Global Ocean Science Report

EXECUTIVE SUMMARY

The Current Status of Ocean Science around the World

United Nations
Educational, Scientific and
Cultural Organization

Intergovernmental
Oceanographic
Commission

Sustainable
Development
Goals

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Scope and Purpose

The ocean is the largest ecosystem on our planet, regulating change and variability in the climate system and supporting the global economy, nutrition, health and wellbeing, water supply and energy. The coastal zone is home to the majority of the world population; dependency on the ecosystem services provided by the ocean is likely to increase with population growth. The ocean was once thought to be a vast and indefinitely resilient compartment of the Earth system, able to absorb practically all pressures of the human population, from resource exploitation to fisheries and aquaculture development to marine transport. However, according to the First World Ocean Assessment,[1] our civilization is running out of time to avoid the detrimental cycle of decline in ocean health that will have dramatic repercussions on the ability of the ocean to keep providing the support we need. To achieve global sustainability and adequate stewardship of the ocean, as called for in the United Nations 2030 Agenda for Sustainable Development (2030 Agenda), ocean science is crucial to understand and monitor the ocean, predict its health status and support decision-making to achieve Sustainable Development Goal 14 (SDG 14) "Conserve and sustainably use the oceans, seas and marine resources for sustainable development".

Ocean science definition applied in the Global Ocean Science Report[2]

Ocean science, as considered in this report, includes all research disciplines related to the study of the ocean: physical, biological, chemical, geological, hydrographic, health, and social sciences, as well as engineering, the humanities, and multidisciplinary research on the relationship between humans and the ocean. Ocean science seeks to understand complex, multi-scale social-ecological systems and services, which requires observations and multidisciplinary and collaborative research.

The IOC-UNESCO Global Ocean Science Report (GOSR) aims to provide a status report on ocean science. 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. It 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. As the first consolidated assessment of global ocean science, the GOSR assists the science-policy interface and supports managers, policy-makers, governments and donors, as well as scientists beyond the ocean community. The GOSR offers decision-makers an unprecedented tool to identify gaps and opportunities to advance international collaboration in ocean science and technology and harness its potential to meet societal needs, address global challenges and drive sustainable development for all.

There is no commonly accepted definition of ocean science; the *1982 United Nations Convention on the Law of the Sea* does not provide a definition of marine scientific research. For the purpose of this report, ocean science is considered to be a combination of disciplines classified into eight categories that cover integrative and interdisciplinary strategic research areas often recognized as high-level themes in national and international research strategies and policies (Figure ES1). This classification enables global comparisons and interdisciplinary analyses in line with the 2030 Agenda.

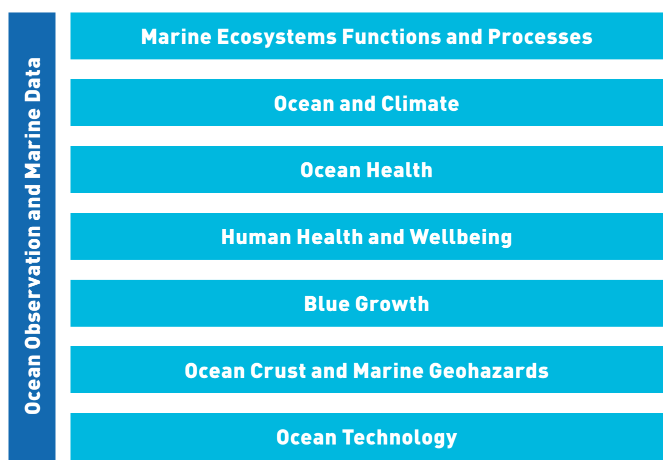

Figure ES1. Ocean science categories considered in the Global Ocean Science Report.

The report draws on a range of information sources. In addition to tailored questionnaires developed for the GOSR, ocean science output data (bibliometrics) by Science-Metrix and supplementary resources (e.g. web-based assessments and reports produced by intergovernmental organizations) were compiled to form the data set for the GOSR analysis.

1 The First Global Integrated Marine Assessment: World Ocean Assessment I (Group of Experts of the Regular Process, under the auspices of the United Nations General Assembly and its Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, 2016).

2 This definition was presented by the Expert Panel on Canadian Ocean Science in the report "Ocean science in Canada: meeting the challenge, seizing the opportunity" (Council of Canadian Academies, 2013).

