit a particular behaviour (Renninger and Hidi, 2015). Individuals tend to possess greater knowledge in topics that interest them, and as a result, they are more prone to adopting strong attitudes. (Renninger and Hidi, 2011). These interests can shape the worker's views and behaviours related to ocean sustainability or their willingness to engage in sustainable practices. For example, the personal interest of workers might drive those who are interested in accessing a clean and healthy ocean for leisure purposes, or those who are in pursuit of good water quality for fishing or the establishment of tourism-related activities.

The five dimensions of ocean literacy identified in this article may be used as a reference for future ocean literacy research in the blue economy. These dimensions should be taken into consideration when designing and evaluating the effectiveness of training initiatives to ensure that these initiatives capture the multidimensionality of the concept.

4.1.4.1 Maritime Workforce Segmentation Based on Ocean Literacy Levels

Our cluster results suggest certain patterns that groups maritime workers with similar sets of ocean literacy skills (**Figure 4.4**). The *ocean champions* cluster represents workers that take an active role in preserving the ocean through their knowledge, attitudes and actions. Surprisingly, the *ocean champions* cluster membership was not delimited by a clear majority, which suggests that there might be other factors characterizing this cluster that were not considered in this study, both external (institutional, economic, social and cultural) and internal factors (emotions, responsibilities, priorities) (Kollmuss and Agyeman, 2002).

The *ocean enthusiasts* cluster comprised maritime workers that care about the ocean but may not have a deep understanding of the topics related to ocean sustainability. This group is associated with a higher percentage of workers that grew up close to the coast and worked in Southern EU. The coastal origin and working place of an individual can both play a significant role in shaping an ocean literate worker. Individuals who have grown up in coastal communities may have a greater connection to the ocean and its ecosystems, and may be more likely to engage in ocean-friendly behaviours (Daigle et al., 2016; Halkos and Matsiori, 2014; Steel et al., 2005a). However, other authors found that factors such as age or generation can influence perceptions towards the marine environment even more than the proximity to the coast (Potts et al., 2016). Likewise, people working in Southern EU (Mediterranean Sea) have traditionally depended on the sea for their

economic activities such as maritime transport, fisheries and tourism (European Commission, 2022) and have socio cultural reasons to support their connection with the sea. This is in line with research mentioning that place of residence relates to the perceptions concerning the marine environment (Gkargkavouzi et al., 2020).

In the *ocean detractors* cluster, maritime workers actively acted against the ocean by exploiting the ocean's resources without regard for its well-being, despite their good knowledge. This knowledge-behaviour gap has been covered already by previous research, that claimed that good levels of knowledge do not necessarily translate into positive attitudes and good behaviours, and that similarly, responsible behaviours do not necessarily occur in individuals with high levels of knowledge (Kennedy et al., 2009; Kollmuss and Agyeman, 2002). This gap is possibly explained by other factors involved such as attitudes, values, intentions (Liu et al., 2023, 2020; Maurer and Bogner, 2020). The *ocean detractors* workers tend to be young (19-29 years old), male workers, highly educated (professionals), and worked in Western EU. Extent literature has pointed out that age can influence people's behaviour (Jefferson et al., 2015). For example, older people reported engaging in more pro-environmental behaviours than younger people (Pinto et al., 2011), suggesting the existence of a cohort effect that could potentially be attributed not to the natural process of aging, but rather to events that significantly influenced one age group more than another (Gifford and Nilsson, 2014).

Other authors attributed these findings to the 'shifting baselines effect', which denotes a psychological inclination to establish the reference point for environmental quality according to the period when individuals initially experienced marine environments in their personal or professional capacities. For instance, within the fishing industry, older generations have witnessed changes over an extended timeframe and recall marine environments that exhibited better conditions in comparison to the more recent cohorts (Pauly,

1995). In line with this, our findings suggest that more effort is required to engage younger generations of maritime workers in ocean sustainability issues, particularly providing action-oriented training.

Gender differences have been previously reported in which women had stronger environmental attitudes and behaviours than men, and that the later have more utilitarian views about the ocean (Gifford and Nilsson, 2014; Jefferson et al., 2014). There is a clear pattern in the gender results that translates into potentially different drivers for interacting with the marine environment. Surprisingly, this cluster is mainly represented by highly educated workers "professionals", suggesting that despite a good understanding of ocean-related topics, this group of workers seems to have more utilitarian views of the ocean and its resources. Ocean detractors are mainly represented by workers from Western EU, where more than 80% of the current European oil and gas production takes place offshore (European Commission, 2022). The linkages between poor behaviour towards the ocean and region can be explained by the fact that these workers belong to extractive industries.

The *ocean disengaged* cluster included maritime workers who may not be aware of ocean-related topics, and who do not prioritize ocean sustainability in their actions or attitudes. This group comprised senior workers, from the maritime transport sector, with technical education. Although education levels can influence attitudes and behaviours towards the marine environment (Potts et al., 2016), the reasons for this group to act in a disengaged way might rely on socio cultural factors. Workers in this group may prioritize short-term goals, such as meeting tight deadlines or fulfilling orders quickly, over long-term sustainability objectives. This focus on immediate needs can make it difficult to prioritize sustainability efforts. Perhaps, they lack the authority or ability to influence their companies' sustainability practices and this feeling of powerlessness can lead to disengagement and apathy. Possibly, some workers may feel that their

individual actions have a minimal impact on ocean sustainability, which can lead to a sense of futility and disengagement. Additionally, maritime workers might encounter barriers when engaging in sustainable actions, such as personal cost (finance and time) and lack of structural support at their companies (recycling schemes and efficient protocols).

Understanding what motivates ocean-protective or destructive behaviour is critical for designing and implementing effective trainings, campaigns, incentives and policies that encourage maritime workers to actually engage in ocean-friendly behaviours. Our results might help companies to understand that for certain groups of maritime workers enhancing knowledge alone is not enough to achieve ocean-friendly behaviour. Other ways of ensuring their employees engagement with ocean sustainability seem appropriate. For instance, companies may provide resources for workers to implement sustainable practices, which can help to overcome cost concerns and perceived limitations.

4.1.4.2 Implications for the Blue Economy

Our study provides new insight on the connection between maritime workers and the ocean and highlights the need for an ocean-literate maritime workforce to contribute to a sustainable future. The need for such workforce has grown with the increased recognition of the importance of sustainable ocean use and green transition. The EU has recognized the importance of ocean literacy in and beyond the blue economy, and has implemented policy instruments to promote it, including the European Green Deal, the Sustainable Blue Economy Strategy and the European Skills Agenda (European Commission, 2019, 2020f, 2021). These policy instruments acknowledge the importance of ocean literacy and citizen engagement as key actions for informed decision-making that will enable the conditions for sustainable governance. Despite these efforts, there are insufficient initiatives working to increase the ocean literacy levels of maritime workers

(Fernández Otero et al., 2019; MATES Project, 2022). We argue that investing in an ocean-literate maritime workforce can contribute to consolidate a sustainable blue economy, ensure the green transition, and support the goals of the European agenda.

We propose the definition of an ocean-literate maritime workforce to refer to individuals who possess the knowledge, skills, and attitudes necessary to understand, communicate and manage sustainably the ocean and its resources. Having an ocean-literate workforce can have significant implications for the blue economy such as improving sustainability, innovation and competitivity as well as facilitating collaboration and public engagement (Vidican Auktor, 2020). An ocean-literate workforce would have a better understanding of the ocean's value and the impacts of economic activities on the ocean and its ecosystems. This set of ocean literacy skills could motivate them to make more informed decisions at their workplace that prioritize sustainability and the long-term health of the ocean (Papandreou et al., 2021). Moreover, ocean-literate maritime workers could drive innovation by identifying new opportunities for sustainable harnessing of ocean resources and the development of new technologies, products, and services that are better aligned with sustainability criteria (Stuiver et al., 2021). Such workforce can even anticipate changes in the regulatory environment and identify new opportunities for blue businesses (Doussineau et al., 2020).

Besides, they could facilitate collaboration between different stakeholders in the blue economy, including government agencies, businesses, trade unions and NGOs. This collaboration could lead to more effective management of the ocean and its resources and improved outcomes for all stakeholders. In addition, an ocean-literate workforce could help to improve public engagement and awareness around blue careers. This could lead to more youngsters opting for blue careers in the maritime sector and consequently reducing the current shortage of skilled maritime workforce (MATES Project, 2022).

4.1.4.3 Limitations of the Study

With respect to the application of convenience sampling in our study, this approach proved to be the most feasible and appropriate tool for gathering data during the pandemic, as it allowed participants to complete the survey remotely from their own computers or mobile devices. With social distancing measures in place and many people working remotely or on reduced schedules, it was impossible to reach a representative sample using other sampling methods such as random sampling. Nevertheless, we tried to get as near as possible to random sampling. Despite the usefulness of this practice to deploy surveys (Giakoumi et al., 2021; McKinley et al., 2022), we recognize that this approach might occasionally result in a biased view, as some part of the maritime population was not reached by the survey (e.g fishermen), making it empirically unwarranted to generalize our findings to the entire maritime population. Additionally, it is important to note that while translating the survey, certain items may have partly changed from the original version, potentially influencing cross-cultural validity (Beaton et al., 2000).

4.1.4.4 Further Research

Future research should consider a wider, more representative sample and should apply a multi-method approach that combines survey data, qualitative data from interviews, and experimental studies that can provide a comprehensive understanding of ocean literacy over time and across sectors. This study can serve as a benchmark for research on other industrial domains such as textile, automotive, agricultural and construction to better understand sustainable behaviour in the workplace. There is a need for research that engage the private sector to measure the ocean literacy levels of its employees so relevant trainings can be adapted to their actual needs. This is specially the case for emergent sectors such as tidal and floating solar energy and submarine cables, for which little information is available.

Furthermore, these efforts could feed current initiatives aligned with the European Skills Agenda such as the Observatory of Skills Needs and global initiatives like the Ocean Literacy with All (UN Decade Programme - OLWA)[20].

4.1.5 Conclusions

By measuring the ocean literacy levels of maritime workers, this study found that industry-related factors such as region, sector and occupation, as well as sociodemographic factors like age and gender, had a significant effect on the levels of ocean literacy. Moreover, we unpacked five dimensions of ocean literacy relevant to the blue economy which enabled to identify clusters of maritime workers with shared characteristics and similar sets of ocean literacy skills, which have not yet been reported for this sector. In particular, young workers that have recently joined the blue economy reported poor behaviours towards the ocean regardless of their higher education degree. This suggests that, while knowledge is important for improving our understanding about the ocean, it is also important to consider other factors such as attitudes, behaviours and interests. Our findings provide scientific evidence for the need to integrate ocean literacy content into the trainings of maritime workers, especially for those young workers entering in the blue economy, which seem to be the least engaged. Moreover, these efforts should aim beyond increasing knowledge, and focus on promoting action-oriented trainings specific for sectors and regions. This study provides a baseline for ocean literacy levels in the blue economy and expands our understanding of the factors involved in the way maritime workers connect to the ocean. Hopefully, it can set an example for other industries looking to implement initiatives aligned to the current policy instruments promoting sustainable use of the ocean, green energy transition and skilled workforce.

[20] Ocean Literacy with All - https://oceanliteracy.unesco.org/ocean-literacy-with-all/

Chapter 4: Part II

Application of the Blue Survey 2.0: Assessing Differences in Ocean Literacy Levels Among Peru LNG Workers

Paredes-Coral, E., Benavides, M., Vildoso B., & Velez-Zuazo, X.

4.2.1 Introduction

Peru has one of the most productive marine ecosystems, contributing to 7.1% of the total global fishing production (FAO, 2022). However, despite the economic relevance of the ocean and its contribution to the national economy, the full potential of the blue economy has yet to be unlocked (McKinley et al., 2019). The Peruvian coastline stretches over 3000 km from Ecuador in the north to Chile in the south, encompassing diverse ecosystems including coastal wetlands, mangroves, bays, islands and capes (Pérez et al., 2020; Seminario-Córdova et al., 2022). Given the high biodiversity and productivity of Peru's marine ecosystems (Gutiérrez et al., 2016; Tarazona et al., 2003), there is a significant opportunity for the development of a thriving and diverse blue economy (McKinley et al., 2019). The maritime sector plays a crucial role in the Peruvian economy, as it encompasses key industries such as fisheries, oil and gas, maritime transport, tourism and guano, which collectively generate a substantial number of employment opportunities (Christensen et al., 2014; Fréon et al., 2014; Guidino et al., 2020; Rossello et al., 2022). In the oil and gas sector, PERU LNG is a key player in the maritime sector by operating the first liquified natural gas plant in South America.

The company transports natural gas from the Peruvian andes (Chiquintirca) through a 408 km-pipeline and liquifies it in their processing plant in the coastal area of Pampa Melchorita that includes a maritime terminal (**Figure 4.5**; Sahley et al., 2017). As part of its environmental responsibility programs, the company carries out monitoring, prevention and control activities. In partnership with the Center for Conservation, Education and Sustainability of the Smithsonian Conservation Biology Institute, they conduct a Biodiversity Monitoring and Assessment Program (BMAP)[21]. This joint effort is focused on conserving the biodiversity throughout the

[21] Biodiversity Monitoring and Assessment Program - https://www.bmap.pe/the-bmap

project's construction and the subsequent operation of the gas pipeline, operations plant and maritime terminal. As part of the BMAP activities, an initiative to assess the levels of ocean literacy of the workers in the Melchorita Plant was carried out.

Figure 4.5. Map indicating location of the PERU LNG 408 km-pipeline, the processing plant and maritime terminal in Pampa Melchorita. Source: Sahley et al., (2017).

4.2.2 Materials and Methods

4.2.2.1 Pilot testing

The Spanish version of the Blue Survey 2.0 was deployed between June and July 2022 using the online tool SurveyMonkey Inc (2021) and was distributed using the mailing list of PERU LNG. The survey included a total of 38 items, from which, 17 items belonged to the knowledge dimension, 9 items to the attitudes towards ocean sustainability dimension, 4 items to

the ocean-friendly behaviour dimension, 3 items to the attitudes towards the use of the ocean dimension, and 5 items to personal interest dimension.

4.2.2.1 Data analysis

Data was analyzed following the methodology presented in section 4.1.2. The influence of industry-related and sociodemographic factors on the levels of ocean literacy was investigated for each of the five dimensions presented in section 4.1.3.2 Before conducting data analysis, missing data were managed using listwise deletion method.

4.2.3 Results

4.2.3.1 Respondents' Characteristics

From a total of 98 participants, 54 complete responses were collected and used for analysis. Among the participants, 5 (9.3%) were between 20-29 years old, 14 (25.9%) were between 30-39 years old, followed by 25 (46.3%) between 40-49 years old and 10 (18.5%) between 50-59 years old. The majority of respondents were male (44; 81.5%). People growing up close to the coast represented 74.1% (40) and those growing up far from the coast 25.9% (14). Participants were classified according to their level of education with 9 (16.7%) with secondary/technical level, 32 (59.3%) with an undergraduate degree and 13 (24.1%) with a postgraduate degree. Using the European Skills, Competences, Qualifications and Occupations classification (ESCO) as a reference, respondents were classified as professionals (29; 53.7%), technicians (12; 22.2%), blue collars (9; 16.7%) and armed forces officers (4; 7.4%). Additionally, respondents represented mainly four company's functional areas, including administration (9; 16.7%), innovation and technology (4; 7.4%), operations (34; 63%%) and sustainability (7; 13%) (**Table 4.5**). Due to the insufficient number of participants (KMO<0.5), it was not possible to perform Exploratory Factor Analysis.

Table 4.5. Descriptive variables (N=54): n: subset of the sample; %= subset percentage of the sample. Occupations were based on the European Skills/Competences, Qualifications and occupations classification (ESCO)

Variable	n	%
Age		
20-29	5	9.3
30-39	14	25.9
40-49	25	46.3
≥50	10	18.5
Gender		
Male	44	81.5
Female	10	18.5
Hometown location		
Grew up close to the coast (in a range of maximum 15km)	40	74.1
Grew up far from the coast (more than 15km)	14	25.9
Level of education		
Secondary/Technical	9	16.7
Undergraduate	32	59.3
Postgraduate	13	24.1
Occupation		
Professionals	29	53.7
Technicians	12	22.2
Blue collars	9	16.7
Armed forces officer	4	7.4
Company's functional area		
Administration	9	16.7
Innovation & Technology	4	7.4
Operations	34	63.0
Sustainability	7	13.0

4.2.3.2 Differences in Ocean Literacy Levels According to Industry-Related Factors (Occupation and Company's Functional Area)

Our results imply a significant effect of occupation in ocean-friendly behaviour ($F_{3,50}$ =2.356; p = .083), with technicians reporting more ocean-friendly behaviours than professionals (p = .04).

The company's functional area also had a significant effect on the worker's attitudes towards the use of the ocean ($F_{3,50}$ = 3.317; p = .03), with workers from the sustainability area reporting more positive attitudes towards the use of the ocean than workers from the operations area (p = .03) (**Figure 4.6**).

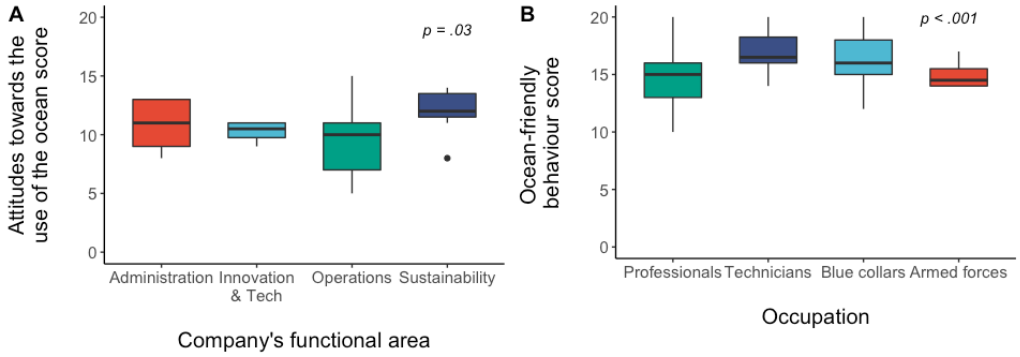

Figure 4.6. Industry-related factors influence the levels of ocean literacy among PERU LNG workers **(A)** Differences in attitudes towards the use of the ocean among workers according to the company's functional areas, N=54 **(B)** Differences in ocean-friendly behaviour among PERU LNG workers according to ESCO occupations, N=54.

4.2.3.3 Differences in Ocean Literacy Levels According to Sociodemographics (Gender, Level of Education and Hometown Location)

Our findings indicate a significant effect of gender in ocean-friendly behaviour, with female workers showing more ocean-friendly behaviours than male workers ($F_{1,52} = 4.051$; $p = .04$). Hometown location also had a significant influence in knowledge levels. Participants who grew up near the coast showed more knowledge about the ocean than those who grew up far from the coast ($F_{1,52} = 4.583$; $p = .037$). Attitudes towards the use of the ocean were influenced by the level of education ($F_{2,51} = 5.42$; $p = .007$). Significant differences were reported between workers with technical education and those with a postgraduate degree ($p = .008$), and between workers with an undergraduate degree and those with postgraduate degree ($p = .04$) (**Figure 4.7**).

Finally, our results suggest that attitudes towards ocean sustainability and personal interests were not influenced by the industry-related and sociodemographic factors assessed in this pilot study.

4.2.4 Discussion

This pilot study provided an excellent opportunity to test the Blue Survey 2.0 in a different community of workers and in a different ocean basin. In addition, it enabled us to obtain novel information on the levels of ocean literacy among Peruvian workers from a gas company with maritime activities in the central coast of Peru. The main findings of this pilot study are (1) the identification of occupation and company's functional area as the most relevant factors related to the industry that can significantly influence the attitudes and behaviours of workers at PERU LNG. This is consistent with the results reported in section 4.1.3.3, in which occupation is a key factor related to the industry that influences ocean literacy levels.

Nevertheless, for European maritime workers, occupation has an influence on the knowledge dimension, whereas for the PERU LNG workers, occupation has an influence on the behaviour dimension. The finding that technicians reported more positive behaviours towards the ocean than professionals, could potentially imply several explanations, yet, further investigation would be necessary to draw definitive conclusions. One possible interpretation is that technicians, who are likely to be directly involved in fieldwork activities at (or near the) sea, may have a deeper and more intimate connection with the marine environment (Bögeholz, 2006; Lindemann-Matthies, 2005).

