Systems Approach: A Shortcut to the Ocean We Want

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ABSTRACT

The ocean is a unique system connecting ecological, economic, social, and cultural components, through which goods and services regulate the planetary condition and support the development of mankind. However, its increasing use has followed the exponential growth of the global economic system, outpacing humanity's ability to develop the knowledge necessary to establish a basis for its proper use. Hence, there is an added perception that our necessary knowledge about the functioning of the ocean for its appropriate planning and management, advances at a slow pace, with which the ocean would be losing quality and sustainability. Systemic views of the ocean tend to highlight dominant components and processes instead of structural details, establishing a quality shortcut to the knowledge where society can understand current and future ocean conditions. To achieve the desired ocean health and sustainability, we propose the formation of a base of knowledge of the marine and coastal environments, capable of supporting best practices and policies for planning and management. We drew from the interdisciplinary research developed by the Brazilian research group "Ecosystem-Based Marine and Coastal Management (Eco-MCM)," which has been developing projects based on three fundamental steps: (1) systemic analysis of the marine and coastal environments, highlighting their ecosystems, ecosystem services, social and economic benefits produced by the services and the stakeholders benefited; (2) modeling of the studied systems, and (3) propositional phase to incorporate models to support the practices and policies for their planning, management, and governance. As such, they are aligned with the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) challenges and outcomes.

Descriptors: Global Ocean System, Systems approach, Eco-MCM, Ocean policy, Decade of Ocean Science.

SETTING THE SCENE

There are several ways to analyze or understand the ocean. It is a dominant feature covering two-thirds of the Earth's surface. It can also be viewed as a large environmental space composed of multiple physical (abiotic), biological (a great diversity of living beings), and socioeconomic components, the latter characterized by human activities that take place in it or depend on its resources (Inniss and Simcock., 2017).

This macro division into its main components reflects the endless advance in knowledge through a gradual process of identification, registration, and classification of an ever-increasing number of elements from areas that, once combined, define the ocean (Vallega, 2002). Additionally, given its dimension and meaning, the ocean is also defined or understood, historically, in ways that are not objective, but instead personal, artistic, poetic, or even religious and mystical. A broad way of defining and understanding the Earth's "oceans, seas, coasts, and islands" is through a systemic vision that we define as a "Global Oceanic System-GOS", which integrates and connects various marine spaces and the ocean as an organized unit.

Like other systems, the ocean has limits, is composed of several elements (its structure) and processes that interconnect them (its dynamics), and depends on energy sources for its functionality and sustainability. Additionally, the GOS is influenced by and influences other components of the planetary (and even extra-planetary) system when it establishes relationships beyond its limits. In a simplified and assembled expression, the ocean can be understood as an environmental system composed of four macro-components - ecological, physical, economic, and social (including political and cultural subsystems) - that interact with each other and with other systems permanently (Österblom et al., 2016). In general, the GOS depends on or is influenced by some dominant forms of energy, such as solar, gravitational, geothermal energy, or energies from the influence of anthropic uses, as the use of fossil fuels, such as oil and coal. Such energy sources, processed in their functional structure, generate a multitude of goods and benefits of high environmental (ecological), social, and economic interest (UN Environment, 2019).

Based on our perception and consideration of the ocean as a Global Ocean System (GOS), this article explores this systemic approach and how to apply it to considerations on sustainability and possible actions involving its planning and management, under the Decade of the Ocean. Likewise, we sought to explore the outstanding functional aspects of the ocean, expressed by the main ecosystem services it offers and its relationship of dependence of ecosystem services with The United Nations Sustainable Development Goals (UN SDGs) (UN, 2016) and, ultimately, with the main outcomes expected from of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) (IOC-Unesco, 2018). As an example of this approach, reference is made to several projects developed by the Research Group "Ecosystem-Based Marine and Coastal Management (Eco-MCM)", with operations concentrated on the southern Brazilian coast. The methodical process involved two primary aspects, a review of literature on the topic and the performance of expert opinion dynamics (Krueger., 2012; Martin et al., 2012; Nordlund et al., 2016; Asmus et al., 2018), using the experience of the authors in the Eco-MCM group in recent years. This is a hypothetical-deductive process, whereby the scientist, through careful observation, skillful anticipation, and scientific intuition, develops a set of postulates regarding the phenomena of interest (Kaplan, 1972).

For the expert opinion dynamics procedure, the Eco-MCM Research Group performed six workshops during the first half of 2021. The dynamics were critical in order to consensually conceive relationship schemes between Ecosystem Services, SDGs, and expected outcomes from the Decade of the Ocean, (Tables 1, 2 and 3) that provided the basis for the elaboration of a Sankey diagram (Schmidt, 2008) (Figure 1). Workshop participants included the authors of this article and scientists from their collaboration networks. The Ecosystem Services classification observed the Millennium Ecosystem Assessment (MEA, 2003) and publications of De Groot et al. (2002), De Groot et al. (2010), and Díaz et al. (2018).

THE GLOBAL OCEAN SYSTEM - GOS

The oceanic system generates a series of goods and services capable of producing countless economic and social benefits to humanity, in addition to benefits to the planet's ecology (Folke, 2013; Sunagawa et al., 2020), through its structure and functioning . Such services can be considered "oceanic services," "systemic services," or, more specifically, "ecosystem services (ES)," since the ocean is a large socio-ecological system (Berkes and Folke, 1994; Berkes and Turner 2006) or ecosystem (Odum 1953; Odum; 1983; Golley, 2019). Ecosystem services have been defined as functions generated by ecosystems that provide social benefits and are often classified as provision services, regulatory services, support services, and cultural services (Costanza et al., 1997; De Groot et al., 2002; MEA, 2005; Díaz et al., 2018). In the GOS, this classification is visibly represented by a series of typical services. In the oceanic system, provision services are represented by the ability to provide energy resources (fossil fuels such as oil and gas, wave energy, tides, winds, among others) (Pelc and Fujita, 2002; Inman, 2009; Gray, 2012), mineral resources and biological resources in the form, for example, of fishing stocks, and chemical and biochemical resources, with a wide application as raw materials (Worm et al., 2009; Gray, 2012; Petersen, 2015; Gajaria et al., 2017). Similarly, the GOS provides important regulatory services. For example, we can consider the fundamental role of the ocean as a regulator of planetary climate at various time and space scales, its influence on atmospheric composition, its modulating role on the shape of continents, and its influence on and regulation of the macro distribution of a considerable number of biological species (Heinze et al., 2015; Stock et al., 2019).