Key Findings

1. **Global ocean science is 'big science'**. Conducting ocean science requires numerous staff and large and costly equipment such as ships, ocean installations and laboratories located on the coast. These resources are distributed around the world comprising, for example, 784 marine stations, 325 research vessels, and more than 3,800 Argo floats.
2. **Ocean science is multidisciplinary**. Most ocean science facilities work across a broad range of issues (39 %), whereas others specialize on observations (35 %) or fisheries (26%).
3. **There is more equal gender balance in ocean science than in science overall.** Female scientists represent on average 38 % of the researchers in ocean science, about 10 % higher than science overall.
4. **Ocean science expenditure is highly variable worldwide**. According to available data, ocean science accounts for between 0.1 % and 21 % of natural science expenditure and between < 0.04 % and 4 % of total research and development expenditure. From 2009 to 2013, ocean science expenditure varied among regions and countries, some increased their annual expenditure on ocean science, while others significantly reduced it.
5. **Ocean science benefits from alternative funding**. Private funding, including philanthropy, in some cases provides supplemental support for ocean science and enables the development of new ocean science technologies.
6. **Ocean science productivity is increasing**. Ocean science is expanding in magnitude and scope, resulting in greater scientific output. When comparing the time periods 2000–2004 and 2010–2014, China, Iran, India, Brazil, Republic of Korea, Turkey and Malaysia show the strongest relative growth in scientific output. China has become a major source of new publications, with the USA, Canada, Australia and European nations (UK, Germany, France, Spain and Italy) continuing as top producers of ocean science publications.
7. **International collaboration increases citation rates**. Generally, North American and European countries have a multiplying factor or impact factor (ratio of citations to publications) higher than countries from other parts of the world. The extent to which a country is engaged in international collaboration influences its citation rates. On average, publications that are co-authored by scientists from many countries are cited more often than publications for which all the authors are from the same country.
8. **Ocean data centres serve multiple user communities with a wide array of products**. At the global level, the main type of data archived by ocean data centres is physical data, followed by biological and then chemical data. Less than half of ocean data centres provide data on pollutants or fisheries. The top three ocean data/information products provided by ocean data centres are metadata, geographic information system (GIS) products and raw data access. Ocean data centres provide three main services: data archival, data visualization and data quality control.
9. **Science-policy interactions can occur through many avenues**. Current ocean science policy and science diplomacy focuses on prioritizing scientific research areas and steering the production and use of knowledge to address societal needs and prepare nations for future challenges at national, regional and global scales.
10. **National inventories on ocean science capacity exist only in few countries.** The multidisciplinary nature of ocean science complicates efforts to establish reporting mechanisms to map ocean science capacities; the organization of national, academic, and federal capacities for marine research varies greatly.

What is true for the ocean, its resources and ecosystem services, is also true for ocean science capacities: you cannot manage what you do not measure.

To foster ocean-based sustainable development, a baseline is needed of where and how existing ocean science capacities are being used to empower society, sustain the environment and generate knowledge to support ocean management and develop useful products, services, and employment. The GOSR offers a tool to help address this gap. It identifies and quantifies the key elements of ocean science at the national, regional and global scale, including workforce, infrastructure and publications.

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1. **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.
2. **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.
3. **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.
4. **Enable ocean science-policy interactions through diverse avenues.** The changes in the global ocean pose a multitude of challenges to understand ocean functions and translate 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.
5. **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.

Facts and Figures

Who is doing ocean science?

Ocean science depends on skilled individuals and a broad array of infrastructure. Technological advances and international collaboration to transfer marine technology are key to leverage investigation and observation of the global ocean. The 'human resources' that drive ocean science are concentrated in certain countries and vary worldwide by age and gender (Figure ES2).

The number of researchers per capita varies substantially among countries around the world (> 300 to < 1 per million inhabitants).

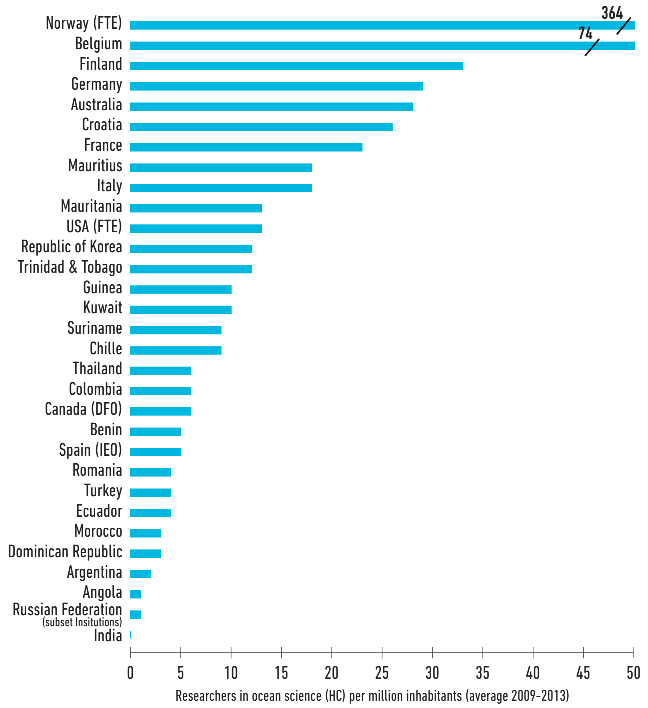


Figure ES2. Average number of national ocean science researchers (headcount, HC) employed per million inhabitants (2009–2013). In some cases, the reported information was not the national average: for Norway and the USA data represent full time equivalent (FTE) ocean research positions, for Canada HC information was provided only for Fisheries and Oceans Canada (DFO), and for Spain HC represents only the Spanish Institute of Oceanography (IEO). Sources: GOSR questionnaire, 2015; UNESCO Institute for Statistics (UIS), 2015.

Female scientists comprise on average 38 % of the researchers in ocean science, about 10 % higher than the global share of female researchers. However, gender balance differs significantly between different categories of ocean science and between countries (Figure ES3).

