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Ocean science, data, and services for the UN 2030 Sustainable Development Goals

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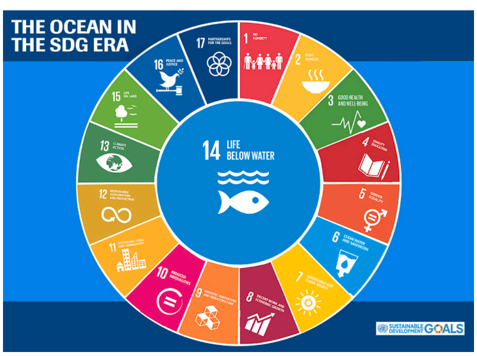
G R A P H I C A L A B S T R A C T

Relating the Sustainable Development Goal (SDG) 14 for Ocean and Life Below Water to the 16 remaining SDGs in the UN 2030 sustainable development agenda. A holistic approach that embraces sustainable Ocean stewardship informed by best available science, data and services to support society and the economy is required to create the 'Future We Want'. The UN Decade of Ocean Science for Sustainable Development is an essential foundation to achieve this objective.



1. Introduction

In 'The outcome statement of the UN's first Ocean Conference (UNOC) titled 'Our ocean, our future: call to action' [1], the world leaders said:

> 'We are mobilized by a strong conviction that our ocean is critical to our shared future and common humanity in all its diversity. As leaders and representatives of our Governments, we are determined to act decisively and urgently, convinced that our collective action will make a meaningful difference to our people, to our planet and to our prosperity. We recognize that our ocean covers three quarters of our planet, connects our populations and markets and forms an important part of our natural and cultural heritage. It supplies nearly half the oxygen we breathe, absorbs over a quarter of the carbon dioxide we produce, plays a vital role in the water cycle and the climate system and is an important source of our planet's biodiversity and of ecosystem services. It contributes to sustainable development and sustainable ocean-based economies, as well as to poverty eradication, food security and nutrition, maritime trade and transportation, decent work and livelihoods.'

The statement further called for an 'integrated, interdisciplinary and cross-sectoral approach' based on the 'best available science' to support sustainable development and provide stewardship of the one Ocean on the blue planet. The UNOC, led by Fiji and Sweden, built on the foundation of another first: A Sustainable Development Goal (SDG) devoted to the Ocean - SDG 14 to 'Conserve and sustainably use the ocean, seas and marine resources for sustainable development'. In 2018, a group of 14 world leaders came together co-chaired by the heads of state of Norway and Palau in the High Level Panel (HLP) for a Sustainable Ocean

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Economy that will present a comprehensive report and action agenda (https://oceanpanel.org/). The elevation of the Ocean to a prominent role in global diplomacy reflects its importance in the Earth system.

Ocean resources, data, science and services are critical to achieving all 17 SDGs in accordance with the three UN pillars of sustainability: environment, society and economy [2]. The SDG targets are far reaching and require a strong science foundation provided by Earth observations and models [3–5]. Decision-makers and other stakeholders now face the challenge of implementing the UN 2030 Agenda [3] and supporting UNOC outcomes while navigating an increasingly wide range of scientific information and variety of data products and services. The 'Essential Ocean Variables' (EOVs), 'Essential Climate Variables' (ECVs), and 'Global Climate Indicators' [6–8] are designed to meet the needs of Ocean communities and stakeholders from citizens to governments and to scientists. Operational services, Ocean (marine) and climate services, rely on EOVs, ECVs and Global Climate Indicator frameworks to provide periodic updates on the state of the climate and Ocean, as well as outlooks, forecasts, projections, and product delivery.

Connecting scientific knowledge and Ocean data products with the pillars for sustainable development remains a challenging task. The motivation for this paper is to underscore the importance of environmental observations (remote sensing and in situ) for state analysis (assimilation), model constrains, and managing the Ocean in a changing climate to support Ocean dependent nations to achieve the SDGs. The UN Decade of Ocean Science for Sustainable Development (2021–2030) [9] provides a timely framework for channeling Ocean science, Ocean observations, data sharing and capacity building activities including Ocean literacy towards support of the Agenda 2030 [3,10] and aims to provide both diagnostics of the situation in the Ocean and point to solutions. This paper highlights the opportunities for Ocean observations to inform SDG reporting and support progress towards meeting the goals and targets by informing ocean stewardship, policies and decisions in accordance with the vision of the UN Ocean Decade: "The Science We Need for the Future We Want". Throughout the paper we use Ocean capitalized, just as one does for Earth. We use Ocean in the singular to reinforce the idea that Earth has one interconnected Ocean, the same convention followed in the title of the Intergovernmental Panel on Climate Change (IPCC) *Special Report on Ocean and Cryosphere in a Changing Climate (SROCC)*. The term sustainable blue economy refers to *'projects and activities that contribute directly to the achievement of SDG14, to conserve and sustainably use the Ocean's resources, and other SDGs, especially those that contribute to good governance of the Ocean'* – a definition which has been adopted from the Declaration of the Sustainable Blue Economy Finance Principles [11] developed under a partnership between the European Commission, the World Wildlife Fund, the Prince of Wales's International Sustainability Unit and the European Investment Bank.

2. The Ocean Climate Nexus

The Ocean-climate nexus and our call for integrated management of the Ocean is a complex web with diverse opportunities, contradictions, mandates and goals in the science-policy 'oceanscape' (Fig. 1). The 2021–2030 UN Decade of Ocean Science for Sustainable Development aspires to overcome the challenges to create a more holistic and integrated approach to managing the shared Ocean resources of the blue planet anchored by decades-long efforts originally codified in Chapter 17 of the 1992 Agenda 21 [12].

Science is recognized as crucial to achieve Ocean health and support marine biodiversity in SDG target 14a: *'Increase scientific knowledge, develop research capacities and transfer marine technology taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular Small Island Developing States (SIDS) and Least Developed Countries (LDCs)'*.

The first UNOC in 2017 addressed the importance of science: *'Dedicate greater resources to marine scientific research, such as interdisciplinary research and sustained ocean and coastal observation, as well as the collection and sharing of data and knowledge, including traditional knowledge, in order to increase our knowledge of the ocean, …to promote decision-making based on the best available science, to encourage scientific and technological innovation, as well as to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries;'* [1].

The complications of Ocean governance described in a separate box in the first chapter of the IPCC SROCC extends to Ocean observations [13]. No high-level international agreement guarantees Ocean data collection nor access despite a proliferation of public and private data

