Ocean and the Law of the Sea

Contribution of the Intergovernmental Oceanographic Commission of UNESCO to the Report of the UN Secretary-General (24 January 2019)

I. Advancing ocean science and identifying and addressing gaps in knowledge of the ocean

Ocean Science should be interpreted broadly as encompassing natural, social sciences and human dimensions; the infrastructure that supports ocean science (observations, data systems); the application of science for societal benefit, including knowledge transfer and applications in regions that are lacking science capacity; and the science-policy/user interface. Ocean science comprises research and observations on multiple drivers and issues affecting the state of the ocean and trends in ocean health and sustainability. Some of these drivers and issues have been known to science for some time and are in the process of being progressively addressed; other issues remain unresolved, and yet others are emerging. Ocean science is therefore critical to understanding and tackling factors affecting changes in the ocean.

Scientific understanding of the ocean responses to pressures and management action is fundamental for sustainable management. Ocean research is also essential to predict the consequences of change, design mitigation and guide adaptation to cope with the many ways the ocean affects human lives and infrastructure at different spatial and temporal scales. Nations around the world have increased investment in ocean research, this manifests in the number of marine scientists, research and education institutions and significant infrastructure investments for ocean observation. Developed countries are rapidly enhancing and networking data streams on oceans, climate and human activity, to deliver near real-time understanding of status, weather and approaches to disaster risk reduction. Advances in observation technology, trans-ocean and regional communication systems are notable, and can make data visible to allow decision makers to better approach extractive and non-extractive activities, or deal with risk in near-real time. However, gaps in human and institutional capacity and lack of resources still hamper less developed countries from taking advantage of what is on offer to enhance action and to focus on the factors that degrade the ocean health. In most cases, national ocean research policies as well as scientific advisory mechanism that could define a pathway to support such development are missing, while acquisition of sufficient credible scientific data and information still requires major investment. Enhanced international and interdisciplinary scientific collaboration paired with technology transfer is needed to fill these knowledge gaps.

Several gaps in our knowledge remain despite great advancements in the last 50 years of ocean research and observations. As stated by the first UN World Ocean Assessment (WOA-I), many areas require further investigation to fully comprehend the role of the ocean in the earth system. Our knowledge of human interaction with the ocean is also very partial in terms of the ways in which we benefit from it. It is not yet possible to place an explicit value on the ecosystem services derived from the ocean. There are many gaps in the information needed for such a valuation exercise. Information on the effects of changes in the ways in which the planetary ecosystem works needs to be collected and evaluated, in order to define sustainable management options.

IOC is active in the area of ocean science. The current ocean science portfolio of activities of IOC deals with issues that chiefly reflect the concerns of the Member States with regard to the need for science advice on such issues. The portfolio promotes international scientific collaboration in the elucidation of problems of the ocean, provides a platform for the design of collaborative international research and observation programmes; and facilitates the development of capacities in ocean science. The main areas of emphasis of IOC's work in the area of ocean science are as follows:

Ocean acidification. Ocean has absorbed around approximately 30 percent of carbon dioxide (CO_2) released to the atmosphere as a result of human activities. As CO_2 dissolves in seawater, it forms carbonic acid, decreasing the ocean's pH. This is called ocean acidification. The acidity of the ocean has increased by 26 percent since the beginning of the industrial era.
As a consequence of carbon absorption, the ocean's future capacity to store carbon dioxide and help regulate the climate will be affected. Ocean acidification has been shown to affect organisms and ecosystems, impacting ecosystem services such as food security, by endangering fisheries and aquaculture. It also affects coastal protection (for example by weakening coral reefs shielding the coastline), transportation and tourism.

De-oxygenation. Oxygen is declining in the ocean. Since the 1960s, the area of low oxygen water in the open ocean has increased by 4.5 million km_2 and over 500 low oxygen sites have been identified in estuaries and other coastal water bodies. Burning of fossil fuels and discharges from agriculture and human waste, which result in climate change and increased nitrogen and phosphorus inputs, are the primary causes of oxygen decline in both the open ocean and coastal waters. Dense aquaculture can contribute to deoxygenation by increasing oxygen used for respiration by both the farmed animals and by microbes that decompose their excess food and faeces. Deoxygenation (a decline in oxygen) occurs when oxygen in water is used up at a faster rate than it is replenished. Both warming and nutrients increase microbial consumption of oxygen. Warming also reduces the supply of oxygen to the open ocean and coastal waters by increasing stratification and decreasing the solubility of oxygen in water. The quality and quantity of habitat for economically and ecologically important species is reduced as oxygen declines. Finfish and crustacean aquaculture can be particularly susceptible to deoxygenation because animals are constrained in nets or other structures and cannot escape to highly-oxygenated water masses.
Deoxygenation may also contribute to climate change through its effects on the nitrogen cycle. Global warming is expected to worsen deoxygenation during the twenty-first century due to continued greenhouse gas emissions. The global discharge of nitrogen and phosphorus to coastal waters may increase in many regions of the world as human populations and economies grow. It is expected that many areas will experience more severe and prolonged hypoxia than at present under the same nutrient loads. Slowing and reversing deoxygenation will require reducing greenhouse gas and black carbon emissions globally as well as nutrient discharges that reach coastal waters. More accurate predictions of ocean deoxygenation, as well as improved understanding of its causes, consequences and solutions, require expanding ocean oxygen observation, long-term and multi-stressor experimental studies, and numerical modelling. Accurate oxygen measurements with appropriate temporal resolutions and adequate spatial coverage in the marine environment are needed to document the current status of our ocean, to track changing conditions, to build and validate models that can project future oxygen levels, and to develop strategies to slow and reverse deoxygenation. Steps required to restore the ocean's breath can directly benefit human health and well-being. Sewage treatment and limiting global warming, for example, have societal benefits that extend beyond improving oxygen in our ocean and coastal waters.[1] In order to educate and build expertise in this issue area, IOC and Xiamen University have organized a summer school on De-Oxygenation, which will take place in Xiamen, China in September 2019.[2]

