World Ocean Assessment II, Chapter 23, Developments in the exploration for and use of marine genetic resources

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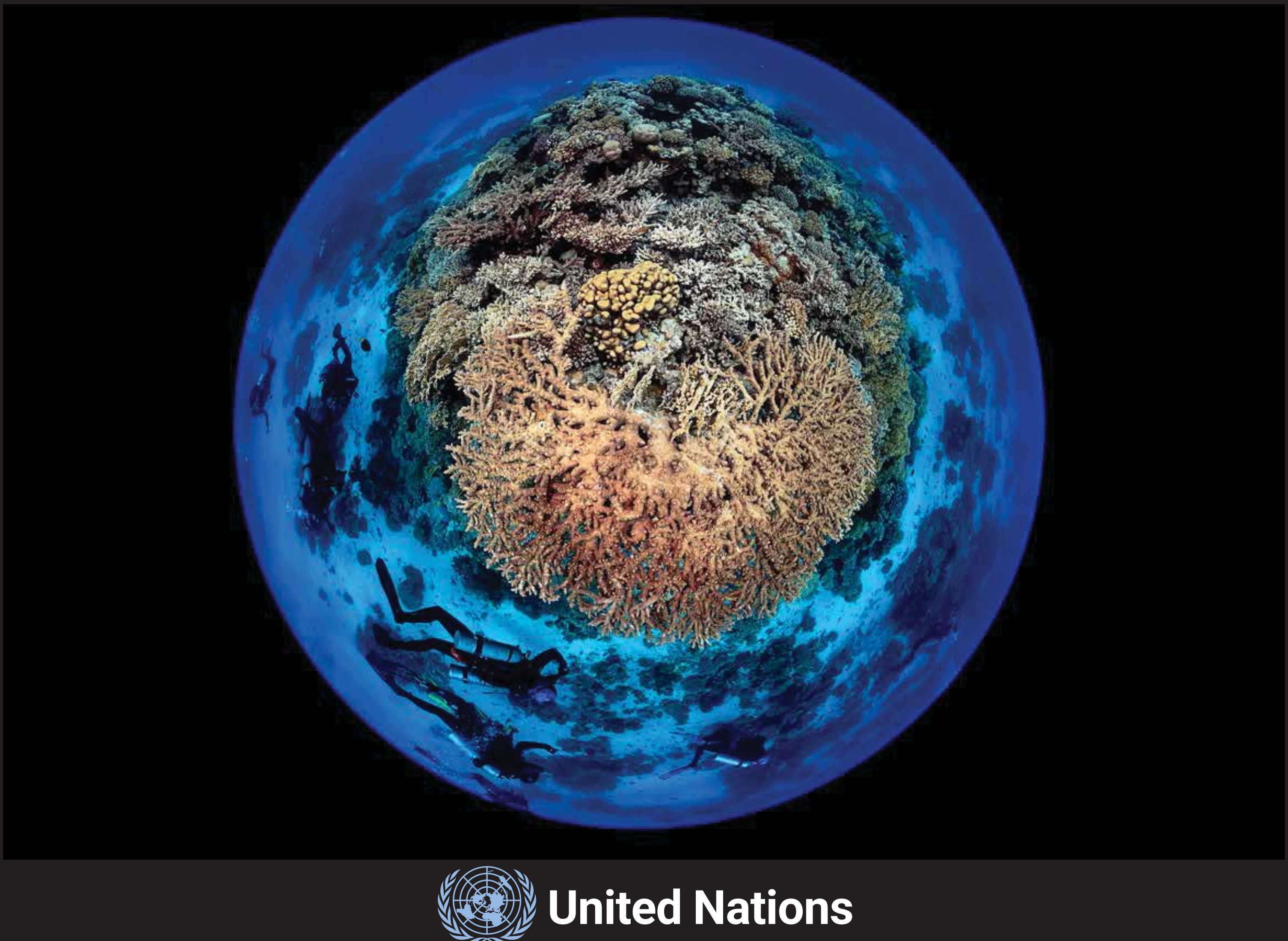
The Second World Ocean Assessment

WORLD OCEAN ASSESSMENT II

Volume II



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The Second World Ocean Assessment

WORLD OCEAN ASSESSMENT II

Volume II

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Chapter 23
Developments in the exploration for and use of marine genetic resources