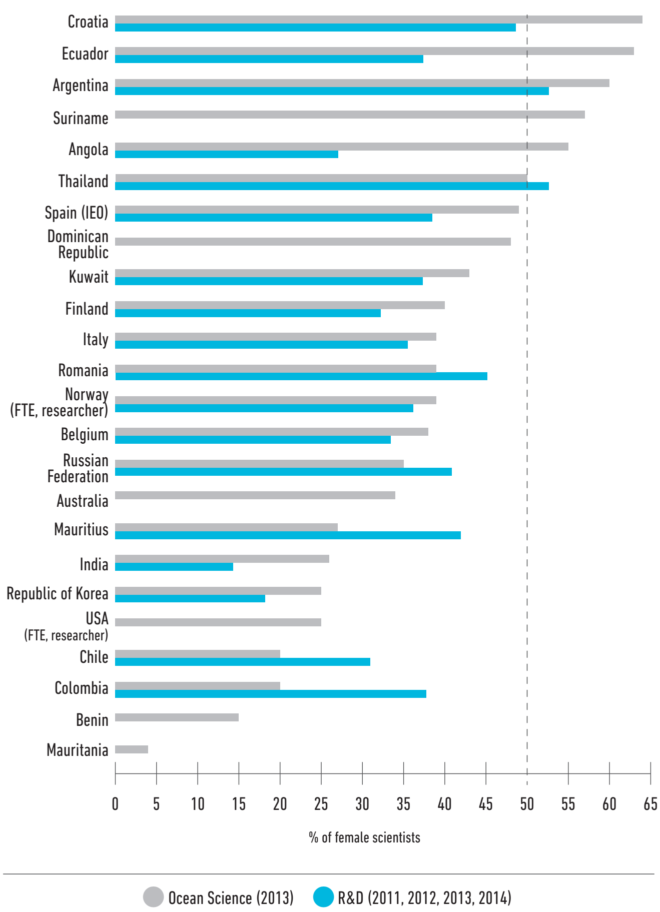


Figure ES3. The proportion (% total) of female researchers in ocean science (headcounts; grey bars) and in R&D (blue bars). Sources: GOSR questionnaire (ocean science), 2015; UIS (R&D), 2015.

What is used for ocean science?

Ocean science institutions and marine laboratories play a vital role in support of ocean research. They are critical for addressing several scientific issues, including studies of the structure and functioning of marine and coastal food webs, ecosystem biodiversity, and human impacts on coastal environments. The global landscape of ocean science research institutions, marine labs and field stations depends on national research focus areas and research organizations.

Worldwide, many (39 %) ocean science research institutions work across a broad range of issues, whereas others specialize on more limited themes such as observations (35 %) or fisheries (26 %).
The USA has the highest number of research institutions varying in size (315)—roughly equal to the total number of research institutions in Europe combined and greatly exceeding the number of institutions operated in Asia and Africa.

Marine field stations and laboratories provide access to a range of environments, including coral reefs, estuaries, kelp forests, marshes, mangroves, and urban coastlines. Globally 784 marine stations are maintained by 98 countries, the majority are located in Asia (23 %), followed by Europe (22 %), North America (21 %), Antarctica (11 %), South America (10 %), Africa (8 %) and Oceania (5 %).

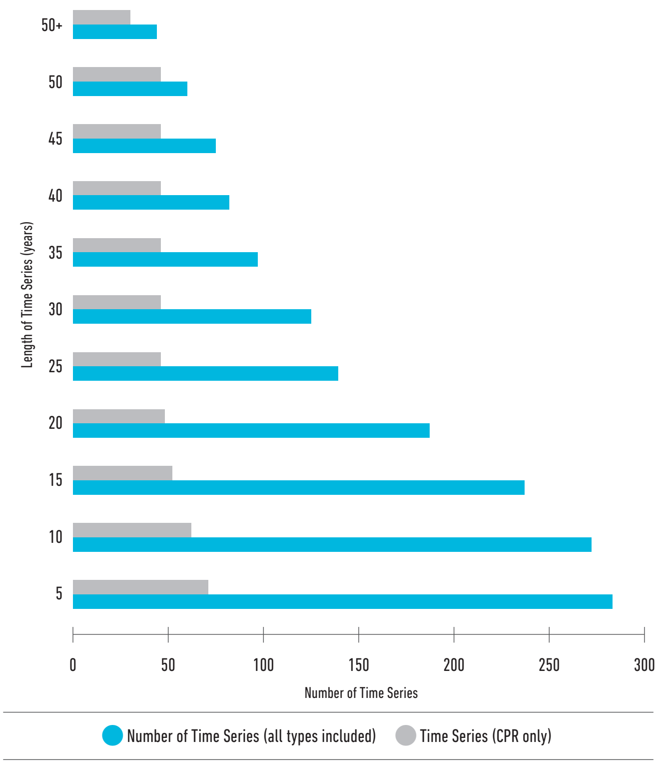
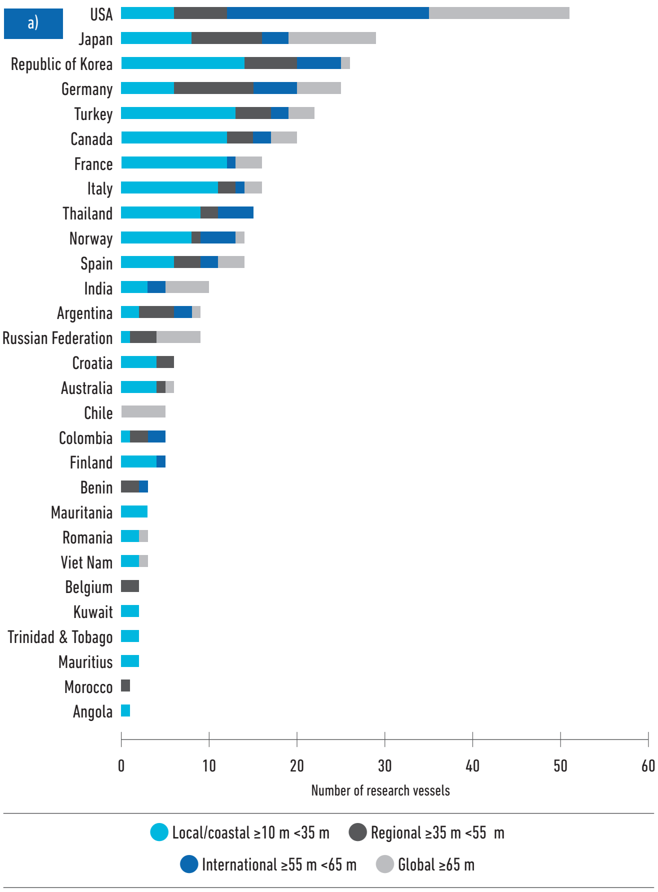