Table 1. Global Oceanic Ecosystem Services (GOES) and the conceived relationship with the Sustainable Development Goals (SDGs).

System	Classification	GOES	SDGs
GOS	**Support**	basis for biodiversity	14
		nutrient cycling	14;6
		space for activities (fishing, aquaculture, energy production, communication cables, etc.)	1;2;8;9
		navigability	8;9
	Provision	biomass production (phytoplankton, zooplankton, fish, etc)	1;14
		ocean renewable energy sources (energy from wind, waves, and tide)	7;9
		chemical, biological, and biochemical resources supply	3;9
		mineral resources supply	9
	Regulation	climate regulation	1;2;6;11;13;14;15
		atmospheric regulation	3;13;14;15
		water cycle regulation	1;2;3;6;13;14;15
		dilution and purification of effluents	3;6;14
		carbon sequestration	13;14;15
		continent modulator	15
		socioeconomic regulation	1;8
	Cultural	scenario generation	
		recreation areas	
		educational/scientific purposes	4
		interests and values (cultural, religious, etc.)	
		cultural livelihood reproduction	4

Sustainable Development Goals (SDGs): 1. No Poverty; 2. Zero Hunger; Good Health and Well-Being; 4. Quality Education; 5. Gender Equality; 6. Clean Water and Sanitation; 7. Affordable and Clean Energy; 8. Decent Work and Economic Growth; 9. Industry, Innovation, and Infrastructure; 10. Reduced Inequalities; 11. Sustainable Cities and Communities; 12. Responsible Consumption and Production; 13. Climate Action; 14. Life Below Water; 15. Life on Land; 16. Peace, Justice and Strong Institutions; 17. Partnerships for the Goals.

Table 2. Global Oceanic Ecosystem Services (GOES) definition

Classification	GOES	Definition
Support	Basis for Biodiversity	Primary and secondary production, and vital space that increments the oceanic-coastal trophic levels.
	Nutrient Cycling	Nutrients movement between and within biotic and abiotic components, with conversions between forms (gaseous, mineral, inorganic and organic) mediated by oceanic-coastal systems.
	Space for activities (fishing, aquaculture, energy production, communication cables, etc).	Adequate physical space for the development of socio-economic activities.
	Navigability	Waterway system connectivity, essential to ensure flow as well as reduce travel time and related transaction costs.
Provision	biomass production (phytoplankton, zooplankton, fish, etc)	Elevated plant, animal, and debris biomass production, guaranteeing the food supply and nutrients necessary to fish stocks. The biomass also promotes conditions for food cultivation, harvesting, hunting, or fishing.
	ocean renewable energy sources (energy from wind, waves, and tide)	Oceanic-coastal system energy sources such as biomass, tidal, and wind power.
	chemical, biological, and biochemical resources supply	Chemical elements and organisms with therapeutic potential, which are used in traditional and popular medicine and the development of pharmaceuticals. In the same way, genes and genetic information are used by the biotechnology industry and in the reproduction of species and food production.
	mineral resources supply	Rock and minerals variety that can be extracted, providing one or more socioeconomically useful materials, such as sand used in beach nourishment.
Regulation	climate regulation	The ocean system influences the local and global climate. Through the interaction with the atmosphere and ocean currents, it distributes heat across the globe.
	atmospheric regulation	Maintenance of the atmospheric components and their chemical concentrations; wind and air masses generation.
	water cycle regulation	Balance of coastal watersheds, contribution to rainwater, water circulation.
	dilution and purification of effluents	Filtration, dilution, and decomposition of effluents and toxic substances.
	carbon sequestration	Removal of atmospheric carbon dioxide and storage of carbon in different components effectively.
	continent modulator	Maintenance of sedimentary budget.
	socioeconomic regulation	Control effect over social and economic processes.

Table 3. Expected Ocean Decade outcomes and related Sustainable Development Goals (SDGs).

Expected Ocean Decade outcomes	SDGs
A clean ocean	6;7;11;17
A healthy and resilient ocean	6;13;14
A predicted ocean	4;9
A safe ocean	4;13;17
A sustainably harvested and productive ocean	7;12;14;17
A transparent and accessible ocean	4;5;10;16;17
An inspiring and engaging ocean	4;10;16;17

With respect to the supply of support services, two aspects can be viewed as dominant in the ocean. The first concerns the conception of support service as "support for another type of service." An example of this would be the support that the aquatic structure provides for enormous photosynthetic biomass (algae and other aquatic plants) to locate nutrients and support in a photic zone and generate the primary organic production of the ocean (Pauly and Christensen, 1995; Holmlund and Hammer 1999).
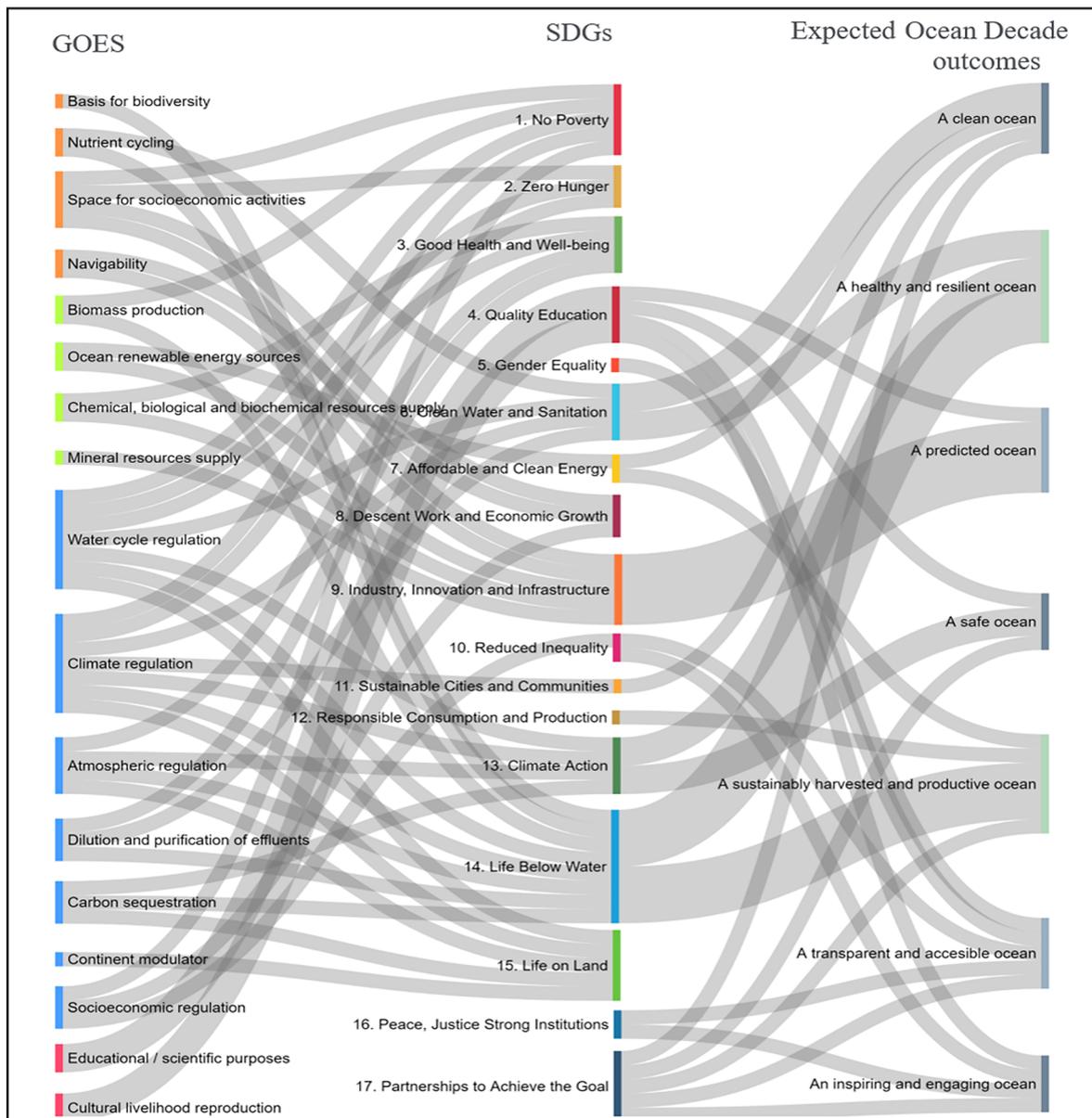