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Keynote points

- Marine genetic resources continue to be the focus of an expanding range of commercial and non-commercial applications.
- Rapidly decreasing sequencing and gene synthesis costs and swift advances in the metabolic engineering and synthetic biology fields within the biotechnology sector have rendered scientists less reliant on physical samples and increasingly dependent on the exponentially expanding public databases of genetic sequence data.
- Sponges and algae continue to attract substantial interest for the bioactive properties of their natural compounds.
- Within the context of the Sustainable Development Goals,[1] capacity-building issues persist, with entities in a handful of countries conducting the majority of research and development associated with marine genetic resources.
- International processes and agreements with relevance to marine genetic resources include the Nagoya Protocol[2] on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity, and the intergovernmental conference on an international legally binding instrument under the United Nations Convention on the Law of the Sea[3] on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction.[4]

1. Introduction

The ocean is home to a vast diversity of life forms constituting a rich source of marine genetic resources, that is, genetic material of marine origin containing functional units of heredity of actual or potential value, characterized by high biological and chemical diversity (Appeltans and others, 2012; United Nations, 2017). Over 34,000 marine natural products have been described, with recent discovery rates reaching more than 1,000 compounds each year (Lindequist, 2016; Carroll and others, 2019). A total of 188 new marine natural products from deep-sea organisms (Bryozoa, Chordata, Cnidaria, Echinodermata, Mollusca, Porifera and microbes) have been described since 2008 (Skropeta and Wei, 2014). Approximately 75 per cent of those novel products have remarkable bioactivity, with 50 per cent exhibiting moderate to high cytotoxicity towards a range of human cancer cell lines. Although the bioactivity of many marine natural products suggests high potential for drug discovery, only 13 marine-derived drugs have gained market approval to date (Liang and others, 2019; Mayer and others, 2010).[5] However, at the time of writing, 28 candidates were in clinical trials (Alves and others, 2018). Marine antifoulant research is currently focused on identifying viable non-toxic substances, and a recent review has estimated that more than 198 antifouling compounds have been obtained from marine invertebrates, specifically sponges, gorgonians and soft corals (Qi and Ma, 2017), in addition to the products derived from macroalgae and microalgae highlighted in the first *World Ocean Assessment* (United

1 See General Assembly resolution 70/1.
2 United Nations Environment Programme, document UNEP/CBD/COP/10/27, annex, decision X/1.
3 United Nations, *Treaty Series*, vol. 1833, No. 31363.
4 See General Assembly resolution 72/249.
5 See Midwestern University, “Clinical Pipeline, Marine Pharmacology”.

Nations, 2017). Innovative research has also identified ingredients from discarded fish that are suitable for use in high-end cosmetics and a number of other products (Young, 2014). As of 2018, a total of 76 publicly available cosmeceutical ingredients from marine natural products had been marketed, reflecting a new growth sector (Calado and others, 2018).

At the same time, consumer demand for nutraceuticals has increased rapidly, as foreseen in the first Assessment. The global nutraceutical market is expected to reach $580 billion by 2025, more than triple the $180 billion projected for 2017 in the first Assessment, and market growth has been linked to increased innovation and consumer awareness (Grand View Research, 2017). Marine nutraceutical products such as fish oil and collagen represent a large portion of the global market, and demand for those products is expected to grow in the Asia-Pacific region, in particular in China and India (Suleria and others, 2015).

While marine genetic resources are of growing importance to the global blue economy, most commercial activity is concentrated in a comparatively small number of countries, suggesting that there is potential for technology transfer and capacity-building (Thompson and others, 2017; Blasiak and others, 2018). Several international processes addressing genetic resources, including marine genetic resources, are currently under way.

2. Trends between 2010 and 2020

Technological innovations have been key to the recent advances in the exploration for and exploitation of marine genetic resources. The discovery of new marine molecules, and their sources, has been increasing rapidly, especially since the 1970s (figure I). By November 2019, a total of 34,197 marine natural products had been documented (Carroll and others, 2019). Such growth is most likely to have been driven by modern sampling and analytical techniques that have allowed the collection of novel marine genetic resources from deeper environments and covering a wider range of chemical diversity. Approximately 11 per cent of marine genetic resources associated with patent applications are found in deep-sea and hydrothermal vent communities, reflecting increased research in remote and extreme ocean environments (Blasiak and others, 2018). However, the number of marine genetic resources collected at depths of more than 50 m remains insignificant when compared with the whole library of marine natural products (Skropeta and Wei, 2014). The discovery of enzymes from marine organisms is also accelerating thanks to the development of innovative screening methodologies (Ferrer and others, 2019). Enzymes from microorganisms adapted to extreme conditions are of particular interest for their application in industrial processes, as they are often active under challenging operational conditions (Birolli and others, 2019).