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[1] Breitburg, D., Grégoire, M. and Isensee, K. (eds.). Global Ocean Oxygen Network 2018. The ocean is losing its breath: Declining oxygen in the world's ocean and coastal waters. IOC-UNESCO, IOC Technical Series, No. 137 40pp.
[2] https://mel.xmu.edu.cn/summerschool/go2ne/Logistics.html.

Eutrophication and research on nutrients. The mobilization of nitrogen (N) and phosphorus (P) due to agriculture, aquaculture and wastewater from households and industries has been increasing rapidly in recent decades. N and P, which have played a major role in boosting food production, have found their way into nearly every water body across the globe and lead to enhanced growth of aquatic plants. This creates anaerobic conditions (hypoxia, dead zones), where organic matter decay consumes oxygen faster than its diffusion from the oxygen-rich surface.
With the expected fast population growth from the current 7 billion to expected 9 billion in 2050, this nutrient loading will continue growing. Moreover, there is also distortion of nutrient compositions in inland and coastal marine waters. Silicium (Si) is an essential nutrient for siliceous algae (diatoms), which stems almost entirely from rock weathering. Diatoms are considered to be non-harmful algae. Si is increasingly trapped in rivers due to enhanced Si retention in reservoirs. As a result, community structures change since siliceous algae require Si in balance with N and P and, where N and P are present in excess relative to Si, phytoplankton communities are dominated by non-diatoms and often toxic algae and cyanobacteria proliferate. IOC and UN Environment are working closely on capturing the risk of both the enhanced growth, decay and oxygen depletion and nutrient distortion in the Index for Coastal Eutrophication Potential (ICEP), which provides the method to measure indicator SDG 14.1.1. The methodology, still under refinement, will deliver an integrated generic model that links societal processes (e.g. food and energy production, nutrient and water management) and global change (e.g. global warming and hydrological alteration) for simulating nutrient mobilization from the land towards the coastal ocean, and ICEP estimates for all global rivers.

Harmful Algal Blooms and health. Harmful algal blooms (HABs) are natural phenomena that occur in all aquatic systems and cause worldwide problems with significant economic, social, and human health consequences. Their frequency and occurrence may alter of increase due to human activity such as nutrient pollution, climate change and intensified exploitation of the coastal environment. A central scientific problem is to understand and quantify the critical features and mechanisms underlying the population dynamics of HAB species in different aquatic habitats. This understanding is required as the basis for monitoring, modelling, and predicting HAB occurrence. In turn, monitoring and prediction are essential for management and mitigation of the impacts of HABs in the environment, human health and well-being, and to ascertain the effects of global or local climate change on these events. The IOC of UNESCO has for more than two decades been leading international collaboration to enhance capacity for mitigating the effects of harmful algae, enhance scientific understanding of the underlying mechanisms for HAB occurrences, global sharing of HAB data and to develop improved monitoring and forecasting systems. Continued capacity development, systematic and open access to HAB data and integration of HAB forecasting in both food safety programmes and coastal hazard warning systems is a priority.

Research on climate and climate change. The world ocean absorbs approximately 30 percent of human-induced CO_2 emissions and 93 percent of the excess heat of the planet that results from such emissions. There is a need to continue studying the role of the world ocean in the global climate system and in mitigation of climate change. IOC co-sponsors the World Climate Research Programme (WCRP) together with WMO and the International Science Council (ISC). 2018 has been a key year for WCRP. In 2017, an independent review of the Programme was undertaken and, in June 2018, after considering the outcomes of the review and its implications for WCRP and for IOC in June 2018, the IOC Council deliberated accordingly, providing guidance on how IOC should continue guiding the way in which the Programme will unfold in the future, in light of the UN Decade of Ocean Science and the 2030 Agenda; as well as to benefit from it.

