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Ocean Literacy: Understanding the Importance of Sharks in Marine Ecosystems

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by

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“We must respect, protect, and conserve sharks if we want to ensure the health of our oceans.”

-Sylvia Earle

“The sea, once it casts its spell, holds one in its net of wonder forever.”

-Jacques Yves Cousteau

To my daughter Elena, family and friends for your encouragement and support during these past years. Thank you to my Capstone Committee. Your patience and guidance assisted me to complete this project. Special thanks to the Sharks Educational Institute and the Shark Team-FWF you inspired me and helped to shape this capstone project. I have learned so much about shark science and conservation. To our amazing ocean-a truly magical place!

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Abbreviations and Acronyms

CS - Citizen Science

COP - Conference of Parties

EEZ -Exclusive Economic Zone

EU - European Union

FWF- Fly Without Fins

IMO- Integrated Ocean Management

IOC - Intergovernmental Oceanographic Commission

IUCN - International Union for the Conservation of Nature

IUU - Illegal, Unreported, and Unregulated fishing

MPA - Marine Protected Area

NGSS - Next Generation Science Standards

NGO - Non-Governmental Organization

NMEA - National Marine Educators Association

NOAA - National Oceanic and Atmospheric Association

SEI - Sharks Educational Institute

SDGs - Sustainable Development Goals

UN - United Nations

UNCED - United Nations Conference on Environment and Development

UNESCO - United Nations Educational, Scientific and Cultural Organization

CHAPTER ONE

Introduction

Chapter Overview

Our ocean is a large, interconnected body of salt water that covers 71% of our planet and holds 96.5% of its surface water (Shiklomanov, 1993). Indeed, the "blue-hued" photographs of our planet taken from space also magically portray it as our "blue" or "water" planet. Our global ocean is just as vital for our survival as is our land-based environment; its complex underwater ecosystems support a large array of human necessities from the oxygen we breathe to the food we eat as well as global, ocean-based economies. The interconnections of one global ocean also impacts the health of our planet, as its ocean currents regulate our climate zones and weather patterns. In addition, ocean waters mitigate climate change by acting as an important large "carbon sink" absorbing about 31% of carbon dioxide (CO2) emissions released into the atmosphere (NOAA, 2024).

The past decade has seen an increase not only in our human population, but also in plastic and marine pollution, acidification, illegal and overfishing, and extreme climate change events. All these factors have increased the urgency for people to be more aware of our relationship with the ocean and its reciprocal nature. Our ocean does not live in isolation; it is interconnected with the Earth's systems in a complex network of interactions between our atmosphere, biosphere, and on land. Understanding and managing these interactions is vital in order to sustainably mitigate the impacts of human activities on the ocean and our land. Our marine ecosystems and the survival of marine

species, such as sharks, are currently being affected not only by overfishing but also the effects of climate change on the ocean.

In the 2000's, an ocean literacy movement made up of marine scientists, educators, and policymakers emerged in the USA. The goal of this movement was to achieve an ocean-literate society with greater understanding of what could be done to better protect the health of our ocean (Costa & Caldeira, 2018). As the oceanographer Dr. Sylvia Earle, states "everyone should be literate about the ocean, and no child should be left dry"(National Geographic 2023). In other words, understanding human—ocean interactions at an early age in both formal and informal education is vital. It is important to create interest and opportunities for learning so that the appreciation of the ocean's importance and one of its key predators,-the shark- could be developed and highlighted by educators within all subject areas.

This paper and capstone project examines the following question: *How can ocean literacy enable elementary teachers and students to better understand sharks and their role within marine ecosystems?* Understanding the ocean and our interactions with it at an early age is vital in both formal and informal education. A recent Australian National Ocean Literacy Strategy case study showed that Australian elementary teachers value the importance of ocean education. However, it concluded that teachers rarely covered the marine science topic within classrooms due to the lack of available ocean-related educational resources (Freitas et al., 2022). Therefore, the objective of my capstone project is twofold.

- First, to provide: teachers with up-to-date resources to connect with our vast marine world so that they can primarily gain a deeper understanding of the key role that sharks play within marine ecosystems. The knowledge and understanding gained will facilitate their teaching about sharks.
- Second, to demystify: the negative and bloodthirsty image of sharks regularly portrayed in the mass media. Studies have shown that such portrayals negatively influence a child's perception about sharks (Tsoi, 2011).

My project aims to be cross-curricular and to support both formal and informal elementary educators. A user-friendly bilingual (English/Portuguese) and interactive educational weblog or blog titled *Teachers4Sharks* will be made available for educators through the official website of the Sharks Educational Institute (SEI), a non profit and non-governmental marine organization. Here information, ideas and thoughts will be centralized, and shared, including a forum for discussions. This will include a blue e-library with reliable shark- and ocean-related resources, news, and information for teachers of science but also for specialists in other subjects including language arts, social studies, foreign languages, music and art. The objective is to provide support to marine education lesson plans as well as extracurricular activities, thereby assisting teachers and their students to not only connect with ocean literacy but also gain a deeper understanding of the key role that sharks play within our marine ecosystem while demystifying their negative and false representation by the mass media. The long term goal is to offer continual professional development (CPD) opportunities and to create a

national (and later international) network of teachers and schools interested in teaching about ocean literacy and shark conservation.

The first chapter of this paper examines the context of the development of the research question and project while providing the rationale for understanding the important role of sharks in our ocean's ecosystems through the principles and framework of ocean literacy. More specifically, the project is designed to align with the Ocean Literacy Framework and with the United Nations (UN) Sustainable Development Goal (SDG) number 14 "Life Underwater" and its ten action targets to conserve and sustainably use the ocean. My objective is to enable educators, especially those with limited access to the coast, to use this resource as a complementary tool within their classroom curricula.

My Background and Voyage

Growing up in Portugal, my love and passion for the Atlantic Ocean started at an early age. Living in a coastal fishing town gave me the privilege to always be close to the vast, blue Atlantic and enjoy both its views and its resources. My family and I enjoyed outdoor activities such as swimming, sailing, surfing, snorkeling, and various other water-related sports. On warm early summer mornings, I would often comb the beaches and observe tide pools along the shoreline at low tide as well as rolling down the sand dunes. All these experiences helped me to develop a deeper connection with the ocean's ecosystems and to learn to respect it from an early age. My overall interest in science and the outdoors also appeared early on when my passion for the environment flourished both at home and in the garden. In elementary school at age nine, I first became a member of

the Worldwide Fund for Nature (WWF), an international environmental protection group with a keen desire to join the campaign to protect panda bears and other endangered animals both on land and in the ocean.

University and Beyond

My interest in marine and land-based environment issues continued to grow over the years. Due to my parents' engineering and construction business, both my elementary and middle school years continued in Portugal. I studied at two international schools both of which educated me to become a true global citizen. Graduating from high school at the American International School with invaluable parental support enabled me to return to the USA for my university studies. However, my initial plans of pursuing a more specialized science degree were set aside when I realized that the combination of global environment and development courses focusing on policy and natural resources issues was more intricately linked to both my international interests and background. Although a degree in sustainable development was unavailable at the time, I was fortunate enough to pursue an international relations degree, recently-created at the time, focusing on natural resources and development issues.

Shortly after receiving my Bachelor of Arts degree, the UN report “Our Common Future” was published in which the term sustainable development is officially defined as “development that meets the needs of the people without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). This report, also known as the Brundtland Report in honor of former Norwegian Prime Minister, Gro Brundtland, effectively stated that critical global environmental problems were the result of extreme

poverty in the South and the unsustainable patterns of consumption and production in the North.

This concept was exactly what I had concluded during my four years at university: only by respecting our environment and natural resources, both on land and in our ocean, could we develop efficiently and move forward successfully without polluting and causing other grave damages to our planet. The sustainable use of all our resources both on our land and in the ocean would need to be respected on a global level. As this concept has grown over the past three decades it has impacted and greatly influenced both the environmental education and environmental sustainable development fields. Today the term sustainability is now widely used, or even overused, by politicians and businesses with many accused of as "greenwashing." For this reason credible information about sustainability both on and and in the ocean is crucial.

My Professional Life and Experiences

As my journey as an environmental advocate and activist continued, I sought out more practical and professional experiences. Between 1989 and 1990, as the Cold War era was fading away in Europe, both national and international environmental advocacy groups and their campaigns worldwide were beginning to gain more visibility. My first job with a well-known international environmental non-governmental organization (NGO), Friends of the Earth International, allowed me to combine my passion for the environment and learn more about the need for an environmental justice movement according to which all people have the right to a safe and healthy environment. Here I learned about the importance of international networks, and campaigns, as well as the and

the urgent need to inform citizens about important marine environment and sustainability issues.

The Earth Summit

As the non-sustainable use of the world's resources continued to rise, it became clear that to put the concept of sustainability into practice effectively and take action, member states needed to convene on an international level. For this reason, in 1992 the United Nations Conference on Environment and Development (UNCED), commonly known as the "Earth Summit" took place in the coastal city of Rio de Janeiro, Brazil. This was the first time that these groups had met to promote development and economic issues aiming to reduce poverty (UPI, 1992). Youth groups, women's groups, and religious groups also met at the parallel Global Forum in Rio for the same purpose (UPI, 1992). The final Agenda 21 adopted at the conference, resulted in a detailed plan of action for organizations to implement at the local, national, and global levels.

Working on the international team of a European progressive umbrella youth environmental group enabled me to attend the parallel events of this important conference. There I assisted in networking with Brazilian youth groups on global environmental development issues for an international youth conference. Youth groups, at this time, were not officially linked to climate governance nor were they recognized as such (Thew, 2018). Making our voices heard at the time was exciting but also challenging. Meeting and listening to indigenous leaders from the Brazilian Amazonian Kayapo group and environmental activists such as food sovereignty advocate and author Vandana Shiva, and the late Wangari Mathai from the Kenyan Green Belt Movement was

truly inspiring and motivating. Participating in the parallel conference had a significant impact on my vision for the urgent need to protect both our land-based and marine environments. My journey toward a global sustainable environment and development to defend our planet, both on land and in the water, was destined to continue. However, participating in the peaceful protests and sit-ins at the official governmental venue, overlooking the hills dotted with “favelas", made me realize that this would be a long, yet necessary, journey.

Living and Teaching Abroad

Aside from working as a volunteer for environmental and developmental NGOs, instructing elementary students at an international school later became my full-time job. This career choice naturally fell into place as I enjoy working with children and was already a strong supporter of environmental and marine education. I also strongly believe that education is key to learning about the importance of protecting both our terrestrial and marine environment. In the words of Nelson Mandela (1990), “Education is the most powerful weapon which you can use to change the world.” I continue to hold strong beliefs about the importance of children learning and experiencing land- and ocean-based nature. My personal experiences have shown how becoming involved with environmental issues at younger ages allow our connection with nature to grow stronger over the years.

The term *nature-deficit disorder* (Louv, 2013) refers to the mental and physical consequences when humans are not connected to land- and/or water-based nature. Children are at the highest risk of this disorder as they now spend more time growing up with technology than being out in nature (Louv, 2013) and in connection with water such

streams, rivers, lakes and the ocean. In response, environmental studies as an interdisciplinary science, incorporates information and ideas from multiple subjects including education and enables students to be more connected with their surroundings. I also strongly support cross-curricular teaching and see it as an ideal way of combining marine and environmental issues into the elementary curricula of all subjects. Integrating specific issues of marine science, such as shark conservation, into different academic subjects allows us to establish creative ways of developing knowledge, understanding and practical skills through the study of interconnected topics.

The United Nation's Ocean Decade

While my professional life continued in education, my passion for the ocean and interest for environmental issues remained close to my heart both in and out of school. My volunteer work with NGO Sharks Educational Institute (SEI) not only allowed me to learn more about sharks but also the urgent need for their protection alongside the importance of being ocean literate. The recent UN campaign titled: Decade of Ocean Science for Sustainable Development (2021-2030), more commonly known as the Ocean Decade, was my personal stepping stone to continue studying and volunteering on marine issues. Its motto "The Science We Need for the Ocean We Want" highlights the need to manage a sustainable ocean through identifying, generating and applying critical ocean knowledge (2023). I clearly identified with this message and since 2020, through Ocean Decade initiatives, I became more dedicated to marine environmental issues and a regular volunteer at SEI.

In June 2022, as a representative of SEI, I attended the second (UN) Ocean conference, co-hosted by the governments of Kenya and Portugal, held in Lisbon. Alongside promoting global cooperation for the protection of our ocean and its ecosystems, the main theme of the conference was to support the implementation of the SDG 14: “Life Below Water” and its ten target actions to conserve and sustainably use the ocean. This includes scaling up ocean action based on science and innovation. I was able to observe some of the formal governmental meetings, attend informative parallel events to help promote international cooperation and participate in a citizen’s march defending our ocean and marine life including sharks. My time was spent connecting with other national and international marine NGOs, attending workshops and listening to speakers such as “Her Deepness” Sylvia Earle, defender of the ocean and sharks.

During and after the conference I clearly understood that ocean literacy in the educational field is key to achieve a better and deeper understanding of the complex issues surrounding the protection of our marine ecosystems and biodiversity. To communicate about the ocean in a meaningful way I chose to continue campaigning for the conservation of sharks as -our ocean top predator given their importance to the balance of our marine ecosystems. The sharp decline of shark species due to illegal, unreported, and unregulated (IUU), overfishing, finning (fin removal often from live sharks), and climate change has prompted marine and shark conservation groups worldwide to launch specific campaigns to protect them from becoming further endangered or extinct. Since 1970, the oceanic subclass Elasmobranchs, (including sharks and rays) has seen its population decline by 71% due to fishing pressure thereby increasing the global extinction risk of these species (Pacoureau et al., 2021).