2.1. Commercial application highlights

2.1.1. Pharmaceutical applications

Thirteen drugs of marine origin have received market approval from the United States Food and Drug Administration or the European Medicines Agency, six of them since 2010. The majority of drugs of marine origin have been developed for anticancer chemotherapy (Calado and others, 2018; Liang and others, 2019; Mayer and others, 2010).[6] Since the approval of cytarabine as an anticancer agent in 1969,

[6] See Midwestern University, “Clinical Pipeline, Marine Pharmacology”.

sponges have been regarded as one of the most promising sources of anticancer drugs (Hu and others, 2015; see sect. 2.3 below). Other marine invertebrates, such as tunicate and cone snail species, are also very important sources of marine natural products, as are fishes. Trabectedin (ET-743) gained United States Food and Drug Administration approval in 2015 for the treatment of soft tissue sarcoma and ovarian cancer, while Plitidepsin was approved by the Australian Therapeutic Goods Administration in 2018 for the treatment of multiple myeloma, leukemia and lymphoma (see Mayer and others, 2010).[7] Most recently, in 2020, Lurbinectedin was approved for the treatment of metastatic small cell lung cancer (see Mayer and others, 2010).[8] In all three cases, the relevant compounds were derived from tunicates. Macroalgae are also a source of pharmaceutical products. For example, OligoG, an oligoalginate with a defined structure produced from brown algae, is currently in a phase II clinical trial for the treatment of cystic fibrosis (Rye and others, 2018), and the red algae biopolymer Carragelose, which has broad anti-viral properties, is used for treating respiratory diseases (Hackl, 2017).

2.1.2. Cosmeceutical applications

Cosmeceuticals (cosmetics with pharmaceutical properties) are one of the fastest growing markets for the commercialization of marine natural products. They have a shorter development cycle than pharmaceutical and nutraceutical products, resulting in more rapid growth (Rampelotto and Trincone, 2018). Those emerging novel products with biologically active ingredients constitute an entirely new type of beauty care that will be a hallmark of coming decades. The majority of cosmeceuticals are derived from macroalgae and microalgae, but an increasing number are being generated through marine biotechnology processes based on microorganisms such as bacteria and fungi (Calado and others, 2018). There are, however, environmental concerns associated with certain cosmetic ingredients (Juliano and Magrini, 2017).

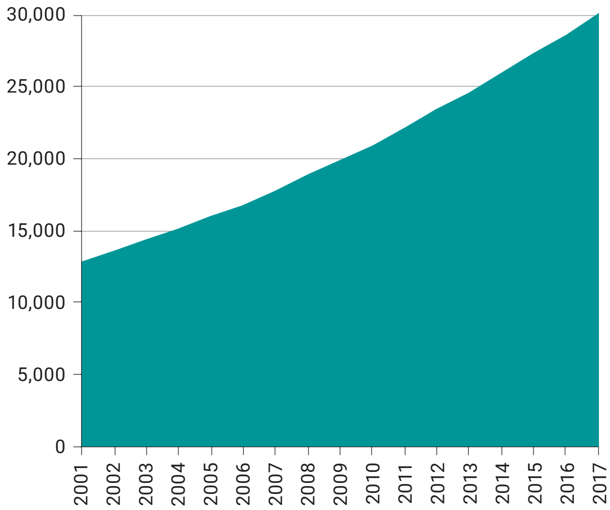
2.1.3. Food and feed applications

The consumption of omega-3 long-chain polyunsaturated fatty acids is linked to multiple positive health outcomes (Ruxton and others, 2007). However, the production of aquaculture species rich in those fatty acids remains reliant on fish-based feeds. The development of algal oils and alternative transgenic crops of omega-3 long-chain polyunsaturated fatty acids has consequently attracted substantial interest. Initial efforts have focused on oilseed crops, with reliance on enzymes from marine species (i.e., marine algae) (Ruiz-Lopez and others, 2014; Zhao and Qiu, 2018). Agro-industrial corporations have filed for patents associated with those innovations and large-scale production is envisaged by 2020 (Sprague and others, 2017). Furthermore, in addition to the direct use of macroalgae as human food, their application as feed additives is showing potential for biological methane mitigation in the cattle industry (Roque and others, 2019; Costello and others, 2019). Microalgae are also emerging as important biofuels (Fedder, 2013).

[7] See Midwestern University, “Clinical Pipeline, Marine Pharmacology”.
[8] Ibid.