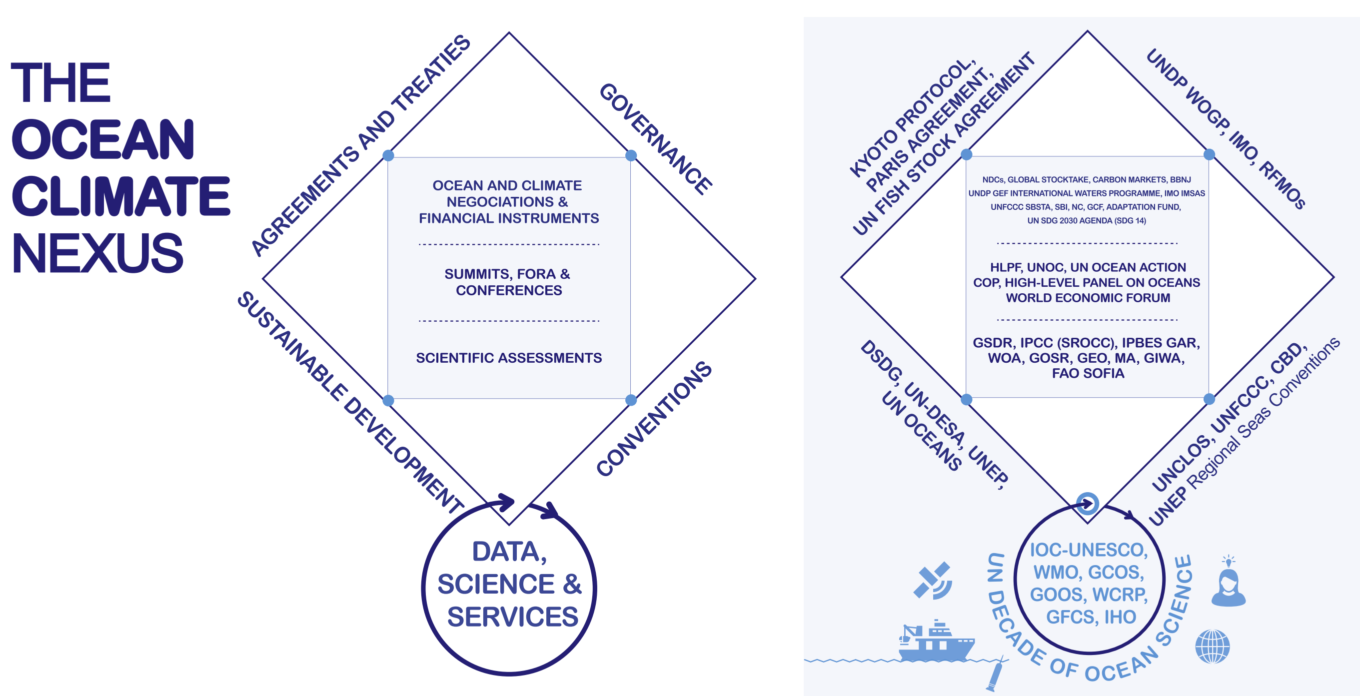

Fig. 1. Linking science and governance at the Ocean Climate Nexus (left panel) illustrated with concrete examples for the international diplomacy oceanscape (right panel). Abbreviations are defined in the acronym table.

collecting mechanisms alliances. Utilization of emerging tools in Ocean science including fisheries, deep sea exploration and exploitation, the physical and biological Ocean and coastal systems depend on the creation or existence of institutions capable of translating observations, modelling, and knowledge into regular "operational Ocean services" for the final users and stakeholders.

Despite the importance of the Ocean as a carbon and heat sink in the climate system [14], the Ocean was mentioned only briefly in article 14 of the United Nations Framework Convention on Climate Change (UNFCCC) original agreement [15–17]: *'(d) Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems; (e) Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, …'* The momentum for including the Ocean in the UNFCCC began to shift with pressure from the SIDS and interested parties [18]. The 2014 SIDS Accelerated Modalities of Action (SAMOA) Pathway emphasized the unique role of the SIDS and the importance of Ocean stewardship [19]. By 2015, the Sendai Framework for Disaster Risk Reduction [20]; the 2030 Agenda for Sustainable Development [3]; and the Paris Agreement on Climate Change signed in December 2015 [21] all included the Ocean, if briefly.

Chile's UNFCCC Blue COP25, held in Madrid in December 2019, has catalyzed attention on the Ocean-climate nexus, connecting SDG 13 and SDG 14, and connecting the Ocean to the UNFCCC with the first ever mention of the Ocean-climate connection in the Conference of the Parties (COP) outcome. The Ocean offers opportunities to face causes and consequences of climate change, globally and locally, calling for a dramatic scaling up of efforts towards ambitious mitigation and adaptation [22–24]. Parties have the opportunity to include Ocean solutions in their revised Nationally Determined Contributions (NDCs), due in 2020 [25,26]. Ocean and climate services will be required to support the implementation of Ocean measures in the new NDCs [27]. The many Ocean meetings scheduled in 2020 have been delayed by the COVID-19 crisis including: marine biodiversity in areas beyond national jurisdiction (BBNJ) negotiations to create a legally binding instrument on the conservation and sustainable use of marine biological diversity [28], the second UNOC, the Our Ocean conference, the UN Biodiversity Conference under the UN Convention on Biological Diversity, and the UNFCCC COP26.

The Global Ocean Observing System (GOOS, goosocean.org) was created on initiative from Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1991. GOOS is a collaborative international network utilizing data collection from ships, Lagrangian and Eulerian buoys, subsurface floats, and the Argo float array [29] together with an information and product management system [9,30]. The Global Climate Observing System (GCOS, gcos.wmo.int) is co-sponsored by World Meteorological Organization (WMO), IOC-UNESCO, United Nations Environment Programme (UNEP), and the International Science Council to ensure that 'climate observations are accurate and sustained, and access to climate data is free and open'. Similarly, the World Climate Research Program (WCRP) addresses climate and Ocean science with an established framework for climate scientists to monitor, simulate and project global climate with unprecedented accuracy, and provide climate information for use in governance, decision-making and in support of a wide range of practical end-user applications [31]. The Coupled Model Intercomparison Project (CMIP), a WCRP product, provides climate model projections to IPCC assessments while the global Coordinated Regional Climate Downscaling Experiment (CORDEX) project coordinates the science and regional climate downscaling climate projections. Building on GCOS and WCRP, the Global Framework for Climate Services (GFCS) provides a mechanism for coordinated actions to enhance the quality, quantity, and delivery of climate services.

Science and services at the Ocean-climate nexus have worked within this network of international coordination to lead the way forward (Fig. 1). The importance of the Ocean to meet societal needs is illustrated by the number of international bodies and policy instruments related to the Ocean (Fig. 1; [13]). The IPCC 1.5 °C and SROCC reports have provided the science to call for immediate action to protect the climate and Ocean systems [14,32]. The recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment Reports (GAR) provide scientific insights into the state of the planet for biodiversity and ecosystem services. Ocean science will continue to be required for sustainable development, a healthy Ocean and a habitable planet Earth. Indigenous local, and cultural knowledge systems need to be interwoven with scientific and technical knowledge systems to provide Ocean and climate services to communities, local and national stakeholders. An interwoven added-value chain for Ocean services is needed in parallel with the GFCS (see section 3).

3. Science, data and services

3.1. Essential variables and indicators

The concept of EOVs is a central element of the framework for Ocean

Table 1

List of GOOS Essential Ocean Variables (EOVs, www.goosocean.org, bold), Ocean relevant GCOS Essential Climate Variables (ECVs, [33]; underlined), variables defined as both EOV and ECV (bold, underlined), and the Ocean relevant Global Climate Indicators [8], the basis for the connection of Ocean information to the SDGs. The EOVs for the next decade are defined by the community white papers of the OceanOb19 conference (https://www.oceanobs19.net/community-white-papers/). GCOS defines the recommended accuracies for EOVs and ECVs. The currently implemented set of GCOS Global Climate Indicators describe essential aspects of climate change: temperature and energy, atmospheric composition, Ocean and water as well as the cryosphere [8,33]. Only the Ocean related indicators are shown in this table. The combination of remote sensing, in situ observations and Ocean re-analyses is critical in calculating the EOVs, the ECVs and the GCOS Global Climate Indicators.