Figure 1. Sankey diagram of conceived relations between GOES, SDGs, and Expected Ocean Decade Outcomes.

The second refers to the support service as the physical space provided by the ecosystem to carry out an action or activity of interest. In this case, an example would be the support of the ocean space for activities such as navigation or communication facilities (submarine cables), energy production (oil exploration platforms, wind generators, etc.), or the cultivation of marine organisms for consumption. Finally, the oceanic system generates numerous cultural services through the seascape and its associated effects (sensations, appreciation, respect, among others) and its historical, cultural, or spiritual meaning. Regarding tourist activity ("tourist trade"), the scenic attractiveness of the ocean – a cultural service – is perhaps the most important element for its development, along with other associations such as the presence of coral reefs, whale migration zones, and the predominance of waves for sporting activities (Rees et al., 2010; Garcia Rodrigues et al., 2017).

A fact to be highlighted when considering the Global Oceanic System is what we call its "ultimate relationship" with Humanity. In this sense, GOS is not simply a system capable of generating various services of social and economic interest, but instead a system that provides goods, services, products, and spaces essential for the sustainability and survival of human life (and many other species). Without the productive role of the ocean, represented by the generation of an incredible amount of food bases (plant and animal proteins) or its role in regulating the climate or atmospheric composition, life on Earth would be either unfeasible, reduced to a minimum, or established in extreme conditions under high environmental stress. Based on its role and global influence, it would not be an exaggeration to consider "Support for the life of the Earth" as the central ocean support service or its "master ecosystem service." In other words, the ocean is vital for humanity, which depends on it for global sustainability (Ryabinin et al., 2019).

When we relate the functionality of the GOS to the vital and socioeconomic aspects of humanity, a relationship emerges that expresses fundamental aspects of social well-being: the relationship between the health of the ocean and the desired Sustainable Development (UN General Assembly, 2017).

In this sense, it is important to note the, perhaps, better representation of the systemic condition of global sustainability, ratified by the international community through the establishment of the Sustainable Development Agenda for 2030 (UN General Assembly, 2015), legitimized by the United Nations in September 2015, of which Brazil became a signatory and incorporated the 17 Sustainable Development Goals (SDGs) into its national agenda. Standing out among them is the conservation and sustainable use of the oceans, seas, and marine resources through Objective n° 14 - Life in Water. Following that, the international community adopted a consensus on the need to strengthen governance mechanisms for these environments. In this context, in December 2017, the United Nations (UN) proclaimed the Decade of Ocean Science for Sustainable Development (2021–2030).

There are different ways to conceive and use the SDGs. As a rule, they can be taken as indicators of a desired situation, embodying significant aspects of continuity, adequacy, dignity, and justice applied to the ecological, social, and economic spheres of the planet (Campagnolo et al., 2018; Clark et al., 2018; Huan et al., 2021). In short, they could be taken as indicators of a desired and necessary scenario for the continuation of human development under appropriate conditions. The proposed systemic approach is related to the 2030 Agenda, which ultimately encompasses the SDGs. In the context of their agendas and scopes, the SDGs are related. For example, SDG 14 (life in the water) dialogues directly with SDG 6 (drinking water and sanitation). This relationship occurs, considering that without sanitation actions, the condition of coastal and marine spaces would be modified and impacted, altering the quality of life, since without drinking water there is no adequate development of society (UN General Assembly, 2015). SDG 8 (decent work and economic growth) depends in part on the condition of the ocean system. It is noted that many families, communities, and social actors depend directly on the ocean and coastal marine environments for their basic food and income needs. Similarly , there are SDG 10 (reduction of inequalities) and SDG 11 (sustainable cities and communities). The sustainability of the ocean also reflects health, life, and socio-environmental relations in the continental sector.

A healthy ocean will provide benefits, such as those related to fishing resources, one of the most common subsistence activities for marine-coastal communities (Lubchenco and Petes, 2010).

While large portions of traditional fishing and extractive peoples and communities depend directly on these ecosystems as a primary source of subsistence (food and income) (Castello, 2010; Kalikoski and Vasconcellos, 2013; Costa and Asmus, 2018), a series of large socioeconomic activities coexist and develop, often exerting high pressures on these traditional spaces (Asmus et al., 2018; Costa and Asmus, 2018; Nicolodi et al., 2018; Stori, et al., 2019). The perception of the dependence of traditional peoples and communities on ecosystem services associated with the oceanic system approximates SDG 12 (consumption and sustainable production), which highlights the need for changes in the forms of consumption and production, given that these groups depend on fishing and extraction. Among these goals, SDG 12, ("to halve the food waste per capita worldwide"), brings us to how the current fishing industry is often configured, which not only is out of step with sustainability, but often wastes the capture due to errors inadequate storage knowledge (FAO, 2014).