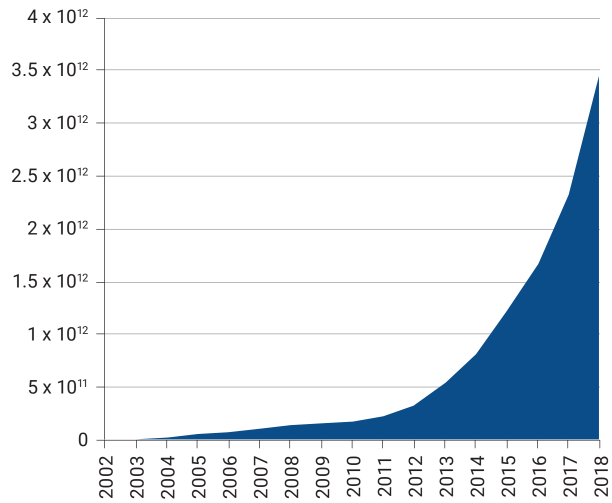
Figure I
Recent trends related to marine genetic resources

Figure I.A
Number of new marine natural products (cumulative)



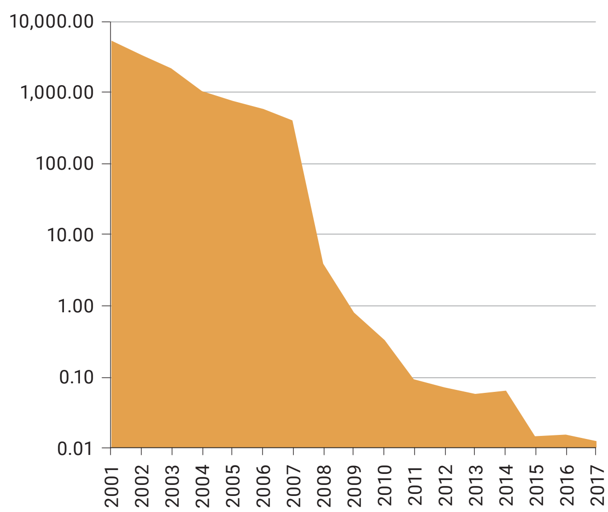
Source: Carroll and others, 2019.

Figure I.B
Number of sequences deposited in GenBank (cumulative number of base pairs)



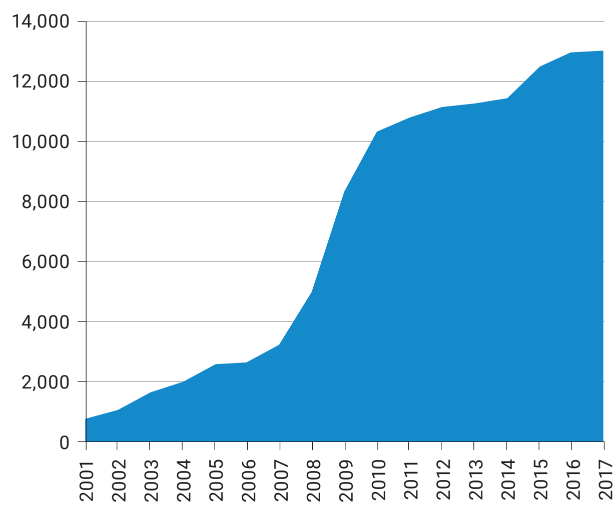
Source: United States National Institutes of Health (Wetterstrand, 2018; National Center for Biotechnology Information (NCBI), 2018).

Figure I.C
Cost of sequencing (dollars per base pair)



Source: National Human Genome Research Institute.

Figure I.D
Number of marine sequences associated with patent filings (cumulative)



Source: Blasiak and others, 2018.

2.2. Growth in public databases of genetic sequence data

Public data archives are integral to modern biological research (Ellenberg and others, 2018; Rigden and Fernandez, 2019), in large part because rapid technological developments over the past two decades have substantially democratized the availability of nucleic acid sequencing technology. The cost per base of sequencing has fallen by more than four orders of magnitude over the past decade alone (Wetterstrand, 2018), in parallel with exponential growth in the size of publicly available repositories (see figure I). Overall, the number of bases in GenBank has doubled approximately every 18 months since 1982 (NCBI, 2018).