Personal Interest and Professional Significance

My environmental NGO work teaching experience, volunteer work with SEI – Portugal, environmental and marine graduate courses as well as inspiring documentaries about sharks such as *Sharkwater Extinction* by Rob Stewart and *Tracking One of the World's Bloodiest Trades: The Shark Fin Hunters* by Aljazeera, have all contributed greatly to my personal interest in shark conservation. Reading research papers and articles about sharks, and listening and meeting marine scientists, have supported my strong belief that both ocean and shark literacy are vital in raising awareness of the importance of all sharks, especially those that are critically endangered, as top predators in the marine ecosystem. This includes providing teachers and students with reliable information and resources as well as appropriate training. With this knowledge teachers can become more ocean literate and feel more confident in teaching their students not only about the ocean but about sharks as its apex predator.

However, living and working overseas brought several limitations in terms of studying for a master's specialized in environmental education. Finding and being accepted to Hamline's education master's on-line course in natural sciences and environmental education (MAEd NSEE) has fortunately enabled me to not only continue my teaching career but also to fulfill my passion for environmental studies and my goal of working in the marine and environmental education field. Using my past educational experiences, I plan to assist elementary teachers, and secondary teachers in a second phase, to become both ocean and shark literate. The objective is for educators to be informed and feel confident in teaching their students about the importance of sharks, as true wonders and "doctors" of the ocean.

Conclusion

My investigation is framed around the question: *How can ocean literacy enable elementary students and teachers to better understand sharks and their role within marine ecosystems?* The research I provide explores how ocean literacy can best support teachers and students to learn more about sharks, their biology, and their significant role as apex predators in providing a sustainable marine ecosystem, as well as the importance of protecting these ancient species. Significantly, misleading media information regarding sharks and their behavior and lack of public teaching materials have made it difficult to campaign for the wellbeing of all shark species worldwide.

In this opening chapter, I explained how growing up overseas in a coastal town greatly influenced my passion for environmental science and marine life issues. My professional work for international environmental NGOs has also furthered my interest not only in the conservation of our land but also the urgent need to protect our ocean and its important, yet vulnerable ecosystems and marine life including sharks. As a teacher, I have always believed in cross-curricular teaching aiming to combine my environmental and marine knowledge and passion, into my class lesson plans, school club activities such as recycling and gardening, and volunteer work with schools through SEI.

Chapter two examines the important relationship between ocean literacy and sharks in greater detail. My literature review focuses on four topics: the ocean's value to Earth's lifesystems; the key role of sharks in our marine ecosystems; ocean literacy, marine education and shark literacy; and pedagogical approaches for effective marine environment education. The argument is clear in that marine education and the ocean

literacy's seven guiding principles play a vital part in informing educators about sharks and their key role in balanced marine ecosystems. Ultimately, in doing so, we will not only be protecting our marine ecosystems, but also learning about our own well-being and the safety of our blue planet.

My capstone project methodology is described in greater detail in chapter three. This includes an explanation of the format of my ocean and shark literacy blog, as well as the context for how formal and informal elementary educators can become informed about sharks, and how they can use this information within their school curricula and extracurricular activities, in a practical manner. chapter four then focuses on my reflections on my capstone project. This includes major learnings throughout the project, as well as its learning implications and limitations.

CHAPTER TWO

Review of Literature

Chapter Overview

This chapter reviews the existing literature focusing on the themes of global ocean sustainability, sharks and marine ecosystems, ocean literacy, and marine science education. First, the ocean's value to Earth's life systems describes the importance of a sustainable ocean ecosystem both for food, and marine resources and its role in regulating our global climate. Second, the shark's vital role in maintaining a balanced ecosystem and the international conservation campaigns to protect sharks is discussed. Third, ocean literacy and educational efforts will also focus on highlighting the human–ocean connection, ocean literacy, its evolution, and revision and reflection. Fourth, various pedagogical approaches and digital technology for an effective marine education and shark conservation program are presented.

Climate change and the excess of carbon dioxide is causing the water in our ocean to heat up causing acidification and deoxygenation both of which negatively affect the ocean's ecosystem negatively. In response, the Ocean Decade (2021-2030) has called for an increase in ocean science within schools, as well as the need for educators and ocean stakeholders to work together towards a sustainable ocean (Ocean Decade, 2022). The year 2022, also known as the "Year of the Ocean," saw a series of international key events and positive breakthroughs representing the start of a new chapter with regards to ocean actions (Roulet, 2022). Nonetheless, it is important to keep up the momentum around the protection of our ocean and support ocean literacy in school curricula. In this

vein, ocean governance seeks to find a more inclusive approach to ocean science and sustainability.

The economic, social, and environmental pillars and benefits of the ocean clearly show its key role in supporting life on Earth. However, despite all its value, profound changes are taking place within the ocean mainly due to human activity. This paper proposes that professional teaching in marine environmental education should focus on highlighting the critical role of sharks as apex predators in aquatic food chains. Such educational efforts include emphasizing their importance in maintaining ecosystem health, addressing the human threats that sharks face, and advocating for their protection to prevent further endangerment or extinction. Threats to sharks include anthropogenic climate change, overfishing, IUU fishing of various shark species, and finning.

Although interest in ocean literacy has increased in the past years, both the concept and terminology need to be looked at more closely and include the human—ocean relationship context (McKinley et al., 2023). In addition, being more inclusive and intricately linked to the ocean such as indigenous people and native science. As such, the purpose of this research is to answer the following question: *How can ocean literacy enable elementary teachers and students to better understand sharks and their role within marine ecosystems?* The term ocean literacy, established two decades ago and aimed at educators, is defined simply as an understanding of the ocean's influence on us and our influence on the ocean (Cava et al., 2005). This concept enables elementary students to understand in greater depth the importance and complexity of the ocean and its marine ecosystems, allowing them to be better informed and more involved in its protection. In turn, ocean-literate students will also become informed about the vital role

of sharks in ocean ecosystem health. With this knowledge, students will also better understand that exaggerated media misrepresentations of the shark as a dangerous, bloodthirsty human-seeking animal are mostly based on fiction versus true facts.

Sharks, a cartilaginous fish and apex predators, play a crucial role in maintaining a healthy and balanced marine environment (Holcomb, 2023). The scientific journal *Nature* reports that since 1970 these top predators have declined by more than 70% due to (often illegal,) fishing pressures (Hopkins & Miller, 2021). As a result, conservation and management is urgently needed to allow low shark populations to recover and connect marine ecosystems to reconnect marine ecosystems to their top predators (Worm et al., 2013). Ocean literacy is an effective tool to raise awareness and change behaviors regarding sharks within classrooms. Moreover, media misinformation and its creation of a negative public image of sharks needs to be reversed to allow for more effective protection. Tsoi et al.'s (2016) study about children's perception on sharks' further states that the current misunderstanding of sharks and their negative public image are hindrances to the several international shark conservation campaigns.

Besides industrial and plastic pollution and IUU fishing, bottom-trawling fishing activities and lost drifting nets (or ghost nets) are a constant threat to marine life worldwide, including sharks. IUU fishing activities destroy marine ecosystems, produce bycatch, deplete fish stocks, and place vulnerable coastal community fishers at a clear disadvantage (Mozumder et al., 2023). The global warming effects and the changes in our climate, due to the increase in temperatures, acidification, and deoxygenation have caused our oceans' capacity to moderate our climate. The connection between our health and our planet's natural systems is the core concept of our planet's health (Talukder et al.,

2023). Appropriate and consistent marine education in elementary schools could play a key role in assisting in the loss of marine biodiversity including sharks.

Next, the Sharks and Marine Ecosystems section focuses on the important role sharks play in maintaining healthy ecosystems and marine life. Delicate interconnected food webs are disrupted by activities such as overfishing and seriously affecting sharks. In 2021 a reassessment of the world's shark and ray population estimated that more than 37.5% of sharks were under threat (Dulvy et al., 2021). Shark species have not only survived for millions of years but 84 years ago roamed the ocean in considerable numbers, as witnessed for the first time by Jacques-Yves Cousteau, in his book *Silent World* (Cousteau et al., (1977). p.187). Today, many shark species are in critical danger and certain species in serious decline which consequently directly threatens our health.

Then, the Ocean Literacy section reviews the evolution of the ocean literacy movement in the US, in the early 2000's, and its attempt to close the ocean science gap in schools across the country. Here, marine scientists and educators together provided a marine curriculum framework for US schools to allow students to gain a better understanding of how the ocean functions. This has since been adapted and supported by the UN under the motto "Make the ocean science we need available for all" (UNESCO, 2020). Connecting people to the ocean is vital if we are to see any change in behavior towards the ocean and its biodiversity. As technology is advancing at a fast rate, digital media and games are also important tools to promote ocean literacy in both formal and informal education.

Lastly, the Marine Science Education section examines science literacy and the role of marine sciences in elementary schools and in aligning ocean literacy to national and state education standards. The importance of including ocean and shark literacy in both formal and informal education is also highlighted. Crucially, ocean literacy has undergone a recent shift from formal education to a more open and flexible paradigm that, besides scientific knowledge, includes multiple forms of knowledge such as local, traditional and indigenous. The literature reviewed is intended as a guide to the capstone project to create a bilingual shark and ocean literacy blog aimed at educators in national and/or international schools located in the Lisbon area (Portugal). The objective is to provide schoolteachers and educators with information and educational resources focusing specifically on sharks' specialized anatomy, the various threats they face as a migratory species, raising awareness around the need for conservation of all 550 shark species worldwide. Despite the negative images that the media often portrays, sharks are shy and generally non-aggressive animals; they should be protected and not feared. In the words of Sylvia Earle, "Sharks are beautiful animals, and if you're lucky enough to see lots of them, that means that you're in a healthy ocean. You should be afraid if you are in the water and don't see sharks" (Earle S., 2021).

The Global Ocean's Value to Earth's Life Systems

Most of the life-supporting environment on our planet is supported by the ocean. It is home to a large biodiversity and regulates and influences our global climate. Our ocean not only provides us with water; it is also responsible for producing about 50% of the oxygen available on Earth. This oxygen is derived from the photosynthesis process by

invisible drifting bacteria and oceanic plants (phytoplankton) thereby sustaining our food systems (Gattuso et al., 2018). Today, over three billion people, mostly living in emergent nations and coastal areas, are directly dependent on marine and coastal resources for their livelihood (United Nations, 2021). We must understand that our ocean is therefore vital not only for our global food security and economy but also our human health. In this way, ocean-literate individuals and communities can play a key role in protecting our ocean and its marine biodiversity including sharks, by understanding the essential principles of the functioning of the ocean, thus ensuring its overall sustainability.

Global marine biodiversity has been under increased pressure due to climate change, water and land pollution, including ocean plastics. IUU fishing, plastic and industrial pollution are other factors affecting ocean marine biodiversity and ecosystems. The unreported removal of fish stocks has affected fisheries data and seriously impacted habitats and ecosystems (Temple et al., 2022). As we have decreased marine fauna, such as sharks, ecological changes in the ocean have directly affected marine food webs, thereby changing ocean ecosystems (McCauley et al., 2015). Ultimately, rebuilding marine life requires a global partnership of many different interests including governments, business, and civil society together with an action plan made up of policy frameworks, science and educational plans (Duarte et al., 2021). Finally, the need to protect marine ecosystems and the diversity of life is not only an ocean literacy principle but a responsibility of all nations. Ocean literacy should also play a key role in this global partnership by highlighting the fact that our ocean is a global common. It is shared by all and not owned by one person or nation. Our ocean is a vital resource that requires

collective protection and management due to its global importance. The impact of its use and preservation goes beyond any country's borders.

An Ocean-Centered Governance

Until recently, no comprehensive regime of law and order or rules governed the ocean's uses and its resources. On the contrary the ocean was viewed as free for all and belonging to no one. In the 17th century national rights and jurisdictions were limited to a narrow part of each nation's coastline. However, more recent concerns over increased marine pollution, declining fish stocks and navies competing for international presence, prompted the UN to codify peaceful, cooperative and legally defined uses of the ocean. With the common benefit of humankind in mind, in 1982, the UN Law of the Sea Convention was adopted and came into force in 1994 (2024). It refers to a set of international laws governing maritime rights and responsibilities of nation states. Its main legal framework is known as the United Nations Convention on the Law of the Sea (UNCLOS); The Law of the Sea,for short, is crucial for marine environmental protection, international trade and dispute resolution. However, it faces a series of challenges including illegal fishing, marine pollution enforcement and boundary disputes (United Nations, 2024).

Despite the ocean being a global shared common guided by the UN Law of the Sea, it currently faces serious threats, which could lead to a collapse of biophysical functions affecting our societies worldwide. The current ocean governance system is insufficient to handle all the challenges facing the ocean; a new system of global governance is required to counteract these ongoing pressures and recognize the ocean's

status as global commons. Traditional nation state and market-oriented mechanisms are no longer viable. Instead, more polycentric governance of the ocean-as-commons is proposed as necessary, focusing on a shared vision of ocean stewardship and not only building upon current transitional dynamics but also recognizing the social-ecological ocean system and its complexity (Brodie Rudolph et al., 2020). With the support of such viable ocean governance, humans and ocean (or more specifically here, humans and sharks), could once again form a healthy relationship as found in traditional cultures, such as those in the Pacific Islands. Sustainable ocean governance would align with SDG 14 (Life Below Water) and its ten action targets, as a framework for the conservation and sustainable use of the ocean; it could also address the major risks related to ocean governance issues. One such risk is the impact of overexploitation of marine resources. Challenging the governance of these issues through various processes and its actions is key, allowing us to make progress towards a more sustainable future and ocean (Haas et al., 2021).