	Physics	Biogeochemistry	Biology/Ecosystems
GOOS Essential Ocean Variable (EOV) GCOS Essential Climate Variable (ECV)	• **Sea State** • **Surface Stress** • **Sea Ice** • **Sea Level** • **Sea Surface Temperature** • **Subsurface Temperature** • **Surface Currents** • **Subsurface Currents** • **Sea Surface** • **Salinity** • **Subsurface Salinity** • **Ocean surface heat flux**	• **Inorganic Carbon** • **Nitrous oxide** • **Nutrients** • **Ocean Colour** • **Oxygen** • **Transient Tracers** • **Particulate matter** • **Stable carbon isotopes** • **Dissolved organic carbon**	• Marine Habitat Properties • Plankton • **Phytoplankton biomass and diversity** • **Zooplankton biomass and diversity** • **Fish abundance and distribution** • **Marine turtles, birds, mammals' abundance and distribution** • **Hard coral cover and composition** • **Seagrass cover and composition** • **Macro algal canopy cover and composition** • **Ocean Sound** • **Microbe biomass and diversity** • **Benthic invertebrate abundance and distribution**
WMO/GCOS Global Climate Indicators	• Surface temperature • Ocean heat content • Sea Level • Arctic and Antarctic Sea Ice Extent	• Ocean acidification	

observing, i.e. a strategy plan of GOOS for the implementation of an integrated and sustained Ocean observing system [7]. The EOVs are identified by the GOOS expert panels based on several criteria, i.e. relevance for climate, Ocean, services, and Ocean health; their feasibility based on science and measurement techniques; and their cost effectiveness. When EOVs are identified, a series of recommendations are created and disseminated by the GOOS expert panels, including what measurements are to be made, various observing options, and data management practices. The concept of ECVs has been introduced by GCOS under similar criteria as for EOVs, except that their relevance is focused on climate. Their specific definition is given as '*an Essential Climate Variable (ECV) is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth's climate*' (e.g. Ref. [6]). GCOS currently specifies 54 ECVs, and the Ocean-related ECVs are listed together with the EOVs in Table 1. Variables addressing marine biology and the deep Ocean are limited. Both, GCOS and GOOS have gone to great lengths to define the EOVs and ECVs required to support SDG 14, SDG 13, the work of the UNFCCC, the IPCC and many marine industries and services.

The OceanObs19 conference statement [34] includes *'Indicators based on ocean observations help nations meet national goals and targets of the United Nations 2030 Agenda on Sustainable Development, the Paris Climate Agreement, the Sendai Framework for Disaster Risk Reduction, the Convention on Biological Diversity, and the Small Island Developing States Accelerated Modalities of Action Pathway. Ocean observations are fundamental to increase the scientific and information content of indicators, contribute to the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) and are coordinated by Global Ocean Observing System (GOOS) and Group on Earth Observations (GEO).'* Together with the UN Decade of Ocean Science for Sustainable Development as discussed in section 2, these international developments offer an added incentive, and we call for a new Ocean indicator framework which provides a holistic view on the Ocean through a focused set of indicators.

Various definitions have been developed for environmental indicators, predominantly for statistical reporting needs (e.g. Ref. [35]). A framework of Global Climate Indicators has been introduced by the WMO in the light of SDG 13 'Climate action' and contains a subset of key indicators designed to be comprehensive and understood by non-scientific audiences [8]. The five criteria for indicator selection included: (1) relevance for a range of audiences; (2) representativeness to provide information of changes to the Earth system related to climate change; (3) traceability of the data and method used for calculation; (4) timeliness and availability of regular updates; and (5) the data adequacy for a robust, reliable and valid indicator delivery [8]. The Global Climate Indicators form the basis of the WMO Statement of the State of the Global Climate (e.g. Ref. [36,37]), and are submitted annually to the Conference of Parties of the UNFCCC. Five out of seven indicators of the WMO Global Climate Indicator Framework are Ocean-related indicators (see Table 1), but with the exception of Ocean acidification, they are limited to physical aspects only, and do not address biogeochemical changes, extreme variability, or marine biology and biodiversity.

We define Ocean indicator as: 'A simple easy to understand tool to describe, measure and monitor a complex Ocean phenomenon. The Ocean indicator may change globally to locally, at different time scales, and can be utilized for Ocean literacy, and to build a sustainable Ocean observing system for holistic scientific assessment and stewardship.' The establishment of an indicator framework specifically dedicated to the Ocean will have various implications such as to foster international collaborations across multiple disciplines and to support the quantification and identification of limitations for observing system capabilities, models and predictions, and scientific assessments. An Ocean indicator framework provides an effective communication tool supporting the implementation of Ocean services, and guides planners and policy makers on the most effective way to use Ocean information and scientific state-of-the art knowledge to support decision making, management and governance, which are targeted and most relevant for their applications (e.g. SDGs). Ocean indicators build upon the already established EOV and ECV frameworks to provide an integrating layer in the so-called added-value chain (section 3.2).

3.2. The added-value chain for Ocean monitoring

Addressing knowledge and implementation gaps through a better use of science-based evidence to inform policy formulation and implementation increases the likelihood of achieving the SDGs [5]. The terminology 'added-value chain' is adopted from economics and is linked to a chain of value adding procedures to develop products and services (e.g. Refs. [38]). The added-value chain for environmental monitoring and reporting illustrates how Ocean observations (remote sensing and in situ), models and Ocean numerical forecast system data can be translated into applications for societal and economic benefit (Fig. 2). Reliable and available observations [39] provide the backbone of the added-value chain for environmental monitoring [40,41]. Oceanographic and technical expert knowledge is needed to transform raw Ocean measurements to useful Ocean products (Fig. 2). Representing uncertainty, and the range of reliable information to the added-value Ocean products is vital for risk-informed decision making.

The EOVs, ECVs and Global Climate Indicators (Table 1) are an evidence-based framework for Ocean and climate services providing a foundation for a sustainable Ocean stewardship supporting international to national decisions to achieve the SDGs. Ocean and marine services provide an added-value chain for Ocean information (Fig. 2) with coordination of up-stream raw data and technical pre-processing, combined with operational oceanographic product processing and reanalysis development (e.g. Ref. [42]). For example, the European Commission Copernicus Marine Service (marine.copernicus.eu) now provides regular and systematic reference information on the physical state, variability and dynamics of the Ocean, ice and marine ecosystems with 10 day forecasts, and consistent retrospective data records for reprocessing and reanalysis in four areas of benefits: (i) maritime safety, (ii) marine resources, (iii) coastal and marine environment, and (iv) weather, seasonal forecast and climate [42]. An example of an implemented added-value chain is the WMO global climate indicator framework, and how it is linked to annual climate reporting and policy for UNFCCC and scientific assessments (Fig. 1, section 3.1).

4. Ocean dependent socio-ecological and environmental systems

4.1. The Ocean and environment SDGs

The Ocean covers 71% of Earth's surface and is a fundamental driver of global environmental, economic and social systems (Fig. 3). By taking up about 90% of the accumulated excess heat in the Earth system from climate change [2,43], and 23% of the anthropogenic CO_2 emissions [44,45], the Ocean provides invaluable ecosystem services to mankind at a cost of Ocean warming and Ocean acidification with widespread impacts on marine ecosystems, fisheries and food security, and coastal protection linked to coral reef loss [46–50]. Ocean warming and land ice mass loss contribute to global mean sea level rise [51,52]. Regional Ocean warming rates can amount to 0.02 °C/year at the sea surface, and up to 2 W/m^2 in the upper Ocean layers in some areas (0–700 m, [53]. According to their large thermal memory, the Ocean is projected to continue to warm in the future [14].