Considering that many of the environmental, social, and economic relations depend in some way on the sustainability of the oceans, it would seem that a cluster of SDGs can also be conceived and structured as an "SDG system" that would offer a hierarchical organization according to its characteristic or region in which it appears. In this cluster of oceanic influence, the SDGs 8, 10, 11, 12, 14 and possibly others such as 2 (zero hunger and sustainable agriculture) and 1 (poverty eradication) would also be considered. SDG 13 (action against global climate change) also has an important relationship with the oceanic-coastal system. The relevance of the oceans in the climate balance is understood and unquestioned. Global climate change already significantly affects the promotion of life (continent and ocean), both biologically through the reduction of species and alteration of ecological niches, as well as through social and human organizations, as observed through the displacement of communities from coastal zones, treated as "climate refugees" (Puthucherril, 2012; UNHCR, 2015). Similarly, SDG 15 (terrestrial life) and the macro relationships and connectivity of terrestrial (continental) systems with the oceanic-coastal system (SDG 14 - life in water), are components integrated into this cluster.

Finally, SDG 17 involves partnerships and the means of implementation at all levels (individual, collective, institutional, governmental). International partnerships have been fundamental to the implementation of the Decade of the Ocean (2021-2030). Thus, in the context of Agenda 2030, partnerships are always encouraged, from planning, through monitoring, and execution. The exchanges between social organizations and government agencies promoted by the Decade, or even between private institutions, promote and favor the implementation of actions and strategies, advancing policies for the ocean's sustainable development.

On the other hand, SDGs can be considered standards of necessary arrangements so that their expression (or indication) is ultimately achieved. In this case, we highlight the relationship between the fundamental role of the ocean, through the multiple ecosystem services it generates, and the condition advocated by the Sustainable Development Goals. It is natural to assume that there is a total or partial dependence on oceanic ecosystem services to achieve the SDGs. This assumption becomes even more expressive when made within the scope of the Decade of the Ocean, that is just beginning. Table 1 presents perceived direct dependency relationships between SDGs and the main global oceanic ecosystem services (GOES).

Simply put, the establishment of the SDGs depends on the maintenance of the GOES and on existing social contexts and structures for the development of policies, strategies, and actions that promote changes for a healthier ocean and more sustainable future. GOES guarantee basic spaces, processes, and resources. SDGs like 5 (gender equality), 10 (reducing inequalities), 16 (Peace, Justice, and Effective Institutions), and 17 (Partnerships and Means of Implementation) are not directly dependent on any GOES but are indirectly linked to all. They meet principles that should be observed in the use of these spaces and processes, potentially depending on participatory and inclusive governance (Wisz et al., 2020).

The development of systemic and integrated scientific knowledge, together with other types of knowledge and information on the structure and functioning of the ocean and coastal systems, must recognize the main interactions, ecosystem services, and social benefits, as well as their social and environmental impacts, and resulting problems.

It is fundamental to support the decision-making of the governance of these spaces (Costa and Asmus, 2020). This statement ties with the discursive and methodological proposal established for the Decade of Ocean Science for Sustainable Development (2021–2030), in which the importance of the relationship between scientists and different actors (civil society, decision-makers, businessmen, and local citizens) is recognized in the co-production of knowledge, as well as in their participation in associated political processes. Such relationships would promote innovation and the dissemination of oceanic science and culture to society, thus strengthening the link and the development of oceanic culture (Visbeck, 2018; Mackenzie et al., 2019; Wisz et al., 2020), promoting sustainability.

By facilitating a paradigm shift in the way knowledge about the oceans is designed and presented, the Decade of the Ocean supports solutions that will contribute to the 2030 Agenda for Sustainable Development (IOC UNESCO, 2020). The process that establishes the Objectives of the Decade of the Ocean, associated with the identification, production, and use of knowledge from the "ocean we have" to the "ocean we want" is highlighted through the proposition of three stages (non-linear and overlapping) in one "Action Plan for the Decade:" i) the identification of knowledge about the oceans necessary for sustainable development; ii) the production of data, information, and knowledge for the development of a global understanding of the oceans, their components, and their interactions; and iii) the use of the knowledge generated and the greater understanding of the oceans for the implementation of solutions aimed at sustainable development. We intend to respond to the ten Ocean Decade challenges understood as the most immediate and urgent to guarantee the sustainability of this Decade of the Ocean. Consequently, each challenge contributes to the achievement of one or more of the seven results expected for this decade (The Ocean Decade Outcomes). Table 3 summarizes our conceived relationship between expected Ocean Decade Outcomes and those SDGs that support them, from a systemic perspective.

To express our proposed logical framework involving relations of influence and dependence between GOES and SDGs, and between Ocean Decade outcomes and SDGs, a Sankey Diagram was elaborated (Figure 1).

This form of diagram is a tool for mapping flows that involve the transfer from an initial stage to subsequent ones, represented by branches (Schmidt, 2008). In our case, there is no expression, nor ranking of importance, nor value between the connections. In fact, they appear as relationships conceived through the exercise of dynamic expert opinion performance, as mentioned in the methodological description of the article. On the left column are the services promoted by GOS, denoted by a colored nodule according to its category (orange for support services, green for provision services, blue for regulation services, and pink for cultural services). The center column represents the SDGs, and on the right are the Ocean Decade outcomes.

Figure 1 reveals two messages in two main scopes, one related to sustainability and the other to integrity. Sustainability refers to development goals (SDGs). More than anything, they establish social and environmental parameters for the maintenance of planetary health or, in an extreme view, for its survival. What is not obvious is the great dependence on the ocean for achieving SDGs and the desired condition of global sustainability. Though common sense values the importance of the ocean for the development of humanity and the preservation of the planet's environmental quality, this importance is generally understood or measured sectorially, taking into account specific elements or conditions such as water quality of a bay or the level of abundance of a given fish stock. The messages treated here go beyond; they present an idea of the ocean as a large environmental system that integrates (the second considered scope) ecosystems capable of generating, through their structures and processes, ecosystem services that make viable the conditions and scenarios proposed by the SDGs. It is, therefore, a relationship of dependence towards sustainability. Although it presents all types of services, it is worth noting, for this perception and classification, the domain of regulating ocean ecosystem services (e.g., regulation of the water cycle, climate regulation, carbon sequestration), in line with the concept of the ocean as a regulating element of the global environmental condition.