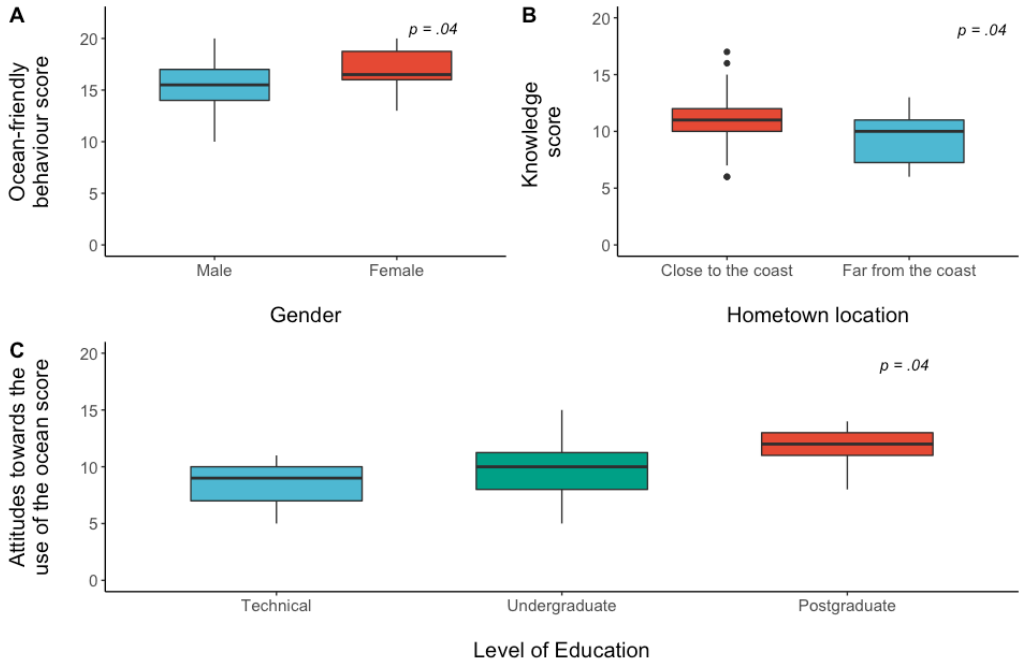

Figure 4.7. Sociodemographic factors influence the levels of ocean literacy among PERU LNG workers **(A)** Differences in ocean-friendly behaviour among workers according to gender, N=54 **(B)** Differences in ocean knowledge among workers according to hometown location, N=54 **(C)** Differences in attitudes towards the use of the ocean among workers according to level of education, N=54.

Their hands-on experience and daily interactions with the ocean may foster a stronger appreciation and understanding of its importance, leading to a motivation to engage in positive behaviours towards its conservation and protection (Maiteny, 2002). On the other hand, professionals may be working in administrative or management roles that are less directly tied to the marine environment, lacking empathy and direct interactions with the ocean. As a result, they may not feel as personally invested in ocean-friendly behaviours (Berenguer, 2007).

The observation that workers from the sustainability area reported stronger attitudes towards the use of the ocean compared to workers from the operations area could have several implications within the industrial context. Firstly, individuals working in sustainability roles possess a deeper understanding about the importance of sustainable ocean use and therefore, their expertise might lead to a greater appreciation for the delicate balance between human activities and ocean sustainability (Kuckertz and Wagner, 2010). On the other hand, workers in the operations area, whose primary focus is likely on the practical aspects of day-to-day operations, might not have the same level of exposure to sustainability criteria, thus assigning a negative connotation to ocean utilization. These findings could indicate a need to consider occupations (job responsibilities) and company's functional area (organizational context) when examining pro-environmental attitudes and behaviours at work (Paillé and Boiral, 2013).

Another key finding relates to the observation that (2) sociodemographic factors such as gender, level of education and hometown location also significantly influenced the worker's behaviour, attitudes and knowledge. These findings are consistent with previous studies where gender differences were reported (Jefferson et al., 2014), in which females reported more pro-environmental behaviours and intentions than males (Li et al., 2022; Triantafyllidis and Darvin, 2021). Likewise, our results are in line with the findings from Daigle et al., (2016) and Steel et al., (2005a), arguing that

people that grew up in coastal areas showed more knowledge about ocean-related topics and a deeper connection to the marine environment. In addition, our results align with research from Potts et al., (2016); and Steel et al., (2005a), in which the level of education is a key factor linked to knowledge, attitudes and concern on the marine environment.

Not least, contrary to what has been reported for European maritime workers, age did not have a significant effect on the levels of ocean literacy. However, it is important to acknowledge that the sample size employed for data collection is relatively small (mostly due to a low response rate), which inevitably imposes limitations on the generalizability of the obtained results (Button et al., 2013). It is crucial to emphasize that generalizing findings from a restricted sample can lead to biased conclusions. Consequently, caution must be exercised when drawing broader implications based solely on this sample, as further investigations involving more extensive and diverse participants are warranted to ensure the robustness and external validity of the findings. Further research should aim to replicate and extend the application of the Blue Survey 2.0 using a larger sample size. A larger sample would not only increase statistical power but also allow for the examination of potential subgroup of workers with different competences and set of ocean literacy skills.

Chapter 5

General Discussion

5.1 Recap of the Objectives, Research Questions and Methods

5.1.1 Objectives and Research Questions

Despite the growing attention on ocean-related issues in contemporary society, little research has been done on the key role ocean literacy can play in promoting good practices in the maritime industries paving the way for the transition into a sustainable blue economy (Bavinck and Verrips, 2020). Moreover, the existing studies are mainly focused on the educational domain at school level, with little consideration to citizens in their professional careers and industrial activities, such as the maritime sector (Fernández Otero et al., 2019). My dissertation aims to contribute to addressing this research gap by expanding the understanding on the status of ocean literacy with a focus on the European blue economy and to assess the levels of ocean literacy across maritime workers.

The following questions have guided my research:

- What is the status of ocean literacy research in terms of its main features, collaboration structure, major thematic areas; and how is this research linked to the blue economy? **(Chapter 2: Mapping Global Research on Ocean Literacy: Implications for Science, Policy, and the Blue Economy)**

- How can we measure the various dimensions of ocean literacy among adults? (**Chapter 3: The Blue Survey: Validation of an instrument to measure ocean literacy among adults)**

- What are the ocean literacy levels of European maritime workers and how are these levels related to sustainable actions? **(Chapter 4: Measuring Ocean Literacy in the Blue Economy)**

- Can we identify groups of maritime workers based on ocean literacy levels? (**Chapter 4 Part I: Navigating towards a sustainable blue economy: Using maritime workforce segmentation to understand how ocean literacy translates into sustainable practices)**

- What are the implications of our findings for marine science, the blue economy and broader goals of sustainability? **(Chapter 5: General Discussion**)

5.1.2 Research Methods

To answer these questions, we employed a series of quantitative research methods. In chapter 2, we conducted bibliometric analyses to assess the development of global research on ocean literacy and identify the gaps in research related to the blue economy. This step allowed us to develop a solid foundation for developing the following chapters.

In chapter 3, we designed and developed an international online survey that measures the various dimensions of ocean literacy among adults, the Blue Survey. Moreover, we used convenience sampling techniques to recruit participants, and we applied construct validity (in addition to face validity) to statistically support that the Blue Survey measured ocean literacy (and not other factors such as reading comprehension). For analysing the survey data, we used exploratory factor analysis. The survey validation enabled us to confirm the complexity of ocean literacy as a concept and encouraged us to explore beyond the cognitive dimension, by measuring ocean literacy across populations, including those closely linked to the ocean, such as the maritime workers.

In chapter 4, we followed the methodology of chapter 3, but we adapted some items of the Blue Survey to a population of maritime workers. Moreover, we employed appropriate statistical tests such as t-tests or analysis of variance (ANOVA) to determine the effects of the ocean literacy dimensions on the levels of ocean literacy. In addition, in chapter 4 Part I, we used cluster analysis to identify groups of maritime workers with similar sets of ocean literacy skills.

A comprehensive literature review and expert consultation were performed to produce chapter 5, that will present a discussion of the main findings previously presented in chapters 2, 3 and 4; as well as their implications in a broader context.

Overall, our research methods involved quantitative analyses such as bibliometric techniques, descriptive survey research, face and construct validity, factor analysis and cluster analysis. This comprehensive approach allowed us to triangulate our findings and provide a more comprehensive understanding of the research topic.

5.2 Overview of the Main Findings

The results found in chapter 2 suggest that ocean literacy is an emerging field of research with marine science at its core and promising trends in research collaboration. These promising trends imply the formation of larger and transdisciplinary research teams, translating into higher scientific impact and productivity. However, only a small proportion of the global ocean literacy research was focused on the blue economy (7.2%), indicating that the coupling of these two fields is still at its infancy. Moreover, our results suggest disparities in the scientific production and collaborations between the Global North and South.

In chapter 3, we propose the Blue Survey as a new instrument to measure ocean literacy in an adult population. This multilingual instrument is a validated tool that combines aspects such as knowledge, attitudes, and behaviours, in the same construct and provides a more integrated perspective on ocean literacy as a means of producing change, which has not been done before for adult populations.

Chapter 4 shows the application of the Blue Survey (version 2.0) to a population of maritime workers. Our findings suggest that the way maritime workers connect to the ocean is complex, but it can be simplified by considering the integration of five pillars including knowledge, attitudes (both towards ocean sustainability and the use of the ocean), behaviour and interest. Moreover, factors related to the industry such as the blue economy sector, region and occupation; as well as sociodemographics, influenced the levels of ocean literacy in European maritime workers. Our results might help companies to understand that for certain groups of maritime workers enhancing knowledge on the ocean alone is not enough to achieve ocean-friendly behaviour and that other approaches for engagement with ocean sustainability seem appropriate. Furthermore, results from the pilot test among employees of PERU LNG showed that industry factors such as occupation and company's functional area along with sociodemographics (level of education, hometown location and gender) had a significant effect on the levels of ocean literacy.

5.3 Discussion of Key Findings

5.3.1 Marine Science as a Core Component of Ocean Literacy

Though new approaches involving digital technologies and arts have been emerging in the last years (Dupont, 2017; Fauville et al., 2021; McCauley et

al., 2021), marine science remains the backbone of ocean literacy (Visbeck, 2018). Marine science plays a fundamental role advancing the field of ocean literacy by providing scientific knowledge of complex ecosystems, processes, the impact of human activities in the marine environment and ocean-based solutions (Schoedinger et al., 2005). Each of the essential principles of ocean literacy and their 45 fundamental components are supported by solid evidence from diverse disciplines in marine science, including oceanography, ecology, marine biology, marine geology, microbiology, zoology, fisheries, genetics, phycology, among others (Cava et al., 2005). For our study, marine scientific knowledge was fundamental for the conception and design of the Blue Survey, presented in chapters 3 and 4. During the design phase of the survey, a comprehensive analysis of the ocean literacy principles and fundamental concepts was carried out in order to translate complex marine concepts into a language for a non-scientific audience. For example, one of the Blue Survey items was formulated as follows:

"The ocean helps to _____ global warming by absorbing human-produced CO_2 from the atmosphere.

Alternatives: accelerate / stop / slow / none of these"

In addition, the marine scientific community actively participated in the validation of the survey, ensuring the accuracy in the item's formulation and the alternatives (also known as face validity process), and translating the survey into Spanish, French, Italian, Portuguese, Dutch, German, Croatian, Greek, Polish and Finnish. Similar applications of marine scientific knowledge to the design of international surveys include the Survey of Ocean Literacy and Engagement (SOLE), the International Ocean Literacy Survey

(IOLS), the Irish Citizen Engagement Ocean Survey, and the Canadian Ocean Literacy Survey (Fauville et al., 2019; Glithero and Zandvliet, 2021; Greely, 2008; McKinley and Burdon, 2020).

The marine research community is taking a leading role in transdisciplinary ocean literacy projects using games, arts, virtual and augmented reality to convey marine science concepts, human-induced threats and nature-based solutions to children (Costa et al., 2022; Pacheco and Faria, 2022), educators (Fauville et al., 2021), policy makers (Dahdouh-Guebas et al., 2022) and the general public (Blanos et al., 2023; de Oliveira et al., 2022).

The fundamental connection between science and society establishes the basis for the need of transdisciplinary participation in ocean literacy (UNESCO-IOC, 2021a). Researchers should have a clear interest in engaging in outreach activities to ensure the preservation of their own research. A society that understands the importance of the ocean will incorporate the value of marine research in safeguarding the marine ecosystems and promoting a sustainable blue economy. Therefore, such a society will actively endorse continuous investment in marine research and other associated activities. Consequently, marine researchers would gain advantages from prioritizing the advancement of an ocean-literate society as the primary objective of their outreach activities (Reuver et al., 2016).

5.3.2 Ocean Literacy in a Global Context

5.3.2.1 Publication and Collaboration Patterns

Scientific publications are the means of researchers to share their findings, and in a way, a reflection of the diverse fields that attract the attention of the scientific community (van Raan, 2019). Like organisms in nature, research fields also emerge, develop, achieve a climax, decline and fade over time. This process allows scientific publications to be good indicators of the development of a research field. They are not only indicators of productivity

and impact but also powerful evaluation tools for policy makers, research managers, funding organizations and individual researchers (Waltman and Noyons, 2018). Since the creation of the term in 2004, ocean literacy has gained acceptance among the research community that started using the term in scientific publications and has now become an emergent field of research (Costa and Caldeira, 2018). The strategic overview that synthesizes 15 years of research, presented in chapter 2, supports the inclusion of ocean literacy as one of the priority areas of research of the Ocean Decade. The slow-growing number of publications rapidly changed since 2019, almost doubling the number of publications in only three years (2020 - 2022).

In this section, I provide an updated overview of the global scientific production on ocean literacy up to 2022, complementing the information presented in chapter 2. For that, I retrieved scientific publications on ocean literacy from Web of Science and Scopus databases from 2020 to 2022. Data were analyzed following the methodology presented in chapter 2 and published in Paredes-Coral et al., (2021). In total, 99 publications were identified in the period 2020-2022, including 87 articles (87.8%), 6 conference papers (6.1%) and 6 reviews (6.1%). This adds up to the scientific production reported from 2005 to 2019 (n=111), making a total of 210 publications for the period 2005 - 2022. A list with the publications used for the analysis for the period 2005 – 2022 is presented in **Table D.1** (**Appendix D**).

The development of global ocean literacy research between 2005 and 2022 is shown in **Figure 5.1**. Since its debut in the scientific literature, the number of publications has fluctuated over the years, growing by 9.2% on average per year (2005 - 2022). It is important to note that this is an average, and the actual growth in any given year may vary. Some years, the growth may be higher than 9.2%, while in others, it may be lower or even negative. However, when we look at the overall trend over the entire period 2005 - 2022, the average annual growth rate comes out to be around 9.2%.

A similar study led by Salazar-Sepúlveda et al., (2023) found a slightly lower amount of published literature in the same time span (192 papers). This growth trend seems to be faster than its analogous concept 'climate literacy' (USGCRP, 2009), that reported 102 publications for the same time span in a search on Web of Science. However, this growth rate is smaller compared to the field of 'science literacy', that reported 451 publications for the period 2018 – 2022 (Wirzal et al., 2022). Likewise, the term 'citizen science' that reports 2645 publications for the period 1995 – 2018 (Pelacho et al., 2021). It goes without saying that the development of ocean literacy expands beyond the academic domain, as it is being used more and more in policy documents (European Commission, 2013b, 2021; French et al., 2015) and national instruments (Canadian Ocean Literacy Coalition, 2021; Freitas et al., 2022; McKinley and Burdon, 2020).

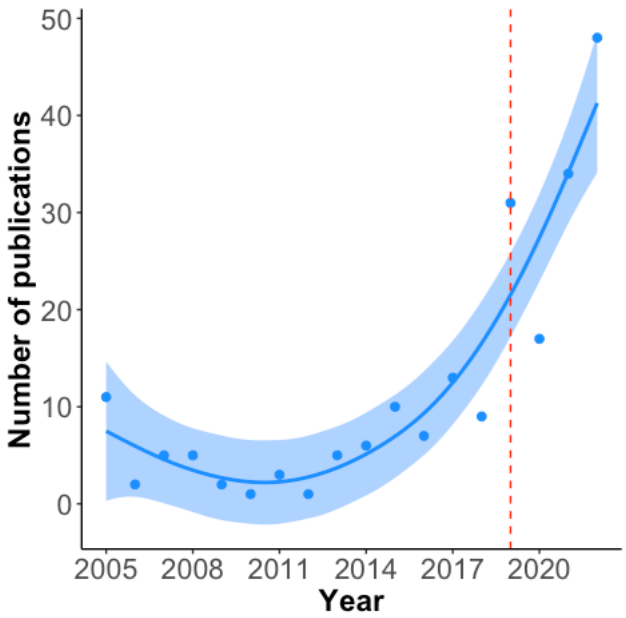

Figure 5.1. Scatterplot showing the number of publications on ocean literacy between 2005 and 2022. GAM fitting of the data revealed a positive trend in the number of publications with a turning point in 2019 (red dotted line).

As ocean literacy reached other regions beyond the US, researchers also expanded their collaboration network to publish about ocean literacy, and this is reflected in the collaboration index (CI), that describes the average number of authors on multi-authored papers. The overall CI from 2005 - 2022 was 4.3, which represents a significant increase compared to 3.8 for the period 2005 - 2019 (**Figure 5.2**).

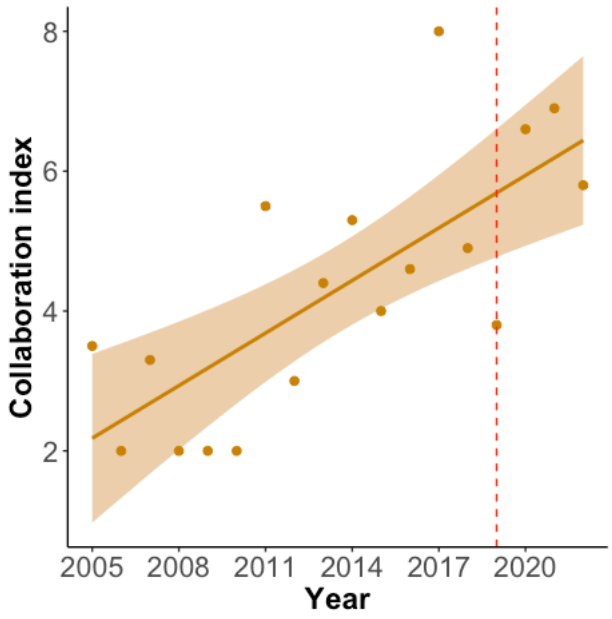

Figure 5.2. Scatterplot showing the collaboration index (CI) per year from 2005 to 2022. Linear fitting of the data revealed a positive trend in collaboration among authors to produce multi-authored papers. Data from 2020-2022 is presented after the red dotted line.

In only three years the number of publications and collaborations highly increased, holding significant implications for academia and society at large. As a cross-cutting and transdisciplinary area of research (Santoro et al., 2017), ocean literacy bridges scientific knowledge with educational practices

and public engagement, aiming to enhance understanding and awareness of the importance of the ocean for a sustainable future (Kelly et al., 2021). From an academic perspective, ocean literacy presents opportunities for collaborative research (Costa and Caldeira, 2018; Salazar-Sepúlveda et al., 2023), innovative pedagogical approaches (Fauville et al., 2021; McCauley et al., 2021), and the development of effective communication strategies (Chambers et al., 2019; Kopke et al., 2019). It also fosters interdisciplinary dialogue, enabling researchers to address and communicate about complex ocean-related challenges (Pace et al., 2023). Moreover, by promoting public understanding of the ocean, ocean literacy contributes to individual and collective informed decision-making and policy development, thus supporting the sustainable management of marine resources.

5.3.2.2 Epistemic Inequalities Between Global North and South

Epistemic inequalities refer to disparities in knowledge production, access, and representation (Wellmon and Piper, 2017). These inequalities manifest, for instance, between regions considered more economically developed (Global North) and those that are less developed (Global South), resulting in certain disciplines having substantially more power than others, in terms of funding and policy influence. Consequently, local and indigenous knowledge, feminist perspectives, and a wider spectrum of valuable approaches for knowing and doing in sciences are far from equally participating in shaping the future of ocean sustainability (Hornidge et al., 2023).

Our findings highlight how ocean literacy research provides a prominent global example of how science programs from the Global North, namely, the US, Europe and Australia, predominantly shape and lead knowledge production of the global science system (**Figure 5.3**). So, although ocean

literacy has a global outreach, certainly in its intentions and aims, the discourse largely has a Global North influence.