Figure ES4. Histogram of ship-based time series sorted by their span in years (2012 status). The Continuous Plankton Recorder (CPR) time series are plotted separately, highlighting the significant contribution to the longer time spans. Source: IGMETS, 2016.

Sustained, ship-based time series, some maintained for more than 50 years, enable investigation of remote locations including along the continental shelf and in the open ocean (Figure ES4).

Ongoing investment in research vessels together with the development and deployment of novel technologies, such as sensors, probes and automated underwater vehicles, help to advance ocean science. Moorings and buoys gather vital information about the global ocean and benefit from international coordination and collaboration, for example, the Argo programme, established in 2000, is maintained by 20 countries.

Globally at least 325 research vessels are currently in operation (Russian Federation, USA and Japan together maintain more than 60 % of the total), ranging from 10 m to more than 65 m in length, with some built more than 60 years ago, while others have been in operation for less than 5 years. The average age of national fleets varies between < 25 years (Norway, Bahamas, Japan, and Spain) and > 45 years (Canada, Australia and Mexico). More than 40 % of research vessels focus primarily on coastal research, while 20 % engage in global research (Figure ES5).



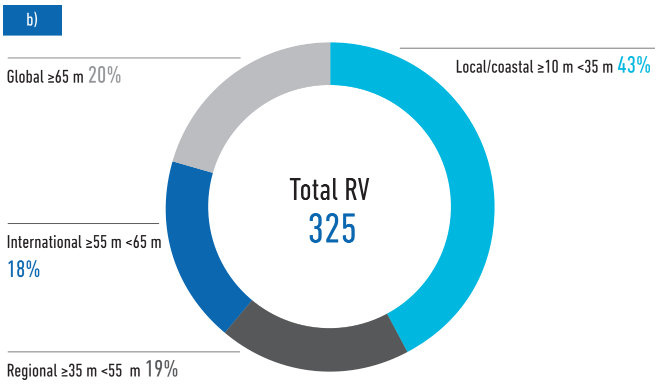


Figure ES5. **a)** Number of nationally maintained research vessels (RV), classified into four different ship size classes: local/coastal ⩾ 10 m to < 35 m, regional ⩾ 35 m to < 55 m, international ⩾ 55 m to < 65 m, global ⩾ 65 m. **b)** Relative proportion of the different ship sizes summarizing all research vessels, accounted for in a). Source: GOSR questionnaire, 2015.

How much do countries spend on ocean science?

The GOSR is the first international endeavour to capture governmental funding of ocean science. This assessment includes the contributions of 29 countries, which responded to the GOSR questionnaire by submitting information for the time period 2009–2013. Despite methodological and data collection constraints, some key trends in ocean science funding were identified. Based on the GOSR assessment, government funding for ocean science remains modest overall. Ocean science funding, like other scientific domains, is facing sustainability challenges in a number of countries.

To support sustainable development, continuous ocean research supported by long-term public and private funding will need to be secured. The GOSR provides baseline information on ocean science funding, which can be used as a starting point for more directed, tailored investment, new capacity development strategies and enhanced marine technology transfer and knowledge exchange.

Ocean science funding varies between < 0.04 % and 4 % of national research and development funding. Countries with large dedicated ocean science budgets include USA, Australia, Germany, France, and Republic of Korea (Figure ES6).