Although the size of public databases has grown substantially, there is good reason to believe that there are still significant gaps in the current state of knowledge regarding the extant genetic diversity in the ocean. Omics-based studies provide the best evidence for that interpretation. The most recent and comprehensive survey of marine eukaryotic genetic diversity identified approximately 53 million genes (Carradec and others, 2018), about half of which showed no similarity to existing proteins (de Vargas and others, 2015). Furthermore, estimates for oceanic plankton suggest the presence of about 150,000 eukaryotic species, which is far greater than the approximately 11,200 species that have been formally described (de Vargas and others, 2015). Large-scale initiatives such as Tara Oceans (Sunagawa and others, 2015) and Ocean Sampling Day (Kopf and others, 2015) are generating vast quantities of information that are increasing understanding of the microbial diversity that exists in the ocean at the global scale (Coutinho and others, 2018). The resulting public data sets available represent an important source of information for sequence-based research efforts (Kamble and others, 2019) and enable new directions in research, such as the use of environmental DNA in molecular ecology and in diversity assessments (Seymour, 2019).

2.3. Highlighted research

Two comprehensive volumes focused on marine biotechnology were published in 2018. The first systematically describes recent developments in the marine biotechnology sector and seeks to define its current and future economic potential (Rampelotto and Trincone, 2018), while the second goes beyond research and development aspects to delve into intellectual property law and the protections offered through patent claims (Guilloux, 2018). Previous studies on patents associated with marine genetic resources (Arrieta and others, 2010; Arnaud-Haond and others, 2011) were updated with an analysis identifying the patent filings associated with 12,998 genetic sequences from 862 marine species (Blasiak and others, 2018). Actors located or headquartered in 10 countries were responsible for patent filings covering 98 per cent of those sequences, while 165 countries were unrepresented (Blasiak and others, 2018).

SponGES,[9] a four-year project funded since 2016 through the European Union research and innovation programme Horizon 2020, is aimed at coupling exploration with bioprospecting for industrial applications, namely, drug discovery and tissue engineering. Sponges and their associated microorganisms are the richest and most prolific source of new marine natural products, accounting for nearly 30 per cent (almost 5,000) of the compounds described to date (Mehbub and others, 2014). From 2001 to 2010, more than 2,400 natural products were discovered from 671 species of sponges (Mehbub and others, 2014). SponGES research has already identified unexpected microbial diversity and resulting biotechnological potential, including unconventional C30 sterols and new barrettides with potential for antifouling activity (Lauritano and Ianora, 2018).

[9] See www.deepseasponges.org.

3. Economic and social consequences and changes

Interest in the exploration for and use of marine genetic resources is increasing, at the same time as rapid advances are being made in the global biotechnology industry and initiatives to explore the potential of the blue economy (Wynberg and Laird, 2018). Divergent views exist regarding the economic potential of marine genetic resources, in particular those from areas beyond national jurisdiction (Leary, 2018; Blasiak and others, 2020). However, the robust pipeline of marine-derived drugs in clinical trials suggests substantial interest, given that the process of bringing a new drug to market can cost as much as $2.8 billion (Wouters and others, 2020) and take 10 to 15 years (Blasiak and others, 2019).

The regulatory framework governing access to marine genetic resources and their subsequent utilization varies according to whether those resources are from areas within national jurisdiction or beyond. The former fall within the scope of the Convention on Biological Diversity[10] and the Nagoya Protocol thereto Marine genetic resources of areas beyond national jurisdiction are one of the topics in a package of issues currently under negotiation following the adoption in December 2017 of General Assembly resolution 72/249, in which the Assembly decided to convene an intergovernmental conference to elaborate the text of an international legally binding instrument under the Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction. Three meetings of the conference were held in 2018 and 2019, and a fourth is due to take place in 2020. The conference is mandated to address the topic of marine genetic resources, including questions on the sharing of benefits, among other issues.

Discussions on whether to address and regulate the use of digital sequence data and information are taking place in the context of both the intergovernmental conference and the Convention on Biological Diversity and the Nagoya Protocol thereto. Different views have been expressed on that issue and the related terminology. In 2019, the Executive Secretary of the Convention on Biological Diversity commissioned studies covering the concept and scope of digital sequence information (Secretariat of the Convention on Biological Diversity, 2020), traceability and databases, and domestic measures. Those studies have now been published following an open review period.

Lastly, in 2017, the General Assembly of the World Intellectual Property Organization (WIPO) extended the mandate of the WIPO Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore and agreed that it should, inter alia, continue to expedite its work on an agreement relating to intellectual property, which would ensure the balanced and effective protection of genetic resources.[11]

All those regulatory frameworks are applicable only to the signatory countries, and they therefore govern only marine genetic resources collected in, or by, States that are parties to the relevant instruments.