A new Strategic Plan 2019-2029 was developed by the WCRP Scientific Committee. Research work on ocean and climate has continued in the context of relevant WCRP core projects, specifically CLIVAR (Climate Variability and Change), including in relation to the El Niño phenomenon and its prediction. Another focal area of IOC and WCRP/CLIVAR, also in collaboration with the Scientific Committee on Oceanic Research (SCOR), is how Eastern Boundary Upwelling Systems (EBUS) may be changing under the effects of climate change. EBUS constitute the most productive fisheries grounds of the planet, with the Canary Current upwelling system only providing approximately 25 percent of proteins from the sea in the whole world. Changes affecting these systems will have clear consequences on food security, and the research needed to generate actionable knowledge on EBUS should be seen as an important bridge between SDGs 14 and 2. IOC and WCRP/CLIVAR have organized a summer school on EBUS, which will take place in Trieste, Italy in July 2019.[3] An Open Science Conference on EBUS is being organized by IOC, SCOR and WCRP/CLIVAR and will be held in 2021 in Lima, Peru. WCRP also continues its work in relation to research aspects of the sea-level balance and sea-level rise. The Programme continues providing a coordinating platform for integrated models of climate change, which provide the basis for the development of the IPCC scenarios.

Marine plastics. Concern about the quantity of plastic debris in the ocean has grown rapidly in recent years. There is increasing interest for research in this area from the private sector, environmental NGOs, the media and the scientific community itself. IOC and IMO co-lead GESAMP WG40. In 2016 the Group completed an initial assessment of 'Sources, fate and effects of microplastics in the marine environment – a global assessment', also contributing to wider studies of marine litter. In 2018 the Group focused on the development of guidelines to achieve a harmonized approach for the assessment and monitoring of plastics and microplastics in the oceans. The working group in its current phase of work is focusing on sampling methodologies of plastics in the marine environment, impacts of nanoplastics and plastics as a vector for organisms. The Working Group is also reviewing existing initiatives and actions plans with a view to providing advice and practical guidance on setting-up a global monitoring and assessment programme for marine plastics and microplastics. Without this kind of research and standardized methodological work, it will be very difficult to understand the problem of plastics I the ocean, in terms of sources and fate, and impacts on the marine food web and human health, and to identify adequate solutions to this global problem.

An essential element of ocean science resides in the way data collected through research and observations are collated, shared and transformed into information, and ultimately knowledge that can inform a multitude of end-users, including policy-makers and the public at large, on the state of the ocean at various scales. IOC's International Oceanographic Data and Information Exchange (IODE) programme has developed, since its establishment in 1961, a global network of nearly 100 oceanographic data centres. During the past decades these centres have developed hundreds of online data and information services and products. These are becoming increasingly difficult to discover and to extract data and information because of their number and differences in language, interface, technology and formats. The IOC has now embarked on the development of the IOC's Ocean Data and Information System (ODIS) aiming to facilitate discovery of, and access to the vast amounts of ocean knowledge. A first prototype service under development if the "ODIS Catalogue of Sources" which will be a top-level inventory of online services and products, produced and maintained by IOC Member States. The system is expected to become online during the first trimester of 2019 and will be the foundation of a more performant system with higher granularity.

II. UN Decade of Ocean Science: initiatives, ideas, proposals, perspectives

The United Nations has proclaimed a Decade of Ocean Science for Sustainable Development (2021-2030) to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders

[3] http://www.clivar.org/events/ictp-clivar-summer-school-eastern-boundary-upwelling-systems-assessing-and-understanding.

worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the Ocean.

It is anticipated that the Decade will:

- Address knowledge gaps through integrated research: whilst the knowledge we need is still available for guiding the first steps to be taken in terms of removing, adapting and mitigating identified impacts, the Decade would establish missing or strengthen weak links of science to marine applications of direct social benefits (adaptation to climate change or marine spatial planning).
- Enable action at all levels: the Decade should provide an unifying framework to the UN-wide system for seeking science-based solutions to the 2030 Agenda priority issues. The Decade will catalyze major investments in ocean science (the Global Ocean Science Report found that ocean science accounts for less than 4% of the total research and development expenditures worldwide), as well as stimulate research agenda at the national level, by aligning science priorities with national commitments towards the sustainable development agenda. The Decade will raise awareness on the truly global dimension of the ocean, its economic services, demonstrating that its well-being affects people locally and globally;
- Build capacities to act worldwide: the Decade will initiate a coordinated framework responding to regionally driven priorities to improve the scientific knowledge base through capacity development, including ocean literacy for nations and groups that are presently limited in capacity and capability, especially SIDS and LDCs.

The Decade will aim to turn the scientific knowledge and understanding into effective actions supporting improved ocean management, stewardship and sustainable development, by procuring:

- A clean Ocean whereby sources of pollution are identified, quantified and reduced, and pollutants removed from the Ocean;
- A healthy and resilient Ocean whereby marine ecosystems are mapped and protected, multiple impacts (including climate change) are measured and reduced, and provision of ocean ecosystem services is maintained;
- A predicted Ocean whereby society has the capacity to understand current and future ocean conditions, forecast their change and impact on human wellbeing and livelihoods;
- A safe Ocean whereby human communities are protected from ocean hazards and where safety of operations at sea and on the coast is ensured;
- A sustainably harvested and productive Ocean ensuring the provision of food supply and alternative livelihoods;
- A transparent and accessible Ocean whereby all nations, stakeholders and citizens have access to Ocean data and information, technologies, and have the capacities to inform their decisions.