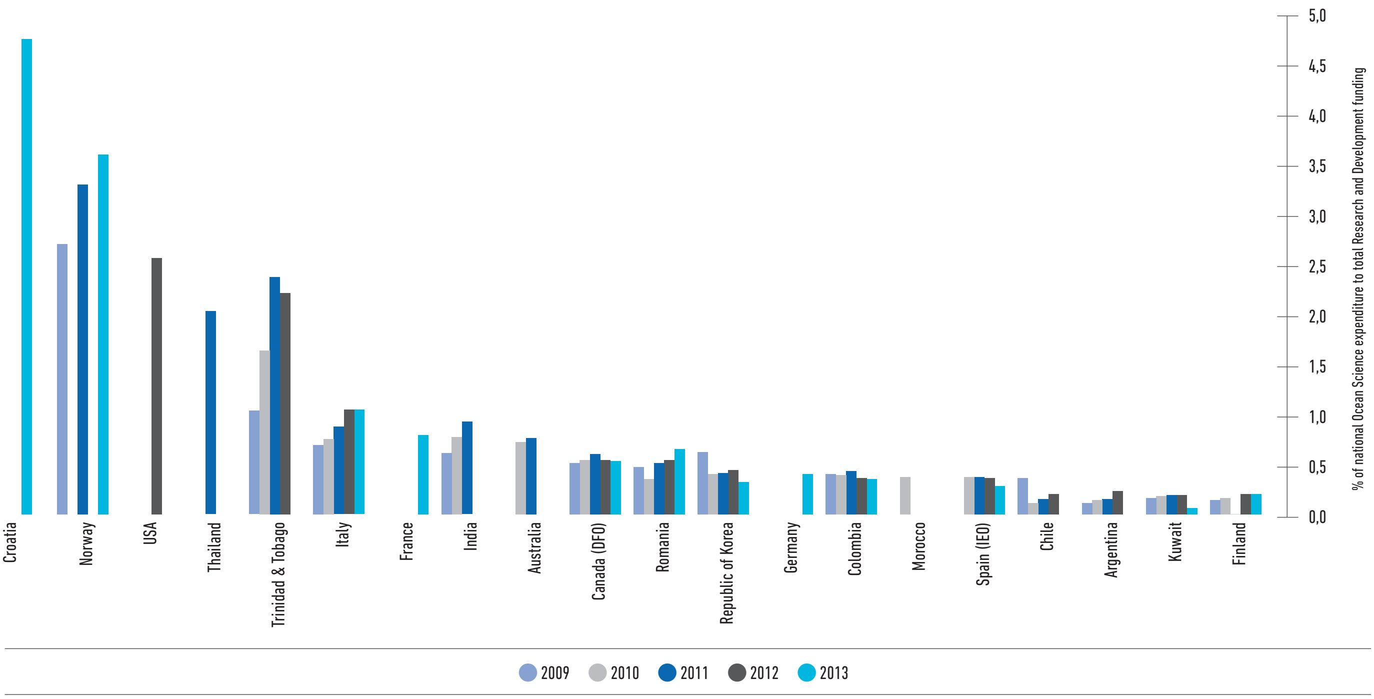
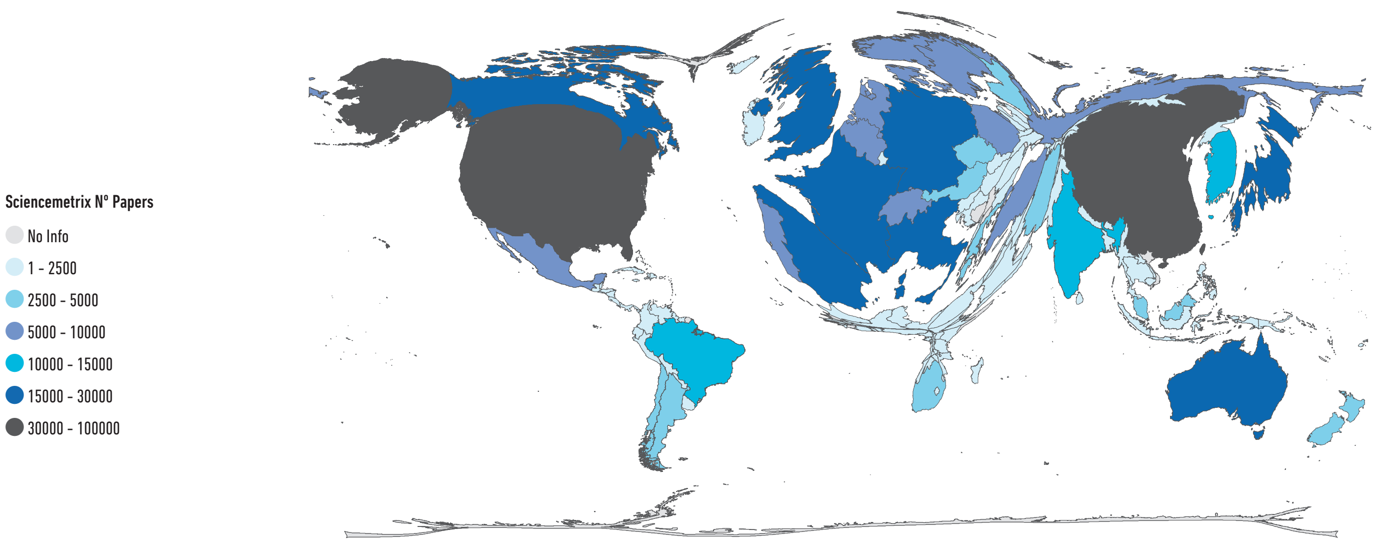


Figure ES6. National expenditure in ocean science as a percentage of national research and development (R&D) expenditure for 20 countries which answered the GOSR questionnaire and provided information regarding national governmental funding for ocean science. Sources: GOSR questionnaire (ocean science funding), 2015; UIS (R&D funding), 2015.

How is ocean science performing globally?

The GOSR examines the evolving global picture of ocean science performance, by individual countries and international collaborations, to illuminate how ocean science knowledge is published and shared. Bibliometrics is used as a tool to assess the quantity and quality of ocean science research output, as indicated by total number of publications and citations. Ocean science performance is analysed according to four categories: production (amount of research performed), quality (impact of publications), topicality (research areas pursued) and collaboration (amount produced through international partnerships and institutional connections).