Though not specifically considered as conditions for planetary survival, the Ocean Decade Outcomes would represent, in an integrated manner, the socio-environmental condition of the ocean that we want during this decade.

These outcomes undeniably depend on adequate oceanic policies and their implementation by governments, users, and institutions. However, and according to the relations proposed in Figure 1, such policies and implementations refer to the modes of use and occupation of spaces and resources offered by coastal ecosystems, to guarantee the achievement of the conditions recommended by the SDGs and based on the maintenance of ecosystems services generated by them. It is not a trivial task. In Brazil, the very delimitation of ecosystems and obtaining information about them in the oceanic environment has proven difficult (Gandra et al. 2018). On the other hand, the perception of structural or functional units in the oceanic environment from a systemic view (Asmus et al. 2018) may provide a feasible path towards overcoming this difficulty, even in the absence of detailed information on the biological and physical composition of the marine ecosystems.

KEY ISSUES: CURRENT STATUS AND TRENDS IN BRAZIL

In countries of the global South, such as Brazil, urban occupation of oceanic and coastal systems, associated with the existence of their various uses, follows the growing and disordered reproduction of world standards. However, within the scope of the "Brazilian sea economy," these activities, including port facilities and operations, different modes of transport and navigation, shipbuilding, industrial plants, tourism, artisanal and industrial fishing, aquaculture, oil, and gas extraction, among others, present a sequence of synergies and account for more than 19 million direct and indirect jobs across the country (Abdallah, 2016; Carvalho, 2018). On the other hand, as they belong to the same system, these socio-economic uses interact and form conflicts, generating numerous impacts and complex environmental problems at different scales, such as the destruction of important habitats for biodiversity, pollution of water bodies, coastal erosion, overexploitation of fishing species, among others (Asmus et al., 2018, Costa and Asmus, 2018; Nicolodi et al., 2018; Stori et al., 2019), which consequently generate more damage and socio-environmental injustices for "unseen" coastal communities (Santos and Mascarello, 2015; Torres and Giannella, 2020).

Many of the emerging problems facing Brazilian coastal systems have been intensified by the feedback from natural processes after human intervention.

The process of systemic climate change in the global ocean presents itself as an extremely impactful condition on the health of coastal ecosystems, and therefore on the well-being of populations and uses present in these spaces. These are the changes to the average temperature of the global ocean, its acidification, bioinvasions, decreased oxygen levels, among other factors, which have been causing several changes in the functioning patterns and capacities of coastal ecosystems to provide essential goods and services (Halpern et al., 2019; Hodgson and Halpern, 2019; Rudolph et al., 2020; Gerhardinger et al., 2020). Likewise, variations in sea level, changes in precipitation rates, erosion, and consequent coastal floods have changed their configurations and restricted benefits to society (IPCC, 2013; Pecl et al., 2017; Silver et al., 2019). All of these variables, among others, increase coastal vulnerability and the risk of disasters for the communities present, especially those in poverty, and their infrastructure (Arkema et al., 2017; Leal Filho et al., 2018; Asmus et al., 2019; Silver et al., 2019). This situation may worsen, considering the effects of the covid pandemic and its consequences for coastal environments and their socioeconomics (Bennett et al., 2020; Ardusso et al., 2021).

Given this brief panorama, the existence of a bibliography and the constant production of information and technical-scientific knowledge about the different components (ecological, economic, and social) of the Brazilian coastal socio-ecological systems can be plausibly seen. Similarly, and systematically, it recognizes the interactions, synergies, services, and benefits, as well as the conflicts and recurring problems faced (Asmus et al., 2018; Costa and Asmus, 2020).

In the Brazilian scenario, Asmus et al. (2018) highlight the fragmentation and insufficiency of scientific information available for the integrated management of the marine and coastal zones. Furthermore, these tend to reproduce reductionist and sectorized models of modern science, in which specialists seek to develop detailed research on aspects and very specific coastal processes. These authors do not disqualify specialized knowledge. Instead, they emphasize its importance in detailing the components, interactions, and processes (structure and functioning) for the proposal of a systemic model for integrated coastal management that recognizes the complexity of coastal ecosystems and demands different information about their physical, biological, socioeconomic, and institutional components.

The use of the proposed model is broad, varied, and yet quite simple. Its applications range from academic work on identifying and characterizing coastal and marine environments, to environmental port management processes, including the development of Ecological-Economic Zonings (EEZs) at the regional level (Nicolodi et al., 2018) and the Macrodiagnosis of the Zone Coastal at the Union Scale (Nicolodi, 2018). Through its potential applications (and replications) in actions aimed at supporting integrated coastal management (or ecosystem-based coastal management), its use can develop through innovation (Asmus et al., 2018).

In this context, several authors (Forst, 2009; Bavinck *et al.*, 2017; Gerhardinger *et al.*, 2018; Costa and Asmus, 2020; Gonçalves *et al.*, 2021) emphasize the need to adopt a systemic approach to the management of coastal systems which recognizes their diverse components and interactions and which integrates interdisciplinary and transdisciplinary academic research, overcoming the dichotomies present between natural sciences and social sciences, as well as between scientific and traditional knowledge. These authors also address a series of current challenges regarding the use and participation of different types of knowledge (scientific, managerial, lay, and traditional) in the decision-making spheres of coastal governance in Brazil.

SCIENCE AND CAPACITY DEVELOPMENT

Currently, there is a global trend for marine management to be based on a systemic view as a way to become truly integrated and sustainable. The systemic view expressed here is beyond the level of the ecosystem and does not correspond only to EBM and ESs, though based on systemic approaches themselves (Agardy et al., 2011; De Groot et al., 2010). A systemic vision for the knowledge of the ocean we desire involves a holistic conceptual focus on the processes involved in the context of research. This research context may eventually involve socio-ecological and political systems related to the ocean. A systemic view on knowledge production mechanisms tends to highlight dominant components and processes responsible for structuring functions and services, decision making, and ordering of the ocean environment. The focus of systemic research is not the knowledge of structural details or sectoral information, but the establishment of a necessary logical framework that elects and orders significant information about ecological, economic, and social components of a system.

It integrates ecosystem information in the same way it does human and political information associated with sectoral aspects. The expression of information based on the systemic approach conceives the functionality of the ecosystems and services generated as well as the components of political processes. Furthermore, it seeks to aggregate into a single context of research various social and human information to manage conflicting uses. As such, the systemic view establishes a quality shortcut for the desired knowledge, where society can understand the current and future ocean conditions under various dimensions.