With warming, global mean sea level rise is accelerating in recent decades as a result of increasing rates of ice loss from the Greenland and Antarctic ice sheets [14]. Global mean sea level is projected to rise by 2100 of 0.43 m (0.29–0.59 m, likely range) relative to 1986–2005 for a low

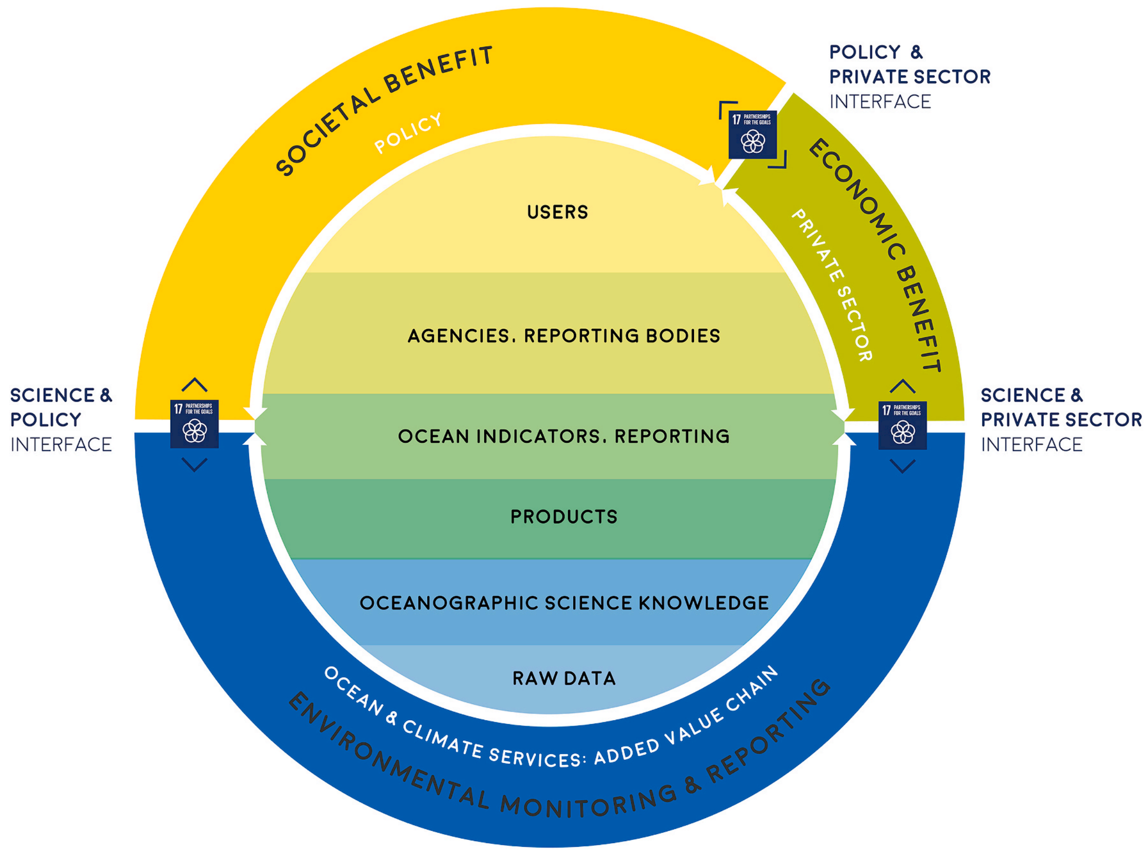

Fig. 2. The role of Ocean monitoring and reporting to support and provide benefit to society and the economy. The added-value chain is the core of Ocean and climate services, and connects raw products (remote sensing, in situ) and oceanographic science knowledge (including models) to high-quality data products which are used for Ocean monitoring and reporting. These added-value products can provide the evidence basis for agencies and reporting bodies, decision makers, other stakeholders and the public, yielding societal and economic benefit. Global partnerships under SDG 17 at the science policy and science/private interface support the optimized use of information in the marine environment through the added-value chain.

greenhouse gas emission scenario,[1] and 0.84 m (0.61–1.10 m, likely range) for a high emission scenario[2] with as much as 2.3–5.4 m of sea level rise projected for 2300 for a high emission scenario [14]. Such sea level rise will have impacts on human populations in coastal and island regions, as well as marine ecosystems [51,54,55]. The Arctic has lost sea ice at a rate of 12.8% ± 2.3% per decade between 1979 and 2018 [14], with impacts on weather, climate, Ocean circulation [56,57], food security [58], marine ecosystems [59,60], transport and shipping route planning [61]. Ocean currents transport heat, freshwater, nutrients, plankton, fish, heat, oxygen and carbon dioxide [14], and their knowledge is vital for marine operations (e.g. navigation, search and rescue at sea, and the dispersal of pollutants) [62]. Changing Ocean currents can impact extreme events [63,64], biogeographic distributions and functioning of ecosystems [65], and regional to global climate (e.g. Ref. [64,66]).

The Ocean is a major freshwater reservoir (~96%) and plays a key role in Earth's water cycle [2]. Hydrological extremes such as flooding, extreme rainfall and droughts [14] can have severe environmental, societal and economic consequences [49]. Nearly half of the production of organic matter (global gross primary production) on Earth takes place in the Ocean [67,68]. All Ocean life depends on the Ocean's primary production, a fundamental source of global food security. Ocean deoxygenation is observed over the past 50 years, disrupting marine ecosystems, affecting fish stocks and aquaculture, and leading to loss of biodiversity [49,69–71]. Global marine species redistribution and marine biodiversity reduction linked to climate change and other anthropogenic pressures (e.g. pollution, overfishing, eutrophication) will challenge the sustained provision of fisheries productivity and other ecosystem services in sensitive regions [49].

4.1.1. SDGs 13, 14 and 15 (Environment)

Tackling **SDG 13** is central for sustainable development. Climate change affects our ability to achieve all of the SDGs. Ocean science, data and service gain relevance for the UN SDGs with the WMO Global Climate Indicator framework (section 3.1). Climate change drives Ocean warming, Ocean acidification, Ocean deoxygenation, sea level rise and loss of sea ice [14], and is reflected in the Ocean-related indicators (Table 1). These climate and Ocean indicators provide the temporal metrics for climate change monitoring to validate and improve the climate projections fundamental to strengthening resilience and adaptive capacity (13.1), meaningful mitigation actions (13.A), effective climate change-related planning and management (13.B), decision making (13.2) and a sustainable blue economy (section 4.3).

'As billions of people depend on the Ocean for their livelihood and food source and on the transboundary nature within the Ocean, increased efforts and interventions are needed to conserve and sustainably use ocean resources at all levels' (https://sustainabledevelopment.un.org/sdg14). Most of the EOVs are relevant to enable the goals' monitoring, information delivery and direct support for the targets 14.1–14.7 and 14.a-14.c. SDG target 14.3 (minimize and address the impacts of Ocean acidification, including through enhanced scientific cooperation at all levels) reporting, can utilize the Global Climate Indicator for Ocean acidification [72]. Sustainable blue

[1] *Low greenhouse gas emission scenario, with high mitigation (RCP2.6). Gives a 2 in 3 chance of limiting warming to below* 2 °C *by 2100. 2081–2100 temperature* = *+1.6°C (±0.7°C), 2081–2100* CO_2 *concentration* = 426 ppm. *Source: IPCC, 2019.*

[2] *High greenhouse gas emission scenario in the absence of policies to combat climate change (RCP8.5). 2081–2100 temperature* = *+4.3°C (±1.1°C); 2081–2100* CO_2 *concentration* = 850 ppm. *Source: IPCC, 2019.*

Fig. 3. The Ocean's multi-faceted role in the UN Sustainable Development Goal (SDG) framework connected to the three pillars of sustainability: environment, society and economy. The three environmental SDGs (13, 14, 15), shown in blue, provide the foundation to support society SDGs (1–7, 11, 16) shown in yellow, and economy SDGs (8, 9, 10, 12), shown in green. Some SDGS, e.g. SDG 6 and SDG 9 cut across the SDG pillars. Clean water (SDG 6) is essential for the environment, society and the economy, Sustainable cities and communities (SDG 9) are an essential component of society and the environment. See also Fig. 6 in [40].

economies require that we meet the targets set out in **SDG 14** including sustainable fishing practices, sustainable management of marine and coastal ecosystems, and expanding marine protected areas (MPAs, SDG 14.5.1). Integrating real time in situ and remote sensing data provides the opportunity for more robust marine spatial planning and sustainable resource management [73]. Ocean pH, EOVs for marine biodiversity (see Table 1), currents, chlorophyll, oxygen and Ocean hydrography (Temperature, Salinity) are required to monitor the overall health of the Ocean. In addition, pollution (14.1) impacts may also undermine the resilience of ecosystems to climate change stressors such as Ocean warming and Ocean acidification [74].