To address the above societal outcomes, the priority research and development areas have been defined in the Decade Roadmap at a global level and will be adapted to the scientific priorities identified during the regional consultation workshops to be conducted in 2019/2020 . The Science Plan of the Decade will combine these global priority research and development areas and the regional scientific priorities, building programmes of research that will have global goals and adapted at a regional level but also duplicated when efficient. The following research and development priority areas are proposed:

1. Comprehensive digital atlas of the ocean;
2. Comprehensive ocean observing system for all major basins;

3. Quantitative understanding of ocean ecosystems and their functioning as the basis for their management and adaptation;
4. Data and information portal;
5. Integrated multi-hazard warning system;
6. Ocean in earth-system observation, research and prediction, supported by social and human sciences and economic valuation;
7. Capacity-building and accelerated technology transfer, training and education, Ocean literacy.

The Implementation Plan will seek to achieve additional specific results, driven by the mission needs of society and science, and produce lasting benefits.

The UNGA resolution (A/RES/73/124) calls for the proclaimation of :

the United Nations Decade of Ocean Science for Sustainable Development for the 10-year period beginning on 1 January 2021, within existing structures and available resources, and called upon the Intergovernmental Oceanographic Commission to prepare an implementation plan for the Decade in consultation with Member States, specialized agencies, funds, programmes and bodies of the United Nations, as well as other intergovernmental organizations, non- governmental organizations and relevant stakeholders.

Since its creation in 1960, the Intergovernmental Oceanographic Commission has provided a global intergovernmental forum for coordinating programmes in research, services and capacity-building, to support Member States efforts in the sustainable use of the marine environment. Because of the nature of its work, its contributions to UN frameworks and collaboration with other UN and non-UN partners and its convening capacity to bring together scientists and government representatives, the IOC is a 'natural convener' to coordinate the preparation of the Decade.

The aims of the Preparation Phase coordinated by IOC are to:

(i) develop and agree governance arrangement, for both the planning phase and for the Decade *per se*;
(ii) outline the form and structure for the Decade;
(iii) engage and consult relevant communities concerning preparations for the Decade;
(iv) develop a resource mobilization (business plan) for the Decade;
(v) communicate the purpose and expected results of the Decade to all stakeholders;
(vi) draft an Implementation Plan for the Decade.

IOC is working within its limited resources to prepare the UN Decade and the development of an implementation plan to be delivered to the UNGA by the end of 2020. In the first part of 2018, a roadmap was developed to guide the development of the Decade in terms of preliminary objectives, societal outcomes, governance and engagement processes. The 51st session of the IOC Executive Council welcomed the roadmap and decided to establish an Executive Planning Group (EPG) consisting of high-level experts to advise the IOC Secretariat, as well as a Stakeholder Forum, open to a broad range of communities (science, technology, ocean management, private sector, civil society) that are interested in contributing to the Decade. Communication and outreach efforts have intensified to present the objectives of the Decade and engage various stakeholders in various fora (UN bodies, international and regional conferences, ocean relevant networks, private sector events) and though various means (presentations, videos, newsletters, website, press releases, social media).

IOC convened the 1st meeting of the EPG on 17-19 December 2018 to brainstorm on scientific, governance, communications, and engagement elements of the Decade ahead of a first Global Planning Meeting and a series of regional consultations foreseen in 2019/2020 (to take place in all ocean basins) that will channel stakeholders' inputs into the preparatory process. Beyond the scientific process itself, there was wide consensus within the EPG that the Decade must transform how nations around the world invest in ocean science, both from the public and private sectors, and how decisions-makers use the available scientific knowledge to make better-informed policies for ocean management.

Experts also sought to lay out the basis for an effective strategy to communicate the objectives of the Decade, engage stakeholders, and ultimately influence behaviors and perceptions of scientists, decision-makers and the public around the value of ocean science for sustainable development. Experts also stressed that capacity development and the transfer of marine technology should be a key and cross-cutting priority, embedded deep into the planning process. The lack of additional resources made available to the IOC Secretariat to lead and coordinate the preparation phase remains a challenge. Only three countries (Korea, Japan, and UK) have made financial contributions to support planning activities. Without additional resources, the Secretariat may not be in a position to deliver a Decade plan which fully reflects the need of all nations, simply because thorough consultations will not have been conducted in all regions.

III Cross-cutting role of ocean science in Sustainable Development Goal 14 of the 2030 Agenda for Sustainable Development

The 2030 Agenda adopted by all nations offers a concerted framework of action to set the ocean on a path to sustainability whilst also highlighting the universal dimension of the ocean in promoting other societal goals, such as gender, equity, sustainable economic development, food security or climate change, amongst a few. These critically important goals are very science intensive by nature, and to deliver the science required, a new transformative approach is needed. Underpinning these global goals, scientific understanding of the ocean response to pressures and management action is fundamental for sustainable management.Promoting science-based solutions and their systematic transformation into informed policies underpin the successful attainment of SDG 14. Marine science plays an important role in the fisheries management process, including for the adoption of conservation and management measures. Science also has an important role to play in managing other human pressures on the marine environment, including cumulative impacts from local pressures such as marine pollution, coastal development and resources extraction that act together with global impacts of climate change. Traditional knowledge, based on generations of close interaction with the ocean environment, can provide a similarly important foundation for stewardship. Education and public awareness are important priorities for producing an informed and engaged population and for raising the next generation of ocean citizens. Technology can support the achievement of SDG 14, for example, by helping to deliver more efficient and sustainable fishing methods, enhance monitoring and surveillance of fishing activities, facilitate pollution prevention and clean-up, and enhance marine spatial planning.