Initiatives to advance a systemic view of the ocean and environmental systems that compose them are not rare. However, to strengthen the systemic knowledge of the ocean we still need progress on at least three fronts: (i) systemic-based diagnosis; (ii) management instruments and adaptation based on the systemic knowledge; and (iii) understanding of the governance process under the systemic approach.

Initially, the systemic basic diagnosis involves the problem of classification or compartmentation of ocean systems and, subsequently, the election of indicators of management processes and ecosystem services. The customary classification logic usef for terrestrial systems, which are based on habitat or land use and cover, do not apply here. This obstacle becomes more evident when working with coastal areas, where the compartmentalization of terrestrial and aquatic systems employing one of these two logics does not meet the need for systemic research. We note that this problem is more easily overcome when we link the environmental system to ecosystem services offered by it during classification.

Here we used the interdisciplinary research group "Ecosystem-Based Marine and Coastal Management (Eco-MCM)" as an example of research initiatives that use a systemic approach for projects based on characterization, planning, and management of ocean and coasts in Brazil. Eco-MCM is a team of researchers from different disciplines based in southern Brazil. This group began activities at the Institute of Oceanography of the Federal University of Rio Grande (FURG) in 2015 and has steadily developed studies on management and marine-coastal governance, using experiences in local, regional, and national projects. Likewise, the researchers have been collaborating closely with international institutions, with an emphasis on actions in Spain.

The Eco-MCM has developed and proposed innovative methodologies for the establishment of a systemic base of knowledge of the marine and coastal environments, capable of supporting good practices and policies for their planning and management.

All the research developed by the Eco-MCM Group has pursued a systems approach (Gallagher, 2010) to the classification of aquatic-terrestrial environments and has succeeded in advancing solutions to classification problems in a significant variety of typologies of spatial units, such as river basins (Gianuca, in prep. - Ecosystem modeling as a subsidy for watershed management: the Mirim watershed case - São Gonçalo, RS) (Rovedder, in prep. - River basins environmental zoning to support integrated coastal management: a case study in Southern Brazil), estuaries (Cunha, 2020; Ribeiro, 2015; Bubolz, 2020; Costa and Asmus, 2018), Coastal Lagoons (Ribeiro et al., 2020), Coastal Environments (Prestes, in prep. - The sustainable use of natural resources in coastal zone: environmental protection areas as an instrument for socio-environmental conservation), among others (Pereira, 2018).

Regarding assessment, there is a need to elect indicators that can be used to express the condition of management processes or ecosystem services, as well as of the typology of data that will be linked to these. Establishing a relationship between beneficiary services, conflicts, and risks is not an easy task. Expressing the quality of environmental system processes requires that the researcher supply a database with information from varied, qualitative, and quantitative social, economic, environmental, and traditional knowledge. Similarly, it is challenging to obtain indicators of processes and services related to ecosystems. Designing indicators of political processes or governance diagnoses can be even more difficult. This information is mostly abstract, diffuse, and reliant on the perception of managers and users. In fact, it often does not exist, and effort is required to develop unpublished indicators or to integrate more than one outcome of known models to prospect possible conditions or scenarios. We have some research experiences carried out by the Eco-MCM group that utilizes environmental systems process indicators. Some are designed to assess sustainability (Prestes, in prep.), compatibility of use of ES (Ribeiro et al. 2020), and loss of services (Asmus et al. 2019), which are arranged in evaluation metrics, modeling, and indexes.

In addition, Scherer and Asmus (2021) deal with an assessment of governance processes through criticality indicators to the development and implementation of marine and coastal management in Brazil.

For ocean and coastal management and planning instruments and their adaptation to systemic knowledge, we understand that there is a need to adapt current tools and methodologies to the quality systemic approach. Adapting existing tools to a systemic knowledge basis establishes an opportunity for a planning application, especially with respect to standardized management tools in Brazil. Some examples of these efforts are observed in Cunha (2020), where official water quality indicators used by the National Water Agency were associated with the potential to qualify the supply of ecosystem services in estuary environments. For the same type of environment, Bubolz (2020) adopts a functional classification of Day et al. (1989), which in turn establishes a dynamic limit for an estuary that varies with the energy balance between the sea and continent. In Rovedder (in prep.) and Gianuca (in prep.) the river basin, while the unit of official territorial planning of the National Water Resources Policy, is being studied to establish governance and management on a systemic basis. The approach of significant environmental aspects of NBR ISO 14001: 2004 was also associated with the systemic approach to implementing port environmental management plans (Scherer et al., 2015); (Prestes, in prep.).

The third challenge relates to management and governance processes in the ocean and how systemic basic science can contribute to this matter. A systemic view allows us to qualify and describe components to identify persistent problems in management processes. It is assumed that without a systemic assessment and necessary repairs to the management structure, the implementation of ocean planning policies becomes more difficult. To the extent of this problem, the challenge emerges from establishing analysis methodologies that generate subsidies for integrated and systemic environmental management. Recent work made contributions by discussing the necessary information base and its influence on governance decision-making in Brazilian coastal territory (Costa and Asmus, 2020) and institutional movements in Brazilian coastal management (Costa et al., 2020; Nicolodi et al., 2021). It also elaborated a conceptual model to comprehen-

sively represent the governance of coastal zones, expressing it as a logical and functional system. In Abrahão et al. (2019), the authors sought to understand the dynamics of governance in conservation units through a systemic vision. Other development works seek to understand decision-making processes in the coastal zone (Costa, in prep. - The decision-making path for coastal zone management: governance for implementation) and the organization of the sea and advances in the Marine Spatial Planning (MSP) (Ribeiro, in prep. - Sea Organization: a systemic view of Brazilian Marine Spacial Planning). While new techniques are necessary, the integration of methodologies already known to carry out systemic evaluations is recommended. Sardinha (2020), when evaluating the governance of archaeological heritage in coastal areas, integrated at least three of these methodologies: decalogue (Barragán, 2004), DPSIR (EEA, 1995), and SWOT matrix. All these efforts, in addition to the evident concern with coastal marine governance, attempt to advance the aggregation of systemic basic information in management processes.

Additional information summarizes and integrates the most recent studies from the Eco-MCM

Group mentioned above. This information, with an emphasis on work in preparation, can be observed in: https://cutt.ly/QkE7jl3. The word cloud presented in Figure 2 synthetically represents the main themes addressed by the group in recent productions.