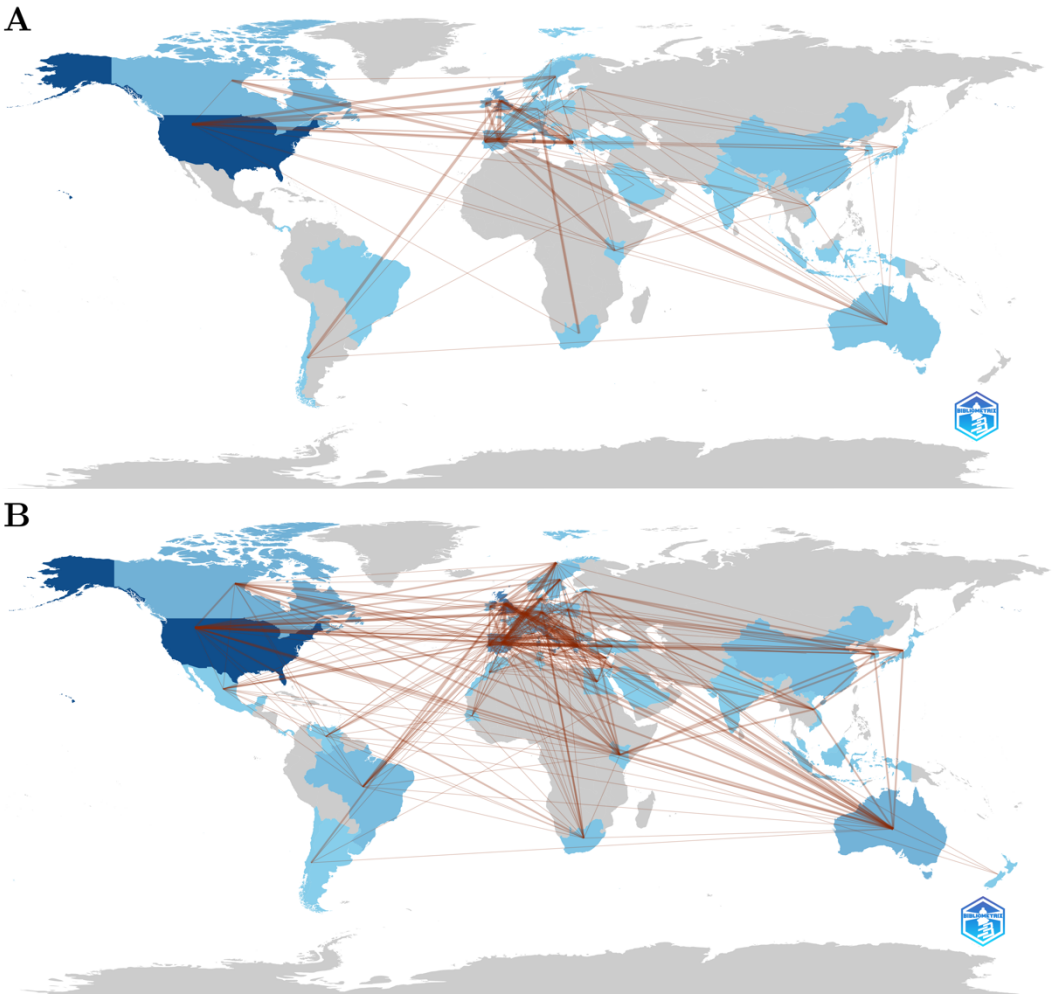

Figure 5.3. The evolution of global collaboration on ocean literacy research. The blue gradient is proportional to the number of publications by country. Gray colour indicates no data and red lines represent collaborations among countries. Line width is proportional to the number of collaborations. **(A)** Study period 2005-2019. **(B)** Study period 2005-2022. World map was created using Biblioshiny app for Bibliometrix R package (version 4.1.3).

Similar disparities at the global level have been shown in other research areas related to marine sustainability, such as marine biodiversity(Tolochko and Vadrot, 2021), biodiversity loss (Tan et al., 2023), tropical marine sciences (Partelow et al., 2020) and citizen science (Leach and Fairhead, 2002), where knowledge on the Global South is primarily produced by researchers in the Global North, even though the marine sustainability challenges faced by the Global South exhibit inherent distinctions.

Addressing these epistemic inequalities is crucial for achieving an equitable and globally sustainable blue economy (Bennett et al., 2019; Cisneros-Montemayor et al., 2021). If the future of ocean literacy is to be based on collaboration, efforts should focus on fostering equitable and durable partnerships that address on-the-ground priorities, recognize the many ways of knowing about the ocean, value the contributions of local and indigenous knowledge, facilitate opportunities for capacity-building and promote knowledge and technology transfer. These efforts are essential for the progression of ocean literacy and the sustainable use of the ocean and its resources.

5.3.3 Ocean Literacy for Education and Training in the Marine and Maritime Sectors

Ocean literacy has the power to significantly impact in different actors of society, particularly through the involvement of key stakeholders in the marine and maritime sectors. Although it is clear that the marine and maritime sectors will require skilled workers to secure employment in the blue economy (OECD, 2016), a significant disparity remains between the expectations of the industry and the resources provided by current education and training systems (Sdoukopoulos et al., 2021; Soukissian et al., 2023; Vincx et al., 2018). These skills would range from digital skills for developing

clean technologies, project management and communication skills, language skills, problem-solving, to green skills including ocean literacy (MATES Project, 2022; QBIS, 2020; Vidican Auktor, 2020).

Lifelong learning holds significant potential for disseminating ocean literacy within the maritime workforce (Akamangwa, 2021). By embracing a continuous learning approach, individuals working in maritime industries can acquire and update their knowledge on the importance of the ocean, human-induced threats and nature-based solutions (Edler and Infante, 2019). Through targeted training programs, workshops, and online courses, the maritime workforce can enhance their ocean literacy, empowering them to make informed decisions, implement best practices, and contribute effectively to ocean conservation and sustainable development within their respective roles (Papathanasiou et al., 2018). The integration of lifelong learning into maritime sectors can drive a culture of knowledge dissemination and improve the overall stewardship of our oceans (Sogor, 2021).

5.3.3.1 Benchmarking Ocean Literacy to Guide Future Initiatives in the Maritime Sector

Benchmarking involves establishing baseline measurements of distribution, abundance, characteristics, among various other factors (Robinson and Peres, 2021). It intentionally uses precisely repeatable approaches to enhance alignment with future replication promoting rigorous quantification of change through time (Robinson and Curtis, 2020). The process of benchmarking usually starts by identifying peers who serve as examples of best practices within a specific activity, function, or process. (e.g., a company in the maritime sector). These exemplary peers who adhere to best practices serve as benchmarks to assess actual performance (Cherchye and Kuosmanen, 2004). Benchmarking is extensively utilized across diverse

industrial sectors and lately has been applied to sustainable development projects (Dinwoodie et al., 2012).

Benchmarking ocean literacy within the maritime industry could play an important role in promoting ocean sustainability. By comparing and evaluating training programs, policies, and practices across different maritime organizations, it would be possible to identify best practices and areas for improvement (Puig et al., 2020). Surveys can be used to assess the level of ocean literacy among industry stakeholders (Paredes-Coral et al., 2022). If applied together with mixed methods, such as interviews and case studies, they can provide insights for the development of standardized indicators and metrics (Cherchye and Kuosmanen, 2004). By benchmarking ocean literacy, the maritime industry can establish performance standards and targets for ocean literacy initiatives, fostering a culture of continuous improvement towards ocean sustainability.

5.3.3.2 Ocean Literacy Skills in the Blue Economy

Ocean literacy skills in the maritime sector are paramount in addressing the human-induced threats faced by the ocean and meeting global sustainability goals (Paredes-Coral et al., submitted for publication). These blue skills are the analogous of the green skills and encompass a combination of knowledge, abilities and experiences to develop and support a sustainable and resource-efficient industry (Vidican Auktor, 2020). These can include good practices related to water and waste management, efficient consumption of energy and materials in operations, along with the ability to strategize and innovate for green solutions for the ocean(Akamangwa, 2021).

Ocean-literate workers involved in marine and maritime activities must be able to understand that ocean productivity and carrying capacity are limited. Consequently, they should be capable of making more practical estimations about the potential outcomes of their operations in the marine

ecosystem. The pressing need to restore the ocean to a healthy state demands leveraging all the currently accessible resources and knowledge. Professionals, technicians, blue-collar workers and managers involved in maritime activities must possess a set of ocean literacy skills to navigate this evolving landscape (MATES Project, 2022).

For those workers involved in managerial roles, a solid understanding of international maritime regulations, such as the International Maritime Organization's (IMO) emissions standards, is essential (Joung et al., 2020). Professionals and technicians involved in operations should also be adept at implementing and overseeing sustainable practices, like efficient fuel consumption, waste reduction, and ballast water management (MATES Project, 2022). Proficiency in data analytics for tracking environmental metrics, along with the skills to design and perform innovative sustainable processes, is crucial (Yan et al., 2021). Among these innovative sustainable processes, we can refer to the knowledge for the harnessing of alternative fuels (methanol, liquefied biogas and hydrogen) and renewable energy sources (energy efficiency and innovative infrastructure design)(Prussi et al., 2021; Stuiver et al., 2021). Blue-collar workers engaged in maritime operations may benefit from practical skills aligned with sustainability criteria. This includes familiarity with ocean-friendly maintenance and repair techniques, safe handling of hazardous materials, and the operation of energy-efficient machinery. Knowledge of waste segregation, recycling, and pollution prevention measures are vital aspects of their skillset (Papandreou et al., 2021).

Nonetheless, considering that the blue economy relies in part on international regulations, stakeholders such as policy makers and decision-makers in the field of the blue economy may also benefit from a set of ocean literacy skills, to effectively lead the way to a more sustainable blue economy (Agarwala, 2022). The difficulty lies in adequately conveying these messages and motivate the maritime stakeholders (workers, CEOs, entrepreneurs,

investors, policy makers) to actively acquire knowledge and take action (Fernández Otero et al., 2019).

5.3.4 The Potential for Ocean Literacy to Contribute to Broader Goals of Sustainability

In the previous sections, the benefits that ocean literacy could bring for the marine and maritime domains have been described, however, ocean literacy has the potential to contribute to broader goals of sustainability, aiming at a harmonious and balanced relationship between societies, the (marine) environment and the economy. These goals often refer to comprehensive and coordinated approaches aimed at preserving and protecting the (marine) natural resources and biodiversity on a regional and global scales. In this subsection, I will discuss about the results and perspectives of this PhD thesis in the context of the 2030 Agenda for Sustainable Development, the UN Decade of Ocean Science for Sustainable Development and the New Approach for a Sustainable Blue Economy in the EU.

5.3.4.1 The 2030 Agenda for Sustainable Development

In 2015, the UN Member States collectively adopted the 2030 Agenda for Sustainable Development, which serves as a common plan for promoting peace, prosperity, and sustainability for current and future generations (United Nations, 2015). At the core of this agenda are the 17 Sustainable Development Goals (SDGs), which demand immediate action from all nations, irrespective of their level of development, through a global partnership. The SDGs provide a framework for addressing the world's most pressing environmental, social, and economic challenges, including poverty, hunger, gender equality and climate change, by 2030 (United Nations, 2017).

The ocean fits neatly in SDG 14 (Life below water) but also plays a vital role in achieving the entire SDGs.

To explore the connection between my PhD topic and the SDGs, we used the "Sustainable Development Goals Toolkit", a self-evaluation tool that maps and analyzes the relevance of a research topic with the SDGs (Barimo et al., 2021). By assigning scores from 0 to 5 to each of the 17 SDGs (0 = no direct connection to the SDG; 5 = expected data directly contributes to at least one SDG indicator), we can gain insights on how a research topic is positioned within the broader sustainable development context. The results obtained from the mapping tool revealed that this PhD thesis primarily contributes to SDG 4 (Quality education), SDG 12 (Responsible consumption and production), SDG 13 (Climate action) and SDG 14 (Life below water). In addition, our research approach showed indirect linkages with the rest of the SDGs, which is aligned with the assessment performed by Carpenter et al., (2021b) (**Figure 5.4**).

The aim of SDG 14 is to conserve and sustainably use the oceans, seas and marine resources for sustainable development (United Nations, 2015). By increasing the understanding of ocean literacy dimensions in the blue economy, our work contributes directly to target 14.A: Increase scientific knowledge, research and technology for ocean health (United Nations, 2017).

Yet, through the identification of the most relevant factors to consider when shaping a maritime worker to act responsibly towards the ocean, done by this PhD thesis, our research indirectly supports all of its 10 targets (**Figure 5.5**). However, we noticed that apart from target 14.A, the link between our research and SDG 14 is imprecise because targets and indicators related to awareness or skills for sustainable ocean development are missing. This missing piece could be added to the limitations previously reported for this SGD, for instance, that it leaves several key challenges inadequately addressed or simply unaddressed (Armstrong, 2020) and that it faces limitations for the quantification of its indicators (Cormier and Elliott,

2017). Based on our findings, SDG 14 could benefit from a new sub-target related to the promotion of ocean literacy skills for ocean sustainability.

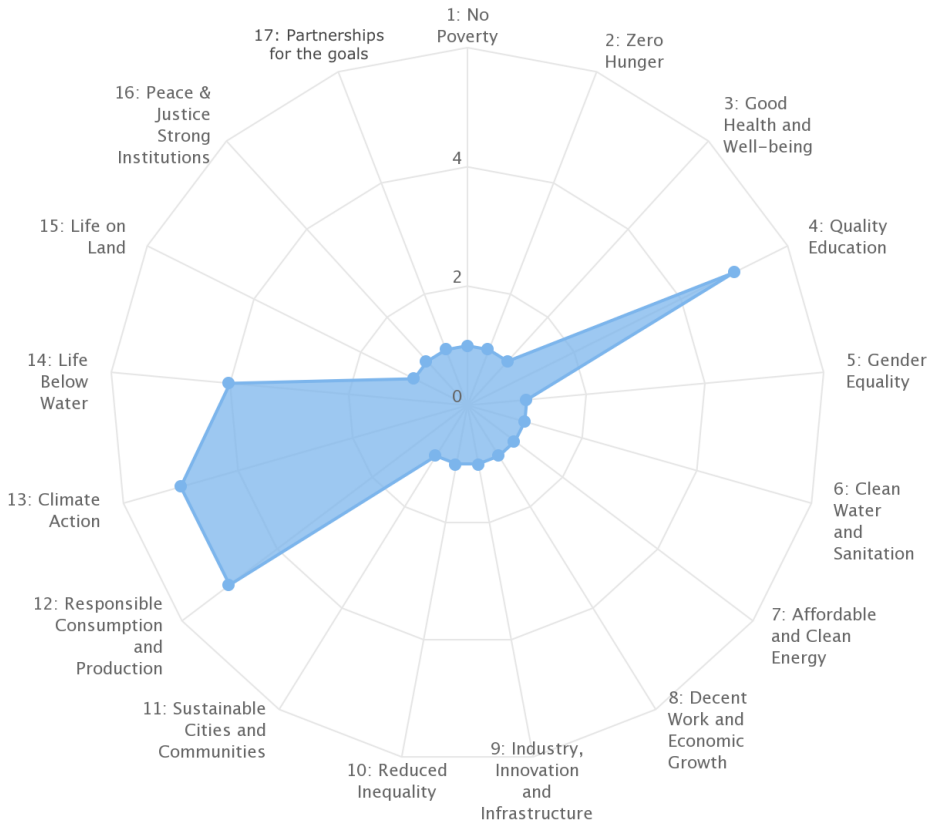

Figure 5.4. Sustainable Development Goals map showing the connections between this PhD thesis and the SDGs. Figure was created using the self-evaluation SDGs Toolkit (Barimo et al., 2021).

SDG 4 (Quality education) together with SDG 12 (Responsible consumption and production) and SDG 13 (Climate action) share similar targets aiming that by 2030, all learners acquire the knowledge and skills needed to promote sustainable development and lifestyles in harmony with nature (United Nations, 2015). Indicators 4.7.1/12.8.1/13.3.1 specifically center on assessing the degree to which national education policies, curricula, teacher training,

and student assessment incorporate global citizenship education and education for sustainable development (United Nations, 2017). Our work on the assessment of ocean literacy levels using an international validated survey, contributes directly to indicators 4.7.1/12.8.1/13.3.1, by measuring the extent to which maritime workers acquire the skills related to ocean literacy needed to promote sustainable development, particularly in the marine environment.

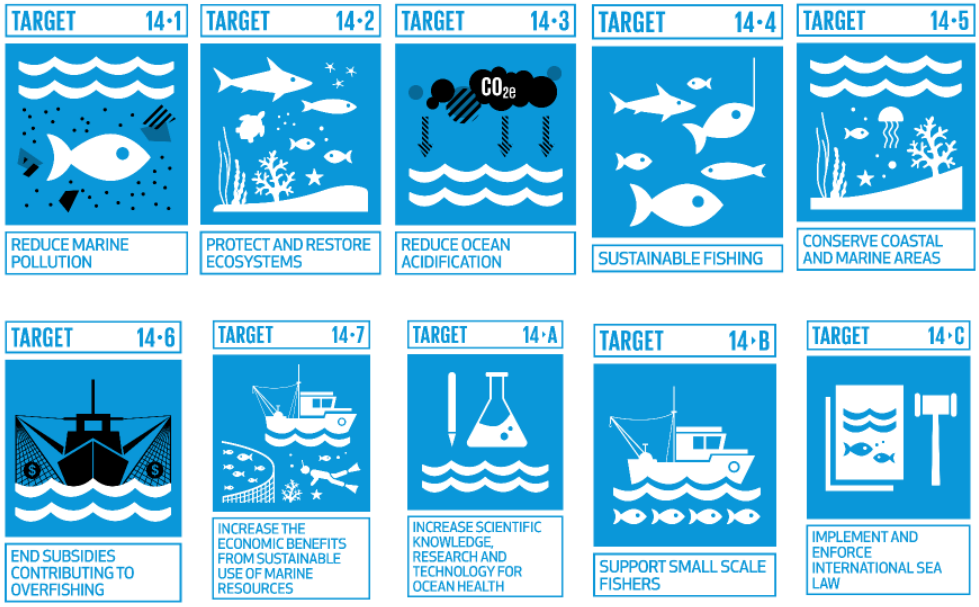

Figure 5.5. Sustainable Development Goal 14 targets and sub-targets. Source: Haas (2023).

Such assessments can provide insights on the gaps in marine and maritime training programmes and suggest the need for curriculum improvements and the integration of the ocean into training programmes at all levels (from lifelong learning and vocational training to PhD programmes) (FLORES Project, 2023; MATES Project, 2022; Sdoukopoulos et al., 2021). This is particularly relevant for maritime workers transitioning from oil and gas

into offshore renewables, as these workers need to include a sustainability perspective in their trainings (Soukissian et al., 2023).

5.3.4.2 United Nations Decade of Ocean Science for Sustainable Development

The UN Decade of Ocean Science for Sustainable Development, also known as Ocean Decade, is a ten-year initiative (2021-2030) aimed at promoting the progression of ocean science and knowledge generation to reverse the deterioration of the state of the ocean and facilitate the emergence of new possibilities for sustainable development (UNESCO-IOC, 2021b). The Ocean Decade aligns closely with SDG 14 and supports its objectives by fostering research, monitoring, and data collection on marine ecosystems to promote sustainable practices (Ryabinin et al., 2019). It includes 10 key challenges related to climate change impacts, marine pollution, overfishing, sustainable blue economy, skills, knowledge and technology, and humanity's relationship with the ocean (UNESCO-IOC, 2021b). The Decade objectives are relevant to all challenges and encompass three interconnected goals aiming at (1) identifying required knowledge for sustainable development, (2) generating comprehensive knowledge and understanding of the ocean and (3) increasing the use of ocean knowledge (UNESCO-IOC, 2021b).

Ocean literacy plays a crucial role in achieving all three objectives through active involvement of society and by enabling collaborative development of ocean science, co-production of knowledge, and the co-delivery of solutions in support of decision-making, policy, management and innovation (UNESCO-IOC, 2018, 2021a).

In line with this, by mapping the status of global research on ocean literacy (chapter 2), our study contributed to the Decade objective 1, sub-objective 1.1 by identifying priority gaps in research linked to the blue economy, and

sub-objective 1.5 by providing an overview of the global collaborations in the scientific community. The primary aim of Sub-objective 1.1 is to establish the scientific foundation for regular integrated assessments of the state of the ocean. Additionally, it seeks to identify priority gaps in various geographical areas and scales, thereby guiding efforts in exploration, observations, and experimentation. Sub-objective 1.5 seeks to conduct periodic evaluations of the status of ocean science capacity in order to recognize and address obstacles related to diversity in terms of generation, gender, and geographical representation (UNESCO-IOC, 2021b).

Furthermore, by engaging multiple stakeholders from the maritime industry such as blue collars, technicians and professional, managers and CEOs, to participate in the Blue Survey, our study contributes to objective 2, sub-objective 2.6 (expand cooperation in ocean-related education, training, capacity development and transfer of marine technology) (UNESCO-IOC, 2021b). In addition, during the design process of the Blue Survey, we translated ecological, biological and oceanographic concepts into non-scientific language addressing diverse stakeholders from the marine and maritime sectors, contributing to objective 3, sub-objectives 3.1 and 3.3. The goal of Sub-objective 3.1 is to effectively disseminate and advance the role of ocean science for sustainable development across various groups of stakeholders. Sub-objective 3.3 aims to undertake interdisciplinary collaboration involving various stakeholders to co-design and co-deliver ocean solutions. These solutions encompass decision-making tools, policy, integrated ocean management frameworks, practical applications and services, as well as advancements in technology and innovation (UNESCO-IOC, 2021b).

5.3.4.3 New Approach for a Sustainable Blue Economy in the EU

Since 2021, the EU has adopted a new approach for making the transition from blue growth to a sustainable blue economy, focusing on achieving long-

term environmental, economic, and social benefits. This approach includes principles of sustainability, ecosystem-based management, and integrated governance, and emphasizes the need to balance economic activities with the sustainable utilization of ocean resources. Furthermore, social inclusivity is a key pillar of this strategy as it focuses on fostering cooperation among stakeholders, including coastal communities, industry, and civil society. This collaboration ensures that decision-making processes are inclusive, transparent, and considerate of the needs and aspirations of all stakeholders (European Commission, 2021). A sustainable blue economy is recognized as a vital component of and will help to achieve the overarching objectives of the European Green Deal (European Commission, 2019).

Ocean literacy plays a crucial role in the new approach for a sustainable blue economy in the EU, due to the need to enhance public understanding and awareness of the importance of the ocean for life on the planet. In section 4 “Creating the conditions for sustainable governance”, sub-section 4.2: “Citizen engagement and ocean literacy”, the new approach recognizes ocean literacy as a tool to improve a sustainable blue economy in Europe (European Commission, 2021; page 16). By integrating ocean literacy into a policy for a sustainable blue economy, the EU aims to ensure the environmental integrity of future undertakings, foster informed decision-making and innovation, and overall, create the conditions for sustainable (ocean) governance (European Commission, 2021). This PhD thesis directly contributes to sub-section 4.2 of this new approach by filling knowledge gaps on the status of ocean literacy research linked to the blue economy and providing novel data on the levels of ocean literacy in the European maritime workforce. These findings underscore the need for targeted training initiatives and awareness campaigns to integrate and further enhance ocean literacy in the maritime industry.

