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Chapter 18

New Technology and the Protection of the Marine Environment

Hilde J Woker, Rozemarijn J Roland Holst, and Harriet Harden-Davies

1. INTRODUCTION

Historically, 'science and technology have been among the major drivers of the law of the sea'.[1] It was the development of an accurate chronometer that made it possible to make accurate ocean charts, enabling States to claim newly explored areas and exploit ocean resources.[2] In the second half of the 20th century, developments in science and technology opened up the oceans to a 'mode and rate of exploitation hitherto undreamed of'.[3] Thus, some of the main issues facing the third UN Conference on the Law of the Sea (UNCLOS III) were 'the impact of the revolutionary developments in science and technology, and the influence of these forces in international law'.[4] International law is not only faced with the challenge of regulating the past and present development and deployment of technologies, 'but also the uncertain futures these technologies pose'.[5] This is certainly true today. Advances in technology impact the international legal framework in many ways and in many fields of international law. In this chapter, we focus on the relationship between new technology and the protection of the marine environment.

What do we mean by new technology? The contemporary literature on the topic either refers to technology as one abstract concept, or alternatively uses single case studies through which to

[1] Jin-Hyun Paik, 'Disputes Involving Scientific and Technical Matters and the International Tribunal for the Law of the Sea' in Tomas Heidar (ed), *New Knowledge and Changing Circumstances in the Law of the Sea* (Brill Nijhoff 2020) 15.
[2] Peter J Cook and Chris Carleton, 'Introduction', *Continental Shelf Limits: The Scientific and Legal Interface* (Oxford University Press 2000) 3.
[3] Jens Evensen, 'The Effect of the Law of the Sea Conference upon the Process of the Formation of International Law: Rapprochement between Competing Points of View' in Robert B Krueger and Stefan A Riesenfeld (eds), *The Developing Order of the Oceans (Proceedings of the 18th Annual Conference of the Law of the Sea Institute)* (Law of the Sea Institute, University of Hawaii 1985) 24.
[4] ibid 25–26.
[5] Rosemary Rayfuse, 'Public International Law and the Regulation of Emerging Technologies' in Roger Brownsword, Eloise Scotford and Karen Yeung (eds), *The Oxford Handbook of Law, Regulation and Technology* (Oxford University Press 2017) 501.

analyse the relationship.[6] In contrast, the purpose of the current contribution is to demonstrate how the relationship between new technology and international law is multifaceted and gives rise to a multitude of complex issues depending on how the technology is used, by whom, where, and for what purpose. Rather than only focusing on one particular type or application of new technology, or technology as an abstract concept, this chapter seeks to map various kinds of new technology and their relationship to (the protection of) the marine environment. It will do so by means of four different (partly overlapping) categories that can be distinguished to classify the relationship between new technology, the protection of the marine environment, and the law: (1) new technologies for marine resource exploitation; (2) new technologies intended to mitigate environmental harm; (3) new technologies that enhance scientific knowledge; (4) new technologies for monitoring and enforcement. The following sections introduce and discuss these four categories in turn. In Section 6, we identify three cross-cutting themes that characterise the multifaceted triangular relationship between technology, the protection of the marine environment, and law. Section 7 offers some concluding remarks.

2. NEW TECHNOLOGIES FOR MARINE RESOURCE EXPLOITATION

Technological developments play a key role in advances in marine resource exploitation. They can enhance the capacity of extractive industries, potentially to the detriment of more sustainable harvesting practices as is the case with supertrawler factory fishing for example, or provide advanced harvesting methods like electric pulse trawling, which - while the environmental risks and benefits are scientifically still debated[7] - has been banned by the European Union as of 2021.[8] New technologies may also open up new uses and applications of particular marine resources, of which the harvesting of marine genetic resources (MGR) by the

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[6] See, *eg*, Steinar Andresen and Jon B Skjærseth, 'Science and Technology: From Agenda Setting to Implementation' in Daniel Bodansky, Jutta Brunnée and Ellen Hey (eds), *The Oxford Handbook of International Environmental Law* (2008); Rayfuse (n 5); Harry N Scheiber, James Kraska and Moon-Sang Kwon (eds), *Science, Technology, and New Challenges to Ocean Law* (Brill Nijhoff 2015); Davor Vidas (ed), *Law, Technology and Science for Oceans in Globalisation: IUU Fishing, Oil Pollution, Bioprospecting, Outer Continental Shelf* (Brill Nijhoff 2010).