Fig. 4 illustrates a science, data and services informed pathway towards sustainable fisheries. The abundance and dynamics of marine organisms are tightly coupled to their physical and biogeochemical environment. In addition to relevant biology/ecosystem EOVs listed in Table 1, EOVs/ECVs such as temperature (thermal sensitivity of organisms), salinity (health of organisms), oxygen (consumption by organisms), pH (environmental stressor, 14.3), chlorophyll (phytoplankton) – and their interactions (warmer waters contain less oxygen, for example) - are valuable for monitoring and management of marine living resources, and could significantly

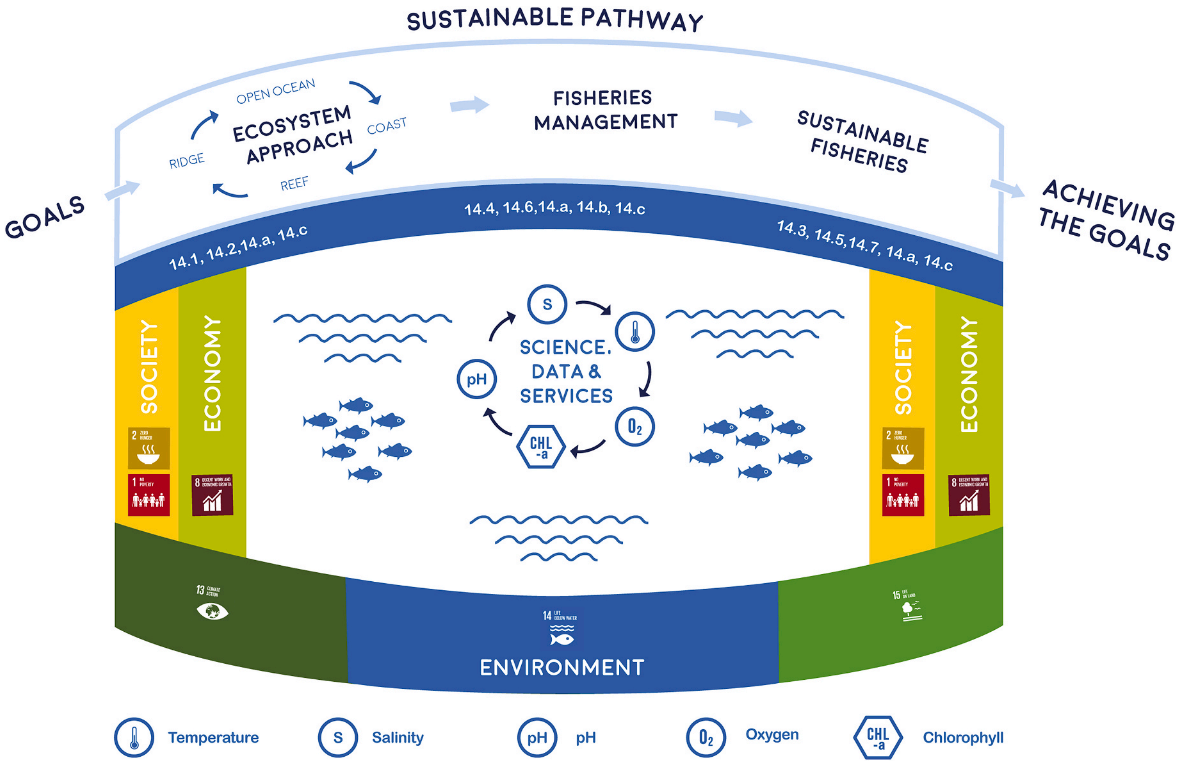

Fig. 4. A fisheries pathway supported by science, data and services to achieve SDGs 1, 2, & 8. The combined use of environmental EOVs/ECVs temperature, salinity, oxygen and pH in addition to biology/ecosystem variables such as fish abundance and distribution can support a holistic ecosystem approach to substantially improve fisheries management (see section 4 for more information) and support the development of sustainable fisheries. In this example, the EOVs/ECVs are key to inform the sustainable stewardship required to meet the SDG targets. Sustainable fisheries will support a sustainable blue economy that simultaneously embraces environmental stewardship to support society and sustainable economy.

improve the day-to-day management of fisheries [75]. By aiming to reduce marine pollution (14.1) and to 'sustainably manage and protect marine and coastal ecosystems' (14.2), this holistic ecosystem approach to fisheries management is increasingly recognized across many domains such as the fishing industry, and international quota agreements [76]. Meaningful actions informed by Ocean science, data and service tools are key to the stewardship required to meet the SDG targets: to restore fish stocks (14.4), to 'combat illegal, unreported and unregulated fishing' (14.6), to increase knowledge (14.A), 'provide access for small-scale artisanal fishers to marine resources and markets' (14.B) and to provide a 'legal framework for the conservation and sustainable use of oceans and their resources' (14.C) to pave the way for a pathway to sustainable fisheries (Fig. 4) for 'Small Island Developing States, least developed countries and all countries' (14.7). The SDG 14 framework will need to be supported by marine protection measures (14.5) and reduction of stressors from climate change (14.3).

SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) is critical for the protection of coastlines and coral reefs. Pressure created by coastal and urban development and the associated sedimentation overlay the temperature and Ocean acidification stress imposed on coral reefs was demonstrated by the widespread coral bleaching in the 2016–2017 El Niño [77]. Protecting lands in the watershed above the reefs is important to shield coral reefs from pollutant and sediment delivery and preserve biodiversity. This is underscored by the 90 million USD Global Environment Facility (GEF) investment in the 14 country Pacific Ridge to Reef Program: 'to maintain and enhance Pacific Island countries' ecosystem goods and services (provisioning, regulating, supporting and cultural) through integrated approaches to land, water, forest, biodiversity and coastal resource management that contribute to poverty reduction, sustainable livelihoods and climate resilience' (https://www.pacific-r2r.org/).

In summary, coral reefs and coastal areas are hotspots for biodiversity requiring protection and the expansion of sustainable coastal development, and sustainable tourism illustrating the connection among the SDGs, UNFCCC and biodiversity. Coral reefs can capture up to 90% of wave energy, thus standing as a first line of defense against coastal erosion with rising sea levels [78]. The management of the so called 'high seas pockets' (those high seas which are enclosed by the Exclusive Economic Zone (EEZ) of surrounding countries) plays a central role in Pacific Biodiversity in Areas Beyond National Jurisdiction (BBNJ) negotiations [13]. Protection and Sustainable Use of BBNJ sits at the intersection of biodiversity, boundary and open Ocean fisheries. Fig. 4 also provides an example for the interconnection of the SDGs. SDG target 14.3 to minimize and address the impacts of Ocean acidification is directly linked to SDG 13.1's target to 'strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries'. The biodiversity hot spots of the coral reefs are under threat from increased Ocean acidification [49], which provide coastal protection (SDG 15), and impacts overall ability to achieve SDGs 1, 2 (section 4.2) and 8 (section 4.3, Fig. 4).

4.2. *The Ocean and society SDGs*

Coastal and megacities are at risk from rising sea levels [51], a risk that has accelerated in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets [14]. By 2010, 28% of the global population (1.9 billion people) were living in areas less than 100 km from the coastline and less than 100 m above sea level, including 17 major cities which are each home to more than 5 million people [2]. With a new coastal digital elevation model, Kulp and Strauss [79] estimate a three-fold increase in the number of people exposed to annual flooding by 2100. To meet the challenges of rising seas, robust urban planning requires an understanding of how urban expansion is impacted by climate change, sea level rise and changing boundaries extending from urban to rural, and from river, delta, coastal zones and territorial seas to the open Ocean.