[10] United Nations, *Treaty Series*, vol. 1760, No. 30619.
[11] See World Intellectual Property Organization, document WO/GA/49/21.

4. Key region-specific developments in knowledge and their consequences

In the first Assessment, the focus was on providing a general review of marine genetic resources rather than regional assessments or overviews. That was in part because regional summaries with information on trends are difficult to obtain. A brief summary of regional issues concerning the Pacific Ocean, the Southern Ocean and the Arctic Ocean, highlighting trends over the past decade, is provided below. The development of marine natural products from the Mediterranean and the Atlantic Ocean has been relatively more limited (Skropeta and Wei, 2014), but the Mediterranean, with its high biodiversity, is a potential source of new pharmaceuticals and nutraceuticals (Briand, 2010).

Skropeta and Wei (2014) conducted an update of their 2008 regional analyses of marine natural products reporting, and found that, while the proportion of marine natural products from Australia was still high (24 per cent), there had been a marked increase in reports of metabolites from deep-sea sediment sampling in the South China Sea (to 18 per cent) and in the Pacific Ocean, including maritime zones off the coast of Guam (United States of America) and Palau (to 17 per cent). That increase was attributed to the increased accessibility of remote deep-sea environments (Skropeta and Wei, 2014), with the regional pattern of discoveries of marine natural products being linked to the level of access to manned submersibles and trawling operations rather than to regional biodiversity. The increased accessibility of deep-sea environments was also reflected in the depth distribution of the discoveries since, in 2008, only 8 per cent of marine natural products were from organisms found at depths of over 1,000 m whereas, by 2013, such organisms accounted for 37 per cent of discoveries (Skropeta and Wei, 2014).

Activities in the Antarctic region are subject to the Antarctic Treaty[12] and the related agreements collectively known as the Antarctic Treaty System (Oldham and Kindness, 2020). Bioprospecting has been discussed under the Antarctic Treaty System, but the matter is very complicated owing to governance issues related to research activity, ethics and benefit-sharing. With increased scientific research taking place in Antarctica in general, biodiversity research has also increased, and a growing number of patents derived from Antarctic organisms are being filed in the United States and in Europe (Oldham and others, 2014; Oldham and Kindness, 2020).

A collaborative international research model has been established for the Arctic (Leary, 2008), although research on the biotechnology potential of Arctic genetic resources is largely being undertaken within the exclusive economic zones of the Arctic States.

5. Capacity-building gaps

Many States face challenges that hinder them from engaging directly in research on marine genetic resources. Such challenges include limited knowledge of biodiversity, limited capacity, in terms of both facilities and technological expertise, limited financial resources for research and development, a lack of experience with access and benefit-sharing mechanisms, and the need for increased collaboration across the academic, government and private sectors

[12] United Nations, *Treaty Series*, vol. 402, No. 5778.

(Thompson and others, 2017). Capacity-building initiatives, such as the National Marine Biotechnology Research Network established in Brazil (Thompson and others, 2018), are key to addressing some of those limitations.

Wynberg (2016) has highlighted the rapid expansion of research activity in the Western Indian Ocean, in particular along the Eastern and Southern African coastlines, the latter of which is associated with higher biodiversity and endemism. Such research is largely being undertaken by developed countries from other regions, with few countries of the Western Indian Ocean – with the exception of South Africa and Kenya – engaged as collaborators. Comparatively few countries operate their own research vessels, and only a handful have the capacity to undertake collections from areas beyond national jurisdiction or deep-sea environments (figure II). Although public databases of genetic sequence data are available globally, many countries lack the cyberinfrastructure to gain access to such data sets or to establish and manage comparable national databases (Thompson and others, 2017).

Figure II.A
Number and distribution of research vessels by flag state as of June 2019