To effectively implement the UN Ocean Decade in the proposed time frame (2020-2030), we urgently need to first recognize the interconnection and interdependence of humankind and the ocean. An ocean-centered approach, which looks at the ocean as a living entity with its own environmental needs and interests, could therefore be adopted (see Appendix A), by human and economic activity are placed within the natural capacity of the ocean and we adopt an integrated, holistic, systems, and life cycle approach" (Bender et al., 2022). With the understanding that we are in a living relationship with the ocean, we therefore need to also transform its governance within the UN Ocean Decade.

As a result, the following five interconnected ocean-centered governance principles have been introduced to help guide the transformation process:

- ocean justice,
- ocean data sovereignty,
- ocean rights,
- ocean protection and
- ocean relationality.

The above principles aim to provide a more inclusive approach to ocean science and sustainability. Educating people to view the ocean as a living entity with basic rights and values is vital. Two of the above principles clearly support the key role that ocean literacy must play in protecting our ocean biodiversity. The “ocean protection” principle states that humans have a collective need and duty to protect and conserve the ocean for the benefit of all marine life but as well as future generations, while the “ocean relationality” principle supports a restorative human—ocean relationship (past, present, and future) through adaptive and preventive actions. Clearly, these ocean-centered governance principles would benefit the necessary protection of all marine biodiversity including sharks.

Ecuador’s Special Law of the Galapagos and its guiding principle for governance, are a good example of using both a sustainable and an ocean-centered approach to protect and manage marine ecosystems. In this Special Law, industrial fishing is banned within the Galapagos Marine Reserve, including no harm to any shark species. The objective here was not only to protect all sharks but also to ensure minimal human interference.

Scientific evidence focused on sharks as top predators and their importance for maintaining a healthy marine ecosystem; ecotourism was also successful and supported the local economy (Bender et al., 2022). An ocean-centered governance together with ocean literacy can also be sustainable for both humans and marine life.

In conclusion, a global ocean-centered governance would meet several anthropogenic challenges. Diplomatic relations amongst all nations but also cross-disciplinary sciences will be required (Polejack, 2021) if we are to create an ocean-literate society that understands the ocean's own rights as a living legal entity, the need for ocean justice respecting indigenous, local and coastal communities rights, and knowledge.

Impact of Climate Change on Marine Life

Acting upon anthropogenic climate change is one of the most critical issues we are facing and where we need to take fast, efficient action. Yet emission reductions, thus far, are insufficient in keeping global temperatures below +2º C. On the contrary, they are continuing to rise. These include acting as a thermal buffer by absorbing about 90% of the Earth's excess heat generated by greenhouse gas emissions (Cheng et al., 2022). In addition, ocean currents assist in redistributing heat around the globe, influencing weather patterns and climate. However, twelve years of satellite data show that even these ocean circulation patterns and meteorology are now being affected by temperature changes and ice melting in the Arctic (Vizza, 2022). The ocean therefore, plays a crucial role in combating climate change through several mechanisms. Ocean biodiversity, including sharks, and planetary health are all affected by climate change in three main

ways: the warming of the ocean, ocean acidification, and ocean deoxygenation (Talukder, et al., 2022). All these impacts, along with sea-level rise, affect our global marine ecosystems and ecosystem services (Gattuso, et al., 2018) contribute to the increase in marine defaunation or the loss of animal life in a specific region (Talukder et al., 2022).

Water temperature is a principal factor in regulating the distribution of different marine species and crucial for preserving a balanced marine ecosystem. Recent research indicates that in 2023, for the fifth consecutive year since records began, the ocean absorbed more heat and continued to warm globally, not only at the surface but also across the upper 2,000 meters (You, 2024). This rise of the temperature of the upper ocean is now reaching deep waters, and is already affecting species in numerous ways, including species diversity, driving extinctions, population size, and habitat alterations. Migrating options for certain species are also greatly limited (Talukder et al., 2022). Sharks, as migrating species, are also sensitive to ocean heat waves, showing that as species reach their temperature limits, critical points of environmental degradation are reached.

Areas of our ocean have been where marine environmental damage is already occurring, indicating specific areas where species have reached their temperature limit (Reis, 2020). For example, a group of marine scientists compared areas in the ocean where marine heat waves have increased the most and examined species that were already near their temperature limit or thermal range (range of temperatures tolerated) to grow and reproduce effectively (Reis, 2020). The study indicates critical points of environmental damage. The red areas on the map (see Appendix B), from the Caribbean Gulf to the Western Pacific, show the proportion of species beyond their 90% thermal

range. In other words where environmental temperatures exceed the central 90% range the fish species are already exposed to conditions that are too hot for them to thrive, leading to stress and even mortality if exposure is severe enough.

Ocean acidification, due to excess and absorption of CO_2, causes the water to have a pH level below 7.0 (neutral) and making it more acidic. This impacts species in diverse ways depending on their trophic levels. For example primary consumers such as sea snails have a protective shell made of calcium carbonate, and secondary consumers (e.g., coral reef fish) depend on coral reefs for their food supply. Moreover, other vital calcium carbonate structures, such as coral reefs, are currently seriously affected by acidic waters. The lack of calcium carbonate essential for the formation of their skeletons, causes them to become weaker and slows their growth. Corals also become stressed in acidic waters and become more vulnerable to "coral bleaching" as they expel their primary energy sources (symbiotic algae) leading to starvation and death (Talukder et al., 2022). The shark's resistant and protective skin denticles, or small tooth-like scales, are also shown to be vulnerable to corrosion due to ocean acidification. For example, experimental exposure of a specific group of puffadder shy sharks (*Haploblepharus edwardsii*) concluded that renewal of denticles compromised both hydrodynamic and skin protection (Reis, 2020). Ocean deoxygenation is the reduction of oxygen in the ocean due to human activities. Coastal activities and warming of our ocean also provoke excess algae growth known as "eutrophication" causing oxygen levels to decrease (Talukder, et al., 2022). A recent study shows how the lack of oxygen in our warming ocean has already affected the catshark's (*S.canicula*) growth and survival rates (Musa et al., 2020).

Including climate change in school curricula, and linking their content to ocean literacy, would allow teachers to not only teach about the impacts of climate change but also allow students to fully understand this connection. In turn this would benefit better decision-making and planning related to the protection of ocean biodiversity including sharks. An innovative Declaration on the Common Agenda for Education and Climate Change was recently adopted at the 28th Conference of Parties (COP) in 2023. This declaration is a positive one and focuses on the link between climate change and education. It calls upon all countries to enhance their overall climate change education and include it in all levels of learning. It acknowledges that education plays an important role in giving students the knowledge, skills and values necessary to be informed and engaged in combating climate change. The declaration states the fundamental principles, goals, and actions required for a strong framework for climate change education; the importance of scientific integrity, inclusivity, empowerment and community engagement are also highlighted. However, during this conference it was also noted that marine biodiversity issues must not be forgotten in the national education strategies as both ocean literacy and climate literacy are intrinsically interlinked.

In summary, our ocean belongs to all of us yet its importance for us all cannot be underestimated. Not only does our ocean directly support life on our planet, and influence our weather patterns, but it also provides food and supports various marine activities ranging from shipping to tourism. However, climate change and ocean acidification, (through our excess production of CO2), plus ocean deoxygenation are seriously threatening marine biodiversity.

The Sharks Role in Marine Ecosystems

Humans and oceans are inextricably interconnected meaning that everyone is responsible for caring for the ocean. Ocean defaunation began after Terrestrial defaunation tens of thousands of years ago (McCauley et al., 2015). Although less severe than on land, our effects on marine animals, including sharks, are increasing both in rate and impact. Many of our major marine ecosystems have been affected by human impact and both large and small marine animals have been greatly reduced (McCauley et al., 2015).

Sharks are one of the oldest species on our planet and have existed on our planet for over 450 million years before dinosaurs or even trees. Their survival over these many millennia is proof of their resilience as apex predators of the marine trophic food web (Byrd et al., 2024). Apex predators in our ocean, like sharks, play a vital role in maintaining the balance of marine ecosystems at all depths of our ocean. Controlling weak, sick and dead fish populations maintains the delicate balance of the trophic food web and provides a healthy ocean for all marine biodiversity. Sharks, rays and skates belong to the elasmobranchs, a subclass of fish that have a skeleton made of cartilage, five to seven gills on the sides of the head and pectoral fins. They have the same five senses as humans with a particular strong sense of smell, and two extra senses (aka shark senses): electroreceptors (ampullae of Lorenzini), or small pores covering the head and snout area that can detect any electrical fields such as prey; and the lateral line from snout to tail that can also detect pressure change and thus locate any potential prey.

Informational facts and educational resources about sharks and their important role as apex predators (vs.bloodthirsty killers) is available for educators but not widely publicized in the US. More scientific information and resources for both educators and the general public is necessary and urgent given the sharp decline of some shark species worldwide.

Major Threats to Sharks

In recent years, fewer shark sightings by recreational divers, an increase in shark meat consumption, and the huge undeclared illegal cargo of shark fins impounded by officials in major fishing ports are all alarming signs worldwide that all is not well with the shark populations. International Union for the Conservation of Nature (IUCN) assessments indicate that more than one-third of sharks are threatened with extinction worldwide (Dulvy et al., 2021). In January 2024, a paper published in Science estimated annual shark mortality at 76 to 80 million per year, with approximately one-third (or about 25 million,) of these coming from threatened species (Worm et al., 2024). Similar to humans, sharks exhibit slow growth, late maturity and fecundity making them more vulnerable to overexploitation (Friedrich et al., 2014). These numbers clearly illustrate that sharks are not only being overexploited but can also now be considered one of the most threatened wildlife species on our planet, and thus receiving an increase in scientific and regulatory scrutiny. Misinformation and disinformation about sharks and shark meat consumption are also not supportive of the need for stricter fishing regulations and overall protection.

Our ocean and its biodiversity are currently threatened due to a variety of issues. Marine pollution in coastal areas is increasing as plastic, industrial and agricultural runoff regularly end up in the ocean. For decades IUU fishing has been an ongoing global threat to ocean sustainability in terms of fish stocks, including sharks. The basic human rights of fishing communities are also affected. The (UN) SDG 14 “Life BelowWater” is seriously undermined by these decade long fishing practices and a collaborative effort is needed for an effective international response (Auld et al., 2023). The economic and environmental impacts of IUU fishing and its social impacts are all well-known. Monitoring, control, and surveillance activities are required to successfully address IUU fishing policy, regulation, and management strategies (Temple et al., 2022). However, experience shows that these activities are difficult to implement due to the economic incentives. The illegal and lucrative trade of shark fins in Peru and Ecuador, for example, is thriving and threatening shark species off their coasts. The understanding of IUU fishing and identifying priority information gaps that hinder management efforts of fisheries, such as sharks, is necessary to recognize all the impacts of IUU (Temple et al., 2022).

Overfishing has put three-quarters of sharks at risk of extinction (Stokstad, 2021). Recent studies show that shark and ray populations have fallen by 71% from 1970 to 2020 due to increasing pressure in fishing (Pacoureau et al., 2021). People in many countries prefer shark meat as it is inexpensive and it is also an essential ingredient in traditional recipes. A recent global survey of coral reefs discovered that commercial overfishing is causing the extinction of resident sharks: global declines of 60-73% for five common resident reef shark species were reported through a species-level analysis.

Human communities worldwide will be affected if no action is taken to address these diversity deficits and the functioning of ecosystems (Simpfendorfer et al., 2023).

While sharks may be hunted selectively, in most cases, they are also bycatch of commercial tuna and swordfish fishing which sharks also hunt for food. Finning is an unselective method of fishing and does not consider species, size, and age of shark. This brutal and inhumane practice of cutting the fin often on live sharks, still takes place in the high seas. This is an area defined by international law and is part of the ocean outside a country's Exclusive Economic Zone (EEZ). Fins are in high demand in China, Hong Kong, Taiwan and Thailand and the star ingredient in the traditional shark fin soup. Every year around 73 million sharks die only for their fins (StopFinningEU, 2023). Bottom trawling, or the dragging of very long nets at great depths or along the seafloor, is another common practice worldwide. However, this fishing technique produces enormous amounts of bycatch causing a sharp decline in, for example, the angel shark populations that live near the seafloors (Bargnesi et al., 2020). Deep sea fishing should also be banned, and overall fishing decreased to allow for the recovery of damaged ecosystems of oceans, coral reefs, and lagoons (Porcher et al., 2021). Global coalitions such as Transform Bottom Trawling (TBT) highlight the destruction of the large amounts of marine life caused by this type of fishing through discussions, dialogue between parties, and public education.

Rebuilding our diverse marine life support systems is now urgent. Both the SDGs and the Ocean Literacy Principles and Framework play a significant role in not only conserving and sustainably our ocean (SDG 14) but also protecting the diversity of life and ecosystems (Ocean Literacy, Principle 5). Their conclusions show that it is possible

to achieve these goals by 2050 across the board. However, this means reducing pressure immediately, which includes climate change, safeguarding areas where marine life is plentiful, and recovering depleted habitats: “Rebuilding marine life requires a global partnership of diverse interests, including governments, businesses, resource users, and civil society” (Duarte et al., 2020, p.22). Educating and informing people about the urgent state of sharks in decline is likewise urgent. Accordingly, ocean literacy in elementary schools is fundamental to inform students about the ocean’s influence on us and our influences on the ocean, while also highlighting the important role of sharks in our ocean and the need to reduce their sharp decline worldwide. Building up protective measures and stricter fishing management rules together with viable information about consumption for formal and informal educators are important steps.