Providing clean water and coastal protection to the increasing number of people living in cities is a growing challenge. Availability of clean water is compromised by extreme events e.g. tropical cyclones, storm surges, inundation, and saltwater intrusion [80]. Coastal protection is critical for climate adaptation and building resilience [2]. Coastal protection can be provided by nature-based solutions including planting and protecting mangroves, protecting coral reefs and sea grass beds, and setting aside protected areas in keeping with the Convention on Biological Diversity (CBD) Aichi Biodiversity Target Eleven [46,81]. Renaturing cities can protect coastlines and create opportunities for recreation, management of non-communicable diseases through exercise, and connecting with the environment [82].

Disasters create considerable economic and societal burden [55]. The impacts of increased wind speed, increased storm surge and inundation underscore the vulnerabilities [64] of low-lying islands and coasts around the globe requiring Multi-Hazard Early Warning Systems (MHEWS) and disaster risk management [83]. Recent examples of storm damages include for example storm surge related inundation during the 2102 Superstorm Sandy in New York City, the combination of flooding and heavy precipitation from the 2017 Hurricane Harvey in Houston [84], and the impact of wind speed, storm surge combined with population density for the 2013 Typhoon Haiyan in the Philippines [85]. Recent tropical cyclones and hurricanes in the Pacific, central Atlantic and Caribbean illustrate the vulnerability of and devastating impacts on small island States [85–88].

An estimated three billion people depend on marine and coastal areas, for fishing, tourism, trade, transport and energy [55]. Fisheries provide over 15% of the dietary animal protein intake globally and can provide over 70% of protein intake on small islands [89]. Fisheries and aquaculture are an important source for food and income security and a source of protein, omega-3 fatty acids, vitamins, calcium, zinc and iron (e.g. Ref. [90–92]). Between 1974 and 2015, the percentage of fish stocks fished at biologically unsustainable levels increased from 10% to 33.1%, thereby placing more of the world's fish stocks at risk of collapse [93]. As human populations continue to increase, society is likely to turn to the Ocean to provide increased amounts of food [94,95]. Developing and managing fisheries for sustainability will require science, data and services tools as described in Fig. 4.

4.2.1. SDGs 1, 2, 3, 4, 5, 6, 7, (9), 11 and 16 (society)

The multi-faceted sustainable blue economy plays an essential role in particularly supporting society through progress towards **SDG 1** (no poverty), **SDG 2** (zero hunger), **SDG 3** (good health and well-being), and **SDG 5** (gender equality) through the income derived from marine ecosystem services, open Ocean fisheries, small scale coastal fisheries, traditional medicines, and cultural heritage, including crafts. Ocean colour is an indicator for primary productivity (EOV) [67], to identify resource-rich areas for harvestable marine resources, areas of pollution and eutrophication, fish stock assessment, fisheries forecasting and integrated ecosystem modelling and management [73,96]. Ocean subsurface temperature, salinity, oxygen content, and Ocean pH are strongly linked to marine organisms and ecosystem function ([76]; see also Fig. 4). Sea surface temperature is already used for coastal fisheries and coral reef management [97]. Information on bathymetry and other oceanographic and Earth observation data are discussed for fisheries management [40,98]. A transdisciplinary approach incorporating operational oceanographic data (satellite, in situ, and model data across relevant time and space scales) is of great value for the monitoring, management and stewardship of marine living resources [75,76,91].

Sea surface temperature and Ocean acidification (Global Climate Indicators, Table 1) are climate critical and can support monitoring of marine disease outbreak to address **SDG 3**. Ocean acidification is linked to coral bleaching [99]. The Biology EOVs (Table 1) can support management planning, including the maintenance, establishment and extension of marine protected areas (MPAs [100,101]), to support sustainable livelihoods and tourism. MPAs can be complemented by effective area-based conservation measures to support the CBD Aichi Biodiversity Target 11 on marine protected areas [90]. NOAA's coral reef watch product combines in situ measurements with remotely sensed sea surface temperature to calculate a heat stress product used to provide near real time predictions of likely coral bleaching and four-month forecasts of heat stress induced coral bleaching [102]. Ciguatera fish poisoning is linked to coral reef health [103]. Coral reef health is critical for coastal fisheries, tourism and coastal protection (**SDGS 3** and **14**) [78]. In his speech at the Madrid COP 25, Prime Minister Bainimarama committed to protection of thirty percent of Fiji's EEZ with 100% integrated Ocean management by 2030 [104].

For **SDG 4** (quality education), a sustainable blue economy can support education funding and school transport. Sustainable blue economies can address justice and human rights issues (**SDG 16**) while also providing a role for the advancement of women (**SDG 5**) [90,100, 105–107]. For example, women and children have benefited from the ecosystem services provided by mangrove replanting in four villages along Fiji's coral coast. The resulting coastal fisheries, traditional medicine and cultural handicrafts supported education, improved housing (**SDG 9**), and provided economic independence and autonomy for women and girls [108]. Restoring the environment through mangrove replanting supported society and the economy.

Forecasting eutrophication and harmful algal blooms using remote sensing products is increasingly successful and critical for a resilient blue economy [109]. Harmful algal blooms (HABs) often resulting from pollution and fertilizer run off from upstream agriculture, urban lawns and golf courses results in cyanobacteria toxins with repercussions for ecosystem and human health. In the North Atlantic, Caribbean and Pacific, *Sargassum* has increased in density and aerial extent during the last decade, causing problems and potential hazards (e.g. Ref. [110]). When HABs result in eutrophication and oxygen depletion, widespread fish die-off results [111]. In many cases, the forecasting of HABs through Ocean services has implications for health (**SDG3**), clean water (**SDG6**) and a healthy Ocean (**SDG14**).

Targeted information on local sea level change and sea level extremes are fundamental for hydrographic assessments and water management strategies [112]. Saltwater intrusion processes in coastal aquifers can compromise water supply influenced by rising sea level [113] and thus **SDG 6** (clean water and sanitation). Many coral atolls are projected to become uninhabitable by 2040 due to storm surge contamination of the freshwater lens [80]. In pioneering Ocean services in the Pacific Islands, Fiji Meteorological Services is providing monthly outlook forecasts of sea surface temperature combined with Ocean currents to provide zones of likely fish confluence (Misaeli Funaki, Director Fiji Meteorological Service, pers. comm.). The emerging use of Ocean colour to enable bathymetry mapping of shallow waters is an important breakthrough for the unmapped and under-mapped coastal areas of the Pacific Islands [112].

The use of significant wave height and Ocean currents is fundamental for blue renewable energy such as generating electricity from the Ocean through wave energy, tidal energy and marine currents (e.g. Ref. [114–116]), linked to **SDG 7**, sustainable and clean energy. Sustainable blue economies must address marine pollution [117]. Reduction in marine pollution, development of safe housing and environmentally friendly cities with reduced energy consumption, and improved sewer management to minimize the degradation of the Ocean are essential for achieving **SDGs 11,** Sustainable Cities and Communities & **SDG 12,** Responsible Consumption and Production. Ensuring safe, healthy secure coasts, harbors and ports for our cities requires sea surface height for port planning, and near real-time Ocean colour, Ocean heat content, and sea surface temperature for environmental monitoring e.g. bathymetry, coral bleaching and fisheries (**SDGs 9, 10 11, & 12**). Satellite imagery combined with model and remote sensing tools, e.g. cyclonic and eyewall structure, rainfall and wind speed, are critical components to support the development and implementation of the operational capacity of MHEWS to detect and predict e.g. tropical cyclones, severe storms and inundation (**SDG 11**, [40]).

SDG 16 'Peace, Justice and Strong Institutions'. The legal framework for global Ocean governance and sustainable development is provided by the United Nations Convention on the Law of the Sea [118], which was signed by 160 countries in 1982. The governance challenges presented by the Ocean's fluid nature is reflected in the 14 articles required to define the limits of territorial seas and the 20 articles of the EEZ, [13]. Space-based remote sensing platforms, including EOVs, combined with undersea platforms, form the effective and accountable scientific foundation for defining boundaries of territorial seas and EEZs. Australia is leading the way in applying remote sensing to clearly defined EEZ reference frames for the Asia-Pacific region [119].