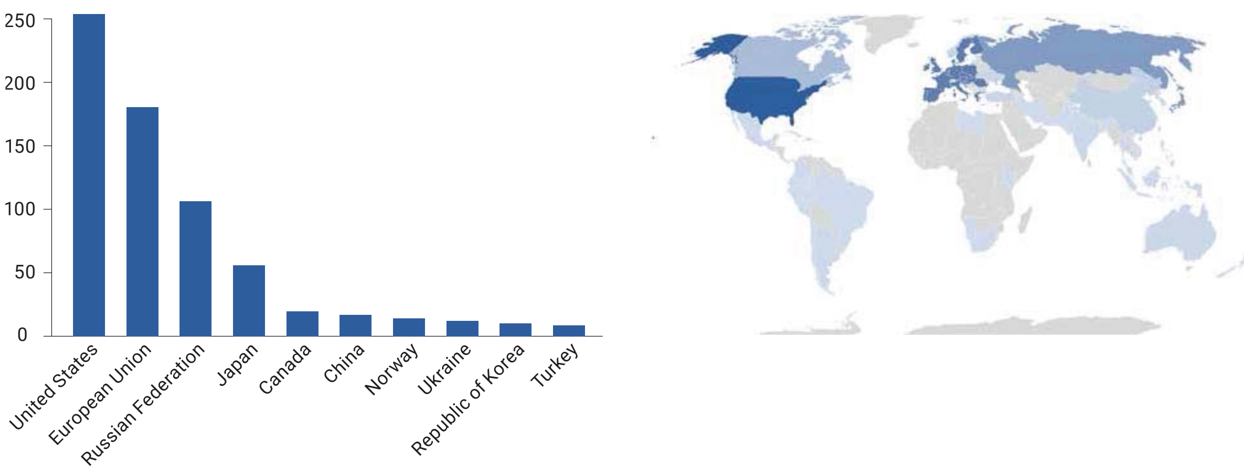
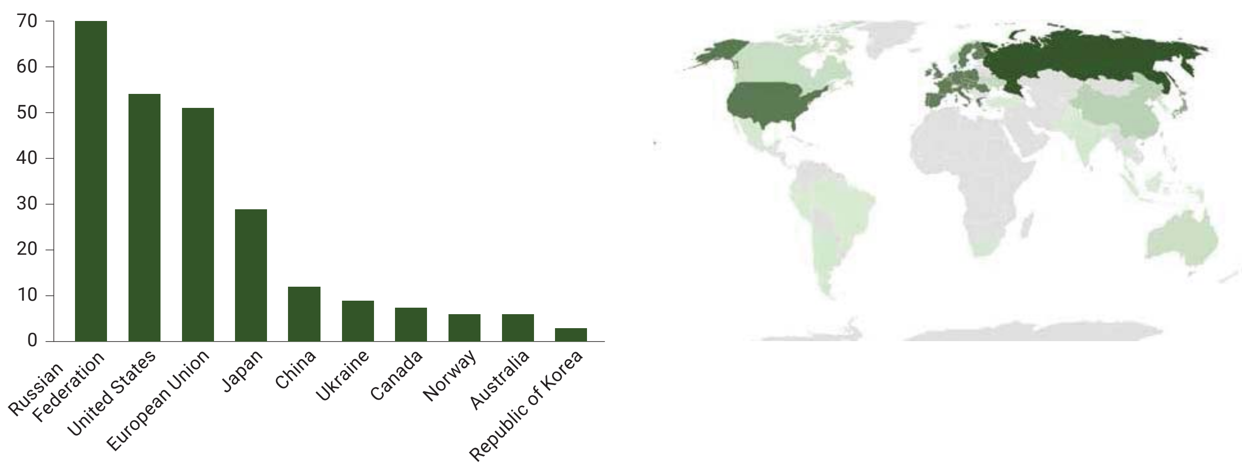


Figure II.B
Number and distribution of research vessels with offshore capacity (60 m or greater in length) as of June 2019



Source: International Research Vessel Database.

6. Methodological challenges and future trends

6.1. New developments in omics approaches

Over recent decades, innovations in technologies for the analysis of biomolecules have facilitated more comprehensive studies of marine organisms and their communities (Coutinho and others, 2018). Sequencing technologies with ultra-high throughput allow high coverage in the analysis of microbial communities, single-molecule sequencing technologies produce long sequence lengths from DNA and RNA, and portable real-time sequencing instruments can be used in the field (Ip and others, 2015). The current focus is on developing sequencing platforms for specific applications, and improving sequence length and output while decreasing sequencing error rates (Wuyts and Segata, 2019). Improvements in sequence length and accuracy are key to the generation of less fragmented data sets. Assembling deduced amino acid sequences, instead of DNA data, can also generate large catalogues of complete protein sequences from complex metagenomic datasets (Steinegger and others, 2019). In contrast with ecological studies, complete proteins and gene clusters are needed for biotechnological applications.