5.3.5 A Critical View on the Use of Existing Approaches of Ocean Literacy

Ocean literacy was originally conceptualized as the understanding of the influence of the ocean on us and our influence on the ocean (Cava et al., 2005). This definition was scientifically supported by seven essential principles and 45 fundamental concepts, and aimed at being integrated into the school curricula of American students (NOAA, 2020; Schoedinger et al., 2010). However, since ocean literacy was embraced by UNESCO in 2017, this definition transformed into a societal approach that stimulates efforts to protect, conserve and sustainably use the ocean in all sectors of society (UNESCO-IOC, 2021a). While this institutional approach enabled the expansion and adoption of ocean literacy at a global scale, it may have also prioritized UNESCO's own interests and agendas. The nature of these interests (e.g. political, economic, or social factors) could have influenced the way the concept was formulated, potentially leading to a biased interpretation of the subject (Dostál, 2019; Hüfner and Naumann, 1986). Consequently, certain aspects of ocean literacy might be downplayed or omitted altogether, possibly leading to lack of conceptual and scientific clarity of the topic. Even though a framework for ocean literacy in the Ocean Decade exists, there is a lack of a recognized guideline in which ocean literacy dimensions are defined. Efforts have been made to propose ocean literacy dimensions based mostly on their theoretical utility (McKinley et al., 2023), however, there is a limited understanding of their practical utility (in the field).

This lack of conceptual clarity is of particular concern when considering the multidimensional nature of ocean literacy, which encompasses cognitive, attitudinal and behavioural dimensions, among others (Paredes-Coral et al., 2022). This absence of clear conceptual delineation can be exemplified by official documents and international initiatives setting goals on the need to promote/enhance ocean literacy (European Commission, 2013b; UNESCO-

IOC, 2021a, 2021b). One may ask to what ocean literacy dimension are these goals referring to? Is it enhancing knowledge? attitudes? or behaviour? A comprehensive understanding of the various dimensions of ocean literacy is essential for defining clear goals and delineating effective strategies at national, regional and global scales (Gerring, 1999).

This holds particular significance within the context of the current research, given that our analyses are based on the ocean literacy definition and the theoretical dimensions in the available literature (Brennan et al., 2019; McKinley et al., 2023). When outlining this PhD research, particularly for chapter 3 and 4, it was clear that our research would go beyond the cognitive aspects of ocean literacy, but it was challenging to identify the other dimensions involved when shaping an ocean-literate maritime worker and at what extent these dimensions were measurable in a real-world setting.

In this study, when we refer to 'enhancing ocean literacy', we mean increasing each of the dimensions of ocean literacy relevant to the maritime sector. For example, it relates to increasing the fundamental knowledge about the importance of the ocean and the threats that is facing, encouraging positive attitudes and promoting positive behaviours towards the marine environment, and inciting interests on certain aspects of the ocean. Then, it is possible for someone to inquire, which dimension is more important to focus on? Our findings support the idea that there is no 'one size fits all' model given that even within the maritime population it seems to be subgroups of workers with different sets of ocean literacy skills. Thus, a tailored approach may be suitable for the maritime population. While some subgroups report better attitudes or behaviours and will benefit from fundamental knowledge about the ocean and its resources, others are more knowledgeable, and they could gain advantages from trainings that stimulate positive and long-lasting behaviours.

Although this study has intended a preliminary analysis of these relationships, a model that simplifies the relationships among these dimensions, weighting the contribution of each dimension and assigning a hierarchy, or the identification of mediators among ocean literacy dimensions have not yet been developed. For that, it is necessary to count with a detailed ocean literacy framework in which each of the dimensions are explained. Further studies should also test and validate the use of the theoretical dimensions in diverse communities and stakeholders, using as an example the work presented in this dissertation. In addition, the current results obtained from exploratory analyses can be used as a baseline for confirmatory analyses in the future.

Finally, it is essential to acknowledge that the working definition of ocean literacy does not explicitly address the role of emotions and interpersonal dynamics in the way humans connect to the ocean. Emotional connections to the ocean have been recently proposed as an additional dimension of ocean literacy (McKinley et al., 2023). Studies on emotions like empathy have shown that empathy can increase by engaging people with future scenarios using either virtual reality or written format (Blythe et al., 2021). These emotions, like ocean empathy, and the consequent behavioural response of one individual may influence others to adopt the same behaviours (van Kleef, 2016). Incorporating these dimensions could enrich the definition, thus providing a more holistic representation of ocean literacy while fostering a deeper and more accurate comprehension among researchers and practitioners alike.

5.4 Limitations and Future Directions

The ocean has been claimed as the new economic frontier for industrial activities (Jouffray et al., 2020) but this blue acceleration is threatened by human-induced activities causing loss of biodiversity, ocean acidification,

overfishing, habitat depletion, among others (Halpern et al., 2015). Safeguarding ocean sustainability lies partly in the hands of individuals (McKinley & Fletcher, 2010), and is (or at least should be) of particular interest to those individuals whose livelihoods depends on the ocean, such as maritime workers. This PhD thesis aims to contribute to the global efforts to build a more informed and responsible maritime workforce, by providing scientific basis and validated tools to assess ocean literacy using transdisciplinary approaches. In the following subsections, I will discuss about the methodological limitations of my study and the future directions and perspectives for research on ocean literacy.

5.4.1 Discussion of Limitations of the Study

While this PhD thesis has broadened our understanding on the status and dimensions of ocean literacy with a focus on the blue economy, we do acknowledge certain methodological limitations of our work. First, the findings on the bibliometric study of ocean literacy research, presented in chapter 2, were gathered from two scientific databases, namely, Web of Science and Scopus. These databases contain collections of peer-reviewed literature such as scientific articles, review papers and conference proceedings. However, the information from these databases may not entirely reflect the landscape of publications on ocean literacy. The utilization of Web of Science and Scopus databases may result in partiality towards publications in natural sciences and engineering, potentially neglecting literature in the social sciences, arts and humanities (Mongeon and Paul-Hus, 2016). Likewise, there is an overemphasis on publications written in English, to the detriment of other languages (Vera-Baceta et al., 2019). Even though our results may present some bias, it provides a comprehensive and structured overview that serves as a powerful tool for research, especially for an emergent field such as ocean literacy.

A second limitation is the utilization of convenience sampling in an online population in Chapter 3 and Chapter 4. During the pandemic, traditional sampling methods like random sampling proved impractical due to social distancing measures and remote work arrangements, making it unfeasible to reach a representative sample (Wardropper et al., 2021). Nevertheless, we tried to get as near as possible to random sampling, but we acknowledge that this method can sometimes introduce bias, as certain parts of the maritime population were not reached by the survey. Therefore, caution is due when extrapolating our findings to the entire maritime population. Still, this approach has proven valuable in survey deployment (Giakoumi et al., 2021; McKinley et al., 2022) and emerged as the most practical and suitable means of collecting data. It allowed participants to conveniently complete the survey from their personal computers or mobile devices, overcoming the challenges posed by unprecedent circumstances like the pandemic.

5.4.2 Suggestions for Future Research to Address these Limitations

Beyond the methodological limitations mentioned in the previous subsection, lie new perspectives for future work to address these limitations. In the second chapter, this PhD thesis demonstrates that ocean literacy is an emerging field with a fast-growing trend, however, still faces limitations for its dissemination in the blue economy sphere. Therefore, we emphasize the need of marine scientists actively engaging in the blue economy process by studying the mechanisms through which ocean literacy initiatives effectively increase the levels of knowledge, positive attitudes and behaviours towards the ocean in the maritime workforce.

Performing scientific research on concepts that are used in policy discourse can sometimes be criticised. Critics may argue that those concepts lack clarity and/or solid theoretical framework. However, in the case of ocean literacy, this can be rather considered a circumstance of an evolving concept,

as it is relatively young and has experienced rapid changes in the last five years. Ten theoretical dimensions have been proposed in the literature and we were able to disentangle five dimensions relevant to the blue economy. So there remains a need to consider how each of the ocean literacy dimensions might impact each other. It is expected that further studies will shed some light on the mechanisms and processes associated to the definition of ocean literacy and/or each of its conceptual dimensions. In addition, considering that ocean literacy has gained attention at the high-level policy agendas, it becomes imperative that efforts should be done for supporting these policies with scientific data (evidence-based policy making).

With regards to the five identified dimensions relevant to the blue economy, the low moderate correlations between them may suggest that the components of ocean literacy could be different for certain people and that might be analysed separately, thus, its utility as components of one concept is arguable. The reported disjunction among the underlying factors of ocean literacy underscores the necessity of a strong theoretical framework for further research.

The dynamic nature of the blue economy highlights the necessity for critical, constructive, and transdisciplinary scientific analyses. To gain a comprehensive understanding of the blue economy, it is crucial to expand the focus of research beyond fisheries and marine protected areas. Like in any other ecosystem, it is essential to consider the connections that exist among various sectors, including but not limited to offshore windfarm and oilrig employees, seafarers, tourism and aquaculture operators, and shipbuilders in different seas and ocean basins. By including the connections between these diverse actors and the ocean, we can obtain a more holistic understanding for a better ocean governance.

In line with our findings, we suggest that further research should aim at extending the coverage and conducting the Blue Survey in other areas

including the Global South countries and industrial settings (e.g. coastal tourism and fisheries). Deploying a validated survey in diverse settings and increasing the sampling size may help to ensure the reliability, validity, and generalizability of the data (Kagawa-Singer, 2000). This would be crucial for obtaining information on the ocean literacy levels of other populations of maritime workers across several sectors beyond Europe. Moreover, we may also benefit from longitudinal studies that investigate any changes in ocean literacy levels that might occur over time. Such longitudinal studies will be suitable for incorporating within Corporate Social/Environmental Responsibility programmes.

5.5 Contribution to Knowledge in the Field of Ocean Literacy

Ocean literacy plays a pivotal role in addressing the challenges of achieving a sustainable economy in the maritime sector (European Commission, 2021). While ocean literacy is still in the early stages of its development as a research field, it is rapidly gaining acceptance within the scientific community and finding its way into policy instruments and management strategies (Costa and Caldeira, 2018; Paredes-Coral et al., 2021; Salazar-Sepúlveda et al., 2023). By examining the findings presented in the previous chapters, we explore the theoretical and practical contributions of this PhD thesis to the field of ocean literacy.

Firstly, this study provided a state-of-the-art overview of the global research on ocean literacy (2005-2022) highlighting the research linked to the blue economy. These results can be used by national agencies to follow the progress of a country in terms of ocean literacy research and collaborations as well as by funding institutions to assign dedicated project calls on ocean literacy initiatives (Waltman and Noyons, 2018). Moreover, as the findings

provide a list of the journals publishing ocean literacy-related topics, it can guide scientists for choosing a scientific outlet to publish their research.

This study also provides novel insights into the dimensions of ocean literacy by identifying, for the first time, the most relevant dimensions of ocean literacy in the blue economy. These dimensions are tailored for maritime workers and include knowledge, attitudes towards ocean sustainability, ocean-friendly behaviour, attitudes towards the use of the ocean and personal interest. These findings underscore the need for a holistic approach of ocean literacy that encompasses not only knowledge acquisition but also attitudinal, interests and behavioural change (McKinley et al., 2023). Moreover, we found groups of maritime workers with low levels of specific competences required for performing sustainable practices. This highlighted the importance of fostering a sense of responsibility, ethics, and stewardship towards the ocean among industry workers, and the need for capacity-development programs tailored to the maritime sector (Carpenter et al., 2021a; Doumbia-Henry, 2016; McKinley and Fletcher, 2010).

Furthermore, we produced two validated international surveys to measure the various dimensions of ocean literacy among professionally active adults (Blue Survey) and its version tailored for those working for the maritime industry (Blue Survey 2.0). To the extent of our knowledge, this is the first survey targeting the maritime workforce to measure ocean literacy levels. The Blue Survey is a legacy of this PhD thesis and emphasizes the importance of crosscutting research and interdisciplinary collaboration between marine sciences, social sciences, educators and practitioners (Santoro et al., 2017; UNESCO-IOC, 2021a). As it was translated in 11 languages, the survey is freely available for researchers that want to deploy it in their regions.

Overall, this PhD thesis set a course for further studies and initiatives aimed at advancing the field of ocean literacy and promoting a sustainable future for the maritime sector.

5.5.1 Explanation of the Originality and Novelty of the Research

This study paves the way for the inclusion of ocean literacy research in the context of the blue economy, expanding the radius of activity beyond pupils at school to other society actors. To understand the originality of this research, it is essential to acknowledge the evolving nature of ocean literacy (McKinley et al., 2023). While ocean literacy has traditionally focused on educational and public awareness initiatives (Fauville et al., 2019; Fletcher et al., 2009; Greely, 2008; Mogias et al., 2019, 2015; Potts et al., 2016), research examining its dimensions within the maritime sector remained unexplored (Paredes-Coral et al., 2021). The integration of ocean literacy research within the maritime sector for a sustainable blue economy presents a novel perspective.

Research on the dimensions of ocean literacy in the maritime sector benefits from an interdisciplinary approach, merging knowledge from fields such as marine science, social sciences, maritime policy and educational strategies (Brennan et al., 2019; McKinley et al., 2023). This interdisciplinary perspective adds to the uniqueness of the research, fostering a holistic understanding of the ocean literacy dimensions that shape workers to perform sustainable practices in the maritime sector.

Another aspect contributing to the originality of this research is its focus on stakeholder engagement in the maritime industry. Understanding the perspectives of various stakeholders, including maritime professionals, blue collars, technicians, managers and even CEOs, allows for the identification of key factors that influence the effective integration of ocean literacy in their lifestyles (Kelly et al., 2021). This research linked academia and the maritime industry to develop a validated survey for the maritime workforce, that can provide insights into how to effectively integrate ocean literacy in this sector.

Finally, this research holds significant policy and management implications. Our findings can inform the development of targeted educational programs, and capacity-building initiatives aiming to enhance ocean literacy among maritime professionals (Edler and Infante, 2019; Harris et al., 2021; Vincx et al., 2018). This, in turn, can drive the adoption of sustainable practices, contributing to a sustainable blue economy.

5.6 General Conclusion

Overall, this study has expanded our understanding into the topic of ocean literacy in the context of the blue economy, both in theoretical and practical aspects. The findings of this research underscore the urgent need for greater awareness, improved attitudes, and responsible behaviours towards marine ecosystems in the blue economy workforce. Through a comprehensive assessment of the current state of ocean literacy research, our findings evidence the emergence of ocean literacy as a field of research. This emergent field is characterized by transdisciplinary and collaborative research, with marine science and education as core topics. Our study shed light into the scarcity of studies on ocean literacy in the context of the blue economy, supporting the inclusion of analogous studies as one of the priority areas in ocean literacy research. By conducting empirical research on the dimensions of ocean literacy, this study provided a validated multilingual tool to measure the various dimensions of ocean literacy among the maritime population: the Blue Survey 2.0 (**Appendix C**, **Table C.2**).

Our findings suggest that the way maritime workers connect to the ocean is complex, but it can be simplified by considering the integration of five dimensions including knowledge, attitudes towards ocean sustainability, attitudes towards the use of the ocean, behaviour, and personal interest. Our results contributed to benchmark ocean literacy in the blue economy, by identifying clusters of maritime workers with shared characteristics and similar sets of ocean literacy skills. Furthermore, we found that factors related to the industry such as the blue economy sector, region and occupation; as well as sociodemographics like age and gender, influenced the levels of ocean literacy in European maritime workers. These findings underscore the need to integrate ocean literacy content into the trainings of maritime workers, especially for young workers, which seem to be the least engaged. By fostering an ocean literate maritime workforce, opportunities for innovation and responsible marine resources management can be

unlocked, leading to a more resilient and sustainable blue economy. In addition, our results might help companies to understand that for specific segments of maritime workers, simply increasing their knowledge on the ocean is insufficient to achieve ocean-friendly behaviour. Instead, alternative strategies for promoting engagement with ocean sustainability appear to be more suitable. Furthermore, it is imperative to acknowledge the inherent limitations in the generalizability of the research findings presented herein. While this study has examined a specific (online) sample in the maritime population, it is crucial to recognize that there were certain parts of the maritime population that were not reached by the online survey, thus, the applicability of these findings to broader or the entire maritime population remains uncertain.

In conclusion, this study provides novel insights into the dimensions of ocean literacy highlighting the need for a holistic approach that encompasses not only knowledge acquisition but also attitudinal, interests and behavioural change. In the future, it is important for additional studies in this domain to build upon the findings presented here. These studies should aim to develop an ocean literacy baseline in maritime communities over time and to assess the mechanisms through which ocean literacy initiatives effectively lead to increasing levels of knowledge, positive attitudes and behaviours towards the ocean. Lastly, this research calls for collective action, emphasizing the importance of transdisciplinary collaboration, public and industrial engagement to navigate the complex waters of the blue economy while safeguarding the ocean and its resources for generations to come.

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Appendix A

Appendix of Chapter 2

Supplementary material for:

Paredes-Coral, E., Mokos, M., Vanreusel, A., & Deprez, T., 2021. Mapping global research on ocean literacy: Implications for science, policy, and the Blue Economy. Frontiers in Marine Science, 8, 648492. https://doi.org/10.3389/fmars.2021.648492

Table A.1. Keyword categories used in Web of Science

	Strategy	**keywords**	**Number obtained**
1	Topic search for the phrase: “ocean literacy”	TS= ("ocean literacy")	93
2	Topic search for the phrase: “ocean* literate”	TS= (“ocean literate”)	7
3	Topic search for the phrase: “ocean AND literacy”	TS= (ocean AND literacy)	151
4	Topic search for the phrase: “ocean AND literacy”	TS= (“coast* literacy”)	3
5	Combination of strategies from 1 to 4 (OR)	**155**	
6	Exclude publications in 2020	**145**	
7	Limit source type to journal articles, reviews and proceeding papers	**132**	
8	Exclude false positives	**83**	

Table A.2. Keyword categories used in Scopus

	Strategy	**keywords**	**Number obtained**
1	Title+Abstract+Keyword search for the phrase: “ocean literacy”	TITLE-ABS-KEY("ocean literacy")	126
2	Topic search for the phrase: “ocean* literate”	TITLE-ABS-KEY (“ocean literate”)	15

3	Topic search for the phrase: "ocean AND literacy"	TITLE-ABS-KEY (ocean AND literacy)	258
4	Topic search for the phrase: "ocean AND literacy"	TS= ("coast* literacy")	3
5	Combination of strategies from 1 to 4 (OR)	**263**	
6	Exclude publications in 2020	**250**	
7	Limit source type to journal articles, reviews and proceeding papers	(TITLE-ABS-KEY ("ocean literacy")) OR (TITLE-ABS-KEY ("ocean literate")) OR (TITLE-ABS-KEY ("coast* literacy")) OR (TITLE-ABS-KEY (ocean) AND TITLE-ABS-KEY (literacy)) AND (EXCLUDE (PUBYEAR , 2020)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re")) **205**	
8	Exclude false positives	**102**	

Merged Web of Science and Scopus records = 185

Excluding duplicates and false positives = 111

Table A.3. Performance of countries publishing on ocean literacy, from 2005 to 2019.

Country	TP (%)	Author collaboration		Country collaboration	
		SAP (%)	MAP (%)	SCP (%)	MCP (%)
USA	53 (47.7)	12 (22.6)	41 (77.4)	49 (92.5)	4 (7.5)
United Kingdom	10 (9.0)	0	10 (100)	6 (60.0)	4 (40.0)
Canada	7 (6.3)	2 (28.6)	5 (71.4)	6 (85.7)	1 (14.3)
Sweden	6 (5.4)	2 (33.3)	4 (66.7)	2 (33.3)	4 (66.7)
Greece	5 (4.5)	0	5 (100)	3 (60.0)	2 (40.0)
Ireland	5 (4.5)	0	5 (100)	4 (80.0)	1 (20.0)
China	5 (4.5)	2 (40.0)	3 (60.0)	5 (100)	0
Germany	3 (2.7)	1 (33.3)	2 (66.7)	1 (33.3)	2 (66.7)
Italy	3 (2.7)	1 (33.3)	2 (66.7)	1 (33.3)	2 (66.7)
Australia	2 (1.8)	0	2 (100)	0	2 (100)
Portugal	2 (1.8)	0	2 (100)	2 (100)	0
Spain	2 (1.8)	0	2 (100)	0	2 (100)
South Africa	2 (1.8)	0	2 (100)	0	2 (100)
Turkey	1 (0.9)	0	1 (100)	0	1 (100)
Brazil	1 (0.9)	0	1 (100)	1 (100)	0
Netherlands	1 (0.9)	0	1 (100)	0	1 (100)
Chile	1 (0.9)	0	1 (100)	0	1 (100)
France	1 (0.9)	0	1 (100)	0	1 (100)
Indonesia	1 (0.9)	0	1 (100)	1 (100)	0
Total	111	20	91	81	30

Country: Corresponding author's country; TP: Total publications; SAP: Single author publications; MAP: Multiple author publications; SCP: Single country publications; MCP: Multiple country publications. For authors with multiple affiliations, we considered the country of the correspondence address.