Ocean observations and research are also essential to predict the consequences of change, design mitigation and guide adaptation to cope with the many ways the ocean affects human lives and infrastructure at different spatial and temporal scales. This enhanced understanding, based on effective communication of scientific knowledge, is a prerequisite for generating commitments among governments and other stakeholders, and for creating a new level of awareness in the public about the state and future of the ocean. This understanding may also trigger and guide substantial technological developments and related transfer of marine technology, including modelling tools, new forecasting capabilities, through sustained cooperation, and new partnerships, also stimulating capacity building.

IOC has been designated as custodian agency to two SDG 14 indicators: the one related to Target 14.3, which deals with ocean acidification; and Target 14.a on ocean science capacity.

In the course of 2018, IOC actively provided technical support to Member States to report towards the SDG indicator 14.3.1. The Commission now provides the methodology with detailed guidance to scientists and countries in terms of how to carry out measurements following the best practices established by the ocean acidification community, as well as how to report the collected information in a manner that ensures it is transparent, traceable and that can be utilized in a global comparison of pH measurements. In this way, IOC and its networks, including the Global Ocean Acidification Observing Network (GOA-ON), directly contribute to the achievement of SDG Target 14.3, which calls to "minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels". The methodology was finalized by the IOC OA expert group GOA-ON and welcomed by the IOC Executive Council at its 51st session. Subsequently, the Interagency Expert Group for the SDG indicators of the UN Statistical Commission agreed to upgrade this methodology from tier III to tier II, thus indicating that the "[i]ndicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries" (the latter is required for the indicator to move to tier I status).

GOA-ON has now more than 480 members from 80 countries (in 2015 those were 150 scientists from 31 countries) and is constantly growing. Many new members joined especially from Small Island Developing States. Currently 12 SIDS and 18 African countries are represented. Thus, IOC's work in the area of ocean acidification also entails a strong capacity development element.

The IOC Global Ocean Science Report (GOSR) aims to provide a status report on ocean science.[4] It identifies and quantifies the elements that drive the productivity and performance of ocean science, including workforce, infrastructure, resources, networks and outputs. The report is intended to facilitate international ocean science cooperation and collaboration, and strategic investments in the field of ocean science to support sustainable blue economies. It also helps to identify gaps in science organization and capacity and develop options to optimize the use of scientific resources and advance ocean science and technology by sharing expertise and facilities, promoting capacity-building and transferring marine technology.

The first edition of GOSR was presented at the United Nations Ocean Conference in New York. GOSR represents the core of the methodology to measure progress on the achievement of SDG Target 14.a, which calls on "increasing scientific knowledge, developing research capacities and transferring marine technology, taking into account the IOC 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 SIDS and LDCs".

Following the publication of GOSR, the Interagency Expert Group for the SDG indicators of the UN Statistical Commission agreed to upgrade the IOC methodology related to indicator 14.1.a from tier III to tier II. It is expected that the second edition of GOSR, which will be presented at the second UN Oceans Conference in 2020, will allow the methodology to achieve tier I status. Following the adoption of Decision XXIX/Dec.5.1 by the IOC Assembly at it 29th session in June 2017, GOSR-II will be corroborated by a GOSR data portal that will facilitate data gathering, analysis, storage and reporting on SDG Target 14.a, including a gender disaggregated manner.

[4] https://en.unesco.org/gosr.

IV. Strengthening observation networks and emerging technologies

Continuous access to the open ocean, coastal zones and watersheds depends on novel infrastructure and technology, from sensors to research vessels to autonomous vehicles. Research vessels are an essential component of ocean research infrastructure as they provide access to both the open ocean and coastal areas. Evolving science needs, cost pressures and newer technologies, such as advances in autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs), have changed ocean science infrastructure. However, this has not lessened the reliance on well-equipped ships. In fact, research vessels are fundamental to deploy and recover new observing technologies and to explore the vast areas of the ocean poorly observed to date. Determining how to size the fleet (e.g. appropriate number of research vessels and their scientific research capabilities) is an essential exercise that should be carried out in order to utilize existing funding efficiently, to plan future investment, to match seagoing capacities with research demands, and to maintain or improve current capabilities Moorings and buoys are also important to gather data on the state of the global ocean by providing continuous measurements of physical and chemical parameters. The Data Buoy Cooperation Panel (DBCP) was formed in 1985 as a joint body of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. It coordinates the operation of surface drifting buoys and tropical moored arrays. The Argo profiling floats programme is coordinated by the Argo Project Office and the Argo Information Centre at JCOMM in situ Observing Platform Support centre (JCOMMOPS). Such coordination and other activities allow JCOMMOPS to maintain real-time maps and statistics on the status of the ocean observing networks such as: DBCP, including drifting buoys, moored buoys, tsunameter buoys and fixed platforms, and the Argo network of sub-surface profiling floats.