While high-throughput sequencing platforms have made the acquisition of sequence data much easier, the assignment of functions to predicted genes, proteins and pathways remains problematic (Woyke and others, 2019). Often a putative function cannot be assigned or only general functional predictions can be made, in particular, for enzymes. The experimental characterization of selected sequences with biotechnological potential is time-consuming and expensive. A combination of gene synthesis, cell-free protein expression systems and sensitive high-throughput screening methods are being developed for the discovery of novel biocatalysts and enzyme variants with improved characteristics (Rolf and others, 2019). Advances in the detection systems used in functional metagenomics – a different bioprospecting approach – are also having a positive impact on biodiscovery (van der Helm and others, 2018).

In spite of recent advances in sequencing technologies, it remains difficult to obtain high-quality near-complete genomes from uncultured microorganisms. The sequencing of the genomes of single microbial cells and the reconstruction of genomes from complex metagenome data sets have generated genomic information from thousands of uncultured marine microorganisms (Parks and others, 2017; Coutinho and others, 2018; Tully and others, 2018), creating a public resource available for bioprospecting efforts. Technological advances are needed, however, to improve the completeness of such genomes and to reduce the level of contamination that exists, prior to amplification, in the DNA cocktail generated using those culture-independent approaches (Woyke and others, 2019). The analysis of genomes from uncultured microorganisms is also being facilitated by metagenomic chromosome conformation capture (meta3C), a technique that can reveal the physical contacts in different regions of the DNA present within a cell. When applied to microbial communities, it both facilitates the assembly of genomes and allows an analysis of their tridimensional organization (Marbouty and others, 2014). Improvements in cultivation techniques for marine microorganisms are also needed, in particular in the context of the utilization of microbial marine genetic resources for industrial purposes.

The exponential growth of data generated by the different omics approaches represents a challenge, and new bioinformatic tools and platforms continue to be developed for the analysis and integration of such data to gain a better understanding of biological systems (Dihazi and others, 2018; Rohart and others, 2017). One example is the United States Department of Energy Systems Biology Knowledgebase (KBase),[13] an open-source software and data platform that enables collaborative analyses of multi-omics information, including genome or metagenome assembly, annotation, transcriptomics and metabolic modelling (Arkin and others, 2018). Through the integration of metabolomics data analysis, that is, the analysis of small biomolecules from organisms or microbial communities, it is possible to validate identified pathways, as well as to link microbial community structure, dynamics, interactions and function (Baidoo and Benites, 2019). Another example of a multi-omics integration tool, focused on data exploration and data mining, is mixOmics (Rohart and others, 2017).[14]

6.2. Marine genetic resources and synthetic biology

Given the exceptional biodiversity of marine organisms, marine genetic resources are a promising source of genes and gene clusters for the artificial redesign of organisms for industrial applications (Bloch and Tardieu-Guigues, 2014; Reen and others, 2015). Synthetic biology, in combination with enzyme and metabolic engineering, can greatly facilitate the development of high-performance strains for the production of chemicals, biomaterials and services. For instance, a synthetic biology approach can be used as an alternative to chemical synthesis for the production of marine natural products, when the extraction from the original source is not sustainable (Kiran and others, 2018). Public health and ethical considerations are important issues in synthetic biology, and the public perception of the safety of genetically modified organisms will also influence the adoption of that technology in the industrial sector (Kiran and others, 2018).

7. Marine genetic resources and the Sustainable Development Goals

Regardless of the scale of the economic benefits associated with the commercialization of marine genetic resources, capacity-building gaps remain (sect. 5), which has major implications for the achievement of the Sustainable Development Goals. The table below summarizes the relevance of marine genetic resources to the Sustainable Development Goal targets that are most applicable.

13 See http://kbase.us.
14 See http://mixomics.org.

Marine genetic resources and the Sustainable Development Goals

Relevant Sustainable Development Goal targets	Relevance of marine genetic resources
14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans **14.5** By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	Ensure that the genetic diversity of populations in protected areas is taken into account, among other things to promote resilience Use marine genetic resources as tools for understanding biotic and abiotic interactions to help to manage ecosystem services Promote and focus exploitation on sustainably harvested or developed marine natural products
14.a Increase scientific knowledge, develop research capacity 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 and least developed countries **9.5** Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending **9.b** Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities **17.6:** Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	Promote inclusive innovation and other mechanisms to ensure broader capacity for States to engage in the exploration for and use of marine genetic resources
3.b Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health, which affirms the right of developing countries to use to the full the provisions in the Agreement on Trade-Related Aspects of Intellectual Property Rights regarding flexibilities to protect public health, and, in particular, provide access to medicines for all	Robust pipeline of marine-derived medicines in clinical trials, and potential of marine organisms as source of new antibiotics

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