In summary, according to the IUCN assessments, major threats to shark survival include bycatch, pollution, habitat loss and degradation combined with slow shark maturity and reproduction rates. To this list we can add; overfishing and IUU, finning bottom trawling, and climate change.

International Shark Conservation Campaigns

The issues around shark conservation are multiple and also complex. Environmental and marine NGOs worldwide focus on shark conservation work to raise public awareness and promote policies for better shark protection. However, despite their engagement in shark conservation, their political influence is limited due to the political and economic interests in fisheries (Friedrich et al., 2014). For example, the Mediterranean Sea is currently a hotspot for shark conservation, yet it has seen a radical

decline in its larger pelagic (open sea) shark population, including some vulnerable and endangered shark species that are still fished commercially (Bargnesi et al., 2020).

After two decades of negotiations, a new UN High Seas Treaty was formally ratified in June 2023. High Seas are defined areas outside each country's designated EEZ. This treaty addresses several governance gaps and provides a legal framework for a set of Marine Protected Areas (MPAs) in large areas of the High Seas, to protect marine life and share genetic resources (McVeigh, 2023). Protection of MPAs has also assisted in the increase of fish in nearby areas, thereby helping fishers financially and preventing overfishing and the marine environment damage (Porcher et al., 2021). Educating fishers to protect damaged coastlines has been successful, and the creation and protection of MPAs have assisted in increasing fish stocks in nearby areas, while also helping the fishers themselves (Porcher et al., 2021).

In pursuit of reversing habitat and species loss, the recently adopted UN adopted biodiversity plan Target three, also known as the 30x30 campaign, calls on all governments for the protection and management of 30% of the world's land, freshwater and ocean by the year 2030. It is the largest conservation commitment to date with 190 countries committed to achieving this goal (Smith, 2020). Only 8% of the ocean is currently covered in this way, and the protection of new and conserved areas as well as managing existing ones is required to achieve the 30% target. Both governmental and nongovernmental organizations plus communities must work together to create lasting protection of the most critical areas, including our ocean and its marine biodiversity such as sharks.

Shark populations worldwide are also threatened by mislabeled shark meat, which contributes to overfishing of the more vulnerable species potentially leading them to extinction. A recent study on the degree, composition, and sources of contamination in the blue shark living in the Northeast Atlantic Ocean concluded that high level of contaminants were found, in most of blue shark and where at least one, including mercury, was found to be unsafe human consumption (Alves et al., 2023). Proximity to coastal urbanized areas in Portugal's EEZ increased the risk of contamination in the muscle of blue sharks. Portugal has one of the highest fish consumptions in the world and consumes blue shark domestically and exports it to other countries such as Spain and Italy (Alves et al.,2023).

Many shark conservation and marine NGOs, including SEI, have recently launched international public campaigns informing citizens on the fact that shark is sold under misleading names all over the world in addition to the health risks, especially children and pregnant women, associated with eating shark meat. For example, the international #*Shark Free* campaign, led by the Rob Stewart Sharkwater Foundation, flags the use of shark products in cosmetics and personal care, pet food, and fertilizers. Consumers are requested to make informed decisions and purchase shark free products, while, companies are asked to commit to keeping all shark ingredients out of their supply chains and products and move to more humane and plant-based squalene alternatives to protect at-risk shark population (2022). Flying without Fins (FWF) is another international campaign targeting airlines, led by two NGOs (Shark Guardians and Shark Project), and supported by many other shark and marine conservation groups. Their aim is to lobby airlines to stop the transport of shark fins onboard both cargo and passenger

aircraft. To date only 15% of the world's airlines have guaranteed to not transport shark fins with the remaining 85% making profits from this horrific business (*FLY WITHOUT FINS | Stop Carriage of Shark Fins by Airlines*, n.d.). All of these campaigns are important to inform educators, students and the general public about the importance of shark conservation and the many levels of intervention and commitment needed.

Public Engagement with Sharks

Current public engagement and support for the conservation of sharks remains largely limited. Sensational mass media and reports of human-shark interactions portray a negative image of the latter to the public. Their physical appearance, such as their large teeth, may also influence people's negative attitude towards them. These negative preconceptions and lack of personal experience could explain the lack of public support for shark conservation (Friedrich et al., 2014). This gap of knowledge requires further research into the various cognitive and emotional processes regarding sharks to better understand the human part of shark conservation (Afonso et al., 2020). Ocean-literate programs are vital for the dissemination of information about the importance of the ocean and the significant role that sharks play. Educational development and nature experience strategies, as well as circulating shark-specific knowledge across society, would therefore be beneficial to improve public perceptions and attitudes towards sharks (Afonso et al., 2020). Using available data on people's attitudes and support of sharks to create intelligent conservation policies is urgently needed, as the current anthropogenic threats continue to threaten shark populations and the marine environment (Afonso et al., 2020).

Summary

In summary, ocean defaunation is directly affecting the decline of marine animals with a significant impact on fragile food webs and marine ecosystems as well as coastal and island communities dependent on fishing. Top predators, such as sharks, play a vital role in keeping our oceans healthy, but as global numbers of various shark species are in decline and on the IUCN critically endangered list. It is now more important than ever for educators to consider marine pollution issues and better understand the issues of: bycatch, overfishing, IUU, finning, and bottom trawling among other issues. Anthropogenic climate change producing more acidic waters is also causing damage to shark's skin. While researched solutions such as the MPAs strategy is challenging these areas have limited human presence and are important in protecting both fish populations and marine biodiversity. The UN's SDG 14 (Life Below Water) and the 30x30 campaign are all crucial steps for the protection of all species including all species of sharks. Educators in both formal and informal settings will also play an increasingly key role in the conservation of sharks: they have a dual role in teaching students the facts about sharks and assisting in demystifying the fictitious negative images portrayed by mass media.

Ocean Literacy and Educational Efforts Focusing on Sharks

Exactly two decades ago, US experts in marine science, ocean education and/or educational policy gathered to discuss the lack or gap in ocean science and knowledge in the national formal school curriculum from kindergarten to grade twelve. Ocean literacy was proposed to increase and promote ocean education (UNESCO, 2021). The following three fundamental issues were agreed upon: the need for ocean literacy; the need for a

definition of ocean literacy; identifying key ocean concepts to include in the school curriculum (K-12); and aligning these to the science standards (Santoro et al., 2017). As a result the collective definition for ocean literacy was defined as “understanding our influence on the ocean and its influence on us” (Cava et al., 2005) and key ocean concepts were not only identified but aligned to the science standards.

A decade ago the Next Generation Science Standards (NGSS) were successfully implemented in more than two dozen states throughout the US and overseas to improve science education, essentially rewriting the paradigm for teaching science (New Meridian, 2023). The NGSS is a set of comprehensive K-12 science content standards designed to provide more in-depth understanding and practical application. Some of the key features of the NGSS are as follows: it encourages interdisciplinary integration combining science with other subjects; it promotes inquiry based learning based on hands-on and investigative learning; and it emphasizes the application of science to real world problems. The alignment of the ocean literacy principles to the NGSS explains why teaching ocean concepts is integral to the NGSS. It also proves that to be science-literate individuals also need to be ocean literate (Payne & Marrero, 2021).

Both the ocean science and the education communities became more unified and showed the importance for marine scientists to be part of this process. Together a framework containing the Ocean Literacy Principles and Fundamental Concepts was developed. The following seven essential principles assisted in the foundation of this framework (NMEA, 2020):

1. The Earth has one big ocean with many features.

2. The ocean and life in the ocean shape the features of the Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes the 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 unexplored.

Ocean Literacy Principle 5 highlights the importance of our ocean in sustaining ecosystems and a diversity of life. The ocean contains most of the major animal groups found on Earth and a range of these major groups are found exclusively in the ocean (2024). For example more than 1,000 known species of sharks and rays live in the ocean. Ocean biology is also unique, and includes examples of life cycles, adaptations, and important relationships, such as predator-prey dynamics and symbiosis among organisms that do not occur on land (2024). Sharks are high trophic level or apex predators in their marine ecosystems and have few natural predators. Within the marine food web sharks feed on live, sick, and dead animals below them, thereby assisting to regulate and maintain a balanced marine ecosystem and very few natural predators (Griffin et al., 2008). Principle 6, meanwhile, indicates that the ocean and humans are interconnected (2024); the ocean provides freshwater (rain), and oxygen, moderates our climate, influences our weather, and ultimately affects our human health. It also provides foods, medicine, minerals, and energy resources. Humans have impacted the ocean in several positive but also many negative ways.

What is taken out and put into the ocean is controlled by laws, regulations, and resource management but often without any oversight. Pollution (point source, non-point source) and noise caused by human development and activity is often illegal. Changes to ocean chemistry have led to ocean acidification or the waters becoming more acidic affecting shell formation, and changes in ocean temperature have caused coral bleaching affecting biological diversity and survival of organisms. Illegal and overfishing affect all marine species. For example, the largest species of shark, the whale shark, is currently listed as endangered on the IUCN red list of threatened species due to overfishing and noise pollution from cargo traffic, in addition to plastic pollution and industrial runoffs. For example, whale sharks are filter feeders (Lai, 2024) and feed on small planktonic organisms such as krill. These are strained through its gills making whale sharks very vulnerable to aquatic pollution. To effectively manage our ocean's resources both individual and collective action is urgently needed.

The Evolution of Ocean Literacy

The translation of the concept and culture of ocean literacy has created a variety of global initiatives. For example, a transatlantic ocean literacy initiative is currently being promoted by Canada, the US, and Europe (2024). Therefore, diverse ocean perspectives, besides those influenced by the US and the EU, have brought multi-cultural and spiritual meaning to the ocean allowing for more accessible and effective ocean literacy efforts (Worm et al., 2021). Both are important for a collective understanding of our relationship with the ocean but also to shape and define individual and collective decision-making. Ocean Literacy, together with the UN Ocean Decade will support the rebuilding and restoring of our marine biodiversity on a wider scale (Worm et al., 2021).

This would include a better understanding of sharks as the apex predators vital to maintaining a balanced and healthy marine ecosystem. Sharks are nomadic and mostly solitary species and are therefore located in most parts of the ocean around the world, allowing students and teachers, especially those in coastal areas, to study species located nearby.

The Human—Ocean Connection

Over the past two decades the human—ocean connection has been further explored. The ocean literacy concept has grown from a smaller group of marine scientists and educators to a larger more diverse and inclusive international movement (Worm et al., 2021). Not only has the concept of ocean literacy been translated into different languages and cultures, but it is also increasingly included by a diverse set of initiatives that span wider audiences than previously considered (Borja et al., 2020). In turn, the creation of the ocean literacy concept has inspired many other significant efforts worldwide. For example, regional networks such as the Canadian Network for Ocean Education (CaNOE) and the European Marine Science Educators Association (EMSEA), have been formed with the intention of promoting ocean literacy within school systems and wider societies. The new regional EU4Ocean coalition is another best practice example of an open hub for organizations and initiatives to connect, collaborate, and mobilize efforts on ocean literacy (Zielinski et al., 2022).

Another primary goal of these ocean literacy initiatives is to promote behavioral change, by which citizens, (including students), become involved in sustainable actions to obtain solutions to marine issues (Kelly et al., 2021). In the case of sharks, it is important

to be informed about the importance and need for shark conservation and finding sustainable solutions to overfishing and finning for example. The need for options and incentives for individual behavior change to better protect, and do less harm to, the ocean and its marine ecosystems and related populations is now urgent (Stoll-Kleemann, 2019). These options and incentives can be provided through information and resources for formal and non-formal educators alike.

Ocean Literacy: Revision and Reflection

As ocean literacy has become increasingly important on a global level, at the same time there is an ongoing debate as to whether it is too simplistic, or even appropriate, as it does not reflect the complex nature of current ocean literacy. Emotional connections (or "emoceans") such as fear, empathy, and enthusiasm, also play a significant role in helping behavior change. To allow for meaningful behavioral change to take place, people's feelings and perceptions must also be considered to better understand the relationship between humans and the ocean (McKinley et al., 2023). In the mid-1970s as numbers of whales declined, several anti-whaling campaigns analogously succeeded in banning commercial whaling. Research confirms that several shark species are likewise critically endangered. For this reason, shark conservation groups are currently campaigning for stricter fishing regulations and a ban on finning to help protect sharks.

In addition, there is an urgent need to include a wider audience of people for ocean literacy to be more effective, accessible, and inclusive. Important perspectives include indigenous, spiritual, art, and ocean users with a close relationship to the ocean

and with deeper knowledge. This would provide a variety of perspectives and enrich the ocean literacy concept beyond the marine science aspects. Such inclusiveness would also allow for greater collective awareness and relationship-building with the ocean and support efforts to restore marine biodiversity worldwide (Worm et al., 2021). Pacific Islanders, for example, are intricately connected to the ocean and sharks play a key role in their culture: sacred stories tell of sharks holding a significant status as a deity, a manifestation of ancestors or as a guide to fishers and voyagers. Such narratives show us a different way of relating to and ultimately co-existing with sharks. Through such awareness-raising comes a clear understanding that the ocean is a highly interconnected and complex marine ecosystem. Providing educators with updated information, professional development, and support could enhance both ocean and shark literacy worldwide.