Combining remote sensing observations, in situ measurements and models becomes even more important in a changing world where warming seas and melting land ice cause a rise in sea level which in turn might lead to redefining boundaries [14]. A strong science foundation will support a variety of SDG targets [120]: Strengthening boundary definitions of Big Ocean StateS (BOSS) will support enforcement of national and international laws in supporting SDG 16.3. Clearly defined boundaries, backed by science, can open the door to increased participation in global governance from developing countries - particularly SIDS supports SDG 16.8. Tackling illegal and unregulated fishing, combined with the human and drug trafficking, represent a growing challenge for crime and terrorism. Critical support for national institutions to address SDG target 16.a is required.

4.3. The Ocean and economy SDGs

The Ocean is a major source of food and provides employment opportunities, recreation, trade, culture and economic benefits to many people throughout the world [92]. The term 'sustainable blue economy' is gaining currency [121,122], following the Rio+20 conference, the Pacific Islands Development Forum Summits (www.pacificidf.org), the SAMOA Pathway (www.sids2014.org), the annual Pacific Island Forum Leaders meetings (www.forum.sec.org), the Pacific Ocean Alliance, and the UNOC where the terms "green growth" or blue-green growth were applied to countries where the Ocean is integral to the economy [123,124] such as the Pacific SIDS also called the Pacific BOSS or large Ocean states. The forty-four member countries of the Alliance of Small Island States (AOSIS) exemplify sustainable blue economy States.

At its core, the sustainable ocean or blue economy, as defined in the introduction, refers to the de-coupling of socio-economic development from environmental degradation [125,126], with particular attention to gender, poverty and vulnerable groups. Sustainable blue economy sectors include marine fisheries, tourism, maritime transport, water desalination, blue energy, marine aquaculture, marine biotechnology and bioprospecting. New emerging markets include carbon sequestration (blue carbon), coastal protection, seabed extractive activities, waste disposal and the protection of biodiversity [127,128].

Fisheries and aquaculture are a major component for the sustainable blue economy and trade (Fig. 4). According to the Organization for Economic Co-operation and Development (OECD) and United Nations Conference on Trade and Development (UNCTAD), global fish production was estimated at 172.6 million tonnes in 2017, supplying around 21 kg/capita per year, hence providing significant employment and economic benefits to countries and local coastal communities [92]. Moreover, thirty-five to thirty-eight percent of the world's fish and seafood production enters international trade, with fifty percent of the trade originating in developing countries. For example, in PSIDS, fishing provides between thirty and eighty percent of exports [129].

At the international level, fisheries governance is guided by a complex series of multilateral and bilateral agreements from UNCLOS to the 1995 UN Fish Stocks Agreement [93] supported by a similarly complex array of organizations with Regional Fisheries Management Organizations (RFMOs) as the core instrument. Ecosystem-based management approaches, including the Large Marine Ecosystem classification [130], for integrated fisheries management is increasingly recognized as an effective tool to better support sustainable fisheries and to meet required international quota agreements ([76]; Fig. 4). A growing number of successful case studies are helping to provide best practices guidance for observations to inform sustainable blue economies [131].

A healthy Ocean is crucial for economic growth and food production, and fundamental for climate change mitigation [2]. Environmental protection requires protection of Ocean and land biodiversity, coastal and Ocean health by establishing MPAs. Soft measures, including planting vegetation, managing upstream development and preventing development in river corridors to protect riverbanks and coastlines, are often more cost-effective than building grey infrastructure [82,132].

Healthy marine ecosystems are required to support society and Ocean-based economies. Marine ecosystems provide a wide variety of ecosystem services ranging from carbon sequestration to coastal protection to fisheries to livelihood to cultural identity and heritage, and medicine (Fig. 1). A sustainable blue economy requires the enhancement and conservation of Ocean ecosystem services including: marine habitat regulation of water, oxygen and carbon cycles; coastal ecosystems and coral reef absorption of wave energy, protection of coastlines, provision of spawning grounds and refuge for fish species, control of erosion, siltation, pollution and detoxification; provision of abundant marine resources (algae, fish, crustaceans, molluscs and genetic resources); and provision of recreation and cultural services (e.g. recreational fishing, scuba diving, sightseeing tourism (e.g. scenery, marine mammals)); and source of cultural identity [92,125,127].

To capture the unrealized economic benefit of protecting the Ocean, quantification of Ocean ecosystem services is underway through the UNESCAP Ocean Accounting program [133] and the International Union for Conservation of Nature (IUCN) [81]. The use of in situ and satellite-based Ocean observations supports the ecosystem service quantification and integrated Ocean management for sustainable blue economies [134–136].

4.3.1. SDGs 8, 9, 10, and 12 (Economy)

Ocean economies drive the global economy 'promoting sustained, inclusive, and sustainable economic growth, full and productive employment and decent work for all' (**SDG 8**). In addition to fisheries and aquaculture discussed above, and in Fig. 4, Ocean renewable energy can support climate change mitigation, and offer an excellent opportunity to reduce reliance on fossil fuel consumption [23–26]. Blue energy can comprise energy extraction from offshore winds, Ocean and tidal currents, wave energy, floating solar, thermal and salinity gradient and algal biofuels, and the emerging demand for renewable energy sources is expected to generate economic opportunities [14]. Ocean observations and research [23,24] and the delivery of timely and reliable relevant EOVs is thus key to support this economic development.

Support to **SDG8** is also interlinked with **SDG9**. For example, replanting of mangroves is essential for blue carbon, but protects roads (**SDG 9**) by preventing coastal erosion [108]. Moreover, coastal protection and harbors are essential for the sustainable blue economy to support of **SDG9** (see links of EOVs for coastal protection in section 3.2.1 and 3.2.2). Increased blue economic development also supports **SDG10** (Reduce inequality within and among countries), and supports target 10.2: 'By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability race ethnicity, origin, religion or economic or other status'.

Impacts of extreme events such as tropical storms on small island communities have created long lasting economic and adaptation burdens, while simultaneously compromising human, water and food security [137]. Improved storm surge forecasting would have saved lives during Tropical Cyclone Winston in Fiji (Fiji, 2016), and will protect people living in cities and villages in the future (**SDG 9**). Disaster risk management requires mapping services and information on the environment and infrastructure to support disaster preparedness as well as rebuilding following disasters (e.g. the Sendai Framework [20], supported by Earth Observation systems within the design of MHEWS [138]). Robust MHEWS design is central to WMO Disaster Risk Reduction strategy [8]. Emergency services, such as the European Copernicus emergency relief programme, can provide immediate access to remote sensing products and mapping following disasters (emergency.copernicus.eu), and are important for both, society and economy.

Lubchenco and Gaines [122] call for a new narrative to protect the Ocean and move away from using the Ocean as waste dumping ground. **SDG 12**, responsible production and consumption, (see also sections on eutrophication in 3.2.1 and 3.2.2) requires the protection of Ocean health through reductions in plastic waste creation and reduction in marine pollution. Action to ban single-use plastic has been taken in many countries and is an important first step. But much more is needed to stop the entry of plastic waste into the Ocean [139]. Better understanding of Ocean currents and gyres is essential to managing plastic pollution once it has entered the Ocean (e.g. Ref. [140,141]). Ocean literacy for conservation and sustainable use of the Ocean, including awareness for pollution, acidification and sustainable fisheries will become progressively more important up to 2030 [9].

4.4. SDG 17

SDG 17 (Partnerships for the goals: Strengthening the means of implementation and revitalizing the global partnership for sustainable development) is critical for protecting Ocean health, preserving marine ecosystem connectivity and providing for the well-being of Ocean dependent people [105,142]. The complexity of Ocean governance and science are illustrated by the variety of policy and science tools: United Nations Convention on the Law of the Sea (UNCLOS), International Maritime Organisation, UNESCO-IOC, IPCC, UNFCCC, IPCC SROCC and the accompanying EOVs, ECVs and Global Climate Indicators.