The production of global ocean science is increasing. Between 2010 and 2014 more than 370,000 manuscripts in ocean sciences were published and more than 2 million articles were cited. There is some relationship between quantity and quality in ocean science performance, however, countries with the largest numbers of publications are not necessarily the most highly cited (Figure ES7).



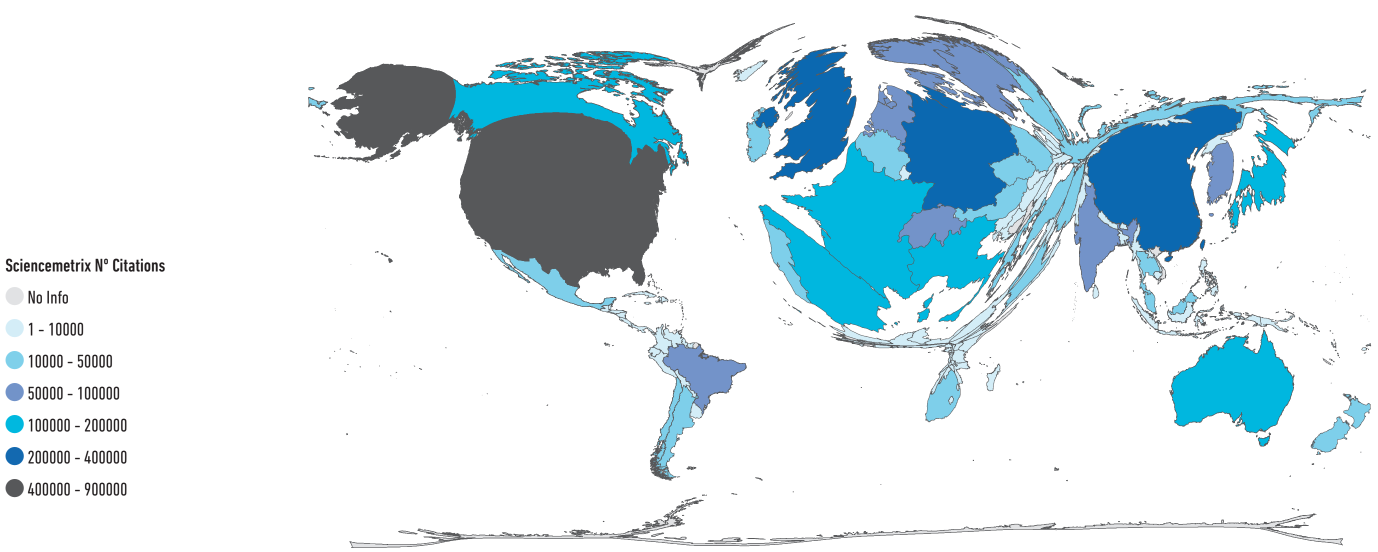


Figure ES7. Publication and citation map of the world. The area of each country is scaled and deformed according to the number of ocean science publications (top) or citations received (bottom). Different colours indicate a different number of publications (top) or citations (bottom). Source: ScienceMetrix, 2015.

Ocean science output is increasing, as measured by number and citation of scientific publications in time periods 2000–2004 and 2010–2014. The strongest relative growth in ocean science output was seen in China, Iran, India, Brazil, Republic of Korea, Turkey and Malaysia. China has become a major source of new publications, with the USA, Canada, Australia and European nations (UK, Germany, France, Spain and Italy) remaining the top producers of ocean science publications.

Specialization in ocean science varies around the world. Some regions specialize in certain categories of ocean science more than others, such as 'marine ecosystem function and processes' in North and South America, 'human health and well-being' in Africa, 'ocean technology and engineering' in Asia, 'ocean and climate' in Europe, and 'blue growth' in Oceania (Figure ES8). National positional analysis in ocean science by categories shows that some countries lead in certain categories, such as Japan and the Russian Federation in 'ocean crust and geohazards'.

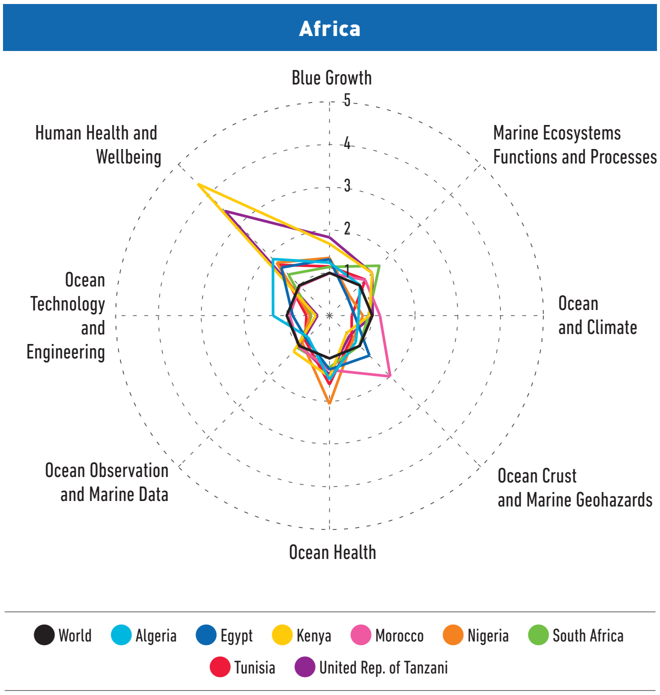


Figure ES8. National strengths (specialization index) in ocean science categories (for African nations accounting for at least 300 publications in the time period 2010–2014) compared to the world average. Source: ScienceMetrix, 2015.