Lastly, ocean literacy terminology also needs to be further examined as interest in the topic continues to grow worldwide. While the concept forms an important basis it was devised over two decades ago and therefore needs to be revised to address other relevant issues. Today technology and social media, for example, have vastly changed the way in which, and the speed at which, we communicate, which has impacted perceptions of the environment (McKinley et al., 2023), including the ocean and its biodiversity. Specifically, four additional dimensions of ocean literacy have been proposed to focus more accurately on the human—ocean relationship: emotional connections, access and experience, adaptive capacity, and trust and transparency (McKinley et al., 2023). The last of these, trust and transparency, focuses on the extent to which people trust ocean information from various sources, including formal education, but also informal

knowledge through digital means, including mainstream media. Here communicating and spreading information quickly through social media is another factor to gauge whether people trust the platform and how this trustworthiness could impact their individual or collective sense of ocean literacy (McKinely et al., 2023). Sharks are often portrayed in a negative way in mass media from movies such as *Jaws,* to computer games like *Maneater*, where provoked or unprovoked human–shark interactions are labeled as aggressive, blood thirsty attacks. Reliable information and resources about shark behavior are therefore crucial for teachers and students to influence their desire to learn more about the unique aspects of sharks and their key role as apex predators and guardians of our ocean.

Summary

The introduction of ocean literacy within national school curricula to enhance ocean science and knowledge within elementary and secondary schools in the USA was successfully achieved in the early 2000s. A framework and materials, developed by American marine scientists and education professionals, allowed for ocean science to be included into national and state standard education. Since 2021 and with the assistance of the UN Ocean Decade the ocean literacy movement has grown internationally. An international framework of action document outlines ocean literacy initiatives and priority areas as well as mechanisms for stakeholder engagement such as collaboration and networking. The creation of a regional and European ocean literacy network has brought further multiculturalism and spiritual meaning into the ocean discourse and greater accessibility to ocean literacy efforts. The ocean literacy terminology is an important basis but may need to be revised to incorporate technology and social media

which are growing at a fast rate. Four additional dimensions portraying the human—ocean relationships are proposed as part of the revision of ocean literacy terminology.

Pedagogical Approaches for Effective Marine Environmental Education

Becoming Ocean Literate

Ocean literacy is now seen as more than just educating or informing the public or marine and maritime stakeholders about the importance of oceans. “Through the use of behavioral change methods and by adopting a systems approach, it aims to facilitate the creation of an ocean-literate society” states Francesca Santoro Programme Officer Ocean Literacy Program, (IOC-UNESCO). A systems approach sees the world where people are interconnected and interdependent of each other; it is a holistic and interdisciplinary way of understanding and solving complex problems. Becoming ocean literate is therefore not only an understanding of how the ocean is important and how it affects us but also our effect on the ocean through your behaviors.

The seven Essential Ocean Literacy Principles were originally developed and defined by American scientists and educators in the final document *Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Science K-12*. In each of the seven Principles several topics of ocean sciences are covered and learning these fundamental topics will allow students to communicate about the ocean in a meaningful way. The Principles also encourage the inclusion of ocean sciences into the curricula of formal education. In the context of this project, Principle 5 (“The ocean supports a great diversity of life and ecosystems”) would also include sharks and their important role in

maintaining balance within marine ecosystems. The content of these Ocean Literacy principles focuses more on an integrated type of science versus an isolated subject. This clearly shows the true interdisciplinary nature of ocean sciences. It also provides for a coherent progression of learning about the ocean in a continuous way from early years into the high school level.

As the global decline of the ocean continued, the need to address growing concerns resulted in the publication, in a partnership between UNESCO and the Intergovernmental Oceanographic Commission (IOC), of an international toolkit titled *Ocean Literacy for All* (Santoro et al., 2017). Based on the original seven ocean literacy principles, this toolkit aims to serve international educators, curriculum developers, and policymakers worldwide. It includes innovative tools, resources, and methods to understand our complex ocean process and functions and highlight the most urgent ocean issues. Later, in 2022, an updated version of this tool kit titled, "*A New Blue Curriculum - a toolkit for policymakers,*" was published and now also aimed at public decision-makers, along with teachers, and curriculum developers (Santoro et al., 2022). With these tools, educators and policymakers can promote the protection of our ocean more effectively.

With great fortune, at the One Ocean Summit in Brest, France, in March 2022, UNESCO's 193 member states committed to include ocean education in their school curricula by 2025: "The international community must make education the pillars of its action for the ocean. Because if we want to protect it, we must teach it better," stated UNESCO Director-General Audrey Azoulay. In this way, the summit's objective was to increase student's knowledge about oceans and assist them in becoming committed and responsible citizens.

Ocean Literacy and Formal Education

Teachers in the US have, for the past two decades, had access to ocean educators as well as numerous resources to align ocean literacy to their science standards at their grade level. These include the NGSS or the US National Science Education Standards (NSES). For example, within the NGSS the Earth and Space Science domain contains science content standards that address ocean topics from the early years in elementary school through to high school. Thereby allowing for a progression of learning allowing for a more in depth knowledge. Project-based learning has also provided opportunities for students to investigate real-world problems and respond in detail to an issue that is both engaging and complex versus a simple problem with a clear-cut solution. Individual and group projects within classes explore ocean-related topics and opportunities for educators to teach about sharks with a significant role in protecting marine ecosystems.

Inquiry-based learning is a student-centered teaching method that requires students to ask questions and investigate real-world problems. It is different from the traditional learning approach, in which the teacher presents the facts and their knowledge about the subject, as students are actively engaged in the learning process, investigating a series of scenarios, questions and problems to explore their natural curiosities (Scholl, 2024). Inquiry-based projects focusing on sharks and marine biodiversity would also allow students to better understand sharks and their vital role in marine ecosystems. For example, a study investigated how Portuguese elementary school students engaged in an inquiry-based project driven by “real-life” contexts. This project focused on marine biodiversity and species adaptation. Three field trips were planned to a fish market, an aquarium, and an intertidal platform. After using the scientific research methods

(observation, document, and content analysis), the results showed that the students successfully acquired scientific knowledge on biological diversity and, equally as important, they showed more autonomy, the ability to make decisions, and better argumentative abilities. Another important conclusion of this paper was that inquiry-based projects that explore diverse types of resources and in outdoor settings could be better managed in elementary science curricula (Guilherme et al., 2015).

Beyond the Curriculum

The idea for ocean literacy began because school curricula lacked topics related to the ocean. The concept of being ocean literate is based around the idea of integrating scientific information about the ocean into forms that were beneficial for both teachers and students. The recently published *UN State-of-the-Art of Ocean Literacy* report indicates that the focus of global communities of ocean literacy researchers and practitioners is now shifting " from a focus on the ocean in formal education towards developing more critically informed, context-specific initiatives for ocean literate societies"' (UNESCO-IOC, 2022). Worldwide more programs are now designed to connect content between subjects and partnership with local communities, businesses and other organizations.

Research has focused on the scope and sequence of ocean topics in school curricula with innovative programs linking content between subjects with local communities, businesses and NGOs. The Blue School Network (Escola Azul), for example, is a Portuguese governmental project whose objective is to support ocean-literate generation students for a sustainable ocean in partnership with local

municipalities, NGOs (including SEI), and industry and other entities that play an active role in ocean literacy (2021). Now the goal is to go beyond the curriculum and support more experiential learning, field trips or extracurricular clubs, which are important "to foster care and positive attitudes towards the ocean in young people" (UNESCO-IOC, 2022). Digital tools and technology, as well as online learning, are all tools that allow learners to visualize complex topics and use the data learned in interactive and playful ways.

Digital Technology and Shark Conservation

To counter the lack of ocean literacy within the formal school curriculum, creative digital, and non-digital solutions may be found to address specific issues related to the conservation of sharks and their role as apex predators in marine ecosystems. Ocean literacy is enhanced through outcomes, experiences, and potential to build the global ocean literacy movement (Fielding et al., 2019). For example, global learning formats, such as free massive open online courses (MOOCs), provide unrestricted access to information and can reach many ocean literacy learners of all levels."*Exploring our Oceans*" (2023) is a successful international MOOC and is based on online teaching techniques that emphasize contributions from an international community of learners. Due to the courses' flexible learning style, additional information and resources about sharks and shark conservation issues within curricula could raise awareness of the need to protect sharks.

While real-world interaction with oceans and its biodiversity, such as sharks, cannot be totally replaced with digital technologies, they have the possibility to involve

and engage students with the ocean. Interactive learning experiences have been shown to improve active student learning and affect the learning process in a positive way (Weiss, 2024). Educational games have been used to change behavior and attitudes, improve learning, and motivation outcomes in areas such as education but also ocean literacy. These platforms have the potential to involve and engage students with the ocean and its marine ecosystem including those with little contact with the ocean or who live in landlocked states or countries. Games that show fun, beautiful, and relevant aspects of the ocean interactions and give immediate feedback plus awards are consistent throughout gamified applications (Leitão et al., 2021). Aside from games, viewing shark satellite tracks on Google Earth is also possible through the University of Miami's Shark Research & Conservation Program (SRC) website. SRC involves young people in hands-on-field research experiences, such as tagging sharks, on board its research vessel. These public shark satellite tracks also assist SRC scientists to better understand the migratory and residency patterns of specific shark species. Another successful method to promote ocean literacy through technology is the use of a digital virtual scuba diving application. Through this application elementary teachers and students in Indonesia, and those without a diving certificate, can observe life under the ocean and see the underwater scenery as well as the biota of underwater locations in Indonesian islands. These images have been shown to raise students' awareness about marine biodiversity, including sharks, within Indonesia (Cahyadi et al., 2021).

Despite the successful use of technologies in schools, the gap separating those who have access to technologies and those who do not, also known as the digital divide, has yet to be fully explored or addressed (Srinuan & Bohlin. 2011). Besides restricted

technical access, social infrastructure, including education, income, and location, all need to be considered. Studies on educational game-based learning need to understand, research, and address this digital or technology divide in schools or communities more closely to present a more realistic image of the situation in, for example, developing countries and propose alternatives. Physical board games, for example, enable students to interact and have discussions and may be used as an alternative to digital educational games. For example, *Ocean Limited* is a table–top, role–playing game created for global and integrated marine sustainability education aimed at high school students (Koenigstein et al., 2020). Similar role–playing games could be designed for younger students to also enable them to have a better understanding of ocean systems and their sustainable governance. Ultimately, all educational games, whether digital or analog, are important ways to promote ocean literacy and highlight the need for the conservation of sharks in educational settings, and they should be made readily available for teachers and students living near and far from the ocean to gain a better understanding of the significant role that the ocean, and its top predators, play in their lives.

Citizen Science and Shark Research

Citizen or community science (CS) has gained popularity among people of all ages and has evolved over the past decade. Its objective is to give the public the opportunity to volunteer and assist conducting scientific research. Citizen scientists are able to assist in different ways including collecting data, analyzing results and solving problems. In turn, professional scientists use these data sets to answer scientific questions and solve important problems (Ulrich, 2024).

Recently the ecotourism industry in areas of shark aggregation has increased globally. An active citizen science (CS) movement has also emerged whereby ecotourists are engaged in data collection for shark research (Bagnesi et al., 2020). Sharks in the Mediterranean Sea, for example, have been declining over the last 50 years, and data on the local population status of various shark species is lacking (Bargnesi et al., 2020). Research shows that CS networks for shark research have also become more effective when they are associated with educational efforts through marine tourism in the popular coastal areas of the Mediterranean Sea (Bargnesi et al., 2020). During the school summer holidays students and teachers could also be invited and encouraged to engage in these CS networks. In the new school year the data collected by the CS networks would then be shared with the students who could then analyze the outcomes to gain a better understanding of sharks, why they are on the decline and potential conservation solutions.

Evaluating Ocean Literacy and Elementary Education

Children are seen as important agents of social change through their own responsible behaviors but also in bringing about wider change through their ability to influence others such as peers, friends, and direct family members. However, there is an overall general lack of ocean literacy worldwide related to school curricula in elementary and secondary schools (Mogias et al., 2019). In response, the information gathered from a study of elementary schools in three Mediterranean countries regarding the level of students' ocean literacy has been to support the design, development, and implementation of marine-friendly elementary marine-friendly curricula, courses, and books, as well as professional development for both current and prospective teachers (Mogias et al., 2019). Although the extent to which marine science is taught in formal education may not be

exactly known, an Australian elementary public school case study investigating marine science teaching practices showed that teachers did not regularly include marine science topics in their lessons.

Overall, the teachers agreed with the importance of ocean education at an early age and two major factors were cited: the lack of ocean related educational resources and the absence of professional development opportunities (Freitas et al., 2022). Scientific support needs to be given to teachers and schools so that they can understand ocean issues and be better able to disseminate ocean literacy. Ocean problems are complex and so require transdisciplinary or cross curricular approaches. To be able to explore and understand ocean issues or problems in innovative and creative ways, contemporary projects involving scientists, schoolteachers, and students are necessary (Barracosa et al., 2019). Discussions and research indicate that marine scientists and educators are primarily those who define and discuss the ocean literacy agenda (McKinley et al., 2023).

The Future of Ocean Literacy

As we shift to a more participatory and inclusive approach to ocean literacy *per se,* the objective is now to deepen our understanding of the ocean and its importance within global societes. Researchers also need a more critical approach to ocean literacy to allow for a smooth transition (UNESCO-IOC, 2022). Both network building and designing new methods for gaining knowledge, awareness and action for the ocean are important, while traditional customs and cultural practices are now being recognized and included as part of the ocean literacy principles. Accordingly, the definition of ocean literacy is becoming more diverse as multiple forms of knowledge local, traditional,

indigenous, scientific are being included in our shared understanding of the ocean. “A more open, flexible, critically informed paradigm for Ocean literacy is necessary to benefit the well being of humans, marine life and environments (UNESCO-IOC, 2022). For example, the Ocean Literacy With All (OLWAL) program aims to promote participatory ocean literacy approaches through international research and activities across the globe that are developed by and for diverse stakeholders. In addition a set of guiding principles provides direction towards critical forms of ocean literacy in the future.