According to the GOSR, the total number of platforms (2,093) comprise drifting buoys (1,536; other than Argo floats), coastal/national moored buoys (398), tsunameter (55) and fixed platforms (104). The USA operates 1,267 drifting buoys, followed by Europe (103), Canada (34), France (29) and Australia (18). Argo is a model on how to share ocean science infrastructure. It has offered new ideas on (i) how to collaborate internationally, (ii) how to develop a data management system, and (iii) how to change the way scientists think about collecting data. Deployments began in 2000 and continue today at the rate of about 800 per year.

There are 3,839 Argo floats listed as active and in operational condition. The array of floats is presently provided by 29 countries. National contributions of floats to the Argo array vary from a single float (e.g. by Kenya and South Africa) to the USA contribution of 2,136, approximately 55% of the global total. A primary focus of Argo is to document seasonal to decadal climate variability and to improve the predictability. Argo is part of the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS). In July 2018, the IOC Executive Council recognized the need to expand capabilities to observe the global ocean and approved the extension of the global implementation of the Argo Program to include the measurement of six new biogeochemical parameters on Argo floats—oxygen, pH, nitrate, chlorophyll, backscatter and irradiance. These new variables will play a vital role increasing our knowledge of the large-scale evolution of the ocean's biogeochemistry and associated impacts on marine ecosystems.

ROVs and AUVs

In addition to buoys and moorings, new marine research technologies include an array of 'vehicles'. A remotely operated vehicle (ROV) is an unoccupied underwater robot that is connected to a ship by a series of cables. These cables transmit command and control signals between the operator and the ROV, allowing remote navigation of the vehicle. A ROV may include a video camera, lights, sonar systems and an articulating arm. The articulating arm is used for retrieving small objects or samples, cutting lines or attaching lifting hooks to larger objects. An autonomous unmanned underwater vehicle (AUV), commonly known as an unmanned underwater vehicle, is one of the technologies that can be used for underwater survey missions such as detecting and mapping submerged wrecks, rocks and obstructions that may be hazardous to navigation for commercial and recreational vessels. An AUV conducts its survey mission without operator intervention. When a mission is complete, the AUV will return to a pre-programmed location where the data can be downloaded and processed. An AUV operates independently from the ship and has no connecting cables, whereas ROVs are connected to an operator on the ship.

Ocean gliders are one type of AUV that are used for ocean science. Since gliders require little or no human assistance while travelling, these little robots are uniquely suited for collecting
data in remote locations, safely and at relatively low cost. Gliders may be equipped with a wide variety of sensors to monitor temperature, salinity, currents and other ocean conditions.

ROVs and AUVs (including gliders) are becoming increasingly important to explore and investigate vast areas of the open ocean. They help to monitor the ocean more closely and to fill knowledge gaps in the existing ocean observation data sets. During the past decade, the research application of AUVs has increased greatly, due to their unique capacity to carry sensors, such as for ocean acidification measurements and for characterizing carbon and nutrient cycles. The widespread application of unstaffed platforms is transforming oceanographic infrastructure. AUVs, including instrumented sea animals and gliders, are ideal platforms to use the newly developed small, low-power sensors for monitoring physical, chemical and biological indicators of dynamic variability and ecosystem variations in coastal and island settings. Previous and ongoing undertakings to assess ROVs, AUVs and gliders were used to confirm and to complement information provided via the GOSR questionnaire. A total number of 339 pieces of equipment (ROVs, AUVs and gliders) was identified in 28 countries. Portugal reported the highest number of ROVs, followed by the Republic of Korea, Greece, Norway, UK and USA. The highest number of AUVs are maintained in the USA (47), followed by the UK (22), the Republic of Korea (13), Norway (9) and Canada (8).

Another example of emerging technology is the SMART Cable Systems which aims to integrate ocean sensors into undersea telecommunication cables. Ocean observing, especially of the deep ocean, remains difficult and costly. SMART cables can provide new data by integrating sensors into undersea telecommunications cables. As new cables are laid, they will carry oceanographic instruments down to the sea floor where they can provide unique real time, high-resolution ocean science data. Undersea cables stretch across the oceans and along coastlines and are replaced or expanded every 10-20 years. Cables employ “repeaters” to regenerate the fiber optic signal every 50-100 km, and each of these repeaters can host sensors. By riding on this existing power and communications infrastructure, SMART cable sensors offer the potential for near global coverage at a cost that is a fraction of single-purpose science-only systems. The initial plan to integrate bottom pressure, temperature, and acceleration sensors into future cables can cost-effectively create a cable-based global ocean sensor network within the 10-20-year refresh cycle. SMART cables complement existing observing streams from satellites, buoys and field sampling. Their data with excellent spatial and temporal sampling can improve models of ocean circulation, sea level rise, and ocean mass. SMART cables would increase the existing small number of deep ocean tsunami pressure sensors from dozens to hundreds, helping to reduce detection time, improve precision of tsunami warnings, and greatly reducing the potential of unnecessary warnings and evacuations. The International Telecommunication Union (ITU), the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO/IOC), and the World Meteorological Organization (WMO) have established a Joint Task Force (JTF) to bring the initiative to fruition. JTF is working with national governments and cable consortiums in the Asia and Pacific Rim regions where the value for sensor-enabled cables is particularly high because of tsunami risk. The first SMART cable pilot programs will prove the wet technology and data integration systems, and validate a pipeline toward off-the-shelf, matter-of-course availability. JTF is seeking development funding and industry partnerships to move from demonstration to full production.