R&D expenditure influences ocean science performance. Countries with high GDP (and high GDP per capita) and R&D expenditure also show high ocean science performance in terms of publications and citations.

Ocean science collaboration networks are changing the global architecture of ocean science and are often formed on a regional basis. International ocean science collaboration is important as it increases citation rates and has a positive effect on science impact (Figure ES9).

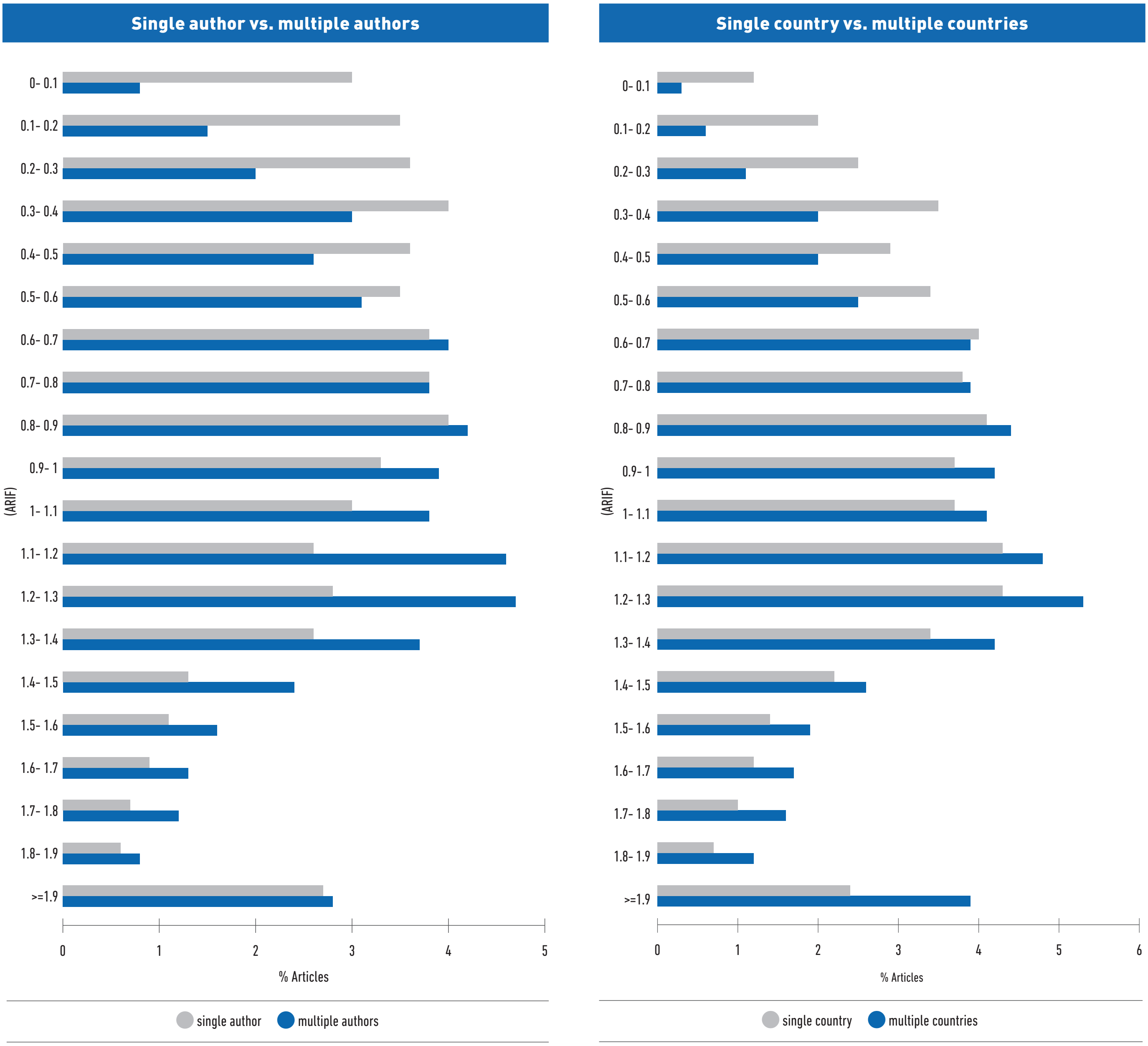


Figure ES9. Comparison of average relative impact factors (ARIF) in articles produced by: single author (grey bars) versus multiple authors (dark blue bars), and authors all from the same country (domestic, grey bars) versus multiple counties (international, dark blue bars). Source: ScienceMetrix, 2015.

How do we store and manage ocean science data?

Modern ocean science and the application of new technology and observation tools produces new kinds of data at an accelerated rate and in an unprecedented amount. These recent developments are creating a demand for novel means of data management and storage to serve the needs of different audiences. Regionally and globally there is a diverse array of organizations, partnerships and programmes working with data and information compilation, sharing and management. The GOSR analysis does not reveal any significant differences between regions in terms of user audiences, except for the Asia/Pacific where national researchers are the top clients.

The majority of ocean data products provided by data centres are metadata, raw data and GIS products (Figure ES10).