CONSIDERATIONS AND RECOMMENDATIONS: SCIENCE AND POLICY TOGETHER

After the set of premises, examples, and considerations addressed thus far, certain questions seem imperative to the Global Oceanic System (GOS) and its desired sustainability: (1) are there innovative approaches and procedures that allow the necessary knowledge of GOS, capable of supporting the adequate planning and management of its resources and spaces, in a time compatible with its growing use and changes?; (2) are there perspectives for innovative proposals that can significantly contribute to Brazilian marine and coastal policy and governance?; and (3) is scientific-political integration (or innovation-governance) a path for the Brazilian contribution to the Decade of the Ocean or the Ocean that we desire?

Figure 2. Word cloud of key terms addressed by the Eco-MCM group in recent productions.

The systemic approach (or the systemic view) is not new in science. The General Theory of Systems, particularly from von Bertalanffy (1968), has been applied in several branches of knowledge. In ecology, it has been used by many and has become emblematic as Systems Ecology through the school of thought specifically implemented by Howard T. Odum (for example, Odum, 1983), with several applications by this author and collaborators of the systemic approach in the study of marine and coastal environments (Cicin-Sain and Knecht, 1988). The systemic view, therefore, is not new in environmental analysis as eventual support for the planning and management of oceans and coasts. However, it has increased in relevance in terms of Ecosystem-Based Management (EBM) (Agardy et al., 2011) applied to management for the sustainability of marine and coastal systems; EBM applied to marine and coastal management can benefit when integrating with Systems Ecology (Yáñez-Arancibia et al., 2013).

In Brazil, EBM is not integrated with national policies related to marine and coastal management and governance (Costa and Asmus, 2020), and few research groups adopt a systemic basis in environmental characterization, diagnosis, and planning projects as the basis for Coastal Management or Marine Spatial Planning. In this Brazilian context, focused on the sustainability of the oceans and coasts, the systemic line of research and development provided by the Ecosystem-Based Marine and Coastal Management Group (Eco-MCM) is innovative (Question 1). There are elements, commented on the set of works previously mentioned herein, that allow, through a systemic approach, for a pace in the necessary process of sufficiently knowing the ocean environment to achieve sustainability. An example is the perception that the ocean is a set of interconnected ecosystems (or environmental systems) as opposed to the sum of numerous components identified individually. Such systemic perceptions facilitate the necessary classification of the oceanic and coastal space for its eventual planning or definition of types of use, as expected from processes of planning coastal territories or marine spaces. Similarly, the systemic approach strives to highlight the functional processes of marine and coastal ecosystems, with an emphasis on ecosystem services generated by them. Simply considering the ES in certain sites can allow us to infer the definition and classification of the oceanic

ecosystems involved. Finally, the systemic approach naturally achieves the desired integration of the understanding of oceanic elements and their management, since the basic conception of ecosystems integrates, as a functional unit, physical, biological, and socioeconomic elements related to their composition and use.

Question 2 refers to the possibility of a systemic innovative proposal contributing to Brazilian politics and governance and its role in global oceanic sustainability. From a systemic approach, we propose a conceptual diagrammatic scheme focusing on the representation of the main processes and components of the complex "Governance - Decision-Making - Implementation - Coastal Socioecological System" on the Brazilian coast (Figure 3).

In brief, *Decision Making* (Process 1) can be understood as a process that concentrates a series of external and internal interactions guided by the established planning and management system (*Management System*) and by the political-administrative system of *Coastal Governance*. The decision taken leaves the *Coastal Governance* system through an information flow, a guideline, a strategy, an instrument, or a recommendation for a defined action (or lack thereof) and has its *Implementation* in the different components (ecological, economic, and social, among others) of the *Coastal Ecological System*. These components interact through various processes (Processes 2, 3, and 4), deriving services and benefits from the socio-ecological system but also sharing spaces and establishing conflicts, impacts, and problems (as mentioned above). The decision should generally act on these processes, ideally integrating different bases of knowledge and participation. Process 5 appears in the form of feedback, a result of the implementation, capable of generating new decision-making (adaptive management).

However, there is still progress to be made to include a systemic basis (or expression of EBM) in the various instruments that support decision-making, such as the Ecological-Economic Zoning, monitoring programs, and management programs. Invariably, such an change in the design of the instruments would involve the inclusion of functional aspects, to the detriment of merely structural ones. In this sense, the use of the concept of ecosystem services as a value to be preserved can be a prominent component in a new and necessary version of support instruments. As an example, Asmus et al. (2018) suggest ecological-economic

zoning (also applicable to MSP) as "the appropriate use of ecosystems and their services (economic), with the necessary care to maintain these services (ecological)."

The application of this logic in a global oceanic environment again refers to Figure 1, where the primary dependence and influence relations, conceived here, are represented between the main ecosystem services of the global oceanic system (GOES), the Sustainable Development Goals (SDGs), and the Expected Outcomes of the Decade of the Ocean. This is a logical relationship based on a systemic approach, as suggested herein, for the conduct of political proposals for ocean management and governance. By this systemic logic, the challenges of the Decade of the Ocean would be made possible through certain outcomes, recognized as essential in the international arena (Polejack et al., 2021), which, in turn, would depend on the total or partial achievement of some of the global Sustainable Development Goals. They key to this view is the recognition that both the outcomes of the Decade of the Ocean and several of the SDGs are strongly dependent on ecosystem services provided by the ocean, in their different typologies (provision, regulation, support, and cultural). In other words, to achieve the desired global oceanic sustainability, we urgently need knowledge about the ecosystem composition of GOS and its ecosystem services. In the same line of political action plans for the ocean, it is essential to know the health condition of ecosystems and their services and how the different types, locations, and intensities of socioeconomic uses of the ocean affect such ecosystems and services.

In the proposed logical framework, for instance, the outcome "a clean ocean" would predominantly depend on four Sustainable Development Goals: "clean water and sanitation," "affordable and clean energy," "sustainable cities and communities," and "partnership to achieve the goal." On the other hand, these SDGs are dependent on ecosystem services; "clean water and sanitation" is dependent on four ecosystem services offered by the ocean, "nutrient cycling," "water cycle regulation," "climate regulation," and "dilution and purification of effluents." Consistent with this, there is a clear need to identify which ecosystems generate such services in the ocean system, their dominant location, how to maintain their proper functioning, and how to plan their use sustainably. It is important to note that some of the SDGs (16 and 17) are not dependent on ecosystem services because they are characterized as political actions, without a dominant

influence of "ecological" aspects. However, it is also important to acknowledge that these SDGs have a dominant role in some outcomes of the Decade of the Ocean, shared with other "ecological" SDGs. Such recognition refers to the demand for the integration of scientific and political actions by seeking the desired outcomes and maintaining the ecosystem services that support them. As such, the concept of oceanic sustainability would be equivalent to maintaining GOES now and in the future. It is in this logical context that Brazilian research groups could develop their set of projects, with the expectation of generating poles for proposing models of analysis and use of marine and coastal ecosystems and, eventually, a Brazilian contribution to the Decade of the Ocean.