Teachers and Shark Awareness

Communicating about and understanding our impact on the ocean and the ocean’s impact on us are both fundamental to ocean literacy. Using these concepts and the need to promote the combined need for local, traditional, and scientific knowledge about sharks, a more inclusive computer based project was designed. To give educators of all subjects and backgrounds, living near or far from the ocean, an opportunity to become ocean and shark-literate and to go beyond mainstream education. This bilingual (English/Portuguese) blog, aims to centralize pertinent information about sharks and shark conservation, but also to raise awareness and encourage discussions among educators in both private and public Portuguese schools and English speaking International schools based in Portugal. Studies have shown that teachers are willing to teach about sharks and ocean related themes but they often lack information as well as professional development for this purpose (Freitas, et al., 2022). The need for a marine friendly curriculum and extra curricular activities in all schools is an urgent one. In response, the proposed blog aims to centralize all the ocean literacy information

applicable to the NGSS, national (US/Portugal) and international curricula. The project supports a similar systems approach to ocean literacy, in that it hopes to create a holistic and interdisciplinary way of understanding sharks and solving complex problems related to their conservation. It also seeks to achieve behavioral change among educators and students—a change in behavior not only in how we affect the ocean and it affects us, but also towards sharks and shark conservation.

Conclusion

The literature review in this chapter is framed around the question: *How can ocean literacy enable elementary teachers and students to better understand sharks and their role within marine ecosystems?* Our one global ocean is vital to our survival and health and the need to protect it is more urgent than ever. That said, a sustainable global ocean is only possible through international cooperation, communication and ocean diplomacy. An ocean-centered governance is needed to show us that the ocean is a living entity, and a more inclusive approach to both ocean science and sustainability is required. Therefore, knowledge of ocean literacy and marine biodiversity will play a key role in promoting this new global governance.

Sharks, as apex predators, are an excellent example of their ability to assist us in the protection and health of marine ecosystems. However, the major threats to sharks (e.g., overfishing and finning) are causing an overall decline in their numbers worldwide, highlighting the urgent need for both shark education and conservation. International campaigns from marine conservation groups are calling for the end to the unregulated fishing and finning of sharks, while also raising consumer awareness of toxic shark or mislabeled shark meat and products containing shark meat and oil. Understanding the

true nature of sharks versus the fictitious exaggerated blood-thirsty image portrayed by the media is equally important to their protection.

Ocean literacy principles, together with the NGSS have already in part been integrated into formal school curricula in the US. Together, they guide the framework to show how humans are greatly interconnected with our ocean and the importance of protecting biodiversity in maintaining marine ecosystems including sharks and shark conservation. Likewise, the human—ocean connection is vital, as ocean literacy is becoming more diverse and inclusive. A change in behavior is also necessary to give citizens and educational communities the incentive and options to individually change their behavior and better protect the ocean, its marine ecosystems, and its marine life such as sharks. Emotional connections and perceptions play an important role in meaningful behavior change, hence the need to better understand sharks outside their misrepresentation in mass media.

Global research is shifting from the individual learning in formal education to the development of a more inclusive and participatory approach to ocean literacy. Many types of knowledge, in addition to science, are required for the understanding of our ocean, including local, traditional, and indigenous knowledge. The objective here is to provide a more flexible and open paradigm for the well being of humans, marine life, and marine ecosystems. Participatory literacy approaches are being promoted through activities and international research developed by and for diverse people. Research confirms that several shark species are also critically endangered. For this reason, shark conservation groups are more necessary than ever.

Chapter 3 presents a more detailed description of a bilingual interactive educational blog aimed at centralizing resources and information regarding ocean literacy and sharks for elementary teachers. A more participatory approach of educators from all subjects is also envisioned. Research literature supporting the importance and success of blogs, as the approach used, along with a description of best practices, is also presented. The project's setting and audience are described and a timeline section explains the length of time for the project's creation together with a proposed timeline for its implementation. Lastly, the assessment section describes how data will be collected for the evaluation of the project's overall effectiveness.

CHAPTER THREE

Project Description

Chapter Overview

This chapter presents a full description of the creation of a blog for elementary teachers. The blog, titled *Teachers4Sharks,* is bilingual (English and Portuguese) and located within the official SEI website with their generous support and permission. Founded in 2016, SEI is dedicated to promoting ocean literacy and the conservation of sharks through marine environmental education. Its main focus is highlighting the conservation of shark species in their natural habitat within schools and increasing public knowledge of marine ecosystems.

The purpose of this capstone project was to answer the following research question: *How can ocean literacy enable elementary teachers and students to better understand sharks and their role within marine ecosystems?* This chapter first discusses

the rationale behind the *Teachers4Sharks* blog, as well as supporting evidence for the importance and benefits of ocean literacy and the need for shark literacy and shark conservation. This interactive blog will be created using state-of-the-art, user-friendly software and a framework to provide information and resources about sharks and the marine ecosystems relevant to elementary teachers of science and specialists. The timeline, setting, and audience are also presented, before a discussion of the assessment of the proposed solution for elementary teachers and their students.

First, this interactive blog aims to provide all elementary teachers with relevant and interactive content as well as information and resources about sharks and our ocean. The ocean literacy's seven essential principles and the UN's SDG 14 (Life Below Water) and its targets were used as guidelines. The NGSS aligned to the ocean literacy principles were also made available. Second, the blog will act both as a resource hub and an ongoing professional development tool for teachers teaching science as well as other subjects to better understand sharks and their role in the delicate relationship with the ocean's ecosystems. Third, the long–term goal envisions establishing a national and international network of informed and committed educators not only teaching about the importance of ocean literacy, but also specifically focusing on sharks and the important role they play in keeping a balanced marine ecosystem as apex predators.

Rationale

The *Teachers4Sharks* blog aims to deepen formal and informal educators' understanding and students' connections to the ocean and sharks, especially when their geographical location is far from the ocean or in landlocked states or countries. As an elementary science co-teacher and marine educator, while I was researching my capstone

question, general information about sharks was readily available on different websites as well as social media, but it was not very centralized nor easily accessible to those outside this restricted scientific community. However, working as a volunteer at the global level within SEI, I have had the privilege of meeting professional shark experts, being part of discussion groups, supporting campaigns such as the current "Stop Finning" EU campaign, and participating at the UN Ocean conference in Lisbon in 2021, all of which have inspired me not only to protect sharks but also to share this knowledge and information with fellow educators both nationally and internationally.

A recent case study also indicated that while elementary teachers in Australia are aware of the importance of ocean education, they rarely include marine science topics in their lessons. Teachers saw the need for more ocean-related educational resources linked to the curriculum and professional development to increase their marine science knowledge (Freitas et al., 2022). The *Teachers4Sharks* blog intends to not only centralize reliable information and communication about sharks but also make it accessible and more personalized for teachers of all subjects to understand and use within their curricula. The objective of this interactive blog is to post regular and credible information that is beneficial to both formal and informal educators for their lessons, thereby also providing a continuous form of professional development in ocean literacy as well as shark awareness and conservation. Blogging is already considered a powerful tool and one of the most beneficial ones in terms of professional development (Wheeler, 2011).

While designing this educational blog an aspirational checklist, for inspiration and planning was consulted. This list, designed by UNESCO and the Ocean Decade, focuses on "developing critically informed, context-specific initiatives for the

ocean-literate societies" (UNESCO- IOC, 2022, p.19). This clearly shows the shift away from the former focus of ocean literacy where researchers and practitioners supported ocean issues primarily in formal educational settings. Although the scope and sequence of ocean topics in school curricula was a crucial and important first step, experiential learning beyond the curriculum is also essential for young people to cultivate positive attitudes towards the ocean. Immersive digital, for example, environments,for example, allow learners to visualize complex topics. National and international marine research institutes providing information through social media is equally important as this enables a connection to audiences outside the institution (UNESCO-IOC, 2022). As such, the *Teachers4Sharks blog* provides educators with contacts and a list of successful case studies to promote informed initiatives. All the successful ocean literacy initiatives emerged with a pattern consisting of the following five key interconnected factors (see Appendix C):

(1) Resources,

(2) People,

(3) Knowledge,

(4) Experience and

(5) Places.

This aspirational checklist was designed to be consulted with a specific context and audience in mind. The Knowledge factor questions whether the integration of various forms of knowledge are respected and used, the knowledge is used in an inspiring way, participants are encouraged to support or take action, and opportunities are given to apply the knowledge gained. In addition, whether technologies are used in optimal ways for the

audience, the infrastructure and services are available to deliver the project, consistent and multiple forms funding are available are all questions linked to the Resources factor. The People factor considers a strong commitment from those involved plus whether the needs and goals are considered and can be delivered; communication and strong cooperation with other entities are also necessary here. The Experience factors, focus on whether special needs and translations are provided, and whether the project is creative and inspiring, and whether opportunities exist for participants to create something individually or together while engaging in multiple senses. Lastly, the Places factor (in–situ/remote) examines whether the project is in a place that is relevant, inspiring and safe, and if internet connectivity is reliable, and the user experience smooth and stable for remote participants. All of these factors were taken into consideration when creating the *Teachers4Sharks* interactive blog to promote both shark and ocean literacy within national and international elementary schools.

Online Tools and Blogs

As both our technological and digital world are making rapid progress, so too is the variety of social media on offer. Studies have shown that high speed internet has not only made communication between people much faster and easier, it has also shown that online communication has changed how people share, interact, and collaborate (Gauntlett, 2013). Today people discover, read and share news, information and content through different technologies and online tools including blogs. These are more related, however, to personal information or news and are provided from the bottom up, enabling dialogue and even co-production between author and reader (Hookway, 2008). Interactive blogs also require active engagement from users and are characterized by instant

text/graphic publishing, an archiving system organized by date, and a feedback mechanism through which readers can comment on specific posts. Blogs also use software programs that enable users with low technical competence to present attractive and regularly updated online material (Hookway, 2008).

Steve Wheeler, associate professor of technology at Plymouth University in the UK, strongly believes that teachers should read and use blogs themselves. One of his seven reasons to use blogs is that they can "open up new audiences" or link up people from different areas. Ocean literacy and the shark's role within the marine ecosystems do not need to be taught in a purely scientific format; rather, they can be approached and taught in an interdisciplinary format. With advances in technology, blogging also allows us to communicate in new and different ways as a platform where "you can find new and creative ways to articulate what you want to say" (Wheeler, 2011). In this way, the *Teachers4Sharks* interactive blog aims to provide a platform bringing educators together to communicate and address ocean literacy and the importance of shark conservation in practical, innovative, and original ways.

Blogs can already be accessed on the websites of various environmental and marine organizations. Information is thus shared and each blog grows to become a place of easily accessible resources. In a successful blog, all the information and resources posted aims to provide images, stories, quotes, videos, audios, and hyperlinks to other resources, allowing for different ways of communicating important messages and information to a wider audience (Wheeler, 2011). In this vein, the interactive bilingual *Teachers4Sharks* blog on ocean and shark literacy was created as a common space to share information and resources but also as a space for discussions or dialogue. The idea

was to encourage interdisciplinary learning, while also acting as a continual professional development tool for formal and informal educators.

Project Description

The *Teachers4Sharks* educational blog provides educators with information about sharks, the threats they face, and ongoing national and international shark conservation campaigns. This blog was also linked to SEI's Portuguese and international official websites. As a first step, 10 Portuguese public and private schools as well as 5 international schools were invited to follow this interactive blog. The objective was to assist elementary formal and informal educators with their lesson plans, projects, and/or curricula while highlighting the urgent need to protect all shark species especially those listed as endangered or critically endangered. The blog entries were divided into the following topics: The Sharks & Ocean Literacy section provides a comprehensive list of resources and information for educators about both topics. The Shark Fact File section adds essential facts about sharks on a monthly basis. The Blue Library & Media Center contains recommended books and videos on sharks and ocean literacy for both students and educators. The Blue Forum section is a space where teachers can ask and answer questions or discuss other related issues. Surveys, quizzes, and social media sharing present additional interactive features to allow for a more positive experience and to obtain feedback. In sum, this blog aims to build capacity and behavior change toward an ocean and shark-literate society which will help ensure a more sustainable development for our global ocean.

Ocean Literacy Principles

In its first phase, the blog aims to promote ocean literacy and provides up-to-date and credible information about sharks for elementary teachers within national and international elementary schools (public and private). Two important frameworks provided information about ocean literacy for both formal and informal educators. The first was developed by the NMEA, focusing on the Seven Essential Principles and Fundamental Concepts and underlining the true interdisciplinary nature of ocean science. Principles 5 and 6, for example, support the fact that there is a great diversity of life and ecosystems on our planet and that humans and the ocean are interconnected. Both principles focus on the need to understand the important role of sharks as top predators in our marine ecosystems in addition to the negative human impacts of overfishing and of pollution on all marine life, sharks included. The *Ocean Literacy Scope and Sequence for Grades K-12* document, is an additional instructional tool that provides guidance to educators, through conceptual flow diagrams and coherent instruction, to assist their students in building a fuller understanding of the ocean (US Department of Commerce, 2019).

The second framework is the *Ocean Literacy for All* toolkit produced by UNESCO in 2018 and is based on the NMEA framework. It is an essential resource for an international audience of scientists, educators and learners to increase their responsibilities around the ocean by sharing ideas, experiences, and initiatives in support of ocean literacy. The first part of the document describes the history of ocean literacy and the existing challenges in marine education, as well as the way forward in developing successful ocean literacy activities in the context of the 2030 Ocean Decade agenda. The second part presents a multi-perspective approach to ocean literacy along with several

practical and tested activities to support marine education initiatives. Crucially, it is necessary and possible to adapt such initiatives to national or local contexts while remaining flexible enough to also include shark awareness activities for example.