Earth observing satellites represent some of the most valued components of the international Global Ocean Observing System (GOOS) and of the Global Climate Observing System (GCOS). Satellite imagery and satellite-derived data are required for mapping vital coastal and marine resources, improving maritime domain awareness, and to better understand the complexities of land, ocean, atmosphere, ice, biological, and social interactions. These data are critical to the strategic planning of in situ observing components and are critical to improving forecasting and numerical modeling. Specifically, there are several stakeholder communities that require periodic, frequent, and sustained synoptic observations. Of particular importance are indicators of ecosystem structure (habitat and species inventories), ecosystem states (health and change) and observations about physical and biogeochemical variables to support the operational and research communities, and industry sectors including mining, fisheries, and transportation. Partnerships between the private, government, and education sectors are needed to enhance remote sensing support and product development for critical coastal and deep-water regions based on infrared, ocean color, and microwave satellite sensors.

V. Science-policy interface

IOC contributes to scientific and technical work underpinning the discussions and deliberations by the UNFCCC and its SBSTA, particularly in the area of research and systematic observations. At its 48th session held in Bonn, Germany, in April–May 2018, the SBSTA (...) encouraged Parties and relevant organizations to address gaps and needs with regard to: The role of the ocean in the global climate system, including for the global energy balance and carbon cycle, and impacts related to, inter alia, ocean acidification, sea level rise and ecosystem services, noting the proclamation by the United Nations of the United Nations Decade of Ocean Science for Sustainable Development (2021–2030), which is to be coordinated by IOC-UNESCO (...)".

IOC was invited to attend the 10th session of the Research Dialogue convened by the SBSTA (Bonn, Germany, 3 May 2018) and to provide inputs based on its activities on the themes of science for understanding: update on research and modelling on human settlements, oceans and land and their importance for the implementation of the Paris Agreement; and science for action: strengthening the link between the research community and action to meet the goals of the Paris Agreement.

In noting the importance of the work of the scientific community under the themes of the Research Dialogue, the SBSTA encouraged Parties and relevant organizations to address gaps and needs with regard to increasing open access to climate-relevant data; the vulnerabilities of terrestrial, marine, coastal and urban ecosystems to climate change and the value of ecosystem-based approaches, particularly synergies of mitigation and adaptation action and related co-benefits; the recent and ongoing rapid changes in the Arctic region; and the analysis of the global carbon cycle. The SBSTA also recognized the importance of continued and enhanced support for climate change research, including enhancing research capacity, particularly in developing countries.

In response, and in collaboration with its co-sponsors of the International Blue Carbon Initiative, IOC has developed a methodology to measure blue carbon storage to assist national efforts and reporting related to the UNFCCC and has promotes science advocacy through the organization of side events during the UNFCCC COP 24, highlighting the potential of blue carbon ecosystems as a Nature Based Solution to be applied in the NDCs to mitigate climate change (Nationally Determined Contributions under the Paris Agreement).

In addition, the IOC Executive Council at its 51st session agreed to establish a new IOC working group focusing on integrated ocean carbon research, federating the work of the main research programmes in this area: IOC, IMBeR, SOLAS, WCRP/CLIVAR, GCP and IOCCP. This expert group will inter alia aim at filling knowledge gaps in scientific knowledge that are hampering policy decisions in the context of the UNFCCC.

IOC also continues to co-sponsor GESAMP Working Group 41 on Geo-engineering in the Marine Environment, which is in a process of redefining membership to address a new set of Terms of References adopted by GESAMP 45 September 2018. This will allow a continued interagency focus at the challenges and possibilities in marine geo engineering, which is also relevant to a number of provisions under the UNFCCC and its Paris Agreement.

VII. Strengthening ocean science in developing countries

As a follow-up to the adoption of the IOC Capacity Development Strategy (2015-2021) through Resolution XXVIII-2 by the 28th Session of the Assembly of the Intergovernmental Oceanographic Commission of UNESCO (IOC), progress has been made with the mainstreaming of the Strategy throughout all IOC global and regional programmes.

The IOC Group of Experts for Capacity Development was established through Decision IOC-XXIX/10.1. (2017). The main objectives of the Group of Experts are to assist the global and regional programmes with the implementation of capacity development (CD) needs assessments, the development of related work plans, mobilization of resources, and provide advice on relevant methods and tools to deliver CD. The Group established 2 task teams: one on assessing CD requirements of SIDS, LDCs and IOC Member States currently not member of one of the regional bodies of the IOC, and a second to start implementation of the Transfer of Marine Technology Clearing House Mechanism (CHM) as requested by the IOC Criteria and Guidelines on the Transfer of Marine Technology (IOC/INF-1203), making use, to the largest extent possible, of existing data and information systems already available at IOC. After a survey of Member States it was decided to develop the CHM/TMT as a global integrated framework of regional information hubs that each have a regional focus and information collection, management and delivery system, while they are also interlinked globally to allow inter-regional information discovery, delivery and reporting. The first prototype is being built for the Latin American region and is expected to be operational by half 2019.