With respect to Question 3, it can be considered that ocean science-oriented decision making has been identified as the key component of international governance of the oceans. This assumption is reproduced in the establishment of the objectives, challenges, and expected results for the Decade of the Ocean. Related to the incorporation of knowledge in national and local governance mechanisms, it is observed that the consideration of the results of scientific research in policy-making processes is far from natural and faces a series of barriers and disconnections. Cooperation between different stakeholders (McKinley and Ballinger, 2018; Schumacher et al., 2018; Buchan and Yates, 2019) for the development of oceanic-coastal research and information in Brazil, for example, is especially complex when there are different levels of interest and infrastructure for participation (Costa and Asmus, 2020). Within the "science and policy / decision-making" interface, it is observed that changes or the incorporation of new approaches (such as those related to sustainability) are often influenced by politics rather than science; the scientific agenda adapts to the opportunities offered by political/administrative management. This contradicts the view of authors who attribute a preponderant role to the communities of specialists in the definition of environmental and management policy agendas. Conversely, the proclamation of a Decade of Ocean Science for Sustainable Development (2021-2030) by the United Nations General Assembly (UN) is a bottom-up movement, predominantly organized by scientists and social actors that expressed extreme concern regarding the condition of the oceans and coastal regions given their increasingly unsustainably exploitation intensity (UNESCO, 2019).

A possible path for a Brazilian contribution to the Decade of the Ocean would be international scientific-political integration (or innovation-governance). Brazil has been promoting a series of activities to achieve the results of the Decade through the work of the Ministry of Science and Technology and Innovations (MCTI) - scientific representative in the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) - integrated with different sectors of the society. This plan was built in a participatory manner since the second half of 2020 through national events and online subnational workshops, a step for each Brazilian region. However, it is necessary to complement national efforts with international cooperation. We identified two barriers and that appear to limit actions in the context of the Decade: coordination failures between countries and national institutions given different priorities and capacities, and communication failures between generators of scientific knowledge and decision-makers. Systemic-based integration between decision-making and implementation of actions, as suggested here, can contribute to overcoming these barriers.

Specifically on the issue of communication, there is an evident need for "translators" or facilitators of communication between science and politics. It is noteworthy that the considered international framework still prioritizes the generation of scientific information rather than communication or improvement of the science-politics interface. Thus, the decade innovates by promoting the dissemination and development of oceanic culture and integration. It is necessary to go deeper to develop the technical-scientific, conceptual, and political basis of this innovative culture. There is an expectation that proposals and visions of a systemic basis for the knowledge, planning, and management of the global oceanic system, as presented herein, become not merely an element of academic advancement but a real contribution towards achieving the Decade's challenges.

FINAL REMARKS

This article proposes an approach to the understanding of the ocean and the systemic way it is considered, studied, represented, so that its use can be planned with a focus on its sustainability. This responds to the instigations derived from the definition of the Decade of the Ocean and efforts to meet the many challenges posed. This is no trivial task, be it from the scientific or political point of view. Neither is the establishment of the necessary global oceanic governance to meet those challenges. Ocean conditions are showing a worrying loss of quality, reflecting an intense, growing, and disordered use of its resources and spaces.

The approach proposed herein starts from a systemic approach that recognizes the ocean as a "Global Oceanic System" (GOS) and considers how to view it as an integrated dynamic system such that it can be fundamentally characterized by its functional pattern. As such, its ecosystem functions and the ecosystem services it generates become a representation not only of its typology but also of its importance to nature and society. The ecosystem approach considered here arguably brings considerably functional aggregation, which simplifies and accelerates the understanding of the GOS, with ways to its sustainable use. A set of initiatives developed by the research and outreach group Eco-MCM, carried out primarily in the southern region of Brazil, was presented as an example of the application of the systemic approach in studies of marine and coastal ecosystems from various perspectives.

By transferring the experience of academic initiatives to the scientific-political scope of the Decade of the Ocean, the systemic proposal on studies of marine and coastal ecosystems can be a proxy for the composition and state of the ocean. But it goes beyond that by establishing a causal chain between the main ecosystem services of the ocean, the objectives of sustainable development, and the outcomes of the Decade of the Ocean.

The successful implementation of decisions is also important for the success of the Decade. These are decisions guided by the interests of various stakeholders, based (to the extent possible) on the best available knowledge, and guided by national and international public policies that define global governance of the ocean. This complexity can be addressed through a systemic approach that couples decision-making and implementation in the socio-ecological space. Again, with such a complex scope of decisions and implementations, the use of reference elements,

such as the ecosystem services of the global ocean or how SDGs are based, can take a representation of value or evaluation of the effectiveness of actions.

It is important to highlight that the conceptual processes discussed herein enabled a series of contributions, already made or in progress, to the analysis and planning of marine and coastal systems. This is a significant factor when considering the potential institutional and governmental cooperation at the South-South level, or as currently considered, at the Global South at Ocean and Coastal Research.

Can the systemic view be a shortcut to the ocean we desire? Everything indicates it can, but the possibilities go further and depend on reaching the challenges of the Decade of the Ocean and on unequivocal institutional and governmental cooperation. These are goals that refer to some SDGs. Understanding that GOS supports life on the planet and thereby provides the ecosystem services necessary to achieve the 15 SDGs considered by the Decade, attention is also paid to the role of society, linked to objective 17 "partnerships and means of implementation," which is in turn the fundamental bridge to achieve 16, "peace, justice and effective institutions."

AUTHOR CONTRIBUTIONS

M.L.A.: Writing - original draft, Conceptualization, Methodology, Investigation, Writing - review & editing.

J.C.C.: Writing - original draft, Conceptualization, Methodology, Investigation, Writing - review & editing.

L.D.P.: Conceptualization, Methodology, Investigation, Writing - review & editing.

G.D.S.: Investigation, Writing - review & editing.

J.G.C.: Investigation, Software, Writing - review & editing.

J.N.A.R.: Investigation, Software, Writing - review & editing.

P.M.F.P.: Investigation, Writing - review & editing.

R.P.B.: Methodology, Investigation.

K.S.G., G.A., J.R., V.C.M.: Investigation.

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