Sustainable Development Goal (SDG) 14

The blog also addresses SDG 14, (Life Below Water,) including its ten targets to create action to conserve and sustainably use our ocean, seas, and marine resources (2024). The most relevant targets to highlight the importance of shark conservation include Target 14.2, which aims to protect and restore ecosystems. Target 14.6, meanwhile, seeks to end certain subsidies contributing to overfishing. Additionally, Target 14.5 calls for conserving 10% of coastal and marine areas, according to national and international law with sound scientific information (2024). Information and resources relevant to elementary educators were selected and included in the blog.

Blog Tool

The ultimate goal of the *Teachers4Sharks* blog is to enable elementary educators to develop a deeper connection with sharks to access sufficient resources and to include shark related topics within their lesson plans or activities The interactive content is intended to be a memorable experience where elementary teachers can access practical and useful tools not available in other blogs. Ideally, readers will spend time on the blog pages interacting with the content and actively participating, becoming a part of the story as well as a regular member (Blog Tyrant, 2024).

After researching several different blogging tools, I chose the WordPress.com tool. Aside from noting that it is a widely used format for blogs I regularly read, it is also

user-friendly and provides guidelines for starting a blog and, tutorials on how to embed interactive content, along with flexible tools for writers. The *Teachers4Sharks* blog aims to be more than a traditional blog, providing interactive content and elements that users can click on quickly and easily encouraging deeper engagement. This includes quizzes, surveys, videos, games, and interactive maps and infographics. Once enough information has been posted on the blog, social sharing will also be enabled to allow users to share blog posts on social media, as well as embedding social media feeds directly to the blog itself.

Blogtyrant.com is a free online resource that offers in depth tutorials, tools and has listed examples on how to make a quiet blog more interactive. To give teachers a more memorable experience of the *Teachers4Sharks* blog, the following examples of interactive content were provided in two phases. First, in a longer article a clickable table of contents, or anchor links, allows readers to directly go to the section of the article that interests them most. This saves teachers time and enables them to find the information that they need or interests them most. This saves teachers time and enables them to find the necessary information almost instantly. To supplement the articles selected, educational video content was also embedded. To summarize or condense information, slideshows were included to better illustrate the points and make the content more lively. Quizzes were added to test the reader's knowledge on a particular topic, which may be a useful tool for teachers who first want to test their own knowledge before teaching a certain shark related topic. Some selected animated graphic interchange format files (GIFs) were also included to make the blog post more engaging, and help break up the

monotony of words on the page and keep the reader engaged for longer (Blog Tyrant, 2024).

In the second phase, a “members only area” is planned for teachers who are also members of SEI and get involved in environmental politics. This forum will allow users to participate through teamwork discussions and interactive chat threads. Exclusive e-learning courses for professional development may also be a future option, through which members could watch video lessons, take quizzes, and track their progress.

Assessment

The effectiveness of the educational blog was assessed in a variety of ways. Besides being open for comments, the data for this interactive blog was collected over a specific period of time. This included the number of people who had accessed the blog or which articles were read most often. Surveys and polls about the blog’s content, for example, were added enabling teachers to share their opinions allowing valuable feedback to be collected (Blog Tyrant, 2024). The question categories used helped determine whether the contents of the blog were sufficiently informative for teachers about the importance of sharks in the ocean and in addressing their needs or requests. Regular and varied assessments, therefore, will assist in evaluating the effectiveness of the different parts of the educational interactive blog.

The intended purpose of this blog was to assist teachers to gain knowledge about sharks and their important role as apex predators in our marine ecosystems, as well as the understanding one of the core principles of ocean literacy (the ocean’s influence on us and our influence on the ocean), communicating about the ocean in a meaningful way,

and making informed and responsible decisions regarding the ocean's resources. In addition, the surveys indicated an increased understanding about the important role of sharks in our ocean; such a deeper understanding of sharks will encourage their protection through marine environmental stewardship.

Setting and Participants

The setup of the *Teachers4Sharks* blog was designed and aimed for an elementary school setting for teachers from kindergarten to grade five, plus secondary students in its second phase. As well as science teachers, additional subject teachers, as well as language arts, English as a second language, foreign languages, social studies, art, music, and so on, were also encouraged to access the information and incorporate it within their own curricula. The blog thus aimed to be an interdisciplinary information resource and in many ways also an ongoing professional development tool as well. Teachers can read, comment, exchange views, and opinions, and request for more information. Topics include: Shark conservation around the world, information about different shark species, educational resources, recent *YouTube* recordings and/or summaries of SEI's "Second Monday" (*Segunda-segunda feira)* monthly online presentations by shark and marine experts followed by Q&A sessions for members and guests. Important news about events related to oceans, ocean literacy tools, guides, and examples of activities were also included.

Timeline

The capstone project had an overall timeline of two semesters. The background information and chapter was completed between February and May 2022. In 2023, the

research for the literature review was undertaken, in addition to taking courses for my now completed graduate-level Environmental Education Certificate. The interactive blog itself was developed and a reflection completed between June and August 2024. First, the content experts and course colleagues provided feedback and suggestions of Chapters for 1– 3. Next, the *Teachers4Sharks* blog template was created online. Specific topics of interest for the blog were then outlined using the template. Educators completed questionnaires sent out to English and Portuguese teachers with feedback and suggestions on what resources would be most useful for them. Content experts provided suggestions and improvements during the drafting stage of these topics and entries; articles and summaries I had recently written were selected, updated and posted on the blog as well. The proposed interactive elements to make the blog more appealing were also added. In the final stage, this being a bilingual blog, the posts were translated into Portuguese, reviewed and edited. Lastly, the capstone project was completed and presented to my capstone course colleagues in August 2024. The presentation was in a format for educators to view the blog and understand both its content and layout. In September 2024, the *Teachers4Sharks* educational blog was posted on the SEI's website for use in the 2024/25 school academic year. Teachers from both national and international schools were invited to follow and give feedback on the interactive blog and what improvements could be made. Surveys and polls to be posted on a regular basis throughout the school year., will also be analyzed to keep the blog active and up-to-date.

Conclusion

Although our ocean is currently in serious decline, having updated and accurate information about our ocean and its ecosystems will allow us to reach our goal of a

healthy and sustainable ocean. The two ocean literacy frameworks presented here, using the Essential Principles designed by the NMEA and the framework of action for the UNESCO Ocean Decade can support not only the science curriculum but the development of links between the sciences and other subjects to allow for a more interdisciplinary learning approach. Today, technology already allows us to access information at a fast pace and blogs are ideal places to find information and discussions around a specific topic. Wheeler (2011) strongly believes that blogs communicate important messages and information in different ways and to a wider audience and encourages teachers to read blogs and find new and creative ways to present information. Lastly, the *Teachers4Sharks* blog aims to support the SEI's international philosophy of using creative education for the protection of our marine ecosystem and the conservation of sharks worldwide. Misinformation and disinformation about sharks, through mass media has depicted the shark as an evil and blood thirsty fish when, in fact, only a few are known to be dangerous, with the overwhelming majority remaining are shy and preferring not to interact with humans at all. Ultimately, the *Teachers4Sharks* bilingual interactive blog aims to be not only informative but also provide useful resources and professional development opportunities for teachers of all subjects.

Chapter 4 focuses on my major learnings throughout the capstone process as a researcher, writer, and learner. First, revisiting the literature review shows and explains what was the most important for my capstone project. Specifically those resources that influenced my work and some of the new contributions I have made to the existing literature. Second, the possible implications of my project, including for policymakers, are presented, in addition to its limitations. Third, future research projects in related areas

are discussed, along with some recommendations based on my findings. Lastly, the final section of the chapter considers how the results of the capstone project can be used and communicated in the future in addition to how it will benefit my wider profession.

CHAPTER FOUR

Conclusion

Chapter Overview

This capstone project aimed to inform elementary educators of all subjects about the following two issues: the importance of ocean literacy as a means of raising awareness about sharks and shark conservation. Demystifying the negative reputations that sharks have gained through mass media makes shark conservation an even more challenging issue to address. Through my research, and my participation in international shark conservation campaigns and conferences, organizing school workshops and beach cleanups to raise awareness about the importance of the ocean and its apex predator, along with discussions with colleagues with SEI, I was inspired to share my knowledge, especially with my teacher colleagues. I concluded that since technology plays a vital role in information dissemination, the best course of action was to create a bilingual interactive blog featuring a variety of resources about ocean literacy, shark science, and conservation. The fact that several shark species are now vulnerable and endangered worldwide is essential knowledge to pass on to educators so that they can feel comfortable enough to instruct their students. Using the information provided will allow teachers to implement cross–curricular activities, project-based learning, and citizen science projects. The objective of the capstone project was to answer the following

research question: *How can ocean literacy enable elementary teachers and students to better understand sharks and their role within marine ecosystems?*

This chapter focuses on the capstone process as a researcher, writer, and learner; I share how the expected and unexpected learnings assisted me in developing a deeper and understanding of ocean literacy principles, and shark science, and conservation worldwide. In addition to this reflection, I describe the implications of the *Teachers4Sharks* interactive blog and some potential limitations. I also discuss how the project should benefit formal and informal elementary educators from all subjects. Lastly, future project ideas are presented, including continuing this project with secondary school teachers. Looking further ahead, the longer-term objective is to build a national network of teachers promoting shark conservation through ocean literacy within their schools and communities; a second phase of this network would also expand internationally to include Portuguese speaking countries located in Africa, Latin America, and Asia.

Research and Project Creation

As a researcher, writer, and learner throughout the capstone process I have had the privilege of gaining a deeper understanding of our ocean's value to Earth's life systems, the shark's important role in marine ecosystems, how ocean literacy and educational efforts can focus on sharks, and the pedagogical approaches for effective marine education science and research. This includes what Worm et al. (2021 p.1) describe as the "continual need for ocean literacy to be more effective, inclusive, and accessible and to include different cultures, indigenous, spiritual, and ocean users so the ocean literacy concept may be enriched and go beyond marine science."

One of the unexpected learnings I encountered was the lack of current research on children's knowledge and perception of sharks including the assessments or methods to measure the impact of ocean literacy activities and the extent of behavioral change involved. Otherwise, the information I researched confirmed the knowledge I have gained over the years from working with environmental NGOs and volunteer experiences with marine conservation organizations.

Throughout the capstone process, I have learned that ocean literacy has progressed significantly over the last two decades, and has now reached an interesting turning point. Starting from its humble beginnings in the US classrooms, then spread worldwide with the assistance of UNESCO and the Ocean Decade, and now flourishes internationally. Ocean literacy began with scientific content structured into principles and concepts for the school curriculum. Next, programs linked the content between subjects into partnerships with local communities, businesses, and other organizations. We are witnessing a clear shift towards a more inclusive and participatory approach versus individual learning of ocean literacy, the goal of which is to deepen understanding of the ocean and its importance for societies globally.

Ocean literacy is now used as a tool for a variety of projects. It is also a source of inspiration to form new networks and design new methods for boosting knowledge, awareness, and action for the ocean. A novel ocean literacy paradigm has at its core a vision to be open, flexible, and critically informed to benefit humans and marine life environments. UNESCO's Program Officer for Ocean Literacy Program, Francesca Santoro, states that ocean literacy is more than simply understanding the importance of the ocean and how it affects you but equally as important is your effect on the ocean

through your behavior. We are all interconnected and interdependent. Essentially, we need to change behavior and adopt a systems approach where complex problems are solved through a more holistic and interdisciplinary understanding.

While undertaking research, two papers were to be most influential, and both assisted in shaping the capstone project. They also confirmed my research question on the need for ocean literacy to integrate shark science and conservation. This will assist educators in better understanding sharks and their role within marine ecosystems, as well as the need to demystify negative portrayals of sharks by mass media. The first case study (Freitas et al., 2022) examined an Australian 2025 National Ocean Literacy strategy. Conclusions from a questionnaire given to elementary educators showed their agreement on the importance of ocean education at an early age. However, the lack of ocean-related educational resources and professional development tools prevented educators from teaching marine science topics. The second study research (Tsoi et al., 2016) focused on shark conservation and children's knowledge and perception of sharks in a Hong Kong school. The researcher concluded that misunderstandings around sharks and their negative public images disadvantage several international shark conservation campaigns.

Additional literature that proved to be important to my capstone question included the following research papers. Bender et al. (2022) reaffirmed the understanding that the ocean is a living entity and the five basic principles proposed for ocean-centered governance model, thus providing a more inclusive approach to ocean science and sustainability. Boris Worm's (2024) research over the last 12 years has focused on conserving and managing shark populations as top predators to help restore marine

ecosystems. His most recent study, published in January 2024 (Worm et al., 2024), included shocking shark mortality figures, and threatened shark species.

Further research by Pacoureau et al. (2021) reinforces the need to create sustainable fisheries to halt and reverse global shark declines and supports my capstone question. Both the aforementioned studies were essential in reaffirming why shark conservation is so critical at this time and the need to include this topic in school curricula. Two decades ago, the Ocean Literacy Principles and the foundation of the definition of ocean literacy were designed. With the advancement of technology and social media, further research (McKinley et al., 2023) has proposed adding four new dimensions to reflect today's human–ocean relationship more accurately. These dimensions also supported this capstone question. For example, the trust and transparency dimensions focus on the need for trustworthy ocean information through digital means such as websites, blogs, and social media, including the provision of reliable information about sharks and their behavior, often based on fiction.