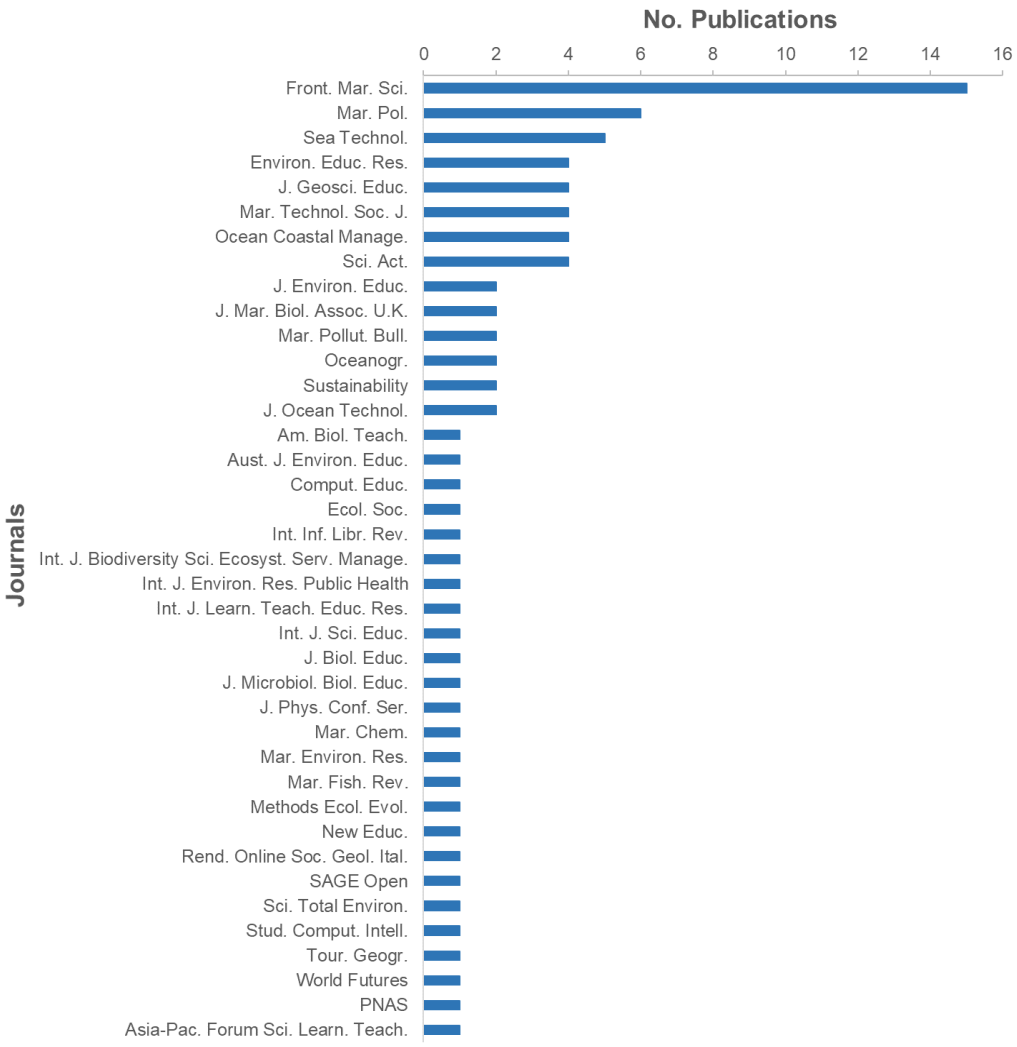


Figure A.1. Journals publishing on ocean literacy, from 2005 to 2019.

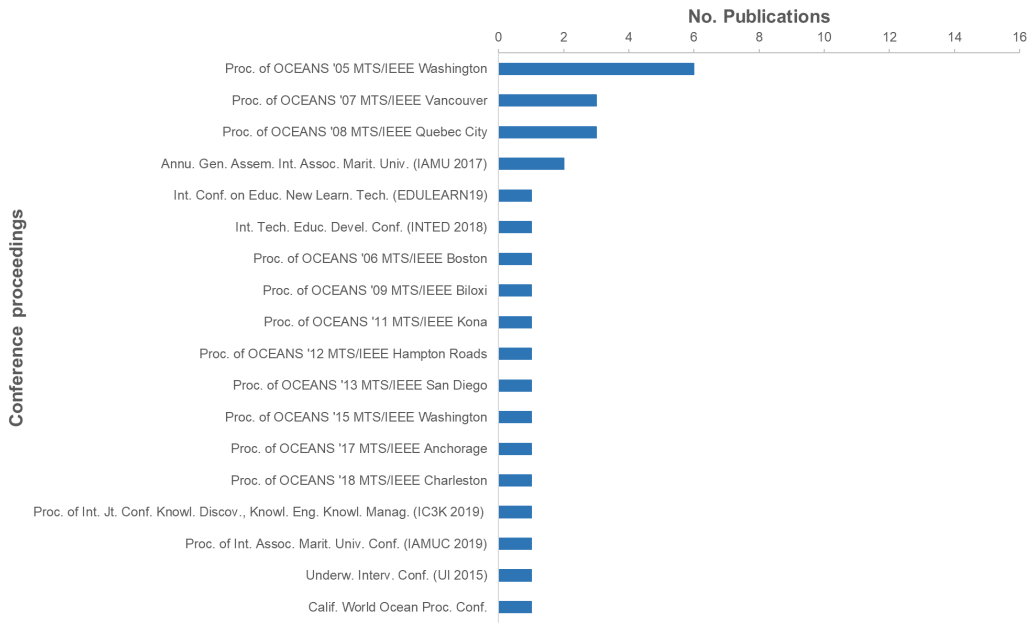


Figure A.2. Conference Proceedings publishing on ocean literacy, from 2005 to 2019.

Appendix B

Appendix of Chapter 3

Supplementary material for:

Paredes-Coral, E., Deprez, T, Mokos, M., Vanreusel, A., & Roose, H., 2022. The Blue Survey: Validation of an instrument to measure ocean literacy among adults. *Mediterranean Marine Science*, 23(2), 321-326 23(2). https://doi.org/ 10.12681/mms.26608

Table B.1. Items from Section I and the specific essential principle that is addressed by each item. The letters next to the essential principles represent the specific fundamental concepts of Ocean Literacy according to Cava *et al.*, (2005) and NOAA (2020).

Items	Essential Principles & Fundamental Concepts	
The ocean affects your life because it	6 a	*
Approximately how much of the earth is covered by ocean?	1 a	
The ocean dynamics (the motion of water within the ocean) is powered by	1 c	*
The ocean is large and finite. Its resources are	1 h	
What is causing sea level rise?	1 d	*
The ocean helps to _____ global warming by absorbing human-produced CO2 from the atmosphere	2 d /3 e,f	*
Which of the following are transported by rivers to the ocean?	1 g	*
Beaches and coastlines are particularly vulnerable to pollution caused by	6 d	
What produces most of the earth's oxygen?	4 a/3 e	*
There are several economic activities collectively taking place in the ocean (e.g., fisheries, shipping, offshore energy, etc). Effective management of the maritime space across borders and sectors should lead to	6 g	
Look at the image. If both cities are at the same elevation, it is likely that:	3 b	*
In the ocean, living spaces and habitats are found	5 e	*
Which of the following options provide habitat for one-third of all marine species?	5 e	
The ocean is the last and largest unexplored place on earth. How much of the ocean remains unexplored?	7 a	
How is the climate change impacting the Arctic?	6 e	*
Oil spills affect the marine environment by	6 d	
Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are	6 d	*
Marine renewable energy industries (e.g., offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as	6 d	*
What are the most frequent effects derived from the concentration of industrial activities near the seashore?	6 d	
Most of the marine invasive species are introduced and dispersed to new habitats by	6 d	

*Items retained after validation.

Table B.2. List of validated questions from The Blue Survey. Items with (*) represent the correct answers.

Knowledge about ocean-related topics

The ocean affects your life because it
☐ provides food and medicine*
☐ provides mineral and energy resources*
☐ regulates the temperature*
☐ provides recreation and jobs*

The ocean dynamics (the motion of water within the ocean) is powered by
☐ tides*
☐ winds*
☐ earth's rotation*
☐ tsunamis

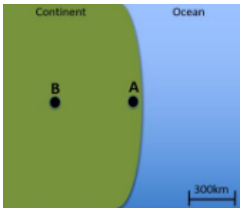
What is causing sea level rise?
☐ warming of the ocean*
☐ ocean acidification
☐ increasing melting of glaciers and ice sheets*
☐ heavy rainfall in the tropics

The ocean helps to _____ global warming by absorbing human-produced CO2 from the atmosphere
○ accelerate
○ stop
○ slow*
○ none of these

Which of the following are transported by rivers to the ocean?
☐ nutrients*
☐ (micro)plastics*
☐ sediments*
☐ pollutants*

What produces most of the earth's oxygen?
○ forests
○ algae in the ocean*
○ both equally
○ none of these

Look at the image. If both cities are at the same elevation, it is likely that:



○ City A will have warmer summers and cooler winters than city B
○ City A will have warmer summers and warmer winters than city B
○ City A will have cooler summers and warmer winters than city B*
○ City A will have similar temperatures as city B in each season
○ none of these

Table B.2. List of validated questions from The Blue Survey. Items with (*) represent the correct answers (*continued*)

Knowledge about ocean-related topics

In the ocean, living spaces and habitats are found
☐ at the surface*
☐ in the water column*
☐ on the seafloor*
☐ none of these

How is the climate change impacting the Arctic?
○ The impact on the Arctic is the same as on the rest on the planet
○ The Arctic is warming faster than the rest of the planet*
○ Ice is melting in some parts of the Arctic and growing in other parts
○ Tropical fish are migrating to the Arctic
○ none of these

Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are
☐ harmless
☐ persistent and accumulative in organisms*
☐ toxic*
☐ none of these

Marine renewable energy industries (e.g. offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as
☐ visual pollution*
☐ collision with seabirds*
☐ underwater noise*
☐ harmful algal blooms

Table B.2. List of validated questions from The Blue Survey. Items with (*) represent the correct answers (*continued*)

Knowledge about ocean-related topics

In the ocean, living spaces and habitats are found
☐ at the surface*
☐ in the water column*
☐ on the seafloor*
☐ none of these

How is the climate change impacting the Arctic?
○ The impact on the Arctic is the same as on the rest on the planet
○ The Arctic is warming faster than the rest of the planet*
○ Ice is melting in some parts of the Arctic and growing in other parts
○ Tropical fish are migrating to the Arctic
○ none of these

Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are
☐ harmless
☐ persistent and accumulative in organisms*
☐ toxic*
☐ none of these

Marine renewable energy industries (e.g. offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as
☐ visual pollution*
☐ collision with seabirds*
☐ underwater noise*
☐ harmful algal blooms

Table B.2. List of validated questions from The Blue Survey (*continued*)

Personal interest in ocean-related aspects					
To what extent do the following aspects of the ocean interest you?	not at all	a little bit	neutral	quite a bit	a lot
I am interested in marine energy	○	○	○	○	○
I am interested in ocean science	○	○	○	○	○
I am interested in maritime jobs	○	○	○	○	○
I am interested in the recreational aspects	○	○	○	○	○
I am interested in the aesthetic aspects	○	○	○	○	○
Ocean-friendly behavior					
Considering a period of one year prior to this survey. How often do you undertake the following actions in your day-to-day life?	never	rarely	sometimes	often	always
I avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms	○	○	○	○	○
I reduce my energy consumption at home	○	○	○	○	○
I take short showers	○	○	○	○	○
I opt for plastic-free alternatives	○	○	○	○	○
Ocean stewardship					
*To what extent do you agree/disagree with the following statements regarding ocean sustainability? *Ocean sustainability focuses on managing our ocean and its services without compromising them for future generations*	strongly disagree	disagree	neutral	agree	strongly agree
I understand the issues facing the global ocean	○	○	○	○	○

The six sub-dimensions obtained by Exploratory Factor Analyses are in bold. Questions with checkboxes ☐ have more than one correct option, participants were asked to check all that applied. The Blue Survey re-used existing items from validated surveys (Cudaback, 2006; Greely, 2008; Chen et al., 2020).

Table B.2. List of validated questions from The Blue Survey (*continued*)

Ocean stewardship					
*To what extent do you agree/disagree with the following statements regarding ocean sustainability? *Ocean sustainability focuses on managing our ocean and its services without compromising them for future generations*	strongly disagree	disagree	neutral	agree	strongly agree
My actions can have a significant effect on the health of oceans and coastal areas	○	○	○	○	○
I have a personal responsibility to work for the health of oceans and coastal areas	○	○	○	○	○
The health of the ocean is important to human survival	○	○	○	○	○
Business and industry should be responsible for ocean sustainability	○	○	○	○	○
Individual citizens should be responsible for ocean sustainability	○	○	○	○	○
Ocean sustainability is more important than economic growth	○	○	○	○	○
Ocean as economic resource					
To what extent do you agree/disagree with the following statements regarding human utilization of the ocean?	strongly disagree	disagree	neutral	agree	strongly agree
It is all right for humans to use the ocean as a resource for economic purposes	○	○	○	○	○
We should no longer use the ocean as a resource for economic purposes	○	○	○	○	○
Maritime economic activities are compatible with ocean sustainability	○	○	○	○	○
Willingness to act					
How often would you be willing to undertake the following responsible actions towards the ocean in your day-to-day life?	never	rarely	sometimes	often	always
I would be willing to avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms	○	○	○	○	○
I would be willing to reduce my energy consumption at home	○	○	○	○	○
I would be willing to take short showers	○	○	○	○	○
I would be willing to opt for plastic-free alternatives	○	○	○	○	○

The six sub-dimensions obtained by Exploratory Factor Analyses are in bold. Questions with checkboxes ☐ have more than one correct option, participants were asked to check all that applied. The Blue Survey re-used existing items from validated surveys (Cudaback, 2006; Greely, 2008; Chen et al., 2020).

Appendix C

Appendix of Chapter 4

Supplementary material for Chapter 4 Part I:

Paredes-Coral, E., Mokos, M., Vanreusel, A., & Roose, H. Navigating towards a sustainable blue economy: Using maritime workforce segmentation to understand how ocean literacy translates into sustainable practices. *Submitted for publication.*

Table C.1. List of countries constituting the European regions

Region	Countries
Western Europe	Germany, Belgium, the Netherlands, France, Austria, Luxemburg, Ireland
Eastern Europe	Croatia, Poland, Romania, Lithuania, Latvia, Bulgaria, Estonia
Southern Europe	Spain, Italy, Greece, Portugal, Cyprus, Malta
Northern Europe	Finland, Denmark, Sweden

Table C.2. List of validated questions from The Blue Survey 2.0. Items with (*) represent the correct answers.

Knowledge about ocean-related topics

The ocean affects your life because it
☐ provides food and medicine*
☐ provides mineral and energy resources*
☐ regulates the temperature*
☐ provides recreation and jobs*

The ocean dynamics (the motion of water within the ocean) is powered by
☐ tides*
☐ winds*
☐ earth's rotation*
☐ tsunamis

What is causing sea level rise?
☐ warming of the ocean*
☐ ocean acidification
☐ increasing melting of glaciers and ice sheets*
☐ heavy rainfall in the tropics

Which of the following are transported by rivers to the ocean?
☐ nutrients*
☐ (micro)plastics*
☐ sediments*
☐ pollutants*

In the ocean, living spaces and habitats are found
☐ at the surface*
☐ in the water column*
☐ on the seafloor*
☐ in the deep sea only

The ocean helps to _____ global warming by absorbing human-produced CO2 from the atmosphere
O accelerate
O stop
O slow*
O none of these

Fossil evidence shows that life most likely first evolved
O on land
O in the ocean*
O under Earth's surface
O in outer space

How is the climate change impacting the Arctic?
O the impact on the Arctic is the same as on the rest on the planet
O the Arctic is warming faster than the rest of the planet*
O ice is melting in some parts of the Arctic and growing in other parts
O tropical fish are migrating to the Arctic
O none of these

Which of the following most influences the depth at which organisms live in the open ocean (away from the shoreline)?
O salinity levels
O crashing waves
O light levels*
O human activity

Approximately how much of the earth is covered by ocean?
O 30%
O 50%
O 60%
O 70%*
O 90%
O 97%

How much of the ocean remains unexplored?
O less than 5%
O 30%
O 50%
O 65%
O greater than 90%*
O none of these

What are the most frequent effects derived from the concentration of industrial activities near the seashore?

☐ water pollution*
☐ erosion*
☐ thermal pollution*
☐ increase of fish populations

Sea level changes have
O reversed the direction that some rivers flow
O changed global temperatures
O changed the shape of the coastline*
O increased fish populations

Most of the antifouling paints that are used to keep ship hulls and floating structures free of marine organisms are
O harmless for the marine environment
O toxic and accumulative in organisms*
O derived from plants
O none of these

The use of satellites, buoys, and remotely-operated vehicles improve our understanding of the ocean because the new technologies
O reduce errors from human measurements of the ocean
O are cheaper than previous tools
O collect much more data than scientists on ships can*
O are in harmony with the marine environment

Most of the marine invasive species are introduced and dispersed to new habitats by
☐ ballast waters*
☐ tsunami
☐ aquarium trade*
☐ vessels hull*

Marine renewable energy industries (e.g., offshore wind, tidal and wave energy) may affect the ocean in a variety of ways, such as
☐ visual pollution*
☐ collision with seabirds*
☐ underwater noise*
☐ harmful algal blooms

Personal interest in ocean-related aspects

To what extent do the following aspects of the ocean interest you?	not at all	a little bit	neutral	quite a bit	a lot
I am interested in ocean science	O	O	O	O	O
I am interested in marine energy	O	O	O	O	O
I am interested in maritime jobs	O	O	O	O	O
I am interested in the recreational aspects	O	O	O	O	O
I am interested in the aesthetic aspects	O	O	O	O	O

Ocean-friendly behaviour

Considering a period of one year prior to this survey. How often do you undertake the following actions in your day-to-day life?	never	rarely	sometimes	often	always
I avoid products with ingredients that are toxic for the marine environment or that are derived from endangered marine organisms	O	O	O	O	O
I reduce my energy consumption at home	O	O	O	O	O
I take short showers	O	O	O	O	O
I opt for plastic-free alternatives	O	O	O	O	O

Attitudes towards ocean sustainability

*To what extent do you agree/disagree with the following statements regarding ocean sustainability? *Ocean sustainability focuses on managing our ocean and its services without compromising them for future generations*	strongly disagree	disagree	neutral	agree	strongly agree
I understand the issues facing the global ocean	O	O	O	O	O
People have been given far too little attention to how human progress has been damaging the ocean	O	O	O	O	O

My actions can have a significant effect on the health of oceans and coastal areas	O	O	O	O	O
I have a personal responsibility to work for the health of oceans and coastal areas	O	O	O	O	O
Humans do not have the right to damage the ocean just to get greater economic growth	O	O	O	O	O
The health of the ocean is important to human survival	O	O	O	O	O
Business and industry should be responsible for ocean sustainability	O	O	O	O	O
Individual citizens should be responsible for ocean sustainability	O	O	O	O	O
Ocean sustainability is more important than economic growth	O	O	O	O	O

Attitudes towards the use of the ocean

To what extent do you agree/disagree with the following statements regarding human utilization of the ocean?	strongly disagree	disagree	neutral	agree	strongly agree
It is all right for humans to use the ocean as a resource for economic purposes	O	O	O	O	O
We should no longer use the ocean as a resource for economic purposes	O	O	O	O	O
Maritime economic activities are compatible with ocean sustainability	O	O	O	O	O

The five dimensions obtained by Exploratory Factor Analyses are in bold. Questions with checkboxes ☐ have more than one correct option, participants were asked to check all that applied. The Blue Survey 2.0 re-used existing items from validated surveys (Cudaback, 2006; Greely, 2008; Chen *et al.*, 2020).