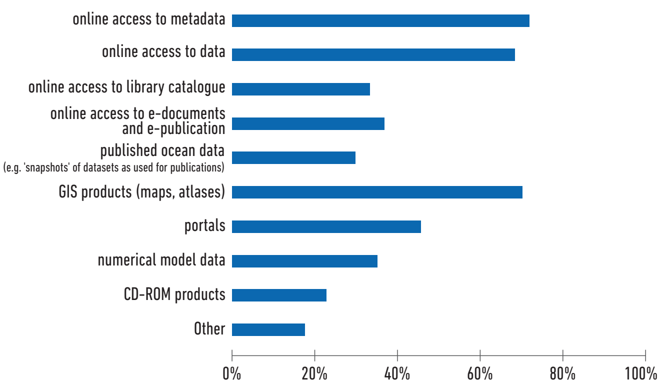


Figure ES10. The data and information products provided to clients by data centres, (% respondents). Source: IODE survey, 2016.

The core users of data, products or services provided by data centres are national and international researchers, as well as the general public, policy-makers and the private sector (Figure ES11).

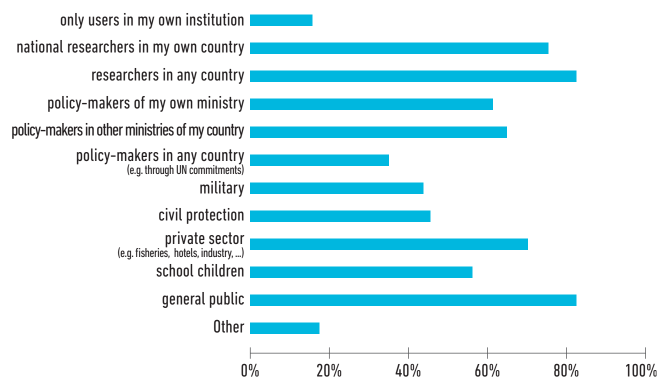


Figure ES11. Clients and end users of data, products or services provided by data centres (% respondents). Source: IODE survey, 2016.

Globally, 63 % of data centres restrict access to "certain" data types and 40 % apply a restriction during a certain period of time (Figure ES12).

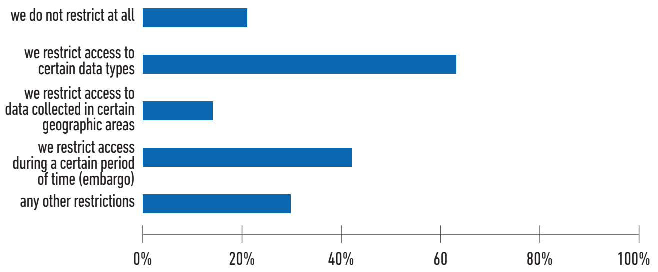


Figure ES12. The percentage of data centres which do not restrict or do restrict access to certain data types, to data collected in certain geographic areas, during a certain period of time, or apply any other restrictions (% respondents). Source: IODE survey, 2016.

Impact of ocean science: science in policy

The GOSR provides examples of how the needs of policy-makers can influence the design of tailored scientific research programmes and how science can influence the development and implementation of marine policy. These examples of the value of ocean science for addressing environmental challenges could be an inspiration for future efforts. Examples considered by the GOSR include:

- reduced eutrophication of marine waters, e.g. under the European Community Nitrates and Urban Waste Water Directives;
- national, regional and global management systems for harmful algal blooms;
- regulation of ocean fertilization, e.g. under the *1972 Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (London Convention) and its related 1996 Protocol (London Protocol);
- regulation of fisheries, e.g. via the total allowable catches agreed by countries fishing in the North Sea; and
- transboundary protection and conservation strategies, e.g. the *Benguela Current Convention*.

Ocean science-policy interaction can play a role in the protection and preservation of the marine environment and the conservation and sustainable use of marine resources.

International ocean science cooperation is essential to increase scientific knowledge, develop research capacity and transfer marine technology (i.e. SDG target 14a). Ocean science is also critical to inform a range of international legal and policy developments concerning, for example, climate change and the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction. The GOSR offers an overview of global ocean science capacity and thus provides a tool to achieve sustainable development and improve ocean health for all.

Ocean science will continue to play a key role to implement the 2030 Agenda and achieve the conservation and sustainable use of the ocean and marine resources as set out in SDG 14.

EXECUTIVE SUMMARY

Global Ocean Science Report

The Current Status of Ocean Science around the World

The Global Ocean Science Report (GOSR) assesses for the first time the status and trends in ocean science capacity around the world. The report offers a global record of who, how, and where ocean science is conducted: generating knowledge, helping to protect ocean health, and empowering society to support sustainable ocean management in the framework of the United Nations 2030 Agenda.

The GOSR identifies and quantifies the key elements of ocean science at the national, regional and global scales, including workforce, infrastructure and publications. It is the first collective attempt to systematically highlight opportunities as well as capacity gaps to advance international collaboration in ocean science and technology. This report is a resource for policy-makers, academics and other stakeholders seeking to harness the potential of ocean science to address global challenges.

A comprehensive view of ocean science capacities at the national and global levels takes us closer to developing the global ocean science knowledge needed to ensure a healthy, sustainable ocean.

For more information:
https://en.unesco.org/gosr

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One Planet, One Ocean

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Sustainable Development Goals