The IOC regional bodies are developing integrated capacity development implementation plans taking into account the 6 expected outputs of the Strategy ((i) human resources developed; (ii) access to physical infrastructure established or improved; (iii) global, regional and sub-regional mechanisms strengthened; (iv) development of ocean research policies in support of sustainable development objectives promoted; (v) visibility and awareness increased; and (vi) sustained (long-term) resource mobilization reinforced.

IOC is also continuing the development of the OceanTeacher Global Academy (OTGA), a capacity development tool developed around 2 main pillars: 1) Regional Training Centres that are better equipped to address the Regions' training needs and 2) sharing of training resources through a common e-Learning Platform. The OceanTeacher Global Academy is currently composed of a network of 9 Regional Training Centres (RTCs) based in Belgium, Colombia, China, India, Iran, Kenya, Malaysia, Mozambique and Senegal, with possibility to expand in the future. The RTC model makes it possible to train a much larger group of participants and to offer training courses in different languages. The RTC model relies on available (lecturing) expertise from the RTCs and the Regions as well contributions from experts using videoconferencing. Training content is shared through the OTGA e-Learning Platform. In 2018, more than 600 people from over 80 countries benefited from the OTGA training activities.

Throught its activities, OTGA contributes to the implementation og SDGs 4, 5, 9, 10, 13 and 14. The UNESCO/IOC Project Office for IODE is a ISO 29990 certified Learning Service Provider.

Funding of ocean sciences

Ocean science relies on sustained funding, international collaboration and support from a variety of funding sources. The GOSR is the first global endeavour to capture governmental funding of ocean science at national levels. This first-ever assessment includes the contributions of 29 countries that responded to the GOSR questionnaire (2015) submitting information for the time period 2009–2013. Despite methodological and data collection constraints, some key trends in ocean science were identified. Based on the results of the GOSR questionnaire, government funding for ocean science remains modest. Ocean science funding, as a share of national R&D funding, varies widely between countries from < 0.04% to 4%. Countries with the largest dedicated ocean science budget include USA, Australia, Germany, France and the Republic of Korea. Ocean science, like other scientific and R&D domains, is facing increased sustainability challenges in many countries. When examining trends over five years (2009–2013), ocean science funding has fluctuated by more than 50% in some countries (e.g. Argentina, Chile and Japan). A growing number of commercial actors from diverse maritime sectors (e.g. oil and gas, offshore wind, aquaculture) have become direct and indirect beneficiaries of ocean R&D and observing programmes. In some countries, there may be potential to increase private investment in dedicated ocean research programmes (e.g. PhDs and postdoctoral researcher positions supported by private grants). As other sources of funding, non-profit institutions (including foundations and crowdfunding) are becoming new mechanisms to fund selected ocean science programmes. However, these sources remain negligible in most countries, with the bulk of funding for researchers still relying on grants from government agencies. Looking ahead, pressures on public budgets for science and R&D may intensify in some countries, with implications for ocean science funding. To secure long-term institutional support, as well as to diversify sources of funding, ocean scientists may need to increasingly demonstrate the high and long-term societal and economic value of investing in ocean research. The ocean economy is already bringing many benefits in terms of employment, revenues and innovation across many domains. Its current development is based on decades of R&D investment by governments around the world. To ensure future environmental sustainability and economic growth, continuous ocean research supported by long-term public and private funding will need to be secured.

Recommendations for strengthening the conduct of ocean science globally

The Global Ocean Science Report identified a number of recommendation in this respect. These are :

Facilitate international ocean science cooperation
Increasing international cooperation will enable all countries to engage in ocean research, develop communication and publication strategies, and ultimately increase global scientific output and impact.

Support global, regional and national data centres for effective and efficient management and exchange of ocean data and promote open access. The adoption and implementation of internationally-accepted standards and best practices for the management and exchange of data will result in more effective and efficient global, regional and national ocean data centres. Benefits from existing and future ocean research would be enhanced through the adoption and implementation of data policies that support open access.

Explore and encourage alternative funding models.
Government funding for academic research is limited, and competition for grants can be expected to remain high in the future. International collaborations in the form of joint ocean science projects and

expeditions, shared infrastructure and new technology development will reduce the costs of field expeditions and enable countries to strengthen their range of scientific expertise.

Enable ocean science-policy interactions through diiverse avenues.
The changes in the global ocean pose a multitude of challenges to understanding ocean functions and translating scientific knowledge to support global ocean stewardship. Given the plethora of organizations involved in ocean management, strong coordination mechanisms to enable science-policy interactions would help prepare society to respond to global ocean change.

Align national reporting mechanisms on ocean science capacity, productivity and performance. Reporting mechanisms to assess and track developments in the technical and human capacities in ocean science worldwide are indispensable to evaluate investments, monitor changes and inform policy- and decision-makers. Aligning reporting mechanisms would support the collation and interpretation of global ocean science metrics. This would enable developments in ocean science to be traced and opportunities and challenges in global ocean science to be identified.