Table C.3. Pearson correlations among the identified five ocean literacy dimensions

Dimension scores	Knowledge	Attitudes towards ocean sustainability	Ocean-friendly behaviour	Attitudes towards the use of the ocean	Personal interests
Knowledge	1				
Attitudes towards ocean	0.2	1			
Ocean-friendly behaviour	0.1	0.4	1		
Attitudes towards the use of the	0.2	0.0	-0.1	1	
Personal interests	0.2	0.3	0.3	0.2	1

Appendix D

Appendix of Chapter 5

Supplementary material for Chapter 5

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
1	MASS TOURISM UNDERWATER A SEGMENTATION APPROACH TO MOTIVATIONS OF SCUBA DIVING HOLIDAY TOURISTS	ALBAYRAK T;CABER M;CATER C	TOUR. GEOGR.	ARTICLE
2	A SOCIAL MOVEMENT IN OCEAN LITERACY WORLD OCEAN DAY	AMARATUNGA C	J. OCEAN TECHNOL.	ARTICLE
3	UNDERWATER PHOTOELICITATION A NEW EXPERIENTIAL MARINE EDUCATION TECHNIQUE	ANDREWS S;STOCKER L;OECHEL W	AUST. J. ENVIRON. EDUC.	REVIEW
4	A CHANGE OF MIND APPLYING SOCIAL AND BEHAVIORAL RESEARCH METHODS TO THE ASSESSMENT OF THE EFFECTIVENESS OF OCEAN LITERACY INITIATIVES	ASHLEY M;PAHL S;GLEGG G;FLETCHER S	FRONT. MAR. SCI.	ARTICLE
5	OCEAN LITERACY TO MAINSTREAM ECOSYSTEM SERVICES CONCEPT IN FORMAL AND INFORMAL EDUCATION THE EXAMPLE OF COASTAL ECOSYSTEMS OF SOUTHERN PORTUGAL	BARRACOSA H;DE L S C;MARTINS C;SANTOS R	FRONT. MAR. SCI.	REVIEW
6	USING DIGITAL GLOBES TO EXPLORE THE DEEP SEA AND ADVANCE PUBLIC LITERACY IN EARTH SYSTEM SCIENCE	BEAULIEU S;EMERY M;BRICKLEY A;SPARGO A;PATTERSON K;JOYCE K;SILVA T;MADIN K	J. GEOSCI. EDUC.	ARTICLE
7	GREEK PRESERVICE TEACHERS KNOWLEDGE ATTITUDES AND ENVIRONMENTAL BEHAVIOR TOWARD MARINE POLLUTION	BOUBONARI T;MARKOS A;KEVREKIDIS T	J. ENVIRON. EDUC.	ARTICLE
8	THE ECOTOXICOLOGY OF PLASTIC MARINE DEBRIS	BRANDER S;FONTANA R;MATA T;GRAVEM S;HETTINGER A;BEAN J;SZOBOSZLAI A;KEIPER C;MARRERO M	AM. BIOL. TEACH.	ARTICLE
9	A SYSTEM DYNAMICS APPROACH TO INCREASING OCEAN LITERACY	BRENNAN C;ASHLEY M;MOLLOY O	FRONT. MAR. SCI.	ARTICLE
10	USING REALWORLD DATA TO INCREASE STUDENTS SCIENTIFIC LITERACY	BREY J;GEER I;MILLS E;NUGNES K	2013 OCEANS - SAN DIEGO	PROCEEDINGS PAPER
11	TEN THOUSAND VOICES ON MARINE CLIMATE CHANGE IN EUROPE DIFFERENT PERCEPTIONS AMONG DEMOGRAPHIC GROUPS AND NATIONALITIES	BUCKLEY P;PINNEGAR J;PAINTING G;CHILVERS J;LORENZONI I;GELCICH S;DUARTE C	FRONT. MAR. SCI.	ARTICLE
12	THE ESTUARY AS A CLASSROOM HARNESSING INTERDEPARTMENTAL SYNERGIES CAMPUS LOCATION AND FACILITIES TO IMPROVE STUDENT ENGAGEMENT IN MARINE TRANSPORTATION AND MARINE SCIENCE	BURBACK T;PARKER A;BROWNE S;SHIMADA E;REIMAN F	ANNU. GEN. ASSEM. INT. ASSOC. MARIT. UNIV. - GLOB. PERSPECT. MET	CONFERENCE PAPER
13	ENHANCING THE NATIONAL GEOGRAPHIC STANDARDS WITH OCEAN CONTENT	CAVA F	CALIF. WORLD OCEAN PROC. CONF.	CONFERENCE PAPER
14	THE MARINE COLAB TAKING A COLABORATIVE VALUES BASED APPROACH TO CONNECT PEOPLE TO THE OCEAN	CHAMBERS R;HART N;RANGER S;BIRNEY C;LORING J;WILLIAMS S;HOOPER L	FRONT. MAR. SCI.	ARTICLE
15	DEVELOPMENT OF OCEAN LITERACY INVENTORY FOR 16 TO 18YEAROLD STUDENTS	CHANG C	SAGE OPEN	ARTICLE
16	RIPPLE EFFECTS SMALLSCALE INVESTIGATIONS INTO THE SUSTAINABILITY OF OCEAN SCIENCE EDUCATION NETWORKS	CHEN R;CRAMER C;DIBONA P;FAUX R;UZZO S	STUD. COMPUT. INTELL.	CONFERENCE PAPER
17	SYSTEMATICS AS A HYPOTHESISBASED SCIENCE AND ITS FUNDAMENTAL ROLE IN UNDERSTANDING OCEANS	COLLINS J;COLLINS A	OCEANS 2005, VOLS 1-3	PROCEEDINGS PAPER
18	BIBLIOMETRIC ANALYSIS OF OCEAN LITERACY AN UNDERRATED TERM IN THE SCIENTIFIC LITERATURE	COSTA S;CALDEIRA R	MAR. POL.	ARTICLE
19	DETANGLING SPAGHETTI TRACKING DEEP OCEAN CURRENTS IN THE GULF OF MEXICO	CURRAN M;BOWER A;FUREY H	SCI. ACT.	ARTICLE
20	MARINE AND COASTAL ECOSYSTEM SERVICES ON THE SCIENCEPOLICYPRACTICE NEXUS CHALLENGES AND OPPORTUNITIES FROM 11 EUROPEAN CASE STUDIES	DRAKOU E;KERMAGORET C;LIQUETE C;RUIZ-FRAU A;BURKHARD K;LILLEB A;VAN O A;BALL-BGANTON J;RODRIGUES J;NIEMINEN E;OINONEN S;ZIEMBA A;GISSI E;DEPELLEGRIN D;VEIDEMANE K;RUSKULE A;DELANGUE J;BHNKE-HENRICHS A;BOON A;WENNING R;MARTINO S;HASLER B;TERMANSEN M;ROCKEL M;HUMMEL H;EL S G;PEEV P	INT. J. BIODIVERSITY SCI. ECOSYST. SERV. MANAGE.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
21	I AM THE OCEAN ARTS AND SCIENCES TO MOVE FROM OCEAN LITERACY TO PASSION FOR THE OCEAN	DUPONT S	J. MAR. BIOL. ASSOC. U.K.	REVIEW
22	BIRD IS THE WORD ON THE IMPORTANCE OF ETHICAL AND EFFECTIVE SCIENTIFIC COMMUNICATION	DUPONT S;PUNCHER G;CALOSI P	J. MAR. BIOL. ASSOC. U.K.	ARTICLE
23	LAYING THE FOUNDATION OF OCEAN POLICY IN 2007	EHLERS C	SEA TECHNOL.	ARTICLE
24	MAKING CURRICULUM DECISIONS IN K8 SCIENCE THE RELATIONSHIP BETWEEN TEACHER DISPOSITIONS AND CURRICULUM CONTENT	EIDIETIS L;JEWKES A	J. GEOSCI. EDUC.	ARTICLE
25	THE GLOBAL INTEGRATED WORLD OCEAN ASSESSMENT LINKING OBSERVATIONS TO SCIENCE AND POLICY ACROSS MULTIPLE SCALES	EVANS K;CHIBA S;BEBIANNO M;GARCIA-SOTO C;OJAVEER H;PARK C;RUWA R;SIMCOOK A;VU C;ZIELINSKI T	FRONT. MAR. SCI.	REVIEW
26	PERSPECTIVES ON CHEMICAL OCEANOGRAPHY IN THE 21ST CENTURY PARTICIPANTS OF THE COME ABOARD MEETING EXAMINE ASPECTS OF THE FIELD IN THE CONTEXT OF 40 YEARS OF DISCO	FASSBENDER A;PALEVSKY H;MARTZ A;GLEDHILL M;FAWCETT J;ALUWIHARE L;PARTICIPANTS C A;PCOMEABOARD ;DISCO X D	MAR. CHEM.	ARTICLE
27	QUESTIONS AS INDICATORS OF OCEAN LITERACY STUDENTS ONLINE ASYNCHRONOUS DISCUSSION WITH A MARINE SCIENTIST	FAUVILLE G	INT. J. SCI. EDUC.	ARTICLE
28	CAN FACEBOOK BE USED TO INCREASE SCIENTIFIC LITERACY A CASE STUDY OF THE MONTEREY BAY AQUARIUM RESEARCH INSTITUTE FACEBOOK PAGE AND OCEAN LITERACY	FAUVILLE G;DUPONT S;VON T S;LUNDIN J	COMPUT. EDUC.	ARTICLE
29	USING COLLECTIVE INTELLIGENCE TO IDENTIFY BARRIERS TO TEACHING 1219 YEAR OLDS ABOUT THE OCEAN IN EUROPE	FAUVILLE G;MCHUGH P;DOMEGAN A;MOLLER L;PAPATHANASSIOU C;LINCOLN S;BATIPTA E;CROUCH F;GOTENSPARRE S	MAR. POL.	ARTICLE
30	DEVELOPMENT OF THE INTERNATIONAL OCEAN LITERACY SURVEY MEASURING KNOWLEDGE ACROSS THE WORLD	FAUVILLE G;STRANG C;CANNADY M;CHEN Y	ENVIRON. EDUC. RES.	ARTICLE
31	OCEAN LITERACY AND KNOWLEDGE TRANSFER SYNERGIES IN SUPPORT OF A SUSTAINABLE BLUE ECONOMY	FERNANDEZ O R;BAYLLISS-BROWN M	FRONT. MAR. SCI.	ARTICLE
32	EXPLORING OUR OCEANS USING THE GLOBAL CLASSROOM TO DEVELOP OCEAN LITERACY	FIELDING S;COPLEY J;MILLS R	FRONT. MAR. SCI.	ARTICLE
33	OCEANS AND HUMAN HEALTH A RISING TIDE OF CHALLENGES AND OPPORTUNITIES FOR EUROPE	FLEMING L;MCDONOUGH N;AUSTEN M;MEE L;MOORE M;HESS P;DEPLEDGE M;WHITE M;PHILIPPART P;SMALLEY A	MAR. ENVIRON. RES.	ARTICLE
34	CMORE SCIENCE KITS AS A CLASSROOM LEARNING TOOL	FOLEY J;BRUNO B;TOLMAN R;KAGAMI R;HSIA M;MAYER B;INAZU J	J. GEOSCI. EDUC.	ARTICLE
35	A NEW ORGANIZATION FOR OCEAN LEADERSHIP	GAGOSIAN R	SEA TECHNOL.	ARTICLE
36	OCEAN LITERACY AN INDEPTH TOP TEN	GARRISON T	OCEANOGR.	ARTICLE
37	PUBLIC AWARENESS CONCERNS AND PRIORITIES ABOUT ANTHROPOGENIC IMPACTS ON MARINE ENVIRONMENTS	GELCICH S;BUCKLEY P;PINNEGAR J;CHILVERS J;LORENZONI I;TERRY G;GUERRERO J;VALDEBENITO A;DUARTE C	PROC. NATL. ACAD. SCI. U. S. A.	ARTICLE
38	WORKFORCE DEVELOPMENT FOR THE BLUE ECONOMY RUTGERS MASTERS IN INTEGRATED OCEAN OBSERVING	GLENN S;SCHOFIELD O;KOHUT J;MCDONNELL J;MILES T;SABA G;ROARTY H;CROWLEY M	OCEANS 2017 - ANCHORAGE	PROCEEDINGS PAPER
39	YOUTH AND THE SEA OCEAN LITERACY IN NOVA SCOTIA CANADA	GUEST H;LOTZE H;WALLACE D	MAR. POL.	ARTICLE
40	CAN CONSUMERS UNDERSTAND SUSTAINABILITY THROUGH SEAFOOD ECOLABELS A US AND UK CASE STUDY	GUTIERREZ A;THORNTON T	SUSTAINABILITY	ARTICLE
41	COMMUNICATING OCEAN SCIENCES TO INFORMAL AUDIENCES A SCIENTISTEDUCATOR PARTNERSHIP TO PREPARE THE NEXT GENERATION OF SCIENTISTS	HALVERSEN C;TRAN L	NEW EDUC.	ARTICLE
42	PUBLIC AWARENESS AND ATTITUDES TOWARDS MARINE PROTECTION IN THE UNITED KINGDOM	HAWKINS J;O'LEARY B;BASSETT N;PETERS H;RAKOWSKI S;REEVE G;ROBERTS C	MAR. POLLUT. BULL.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
43	COASTAL RESIDENTS LITERACY ABOUT SEAWATER DESALINATION AND ITS IMPACTS ON MARINE ECOSYSTEMS IN CALIFORNIA	HECK N;PAYTAN A;POTTS D;HADDAD B	MAR. POL.	ARTICLE
44	PREDICTORS OF COASTAL STAKEHOLDERS KNOWLEDGE ABOUT SEAWATER DESALINATION IMPACTS ON MARINE ECOSYSTEMS	HECK N;PETERSEN K;POTTS B;PAYTAN A	SCI. TOTAL ENVIRON.	ARTICLE
45	THE POWER OF SEEING EXPERIENCES USING VIDEO AS A DEEPSEA ENGAGEMENT AND EDUCATION TOOL	HOEBERECHTS M;OWENS D;RIDDELL D;ROBERTSON A	OCEANS 2015 - MTS/IEEE WASHINGTON	PROCEEDINGS PAPER
46	COSEE COLLABORATIONS TO BRING OCEAN SCIENCE RESEARCH TO THE PUBLIC	HOTALING L;SCOWCROFT G	OCEANS 2009, VOLS 1-3	PROCEEDINGS PAPER
47	INVESTIGATING SOCIETAL ATTITUDES TOWARDS THE MARINE ENVIRONMENT OF IRELAND	HYNES S;NORTON D;CORLESS R	MAR. POL.	ARTICLE
48	ESTUARYLIVE LINKING CLASSROOMS TO THE NATURAL WORLD	IBANEZ A;CORRIDORE A;LOVIN B;COKER E;ALEXANDER G;YOKEL L;SEDLECKY M;LAURSON N;WEIDMAN R;GASKILL T	OCEANS 2005, VOLS 1-3	PROCEEDINGS PAPER
49	UNDERSTANDING AUDIENCES MAKING PUBLIC PERCEPTIONS RESEARCH MATTER TO MARINE CONSERVATION	JEFFERSON R;MCKINLEY E;CAPSTICK S;FLETCHER S;GRIFFIN H;MILANESE M	OCEAN COASTAL MANAGE.	ARTICLE
50	ENHANCING OCEAN SCIENCE LITERACY IN THE US AND ABROAD THROUGH NOAA OCEAN EXPLORATION	KEENER-CHAVIS P	OCEANS 2011	PROCEEDINGS PAPER
51	THE NOAA SHIP OKEANOS EXPLORER CONTINUING TO UNFOLD THE PRESIDENTS PANEL ON OCEAN EXPLORATION RECOMMENDATIONS FOR OCEAN LITERACY	KEENER-CHAVIS P	OCEANS 2008, VOLS 1-4	PROCEEDINGS PAPER
52	THE NOAA SHIP OKEANOS EXPLORER CONTINUING TO UNFOLD THE PRESIDENTS PANEL ON OCEAN EXPLORATION RECOMMENDATION FOR OCEAN LITERACY	KEENER-CHAVIS P;HOTALING L;HAYNES S	MAR. TECHNOL. SOC. J.	ARTICLE
53	THE NOAA SHIP OKEEANOS EXPLORER LIVETO SCIENTISTS AND EDUCATORS ASHORE	KEENER-CHAVIS P;MCDONOUGH J;MARTINEZ F	2007 OCEANS, VOLS 1-5	PROCEEDINGS PAPER
54	SOCIAL LICENSE THROUGH CITIZEN SCIENCE A TOOL FOR MARINE CONSERVATION	KELLY R;FLEMING A;PECL G;RICHTER A;BONN A	ECOL. SOC.	ARTICLE
55	KOREAN ELEMENTARY SCHOOL STUDENTS PERCEPTIONS OF RELATIONSHIP WITH MARINE ORGANISMS	KIM J;ANDERSON D;SCOTT S	ASIA-PAC. FORUM SCI. LEARN. TEACH.	ARTICLE
56	STEPPING OUT OF THE IVORY TOWER FOR OCEAN LITERACY	KOPKE K;BLACK J;DOZIER A	FRONT. MAR. SCI.	ARTICLE
57	THE USS MONITOR A PIONEERING MODEL FOR EDUCATION AND OUTREACH	KROP D;HOLLOWAY A;ALBERG D	2012 OCEANS	PROCEEDINGS PAPER
58	GREATER CLIMATE AWARENESS USHERS IN NEW OCEAN ERA	LAUTENBACHER J C	SEA TECHNOL.	ARTICLE
59	STUDENTS PARTICIPATION IN THE DESIGN PROCESS A STUDY ON USER EXPERIENCE OF AN EDUCATIONAL GAMELIKE APPLICATION	LEITAO R;MAGUIRE M;TURNER S	EDULEARN19: 11TH INTERNATIONAL CONFERENCE ON EDUCATION AND NEW LEARNING TECHNOLOGIES	PROCEEDINGS PAPER
60	OCEAN LITERACY AND INFORMATION SOURCES COMPARISON BETWEEN PUPILS IN PORTUGAL AND THE UK	LEITAO R;MAGUIRE M;TURNER S;GUIMARAES L;ARENAS F	12TH INTERNATIONAL TECHNOLOGY, EDUCATION AND DEVELOPMENT CONFERENCE (INTED)	PROCEEDINGS PAPER
61	PUBLIC PERCEPTIONS OF MARINE THREATS AND PROTECTION FROM AROUND THE WORLD	LOTZE H;GUEST H;O'LEARY J;TUDA A;WALLACE D	OCEAN COASTAL MANAGE.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
62	THE EFFECTS OF STAKEHOLDER EDUCATION AND CAPACITY BUILDING IN MARINE PROTECTED AREAS A CASE STUDY FROM SOUTHERN MOZAMBIQUE	LUCREZI S;ESFEHANI M;FERRETTI C	MAR. POL.	ARTICLE
63	GENERATION NEMO MOTIVATIONS SATISFACTION AND CAREER GOALS OF MARINE BIOLOGY STUDENTS	LUCREZI S;MILANESE M;DANOVARO R;CERRANO C	J. BIOL. EDUC.	ARTICLE
64	MEASURING OCEAN LITERACY IN PRESERVICE TEACHERS PSYCHOMETRIC PROPERTIES OF THE GREEK VERSION OF THE SURVEY OF OCEAN LITERACY AND EXPERIENCE SOLE	MARKOS A;BOUBONARI T;MOGIAS T	ENVIRON. EDUC. RES.	ARTICLE
65	THE CASE FOR COLLABORATION TO FOSTER GLOBAL OCEAN LITERACY	MARRERO M;PAYNE D;BREIDAHL H	FRONT. MAR. SCI.	ARTICLE
66	LIVING CLASSROOMS TEACHING OCEAN EDUCATION THROUGH NOAAS NATIONAL MARINE SANCTUARIES	MARTIN M	OCEANS 2005, VOLS 1-3	PROCEEDINGS PAPER
67	REACHING OUT IN NEW WAYS WORKING WITH ALTERNATIVE SCHOOLS AND UNDERREPRESENTED GROUPS TO IMPROVE OCEAN LITERACY THROUGH THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATIONS OFFICE OF OCEAN EXPLORATION	MARTINEZ C;GORELL F;KEENER-CHAVIS P	OCEANS 2005, VOLS 1-3	PROCEEDINGS PAPER
68	NOAA SHIP OKEANOS EXPLORER TELEPRESENCE IN THE SERVICE OF SCIENCE EDUCATION AND OUTREACH	MARTINEZ C;KEENER-CHAVIS P	OCEANS	CONFERENCE PAPER
69	EXPERT CROWD STUDENTS OR ALGORITHM WHO HOLDS THE KEY TO DEEPSEA IMAGERY BIG DATA PROCESSING	MATABOS M;HOEBERECHTS M;DOYA C;AGUZZI J;NEPHIN J;REIMCHEN T;LEAVER R;ALBU A;FIER U;JUNIPER S	METHODS ECOL. EVOL.	ARTICLE
70	COLLECTIVE INTELLIGENCE FOR ADVANCING OCEAN LITERACY	MCCAULEY V;MCHUGH P;DAVISON K;DOMEGAN C	ENVIRON. EDUC. RES.	ARTICLE
71	MEASURING INDIVIDUALS KNOWLEDGE ATTITUDE AND BEHAVIOUR ON SPECIFIC OCEAN RELATED TOPICS	MCCROSSAN C;MOLLOY O	IC3K - PROC. INT. JT. CONF. KNOWL. DISCOV., KNOWL. ENG. KNOWL. MANAG.	CONFERENCE PAPER
72	EXAMINING THE NOVA SCOTIA SCIENCE CURRICULUM FOR INTERNATIONAL OCEAN LITERACY PRINCIPLE INCLUSION	MCPHERSON K;WRIGHT T;TYEDMERS P	INTL. J. LEARN. TEACH. EDU. RES.	ARTICLE
73	FROM SCIENCE TO POLICY AND SOCIETY ENHANCING THE EFFECTIVENESS OF COMMUNICATION	MEA M;NEWTON A;UYARRA M;ALONSO C;BORJA A	FRONT. MAR. SCI.	ARTICLE
74	MORE THAN ONEWAY TO CATCH A FISH USE OF EFFECTIVE TRANSLATION OF OCEAN SCIENCE TO PROMOTE OCEAN LITERACY	MEESON B;MCDONNELL J;PARSONS C	2007 OCEANS, VOLS 1-5	PROCEEDINGS PAPER
75	REMOTELY OPERATED VEHICLES ROVS A VEHICLE TO ENGAGE STUDENTS IN STEM ACTIVITIES OCEAN LITERACY AND FUN	MILLER-WAY T;MCDONALD R	UNDERW. INTERV. CONF., UI	CONFERENCE PAPER
76	GREEK PRESERVICE TEACHERS KNOWLEDGE OF OCEAN SCIENCES ISSUES AND ATTITUDES TOWARD OCEAN STEWARDSHIP	MOGIAS A;BOUBONARI T;MARKOS T	J. ENVIRON. EDUC.	ARTICLE
77	EVALUATING OCEAN LITERACY OF ELEMENTARY SCHOOL STUDENTS PRELIMINARY RESULTS OF A CROSSCULTURAL STUDY IN THE MEDITERRANEAN REGION	MOGIAS A;BOUBONARI T;REALDON M;MOKOS M;KOULOURI M	FRONT. MAR. SCI.	ARTICLE
78	OCEAN LITERACY OF BLACK GUILLEMOTS AND POLAR BEARS SCIENCE LITERATE CITIZENS VERSUS THE NATURE FAKERS	MOIR R	OCEANS 2008, VOLS 1-4	PROCEEDINGS PAPER
79	A GAME FOR LEARNING OCEAN LITERACY THE RESPONSEABLE PROJECT	PANT E	INT. INF. LIBR. REV.	ARTICLE
80	OCEAN LITERACY FOR WORKFORCE DEVELOPMENT IN THE SHIPBUILDING AND OFFSHORE RENEWABLE ENERGY SECTORS IN EUROPE IN SUPPORT OF THE BLUE ECONOMY	PAPATHANASIOU M;TUDDENHAM P;BISHOP P;FERNANDEZ O R;FRAGA L L	OCEANS 2018 MTS/IEEE CHARLESTON	PROCEEDINGS PAPER
81	WERE GONNA CRUSH IT SEDIMENT CREATION THROUGH DESTRUCTION	PARRISH C;CURRAN M;SAJWAN K	SCI. ACT.	ARTICLE
82	COASTAL RESIDENT KNOWLEDGE OF NEW MARINE RESERVES IN OREGON THE IMPACT OF PROXIMITY AND ATTACHMENT	PERRY E;NEEDHAM M;CRAMER R	OCEAN COASTAL MANAGE.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
83	HUMAN DIMENSIONS OF MARINE FISHERIES USING GIS TO ILLUSTRATE LANDSEA CONNECTIONS IN THE NORTHEAST US HERRING CLUPEA HARENGUS FISHERY	PINTO D S P;FULCHER C	MAR. FISH. REV.	ARTICLE
84	ASSESSING OCEAN LITERACY IN A SAMPLE OF ITALIAN PRIMARY AND MIDDLE SCHOOL STUDENTS	REALDON G;MOGIAS A;FABRIS S;CANDUSSIO G;INVERNIZZI C;PARIS E	REND. ONLINE SOC. GEOL. ITAL.	ARTICLE
85	BUILDING A NEW OCEAN LITERACY APPROACH BASED ON A SIMULATED DIVE IN A SUBMARINE A MULTISENSORY WORKSHOP TO BRING THE DEEP SEA CLOSER TO PEOPLE	SALAZAR J;DOMINGUEZ-CARRIO C;GILI S;GRINYO J;VENDRELL-SIMON B	FRONT. MAR. SCI.	ARTICLE
86	DEVELOPING PHYSICS TEST INSTRUMENT IN THE CONTEXT OF OCEAN LITERACY	SANTOSO P;MUTMAINNA M	J. PHYS. CONF. SER.	CONFERENCE PAPER
87	MOVING FORWARD 21ST CENTURY PATHWAYS TO STRENGTHEN THE OCEAN SCIENCE WORKFORCE THROUGH GRADUATE EDUCATION AND PROFESSIONAL DEVELOPMENT	SCHAFFNER L;HARTLEY T;SANDERS J	OCEANOGRAPHY	ARTICLE
88	MYOSD 2014 EVALUATING OCEANOGRAPHIC MEASUREMENTS CONTRIBUTED BY CITIZEN SCIENTISTS IN SUPPORT OF OCEAN SAMPLING DAY	SCHNETZER J;KOPF A;BIETZ M;BUTTIGIEG P;FERNANDEZ-GUERRA A;RISTOV F;KOTTMANN R	J. MICROBIOL. BIOL. EDUC.	ARTICLE
89	OCEAN LITERACY THROUGH SCIENCE STANDARDS	SCHOEDINGER S;CAVA F;STRANG C;TUDDENHAM P	OCEANS 2005, VOLS 1-3	PROCEEDINGS PAPER
90	ENERGIZING NETWORKS OF FREECHOICE LEARNING ORGANIZATIONS AROUND THE USCOP REPORT AND ONE OCEAN	SCHUBEL J;MONROE C;LAU A	OCEANS 2005, VOLS 1-3	PROCEEDINGS PAPER
91	FROM OCEAN ISSUES TO SOLUTIONS THE ROLE OF PUBLIC OCEAN LITERACY	SCHUBEL J;SCHUBEL K	OCEANS 2008, VOLS 1-4	PROCEEDINGS PAPER
92	EXPLORING INNER SPACE ENGAGING THE PUBLIC WITH OCEAN SCIENTISTS	SCOWCROFT G;COLEMAN D;HAYWARD J;ROMANO C	MAR. TECHNOL. SOC. J.	ARTICLE
93	OCEAN AND COASTAL LITERACY IN THE UNITED STATES	STEEL B	SEA TECHNOL.	ARTICLE
94	PUBLIC OCEAN LITERACY IN THE UNITED STATES	STEEL B;SMITH C;OPSOMMER L;CURIEL S;WARNER-STEEL R	OCEAN COASTAL MANAGE.	ARTICLE
95	UNIVERSITY EXTENSION AND INFORMAL EDUCATION USEFUL TOOLS FOR BOTTOMUP OCEAN AND COASTAL LITERACY OF PRIMARY SCHOOL CHILDREN IN BRAZIL	STEFANELLI-SILVA G;PARDO J;PAIXAO T	FRONT. MAR. SCI.	ARTICLE
96	OCEAN LITERACY MATTERS IN CANADA	STEWART E	J. OCEAN TECHNOL.	ARTICLE
97	FEASIBLE OPTIONS FOR BEHAVIOR CHANGE TOWARD MORE EFFECTIVE OCEAN LITERACY A SYSTEMATIC REVIEW	STOLL-KLEEMANN S	FRONT. MAR. SCI.	REVIEW
98	DESIGN OF THEORY TO TEST WHAT MOTIVATES PEOPLE TO TAKE ACTION TOWARD PROTECTING OUR OCEANS	SZWED P;GONZALEZ B	ANNU. GEN. ASSEM. INT. ASSOC. MARIT. UNIV.	CONFERENCE PAPER
99	IMPACTS OF COMMITMENT AND GOAL SETTING ON PROENVIRONMENTAL BEHAVIORS PEBS TOWARD OCEAN CONSERVATION AN EXPLORATORY STUDY	SZWED P;ROOKS M;GONZALEZ B	COMMEM. ANNU. GEN. ASSEM., AGA - PROC. INT. ASSOC. MARIT. UNIV. CONF., IAMUC	CONFERENCE PAPER
100	CAPTURE ME IF YOU CAN ESTIMATING ABUNDANCE OF DOLPHIN POPULATIONS	THOMPSON J;CURRAN M;COX T	SCI. ACT.	ARTICLE
101	MULTILEVEL EFFECTS OF STUDENT AND SCHOOL FACTORS ON SENIOR HIGH SCHOOL STUDENTS OCEAN LITERACY	TSAI L	SUSTAINABILITY	ARTICLE
102	MEASURING OCEAN LITERACY OF HIGH SCHOOL STUDENTS PSYCHOMETRIC PROPERTIES OF A CHINESE VERSION OF THE OCEAN LITERACY SCALE	TSAI L;CHANG C	ENVIRON. EDUC. RES.	ARTICLE