Building science and research capacity today is needed to meet tomorrow's challenges. Promising efforts by the world's scientific communities include: exploring future pathways through The World in 2050 initiative, advancing sustainability science through the Future Earth collaboration and examining SDG interactions and interdependencies through the investigations of the International Council for Science. Insights can come from many creative approaches and innovative analyses [94,143] and by using the Ocean's natural capital to address 60 targets across the 17 SDGs [144].

Together with peace and justice (**SDG 16**), durable partnerships are needed to achieve the 2030 Sustainable Development Goals (**SDG 17**). Integrated marine spatial planning, incorporating ecosystem services, is a critical tool for ensuring a healthy Ocean and coasts [145]. Combining integrated marine spatial planning within the EEZs with management of large marine ecosystems [146] and management of the High Seas pockets could lay a sound foundation. Integrated marine spatial planning (**SDG 14**) starts at the top of the mountains and ridges (**SDG15**) stretching to coastal zones, EEZs and out to the open Ocean (**SDG 8** for fisheries, **SDG 9** for transport), providing the basis of good Ocean stewardship.

By building sustainable blue economies that include climate mitigation and adaptation solutions (**SDG 7 & 13**), extreme poverty (**SDG 1**) can be alleviated and food security increased (**SDG2**) to provide for healthy educated people (**SDG 3 & 4**) with greater gender equality (**SDG 5**) and reduced inequality (**SDG 10**). Building on Ocean stewardship with integrated marine spatial planning, climate and Ocean services (section 4) can support provision of clean water (**SDG 6**) for sustainable cities and communities (**SDG 11**) through robust urban planning and responsible consumption and production (**SDG 12**).

5. Conclusion

The Ocean is under threat with unprecedented environmental pressures that will continue to impact the pillars of sustainable development at local, national, regional and global levels [14]. Policy, management and governance instruments require sustainable Ocean stewardship informed by best available Ocean science, data and services to meet the SDG targets. Sustained and accessible Ocean observation and modelling systems are required to monitor the many Ocean dimensions from physics to ecosystems and from global to local scales (e.g. outcome statements of the OceanObs19, and related community white papers, oceanobs19.net). Ocean data and science capacities need to be secured by sustained financial and political agreements. Local, indigenous and cultural knowledge systems need to be interwoven with science and technically robust knowledge systems to deliver operational ocean services.

As global citizens, we have the opportunity to take action to protect the Ocean and improve the delivery of Ocean information with end-to-end products developed specifically to inform Ocean stewardship, policy and Ocean governance. The current evolution of the Ocean observing system has provided a transformative boost in capabilities for Ocean monitoring and reporting over the past two decades (e.g. Ref. [41, 147–151]. The UN Decade of Ocean Science for Sustainable Development (2021–2030) commits us to expanding Ocean observations into our uncharted and under-sampled waters, including the polar regions, the deep Ocean, shelves and coastal areas, while re-committing ourselves to the urgently needed science, data and services at the Ocean-climate nexus. The UN Decade of Ocean Science and the IPCC SROCC underscore the importance of elevating local and indigenous knowledge to strengthen the Ocean knowledge base (14.A). An internationally agreed framework for Global Ocean Indicators is critically needed to mark the beginning of the UN Decade of Ocean Science, to ensure we close the decade with the sustainable Ocean stewardship we need for the 'Future We Want'. Policy support is indispensable in securing the sustainability of Ocean observations, local and indigenous knowledge systems, science, and capacity to deliver Ocean services.

The UN 2030 Sustainable Development Agenda delivers clear guidance on the urgent global goals to be achieved by 2030: a path towards a sustainable future for all societies on the blue planet. For policy negotiations, the key ingredient is to establish an ongoing dialogue among decision makers, the private sector and information holders concerned with the Ocean. Ocean science, data and services can help to meet national and regional goals and targets of the United Nations 2030 Agenda on SDGs, the Paris Agreement, the Sendai Framework for Disaster Risk Reduction, the Convention on Biological Diversity, and the SAMOA Pathway. The UN Decade of Ocean Science seeks 'to reverse the decline in Ocean health.' Through stronger international cooperation, the Decade will bolster scientific research and innovative technologies to ensure science responds to the needs of society.

All SDGs are interconnected. A holistic approach that embraces sustainable Ocean stewardship informed by science, data and services to support society and the economy is required to create the 'Future We Want'. Just as UNOC and the Decade of Ocean Science are intimately connected, and just as SDG14 supports the UN 2030 Agenda and the SDGs as a whole, the three tracks of Ocean, biodiversity and climate change are inseparable. The outcomes of UNOC in Lisbon and the CBD's COP15 in Kunming must converge to strengthen the delivery of greatly enhanced ambition for the outcomes of UNFCCC's COP26 in Glasgow, despite the delays invoked by the global COVID-19 pandemic.

CRediT authorship contribution statement

Karina von Schuckmann: Writing - original draft, Visualization, Conceptualization. **Elisabeth Holland:** Writing - original draft, Visualization, Conceptualization. **Peter Haugan:** Writing - review & editing. **Peter Thomson:** Writing - review & editing.

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Acronyms

AOSIS	Alliance of Small Island States
BBNJ	Marine biological diversity of areas beyond national jurisdiction

BOSS Big Ocean StateS
CBD Convention on Biological Diversity
CMIP Coupled Model Intercomparison Project
COP Conference of the Parties
CORDEX Coordinated Regional Climate Downscaling Experiment
DSDG Division for Sustainable Development Goals
ECV Essential Climate Variable
EEZ Exclusive Economic Zone
EOV Essential Ocean Variable
FAO Food and Agriculture Organization
GCF Green Climate Fund
GCOS Global Climate Observing System
GEF Global Environment Facility
GEO Global Environment Outlook
GFCS Global Framework for Climate Services
GIWA Global International Waters Assessment
GOOS Global Ocean Observing System
GOSR Global Ocean Science Report
GSDR Global Sustainable Development Report
HABs Harmful algal blooms
HLP High Level Panel
HLPF United Nations High-level Political Forum on Sustainable Development
IHO International Hydrographic Organization (specifically the IHO Hydrography Capacity Building Programme for Coastal States)
IMO International Maritime Organization
IMSAS Member State Audit Scheme
IOC International Oceanographic Commission
IPBES GAR Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services Global Assessment Report
IPCC Intergovernmental Panel of Climate Change
IUCN International Union for Conservation of Nature
LDCs Least Developed Countries
MA Millennium Ecosystem Assessment
MHWES Multi-Hazard Early Warning Systems
MPA Marine Protected Area
NCs National Communications
NDCs Nationally Determined Contributions
OECD Organization for Economic Co-operation and Development
PSIDS Pacific Small Island Developing States
RFMOs Regional fisheries management organizations
SAMOA Small Island Developing States Accelerated Modalities of Action
SBI Subsidiary Body for Implementation
SROCC Special Report on Ocean and Cryosphere
SBSTA Subsidiary Body for Scientific and Technological Advice
SDG Sustainable Development Goal
SIDS Small Island Developing States
SOFIA State of World Fisheries and Aquaculture
UN United Nations
UNCLOS United Nations Convention on the Law of the Sea
UNCTAD United Nations Conference on Trade and Development
UNGA UN General Assembly
UN-DESA Department of Economic and Social Affairs
UNDP United Nations Development Programme
UNDRR UN Office for Disaster Risk Reduction (formerly UNISDR)
UNEP UN Environment Programme
UNESCO United Nations Educational, Scientific and Cultural Organization
UNFCCC United Nations Framework Convention on Climate Change
UNISDR See UNDRR
UNOC UN Ocean Conference
WCRP World Climate Research Programme
WMO World Meteorological Organization
WOA Global Ocean Assessment
WOGP Water and Ocean Governance Programme

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