The new connections I have contributed to the literature are linked to the topics of ocean–centered governance and the Law of the Sea, both highlighting the fact that the ocean is a living and legal entity. The five proposed applied principles refer to the ocean's ecological needs and interests. For example, the ocean protection principle clearly states that humankind has a collective duty to protect and conserve the ocean and its biodiversity, including that of top predators such as sharks. Now, with the support of the UN Ocean Decade program, Ocean Literacy With All (OLWA), ocean literacy is shifting to support and advance approaches through international research and activities developed by and for diverse stakeholders, including projects from within networks and

communities and with local and international partnerships forming ocean–literate societies.

Implications

The practical implications of the capstone project, *Teachers4Sharks*, a bilingual and interactive blog, provides elementary educators to gain easy and regular access to credible information and resources about ocean literacy and shark science and conservation. Ocean literacy is an interdisciplinary topic by nature, and the project's objective is for all elementary educators to be informed is to use this information as widely as possible in their projects and curricula. The project also intends to contribute to making ocean literacy more accessible and inclusive. Raising awareness about sharks, and their important role as apex predators in marine ecosystems, also necessitates behavioral and attitudinal change. A network of educators is also envisioned to share ideas, information and to foster a culture of inclusion where diversity and inclusion are valued and promoted. Most sharks are portrayed in negative ways by mass media especially in movies but more recently in some video games. There is an urgent need to demystify the myth that all sharks are dangerous bloodthirsty monsters who attack humans. The human—ocean aspect is also important to highlight in subsequent research, with more research needed on children's perceptions and knowledge of sharks.

Limitations

Creating this bilingual interactive blog as the final capstone project proved to be a genuinely educational experience in which I encountered no major unexpected occurrences. A minor issue I did encounter was the need to purchase an upgraded version

of the free blogging platform I chose. This was necessary to give full access to some interactive tools needed to customize my online template. This blog is cost-free and aims to be inclusive, yet specific limitations regarding access and equity exist beyond my immediate control. The fact that the blog is accessible only on electronic devices makes it automatically part of the digital divide or a new form of social inequality due to the unequal access to new forms of information communications.

The digital divide varies depending on the country educators live in and their geographical location. This disparity between access to technology, as well as, variations in both the quality and reliability of internet connections, also needs to be considered. These forms of digital divide are clearly limitations for this project. Solutions to this issue include infrastructure development supporting public Wi–Fi hotspots and provision of affordable digital devices can all help to highlight and solve the digital divide issue.

Future Projects and Recommendations

The interactive blog *Sharks4Teachers,* aimed at elementary formal and informal educators, was created to raise awareness about ocean literacy, the significant role sharks play in marine ecosystems, and the need to promote specific changes in behavior toward sharks. The final stage of the *Teachers4Sharks* blog includes uploading the content to the SEI website in September 2024, at the beginning of the 2024/25 academic school year. Educators will, therefore, become informed about SEI, the blog itself, and the objectives of the *Teacher4Sharks* network. Being part of the network will allow educators to communicate with other educators and include shark science and conservation information within their classes or as a cross-curricular topic. All elementary educators from national and international schools who, for example, have already participated in

SEI events, including presentations, workshops, and beach cleanups, will also be invited to become part of the *Teachers4Sharks* network. Here, they can obtain and exchange information, discuss various related issues, as well as cooperate on common projects regarding shark science and conservation.

A second phase includes expansion of the blog to include secondary school teachers, inviting them to use ocean literacy, shark science, and shark conservation not only in their science classes but also in cross–curricular projects that adopt a more critical ocean literacy approach to increase social well-being, and humanizing the ocean narrative (UNESCO-IOC, 2022). Continuing to advance critical ocean literacy from both the research and grassroots perspectives as a concept, tool, or practice relevant to all areas of human–ocean relations is a key and ongoing requirement during the UN Ocean Decade. Future projects must expand their audiences beyond traditional educational settings and make further direct connections. For example, people working directly with the ocean, such as fishers, seafarers, and those employed in blue careers, could share their local knowledge and understanding of the ocean's properties and life. Coastal communities also possess rich local and traditional knowledge, which could provide for cooperation or partnership opportunities. In this way, formal and informal educators and their students can become ocean-literate and better understand the critical role of sharks in marine ecosystems by studying the work, habits, and lifestyles of these communities.

Once the *Teachers4Sharks* blog and network of active educators are both well established on both a national and a European level, future expansion plans include creating an international network of educators. In the first phase, a pilot project envisions inviting educators and schools from six Portuguese–speaking coastal countries, such as

Brazil, Cape Verde, Angola, and Mozambique, to participate in sharing information about shark science and conservation and working in respect of local needs, and entering a new phase, involving a more critical approach toward ocean literacy. Based on these findings, my recommendations are to continue to promote ocean literacy making it as inclusive and accessible as possible within all communities. This includes being informed by and making use of the UN Ocean Decade's educational resources, as well as digital tools, and technology, and educating the educators with accurate and credible information about shark science and conservation. After two decades of an ocean literacy era based on research and development, we have now reached a stage characterized by more critical approach to ocean literacy (UNESCO-IOC, 2022), one which considers the human—ocean relationship more deeply through the eyes of different communities, and building networks to promote multiple forms of shared knowledge and understanding. By way of supporting this, UNESCO and the Ocean Decade have together proposed an open, flexible, and critically informed ocean literacy paradigm for the well-being of both human and marine life, including sharks, and the environment. Future similar or related research projects to address ocean literacy and the need for shark science and conservation in schools are welcome. These include addressing current knowledge research gaps in ocean literacy; finding the best methods to measure the impact of ocean literacy initiatives and the extent of any behavior change; understanding how to effectively use ocean literacy together with society and politics to inform cross-cutting policy and sustainable ocean use; developing methods of ocean literacy that are both inclusive and accessible; and expanding ocean literacy research beyond Western and

developed countries. Lastly, future research should explore how ocean literacy activities can achieve ocean justice and blue equity (UNESCO-IOC, 2022).

Conclusion

In summary, the capstone process was an enriching and exciting experience as a researcher, writer, and learner. After two decades, the focus of researchers and educators on ocean literacy is now moving from the research and formal education setting to promoting ocean-literate societies through a more critically informed lens and context–specific initiatives. The UN Ocean Decade has presented many opportunities and resources to advance ocean literacy as a concept and, as the research shows, as a tool or practice relevant to human—ocean relations, that can benefit the ocean in several ways: from adding biophysical, health, cultural, social, and economic values to integrating indigenous and local knowledge, all of which are locally and globally connected.

Almost all the literature I researched proved to be necessary in reinforcing the interlinking of the major topics regarding ocean literacy, shark science, and conservation. The two literature sources that influenced and helped shape this question were first, related to students' knowledge and perceptions around sharks, and second, elementary educators' views about teaching marine issues, asking whether ocean literacy can assist teachers in better understanding sharks as top predators, and their role in marine ecosystems. Other research sources that proved to be necessary include ocean-centered governance model to provide a more inclusive approach to ocean science and sustainability; recent studies about the conservation and management of shark populations as top predators, and the need to create sustainable fishing to stop and reverse global shark declines; a proposal to add four further dimensions to the current ocean

literacy principles to better reflect a more technologically oriented society and a change in the human—ocean relationship.

The practical implications of this project are, first, to support the emerging human—ocean relations and inform elementary teachers of all subjects about shark science and conservation, and providing resources to encourage critical ocean and shark literacy into cross—curricular projects. Second, it serves to promote a change in behavior towards sharks, which are so often misrepresented by mass media. One explicit limitation of this blog, besides needing to be prepared financially when creating the template, is the fact it is only accessible via technology. This clearly limits the access to the blog in schools with fewer resources and electronic devices. Ultimately, such limitations become part of the digital divide issue, and government policies, corporate responsibilities, and infrastructure development are urgently needed to address and solve these ongoing issues.

Suggested future projects include inviting secondary school teachers to join the *Teachers4Sharks* network and incorporate a more critical approach to advancing human—ocean relations, in addition to stimulating innovation, increasing knowledge, and enhancing understanding of the ocean's importance for sustainable development and sustainable use of ocean resources within the blue economy. After establishing a solid and successful local and national network of educators interested in collaboration and promoting ocean literacy, shark science, and shark conservation, the project envisions expansion as a pilot project to coastal communities in other Portuguese-speaking countries.

Based on the findings, other recommendations for the future include continuing to follow the UN Ocean Decade's initiatives and publications closely, as well as addressing current

ocean literacy gaps. These include methods to measure the impact of ocean literacy initiatives, assessing children's knowledge and perceptions of sharks, and supporting educators with ocean literacy and shark science resources and professional development pathways. As well as addressing current ocean literacy gaps. These include methods to measure the impact of ocean literacy initiatives. Assessing children's knowledge and perception of sharks and supporting formal and informal educators with ocean literacy and shark science resources and professional development pathways.

In conclusion, I believe my research has successfully answered the question of how ocean literacy can enable elementary teachers to understand sharks better and their essential role in marine ecosystems. Two decades ago, the need for ocean literacy in US school curricula was first addressed. Today, with the assistance of the UN Ocean Decade, ocean literacy has advanced to become an important concept worldwide. Ultimately, there is no one way to be ocean literate; ocean literacy is, however, experiencing an exciting and interesting turning point toward more meaningful long-term collaboration, active participation and discussion, holistic embracing of multiple forms of knowledge and values, and prioritizing diversity, equity, and inclusion.

By creating the interactive bilingual *Teachers4Shark* blog*,* I have also achieved the original purpose for educators to not only become more ocean literate but also gain a better and deeper understanding of shark science and shark conservation. This blog aims to support formal and non-formal elementary educators with information and resources about sharks and ocean literacy into their classroom curricula and create a support network. Lastly, this blog hopes to ultimately not only inform and educate about shark science and shark conservation, but ultimately change people's behaviors and attitudes

toward sharks. Sharks are not the bloodthirsty monsters of pure fiction, on the contrary, sharks as apex predators are crucial for a healthy ocean and also planet. Ocean literacy, through education, can inform us about the shark's important role within those marine ecosystems that are so intrinsically linked to our own lives—on land and at sea.

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Appendix A

Ocean-Centered Principles to Guide Ocean Governance Transformation

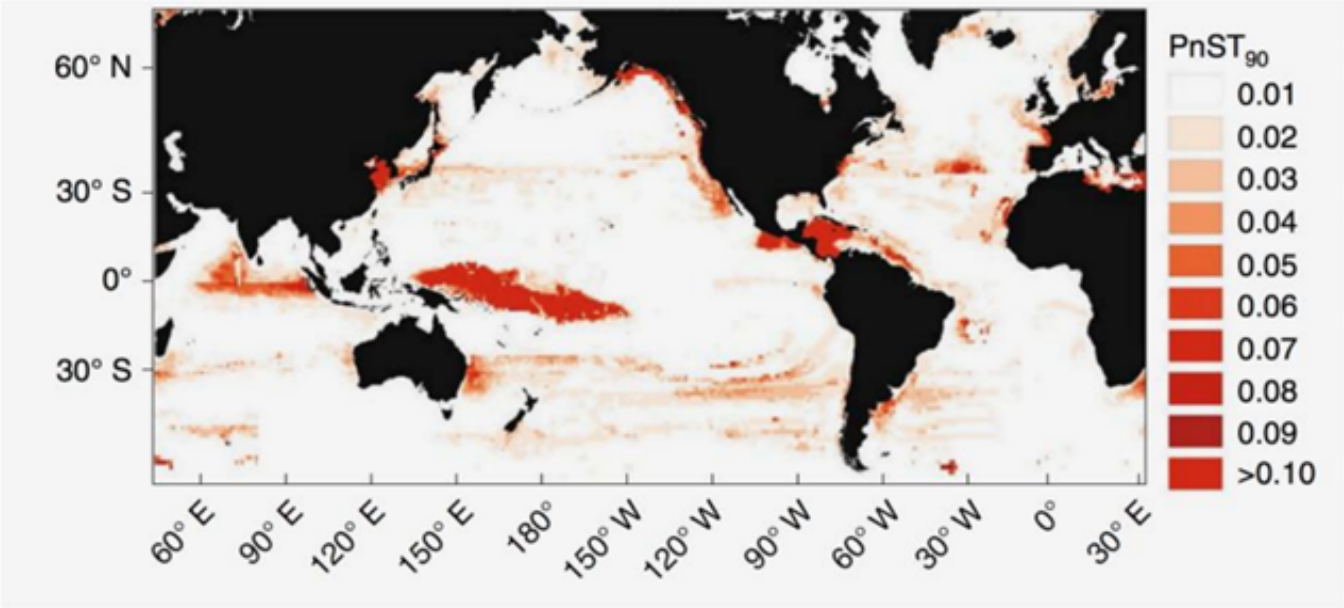
Source: [Living in relationship with the Ocean to transform governance in the UN Ocean Decade, | PLOS Biology]

Fig 1. Ocean-centered principles to guide Ocean governance transformation. Interconnected relationships between Ocean-centered governance principles of justice, data sovereignty, rights, protection, and relationality rippling out from the key understanding that the Ocean is living. Transformation in Ocean governance requires action across all 5 principles. Created by Rachel Bustamante via Canva.com.

https://doi.org/10.1371/journal.pbio.3001828.g001

Appendix B

Proportion of Species Beyond Their 90% Species Thermal Range - PnST90 (Source: Smale et al., 2019.)



Proportion of species beyond their 90% species thermal range – PnST90 (Smale et al, 2019).

Appendix C

Summary of Key Enabling Factors for Successful Ocean Literacy

Source: UNESCO-IOC, State-of- the-Art of Ocean Literacy, p. 19.

https://unesdoc.unesco.org/ark:/48223/pf0000382663