103	AN ASSESSMENT OF FACTORS RELATED TO OCEAN LITERACY BASED ON GENDERINVARIANCE MEASUREMENT	TSAI L;LIN Y;CHANG C	INT. J. ENVIRON. RES. PUBLIC HEALTH	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
104	FOR THE LOVE OF CYBERNETICS	TUDDENHAM P	WORLD FUTURES	ARTICLE
105	METHOD AND APPLICATION OF OCEAN ENVIRONMENTAL AWARENESS MEASUREMENT LESSONS LEARNT FROM UNIVERSITY STUDENTS OF CHINA	UMUHIRE M;FANG Q	MAR. POLLUT. BULL.	ARTICLE
106	THE PATH TO OCEAN SCIENCES LITERACY ESSENTIAL STEPS ALONG THE WAY	WALKER S;KEENER-CHAVIS P	MAR. TECHNOL. SOC. J.	ARTICLE
107	THE CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE COSEE A NATIONAL SUCCESS STORY	WALKER S;STRANG C;COOK S	MAR. TECHNOL. SOC. J.	ARTICLE
108	COASTAL RESIDENTS STINGRAY STYLE SELECTING THE BEST INTERTIDAL CREEKS FOR SEASONAL LIVING	WEBB S;CURRAN M	SCI. ACT.	ARTICLE
109	THE ROLE OF THE GULF OF MEXICO COASTAL OCEAN OBSERVING SYSTEM GCOOS IN K12 EDUCATION APPLYING THE TECHNOLOGY IN CLASSROOM CURRICULUM	WELLS T;WALKER S;SPRANGER M	2007 OCEANS, VOLS 1-5	PROCEEDINGS PAPER
110	REVIEWFORECAST WORKING TOGETHER FOR THE OCEAN	WHITE J	SEA TECHNOL.	REVIEW
111	ECOSYSTEM PEN PALS USING PLACEBASED MARINE SCIENCE AND CULTURE TO CONNECT STUDENTS	WIENER C;MATSUMOTO K	J. GEOSCI. EDUC.	ARTICLE
112	OCEAN LITERACY OF PRIMARY STUDENTS OF INTERNATIONAL SCHOOLS IN RIYADH SAUDI ARABIA	ABOULAIL F;TAJUDDIN A	J. NUSANT. STUD.-JONUS	ARTICLE
113	WHAT TEACHERS SHOULD KNOW FOR EFFECTIVE MARINE LITTER EDUCATION A SCOPING REVIEW	AHMAD-KAMIL E;ZAKARIA S;OTHMAN M	SUSTAINABILITY	REVIEW
114	TOWARD A DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT THROUGH ACOUSTIC ANIMAL TRACKING	ALOS J;AARESTRUP K;ABECASIS D;AFONSO A;ASPILLAGA E;BARCELO-SERRA M;BOLLAND J;CABANELLAS-REBOREDO R;MCGILL R;OZGUL A;REUBENS D	GLOB. CHANGE BIOL.	REVIEW
115	WALKING ON THE SEA TRACES DEVELOPING A PLATFORM TO BRING OCEAN LITERACY AND CITIZEN SCIENCE AT HOME	ALVISI F;BALDRIGHI E;MERLINO M;PANFILI M;COLELLA S;BRONCO S;CICOGNA F;COIAI S;KING E	MEDITERR. MAR. SCI.	ARTICLE
116	PUBLIC PERCEPTIONS OF DEEPSEA ENVIRONMENT EVIDENCE FROM SCOTLAND AND NORWAY	ANKAMAH-YEBOAH I;XUAN B;HYNES C	FRONT. MAR. SCI.	ARTICLE
117	PRINCIPLES AND CONCEPTS ABOUT SEAGRASSES TOWARDS A SUSTAINABLE FUTURE FOR SEAGRASS ECOSYSTEMS	APOSTOLOUMI C;MALEA P;KEVREKIDIS T	MAR. POLLUT. BULL.	ARTICLE
118	USE OF INVESTIGATIVE PRACTICUM TO IMPROVE OCEAN LITERACY FOR STUDENT	ARIFIN U;ANGGRAENI S;SOLIHAT R	AIP CONF. PROC.	CONFERENCE PAPER
119	PEOPLE DO CARE ABOUT THE DEEP SEA A COMMENT ON JAMIESON ET AL 2020	ARMSTRONG C;AANESEN M;HYNES S;TINCH R	ICES J. MAR. SCI.	ARTICLE
120	TELL A STORY TO SAVE A RIVER ASSESSING THE IMPACT OF USING A CHILDRENS BOOK IN THE CLASSROOM AS A TOOL TO PROMOTE ENVIRONMENTAL AWARENESS	AURELIO L;FRANCA S;SEQUEIRA V;BOAVENTURA D;CORREIA M;PINTO B;AMOROSO M;BRITO C;CHAINHO P;CHAVES L	FRONT. MAR. SCI.	ARTICLE
121	BRIDGING THE GAP BETWEEN FORMAL AND NONFORMAL SCIENCE EDUCATION TRADITIONAL FISH MARKETS AS A TOOL TO PROMOTE OCEAN LITERACY	AURÉLIO L;SEQUEIRA V;FRANÇA S;AMOROSO S;BOAVENTURA D;CARDOSO I;AMORIM A;CABRAL H	APPL. ENVIRON. EDUC. COMMUN.	ARTICLE
122	ADSWIM AND WATERCARE PROJECTS MEET KIDS AND YOUTH THE CHALLENGE OF BRINGING THE WORLD OF RESEARCH TO SCHOOL TO MERGE RESEARCH EDUCATION AND COMMUNICATION	BALDRIGHI E;MUZLOVIC P;ANNIBALDI A;PENNA A;MANINI E;ROSETTI E;RENZONI E;GRILLI F;GIACOMINI G;KRISTOVIC I;DURACIC I;KRZELJ M;ORDULJ M;BUCAN M;PENNA P;SPADA V;BILIC J;MARINI M;SUSMEL S	WATER	ARTICLE
123	TEN LESSONS ON THE RESILIENCE OF THE EU COMMON FISHERIES POLICY TOWARDS CLIMATE CHANGE AND FUEL EFFICIENCY A CALL FOR ADAPTIVE FLEXIBLE AND WELLINFORMED FISHERIES MANAGEMENT	BASTARDIE F;FEARY D;BRUNEL T;KELL L;DOERING R;METZ S;EIGAARD O;BASURKO O;BARTOLINO V;BENTLEY B;BOSSIER S;BROOKS M;CABALLERO A;CITORES L;DASKALOV G;DEPESTELE G;ARANDA M;HAMON K;HIDALGO M;KATSANEVAKIS S;KEMPF A;KUEHN B;NIELSEN J;PUETS M;TAYLOR G;TSAGARAKIS K;URTIZBEREA A;VAN H L;VAN V J	FRONT. MAR. SCI.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
124	BRINGING UNDERUSED LEARNING OBJECTS TOTHELIGHT A MULTIAGENT BASED APPROACH	BEHR A;CASCALHO J;MENDES A;GUERRA H;CAVIQUE L;TRIGO P;COELHO H;VICARI R	LECT. NOTES COMPUT. SCI.	CONFERENCE PAPER
125	BRINGING UNDERUSED LEARNING OBJECTS TO THE LIGHT A MULTIAGENT BASED APPROACH	BEHR A;CASCALHO J;MENDES A;GUERRA L;TRIGO P;COELHO H;VICARI R		PROCEEDINGS PAPER
126	A TOOLKIT FOR REMAR TO ENHANCE CLASSROOM OCEAN LITERACY	BEHR A;FREITAS D;CASCALHO J;MENDES A		PROCEEDINGS PAPER
127	MARINE LITTER A REVIEW OF EDUCATIVE INTERVENTIONS	BETTENCOURT S;COSTA S;CAEIRO S	MAR. POLLUT. BULL.	REVIEW
128	PROMOTING OCEAN LITERACY IN ELEMENTARY SCHOOL STUDENTS THROUGH INVESTIGATION ACTIVITIES AND CITIZEN SCIENCE	BOAVENTURA D;NEVES A;SANTOS J;PEREIRA P;LUIS C;MONTEIRO A;CARTAXANA A;HAWKINS S;CALDEIRA A	FRONT. MAR. SCI.	ARTICLE
129	VIRTUAL SCUBA DIVING ACTIVITIES FOR ELEMENTARY STUDENT TO ENHANCE THEIR OCEAN LITERACY	CAHYADI F;TARIGAN D;SASONGKO A;PRAKOSO K;WIDIYANTO K	J. PHYS. CONF. SER.	CONFERENCE PAPER
130	THE MEDITERRANEAN SEA WE WANT	CAPPELLETTO M;SANTOLERI R;EVANGELISTA L;GALGANI F;GARCES E;GIORGETTI F;HERUT B;HILMI K;KHOLEIF S;SAMMARI C;LIANOS M;D'ALELIO D;FRANCOCCI F;GIORGI G;CANU D;ORGANELLI E;POMARO A;SANNINO G;SEGOU M;SIMONCELLI S;BABEYKO A;BARBANTI A;CHANG-SENG D;CARDIN V;CASOTTI R;DRAGO A;EL A S;EPARKHINA D;FICHAUT M;HEMA G;SANTORO F;SCOULLOS C;TRINCARDI F;TUNESI G;ZINGONE A;BALLERINI T;CHAFFAI A;COPPINI G;GRUBER S;KNEZEVIC J;LEONE G;PENCA J;PINARDI N;PETIHAKIS G;RIO M;SAID M;SIOKOUROS Z;SROUR A;SNOUSSI M;TINTORE V;ZAVATARELLI M	OCEAN COAST. RES.	ARTICLE
131	TRIGGERS IN SCIENCE COMMUNICATION THE NAZARE WAVE A TRIGGER FOR LEARNING	CARAPUCO M;TABORDA R;ANDRADE C	CONT. SHELF RES.	ARTICLE
132	AN ENVIRONMENTAL EDUCATION AND COMMUNICATION PROJECT ON MIGRATORY FISHES AND FISHING COMMUNITIES	CARVALHO S;BRAGA H;DE S S;FONTE B;PEREIRA M;GARCIA-VINUESA A;AZEITEIRO U	EDUC. SCI.	ARTICLE
133	THE CONCEPT OF OCEAN SUSTAINABILITY IN FORMAL EDUCATIONCOMPARATIVE OCEAN LITERACY COVERAGE ANALYSIS OF THE EDUCATIONAL STANDARDS OF INDIA AND THE USA	CHANG C;HIRENKUMAR T;WU C	SUSTAINABILITY	ARTICLE
134	IMPLEMENTATION OF A NEW RESEARCH TOOL FOR EVALUATING MEDITERRANEAN SEA LITERACY MSL OF HIGH SCHOOL STUDENTS A PILOT STUDY	CHEIMONOPOULOU M;KOULOURI P;PREVIATI G;MOKOS M;MOGIAS A	MEDITERR. MAR. SCI.	ARTICLE
135	A ROADMAP FOR USING THE UN DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT IN SUPPORT OF SCIENCE POLICY AND ACTION	CLAUDET J;BOPP L;CHEUNG R;ESCOBAR-BRIONES E;HAUGAN J;MASSON-DELMOTTE V;MATZ-LUECK N;MILOSLAVICH P;MULLINEAUX L;VISBECK R;ZIVIAN A;ANSORGE I;ARAUJO M;ARICO S;BAILLY D;BARBIERE C;BOWLER C;BRUN V;CAZENAVE A;DIVER C;EUZEN A;GAYE A;HILMI N;MENARD F;MOULIN C;PATRICIA M N;PARMENTIER R;PEBAYLE A;POERTNER H;OSVALDINA S;RICARD P;SANTOS M;THIEBAULT S;THIELE T;TROUBLE R;TURRA A;UKU J;GAILL F	ONE EARTH	ARTICLE
136	IMPROVING ENVIRONMENTAL AWARENESS AND OCEAN LITERACY THROUGH HANDSON ACTIVITIES IN THE TROPICS	COSTA D;DE L R;CHRISTOFFERSEN M;PIÑEIRO-CORBEIRA C;DOLBETH M	APPL. ENVIRON. EDUC. COMMUN.	ARTICLE
137	LEARNING ABOUT OCEAN CURRENTS ONE TRACK AT A TIME	CURRAN M;RAMSEY A;BOWER A	SCI. ACT.	ARTICLE
138	CITIZEN SCIENCE DRIVEN BIG DATA COLLECTION REQUIRES IMPROVED AND INCLUSIVE SOCIETAL ENGAGEMENT	DALBY O;SINHA I;UNSWORTH L;JONES B;CULLEN-UNSWORTH L	FRONT. MAR. SCI.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
139	THE DEEP SEA AND ME USING A SCIENCE CENTER EXHIBIT TO PROMOTE LASTING PUBLIC LITERACY AND ELUCIDATE PUBLIC PERCEPTION OF THE DEEP SEA	DARR K;EAST J;SEABROOK S;DUNDAS S;THURBER A	FRONT. MAR. SCI.	ARTICLE
140	OCEAN LITERACY AND SCIENTIFIC DATA ACQUISITION THROUGH CITIZEN SCIENCE CAMPAIGNS A MIXED APPROACH IN THE MALTESE ISLANDS TO COLLECT INFORMATION ON PINNA NOBILIS AND PINNA RUDIS	DEIDUN A;PREVIATI M;MARRONE A;GAUCI A;ZAMMIT A;TARASOVA R;GALEA A;GALDIES J;FRASCHETTI S;DRAGO A	MEDITERR. MAR. SCI.	ARTICLE
141	INSIGHTS AND RECOMMENDATIONS FOR INVOLVING YOUNG PEOPLE IN DECISION MAKING FOR THE MARINE ENVIRONMENT	DEVENPORT E;BROOKER E;BROOKER A;LEAKEY C	MAR. POL.	ARTICLE
142	EXPLORING ECOSYSTEMBASED MANAGEMENT IN THE NORTH ATLANTIC	DICKEY-COLLAS M;LINK J;SNELGROVE P;ROBERTS J;ANDERSON M;KENCHINGTON E;BUNDY A;BRADY M;SHUFORD R;TOWNSEND H;RINDORF A;RUDD M;JOHNSON D;JOHANNESEN E	J. FISH BIOL.	ARTICLE
143	TRANSNATIONAL MUNICIPAL NETWORKS AS A MECHANISM FOR MARINE GOVERNANCE TOWARD CLIMATE CHANGE ADAPTATION AND MITIGATION BETWEEN POTENTIAL AND PRACTICE	DUMALA H;LUSZCZUK M;PIWOWARCZYK T	FRONT. MAR. SCI.	ARTICLE
144	SCIENTISTS FOR OCEAN LITERACY AN OCEAN DECADE PROJECT TO EMPOWER SCIENTISTS AS OCEAN CHAMPIONS	EPARKHINA D	MAR. TECHNOL. SOC. J.	ARTICLE
145	TRANSFERRING COMPLEX SCIENTIFIC KNOWLEDGE TO USEABLE PRODUCTS FOR SOCIETY THE ROLE OF THE GLOBAL INTEGRATED OCEAN ASSESSMENT AND CHALLENGES IN THE EFFECTIVE DELIVERY OF OCEAN KNOWLEDGE	EVANS K;ZIELINSKI T;CHIBA S;GARCIA-SOTO C;OJAVEER H;PARK C;RUWA R;SCHMIDT J;SIMCOCK A;STRATI A;VU C	FRONT. ENVIRON. SCI.	REVIEW
146	PERCEPTION OF CITIZENS REGARDING MARINE LITTER IMPACTS COLLABORATIVE METHODOLOGIES IN ISLAND FISHING COMMUNITIES OF CAPE VERDE	FERREIRA J;MONTEIRO R;VASCONCELOS L;DUARTE C;FERREIRA F;SANTOS E	J. MAR. SCI. ENG.	ARTICLE
147	OCEAN LITERACY TO PROMOTE SUSTAINABLE DEVELOPMENT GOALS AND AGENDA 2030 IN COASTAL COMMUNITIES	FERREIRA J;VASCONCELOS L;MONTEIRO F;DUARTE C;FERREIRA F	EDUC. SCI.	ARTICLE
148	CABLED COMMUNITY OBSERVATORIES FOR COASTAL MONITORING DEVELOPING PRIORITIES AND COMPARING RESULTS	FLAGG R;OWCA T;MARSHALL L;SNAUFFER A;BEDARD J;HOEBERECHTS M		PROCEEDINGS PAPER
149	OREGON RECREATIONAL FISHERS KNOWLEDGE SUPPORT AND PERCEIVED IMPACTS OF MARINE RESERVES	FOX H;SWEARINGEN T;MOLINA C	OCEAN COASTAL MANAGE.	ARTICLE
150	OCEAN LITERACY AND SURFING UNDERSTANDING HOW INTERACTIONS IN COASTAL ECOSYSTEMS INFORM BLUE SPACE USERS AWARENESS OF THE OCEAN	FOX N;MARSHALL J;DANKEL D	INT. J. ENVIRON. RES. PUBLIC HEALTH	ARTICLE
151	READING OVER AND UNDER THE WAVES A STUDY OF OCEAN PICTURE BOOKS FOR CHILDREN	FRANCIS P;VENZO P;BELLGROVE A	AUSTR. J. ENVIRON. EDUC.	ARTICLE
152	TOWARDS A 2025 NATIONAL OCEAN LITERACY STRATEGY CURRENT STATUS AND FUTURE NEEDS IN PRIMARY EDUCATION	FREITAS C;BELLGROVE A;VENZO P;FRANCIS P	FRONT. MAR. SCI.	ARTICLE
153	LIFE BELOW WATER CHALLENGES FOR TOURISM PARTNERSHIPS IN ACHIEVING OCEAN LITERACY	GARCIA O;CATER C	J. SUSTAIN. TOUR.	ARTICLE
154	ENHANCING MARINE CITIZENSHIP AS A STRATEGY TO PROMOTE THE REDUCTION OF SINGLEUSE PLASTICS CONSUMPTION IN DIFFERENT CULTURES	GARCIA-VAZQUEZ E;GARCIA-AEL C;MESA M;DOPICO E;RODRIGUEZ N	FRONT. MAR. SCI.	ARTICLE
155	SANDY SHORE ECOSYSTEM SERVICES ECOLOGICAL INFRASTRUCTURE AND BUNDLES NEW INSIGHTS AND PERSPECTIVES	HARRIS L;DEFEO O	ECOSYST. SERV.	ARTICLE
156	INFORMING THE GENERAL PUBLIC ON THE THREAT STATUS OF THE EUROPEAN SPINY LOBSTER PALINURUS ELEPHAS FABRICIUS 1787 THROUGH CITIZENSCIENCE AND SOCIAL MEDIA PLATFORMS A CASE STUDY FROM THE AEGEAN SEA	KAMPOURIS T;KOUTSOUBAS D;KANELOPOULOU K;ZANNAKI C;BATJAKAS I	MEDITERR. MAR. SCI.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
157	PARTICIPATORY MONITORINGA CITIZEN SCIENCE APPROACH FOR COASTAL ENVIRONMENTS	KASTEN P;JENKINS S;CHRISTOFOLETTI R	FRONT. MAR. SCI.	ARTICLE
158	CONNECTING TO THE OCEANS SUPPORTING OCEAN LITERACY AND PUBLIC ENGAGEMENT	KELLY R;EVANS K;ALEXANDER K;BETTIOL S;CORNEY S;CULLEN-KNOX C;CVITANOVIC K;EMAD G;FULLBROOK L;GARCIA C;ISON S;LING S;MACLEOD A;MURRAY L;MURUNGA M;NASH K;NORRIS K;OELLERMANN M;SCOTT J;WOOD G;PECL G	REV. FISH. BIOL. FISH.	ARTICLE
159	SUSTAINABLE BIOCULTURAL HERITAGE MANAGEMENT AND COMMUNICATION THE CASE OF DIGITAL NARRATIVE FOR UNESCO MARINE WORLD HERITAGE OF OUTSTANDING UNIVERSAL VALUE	KENTERELIDOU C;GALATSOPOULOU F	SUSTAINABILITY	ARTICLE
160	A GAMEBASED EDUCATION APPROACH FOR SUSTAINABLE OCEAN DEVELOPMENT	KOENIGSTEIN S;HENTSCHEL L;HEEL L;DRINKORN C	ICES J. MAR. SCI.	ARTICLE
161	OCEAN LITERACY ACROSS THE MEDITERRANEAN SEA BASIN EVALUATING MIDDLE SCHOOL STUDENTS KNOWLEDGE ATTITUDES AND BEHAVIOUR TOWARDS OCEAN SCIENCES ISSUES	KOULOURI P;MOGIAS A;MOKOS M;REALDON G;BOUBONARI M;FORMOSO A;KIDEYS M;PATTI P;KORFIATIS S;JUAN X	MEDITERR. MAR. SCI.	ARTICLE
162	EVOLVING THE NARRATIVE FOR PROTECTING A RAPIDLY CHANGING OCEAN POSTCOVID19	LAFFOLEY D;BAXTER J;AMON D;CLAUDET J;GRORUD-COLVERT K;LEVIN L;REID P;ROGERS A;TAYLOR M;WOODALL L;ANDERSEN N	AQUAT. CONSERV.-MAR. FRESHW. ECOSYST.	ARTICLE
163	OCEAN LITERACY GAMIFIED A SYSTEMATIC EVALUATION OF THE EFFECT OF GAME ELEMENTS ON STUDENTS LEARNING EXPERIENCE	LEITAO R;MAGUIRE M;TURNER S;ARENAS F;GUIMARAES L	ENVIRON. EDUC. RES.	ARTICLE
164	A SYSTEMATIC EVALUATION OF GAME ELEMENTS EFFECTS ON STUDENTS MOTIVATION	LEITAO R;MAGUIRE M;TURNER S;GUIMARAES L	EDUC. INF. TECHNOL.	ARTICLE
165	IDENTIFYING CONSERVATION PRIORITIES FOR GORGONIAN FORESTS IN ITALIAN COASTAL WATERS WITH MULTIPLE METHODS INCLUDING CITIZEN SCIENCE AND SOCIAL MEDIA CONTENT ANALYSIS	LICONTI A;PITTMAN S;REES N	DIVERS. DISTRIB.	ARTICLE
166	THE BEGINNING OF MARINE SUSTAINABILITY PRELIMINARY RESULTS OF MEASURING STUDENTS MARINE KNOWLEDGE AND OCEAN LITERACY	LIN Y;WU L;TSAI L;CHANG C	SUSTAINABILITY	ARTICLE
167	SUPPORT FOR THE RESEARCH AND MONITORING OF MARINE ALGAE A STUDY OF ITALIAN COASTAL USERS	LUCREZI S	MEDITERR. MAR. SCI.	ARTICLE
168	MARINE AND COASTAL BIODIVERSITY STUDIES 60 YEARS OF RESEARCH FUNDING FROM FAPESP WHAT WE HAVE LEARNED AND FUTURE CHALLENGES	MARQUES A;MIGOTTO A;KITAHARA G;COSTA T;OLIVEIRA M	BIOTA NEOTROP.	REVIEW
169	RECENTERING THE ROLE OF MARINE RESTORATION SCIENCE TO BOLSTER COMMUNITY STEWARDSHIP	MCAFEE D;DREW G;CONNELL S	EARTH SYST. GOV.	ARTICLE
170	ANCHORING OCEAN LITERACY PARTICIPATORY IBOOK DESIGN WITHIN SECONDARY SCIENCE CLASSROOMS	MCHUGH M;MCCAULEY V;DAVISON K;RAINE R;GREHAN A	TECHNOL. PEDAGAG. EDUC.	ARTICLE
171	MARINE SOCIAL SCIENCES LOOKING TOWARDS A SUSTAINABLE FUTURE	MCKINLEY E;ACOTT T;YATES K	ENVIRON. SCI. POLICY	ARTICLE
172	DEVELOPMENT AND EXPANSION IN THE MARINE SOCIAL SCIENCES INSIGHTS FROM THE GLOBAL COMMUNITY	MCKINLEY E;KELLY R;MACKAY M;SHELLOCK R;CVITANOVIC C;VAN P I	ISCIENCE	ARTICLE
173	CHALLENGES AND PROSPECTS TO THE INTEGRATION OF OCEAN EDUCATION INTO HIGH SCHOOL SCIENCE COURSES IN NOVA SCOTIA	MCPHERSON K;WRIGHT T;TYEDMERS P	APPL. ENVIRON. EDUC. COMMUN.	ARTICLE
174	PLASTIC AND US LOOKING AT THE MARINE LITTER PROBLEM FROM INSIDE THE RUBBISH AN UNUSUAL TEMPORARY EXHIBITION AT THE NATURAL HISTORY MUSEUM OF THE UNIVERSITY OF PISA	MERLINO S;LOCRITANI M;FARINA S;SORBINI C;BATTAGLINI S;DELLACASA M;SCAGLIA P;MARCHI D;BONACCORSI E	MEDITERR. MAR. SCI.	ARTICLE
175	ARTISTS IN THE FACE OF THREATS OF CLIMATE CHANGE	MICHALOWSKA M	OCEANOLOGIA	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
176	CONTRIBUTION TO THE SPECIAL ISSUE OCEAN LITERACY ACROSS THE MEDITERRANEAN SEA REGION PERCORSI NEL BLU BLUE PATHS A LONGLASTING PROJECT TO INTEGRATE OCEAN LITERACY AND MARINE CITIZEN SCIENCE INTO SCHOOL CURRICULA	MIONI E	MEDITERR. MAR. SCI.	ARTICLE
177	EXAMINING THE PRESENCE OF OCEAN LITERACY PRINCIPLES IN GREEK PRIMARY SCHOOL TEXTBOOKS	MOGIAS A;BOUBONARI T;KEVREKIDIS T	INT. RES. GEOGR. ENVIRON. EDUC.	ARTICLE
178	TRACING THE OCCURRENCE OF OCEAN SCIENCES ISSUES IN GREEK SECONDARY EDUCATION TEXTBOOKS	MOGIAS A;BOUBONARI T;KEVREKIDIS T	MEDITERR. MAR. SCI.	ARTICLE
179	MEDITERRANEAN SEA LITERACY WHEN OCEAN LITERACY BECOMES REGIONSPECIFIC	MOKOS M;CHEIMONOPOULOU M;KOULOURI M;REALDON G;SANTORO F;MOGIAS A;BOUBONARI T;GAZO M;SATTA A;IOAKEIMIDIS C;TOJEIRO A;CHICOTE M;KEVREKIDIS T	MEDITERR. MAR. SCI.	ARTICLE
180	NAVIGATING OCEAN LITERACY IN EUROPE 10 YEARS OF HISTORY AND FUTURE PERSPECTIVES	MOKOS M;DE-BASTOS E;REALDON D;PAPATHANASIOU M;TUDDENHAM P	MEDITERR. MAR. SCI.	ARTICLE
181	HOW TO INCREASE OCEAN LITERACY FOR FUTURE OCEAN SUSTAINABILITY THE INFLUENCE OF NONFORMAL MARINE SCIENCE EDUCATION	MOKOS M;REALDON G;ZUBAK C I	SUSTAINABILITY	ARTICLE
182	AWARENESS OF OCEAN LITERACY PRINCIPLES AND OCEAN CONSERVATION ENGAGEMENT AMONG AMERICAN ADULTS	O'HALLORAN C;SILVER M	FRONT. MAR. SCI.	ARTICLE
183	ROTEIRO ENTREMARES AN EDUCATIONAL APP FOR OCEAN LITERACY PROMOTION	PACHECO D;FARIA C	J. BIOL. EDUC.	ARTICLE
184	ROTEIRO ENTREMARÉS AN EDUCATIONAL APP FOR OCEAN LITERACY PROMOTION	PACHECO D;FARIA C	J. BIOL. EDUC.	ARTICLE
185	STUDENT MEANINGMAKING OF THE ARTWORK IN A SCIENCE TRADE BOOK AN INTERDISCIPLINARY OPPORTUNITY FOR DEVELOPING VISUAL LITERACY	PANTALEO S	LIT. RES. INSTR.	ARTICLE
186	THE DESIGNING OF OCEAN THREAT COMICS BY ELEMENTARY STUDENTS	PANTALEO S	MULTIMODAL. COMMUN.	ARTICLE
187	TRANSBOUNDARY MARINE GOVERNANCE AND STAKEHOLDER ENGAGEMENT IN COMPLEX ENVIRONMENTS AND LOCAL SEAS EXPERIENCES FROM THE EASTERN MEDITERRANEAN	PAPAGEORGIOU M	EURO-MEDITERR. J. ENVIRON. INTEGRAT.	ARTICLE
188	INCREASED KNOWLEDGE AFFECTS PUBLIC ATTITUDE AND PERCEPTION TOWARDS ELASMOBRANCHS AND SUPPORT FOR CONSERVATION	PAPAGEORGIOU M;BENGIL E;SNAPE L	MEDITERR. MAR. SCI.	ARTICLE
189	THE BLUE SURVEY VALIDATION OF AN INSTRUMENT TO MEASURE OCEAN LITERACY AMONG ADULTS	PAREDES-CORAL E;DEPREZ T;MOKOS M;VANREUSEL A;ROOSE H	MEDITERR. MAR. SCI.	ARTICLE
190	MAPPING GLOBAL RESEARCH ON OCEAN LITERACY IMPLICATIONS FOR SCIENCE POLICY AND THE BLUE ECONOMY	PAREDES-CORAL E;MOKOS M;VANREUSEL A;DEPREZ T	FRONT. MAR. SCI.	ARTICLE
191	FANTASEAS PROJECT INCORPORATING INSPIRING OCEAN SCIENCE IN THE POPULAR MEDIA	PARSONS E;SCARLETT A;KORNBLATT A	MAR. TECHNOL. SOC. J.	ARTICLE
192	THE RISE AND FALL OF THE TIDE OCEAN LITERACY IN THE UNITED STATES	PAYNE D;MARRERO M;SCHOEDINGER C	MEDITERR. MAR. SCI.	ARTICLE
193	OCEAN LITERACY FORMAL EDUCATION AND GOVERNANCE A DIAGNOSIS OF BRAZILIAN SCHOOL CURRICULA AS A STRATEGY TO GUIDE ACTIONS DURING THE OCEAN DECADE AND BEYOND	PAZOTO C;SILVA E;BOTELHO A L;DEL F J;SOUZA A C;DUARTE M	OCEAN COAST. RES.	ARTICLE

Table D.1. List of scientific publications on ocean literacy used to perform the bibliometric analyses, retrieved from Web of Science and Scopus for the period 2005 - 2022 (N = 210) (*continued*)

N	TITLE	AUTHOR (S)	OUTLET	TYPE
194	OCEAN LITERACY IN BRAZILIAN SCHOOL CURRICULA AN OPPORTUNITY TO IMPROVE COASTAL MANAGEMENT AND ADDRESS COASTAL RISKS	PAZOTO C;SILVA E;DUARTE M	OCEAN COASTAL MANAGE.	ARTICLE
195	MAINSTREAMING SUSTAINABLE CONSUMPTION OF SEAFOOD THROUGH ENHANCED MANDATORY FOOD LABELING	PENCA J	FRONT. MAR. SCI.	REVIEW
196	PERCEPTION KNOWLEDGE AND ATTITUDES TOWARDS ENVIRONMENTAL ISSUES AND MANAGEMENT AMONG COASTAL USERS OF THE MOST IMPORTANT BEACH DESTINATION IN ARGENTINA	PON J;BECHERUCCI M;PATERLINI C;ADROGUE A;CASTANO F;GARCIA G	OCEAN COASTAL MANAGE.	ARTICLE
197	THE HUMAN DIMENSION DILEMMA IN MARINE SPATIAL PLANNING	RAMADHAN A;SALIM W;ARGO P	MAR. POL.	ARTICLE
198	INTEGRATED RESEARCH FOR INTEGRATED OCEAN MANAGEMENT	RÖLFER L;LICONTI A;PRINZ N;KLÖCKER C	FRONT. MAR. SCI.	ARTICLE
199	INLAND ADULT AND CHILD INTEREST IN THE OCEAN	SCHUMAN C;STOFER K;ANTHONY L;NEFF H;SONI N;DARROW A;CHANG P	INT. J. SCI. EDUC. PART B-COMMUN. PUBLIC ENGAGEM.	ARTICLE
200	AN OCEAN SCIENCE EDUCATION NETWORK FOR THE DECADE	SCOWCROFT G;BISHOP T;HOTALING L;KEENER P;MCDONNELL J;PEACH C;TUDDENHAM P	MAR. TECHNOL. SOC. J.	ARTICLE
201	UNIVERSITY EXPERIENCES OF MARINE SCIENCE RESEARCH AND OUTREACH BEYOND THE CLASSROOM	SIMS R;TALLAPRAGADA M;PAYTON K;PROSSER K;CHILDRESS M	INTEGR. COMP. BIOL.	ARTICLE
202	PILOTING A REGIONAL SCALE OCEAN LITERACY SURVEY IN FIFE	SPOORS F;LEAKEY C;JAMES M	FRONT. MAR. SCI.	ARTICLE
203	TOWARD ACHIEVEMENT OF THE UN OCEAN DECADE DOES CANAL STUDY IN CENTRAL TOKYO BAY AREA ENHANCE OCEAN LITERACY	TSUYOSHI S	MAR. TECHNOL. SOC. J.	ARTICLE
204	CULTIVATING RELATIONAL VALUES AND SUSTAINING SOCIOECOLOGICAL PRODUCTION LANDSCAPES THROUGH OCEAN LITERACY A STUDY ON SATOUMI	UEHARA T;SAKURAI R;TSUGE T	ENVIRON. DEV. SUSTAIN.	ARTICLE
205	PROMOTING SUSTAINABLE BEHAVIOR USING SERIOUS GAMES SEADVENTURE FOR OCEAN LITERACY	VERONICA R;CALVANO G	IEEE ACCESS	ARTICLE
206	RESIDENTIAL MARINE FIELDCOURSE IMPACTS ON OCEAN LITERACY	WINKS L;WARD M;ZILCH J;WOODLEY E	ENVIRON. EDUC. RES.	ARTICLE
207	MAKING OCEAN LITERACY INCLUSIVE AND ACCESSIBLE	WORM B;ELLIFF C;FONSECA J;GELL F;SERRA-GONÇALVES C;HELDER N;MURRAY K;PECKHAM H;PRELOVEC L;SINK K	ETHICS SCI. ENVIRONM. POLIT.	ARTICLE
208	ABUNDANCE OF ENVIRONMENTAL DATA VS LOW PUBLIC INTEREST IN CLIMATE AND OCEAN ISSUES WHERE IS THE MISSING LINK	ZIELINSKI T;BOLZACCHINI E;EVANS K;FERRERO L;GREGORCZYK K;KIJEWSKI I;MROWIEC P;OLESZCZUK B;PAKSZYS P;PIECHOWSKA E;PIWOWARCZYK J;WICHOROWSKI M	FRONT. MAR. SCI.	ARTICLE
209	A BLUEPRINT FOR OCEAN LITERACY EU4OCEAN	ZIELINSKI T;KOTYNSKA-ZIELINSKA I;GARCIA-SOTO C	SUSTAINABILITY	ARTICLE
210	CULTURAL ECOSYSTEM SERVICES PROVIDED BY CORALLIGENOUS ASSEMBLAGES AND POSIDONIA OCEANICA IN THE ITALIAN SEAS	ZUNINO S;CANU D;MARANGON S	FRONT. MAR. SCI.	ARTICLE