[7] This method startles bottom dwelling fish with electric pulses to make them leap into the net. International Council for the Exploration of the Sea, *ICES Special Request Advice Greater North Sea Ecoregion: Request from the Netherlands Regarding the Impacts of Pulse Trawling on the Ecosystem and Environment from the Sole Fishery in the North Sea*, ICES Advice 2020–sr.2020.03, 20 May 2020 <https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/Special_Requests/nl.2020.03.pdf>.

[8] Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019 on the conservation of fisheries resources and the protection of marine ecosystems through technical measures, [2019] OJ L198.

bioprospecting industry is a notable example (see further on MGR in Section 4 below),[9] or possibilities to exploit altogether new marine resources, such as the marine renewables discussed below. The relationship between technological developments in the realm of marine resource exploitation and the marine environment is a complex one, however, and requires a balance of interests to be struck.

An illustrative example can be found in technological advances in offshore renewable energy production, which encompasses a range of different technologies at various stages of development, from offshore wind farms, to ocean energy technologies such as wave, tidal, current, salinity gradient, or ocean thermal energy conversion.[10] Depending on the exact technology, scale and location, these structures may either be floating or anchored to the seabed, and require the construction of, or connection to existing offshore grids.[11] Offshore renewables are an 'environmentally friendly' resource in the sense that they play an increasingly vital role in the energy transition and thereby in reaching global GHG emission reduction targets. At the same time, operating these technologies in the marine environment has certain environmental impacts, including noise pollution, electromagnetic fields, habitat disturbance and potential effects on populations of marine mammals and birds (in case of windfarms).[12] Positive (local) impacts on biodiversity have also been recorded, however, for example when the underwater infrastructure of a wind farm functions as an artificial reef, or due to fishing activities being excluded from the area.[13]

In terms of applicable law, there is no single international instrument that regulates the environmental impacts of offshore renewable energy production. The United Nations Convention on the Law of the Sea (LOSC)[14] sets out the jurisdictional framework, granting coastal States rights to exploit ocean energy sources within their territorial sea, exclusive

[9] Joanna Mossop, 'Marine Bioprospecting' in Donald Rothwell et al (eds), *The Oxford Handbook of the Law of the Sea* (Oxford University Press 2015).
[10] See for an overview IRENA, 'Innovation Outlook: Ocean Energy Technologies' (December 2020) <https://www.irena.org/publications/2020/Dec/Innovation-Outlook-Ocean-Energy-Technologies>.
[11] *Ibid*.
[12] Jens Lüdeke, 'Exploitation of Offshore Wind Energy' in Markus Salomon and Till Markus (eds), *Handbook on Marine Environment Protection : Science, Impacts and Sustainable Management* (Springer International Publishing 2018); Dan Wilhelmsson et al, 'Greening Blue Energy: Identifying and Managing the Biodiversity Risks and Opportunities of Offshore Renewable Energy' (IUCN 2010).
[13] Lüdeke, 'Exploitation of Offshore Wind Energy' (n 12).
[14] United Nations Convention on the Law of the Sea (adopted 10 December 1982, entered into force 16 November 1994) 1833 UNTS 397 (LOSC).

economic zone (EEZ) and continental shelf,[15] subject to a general obligation of due diligence to prevent, reduce and control pollution of the marine environment resulting from such activities.[16] Yet, to give normative content to this general obligation, including its procedural aspects such as environmental impact assessment (EIA) and continuous monitoring, the LOSC is supplemented by a normative 'jigsaw puzzle' of international and regional instruments, non-binding (industry) standards, recommendations, and best practices of corporate social responsibility.[17] While often criticised for its vagueness, lack of uniformity, and reliance on non-binding standards, this 'jigsaw' is not devoid of normative relevance.[18] The majority of regional environmental agreements, for example, prescribe the use of 'best available techniques' (BAT) or 'best environmental practices' (BEP),[19] thereby enabling the general standard of due diligence to adapt as technology evolves over time.[20] At the same time, private and other non-State actors, such as the International Electrotechnical Commission, contribute to the development of technical standards for different marine renewable technologies which, although not binding on States, may nevertheless lay a basis for adapting or developing (future) regulations in light of new developments.[21]

A very different, yet rapidly growing offshore sector that is driven by technological advances is mariculture: the cultivation of marine species for human consumption and use. This sector makes an important contribution to global seafood supply and promises possibilities for seafood production to meet growing demands while 'wild' stocks diminish under the pressures of overfishing.[22] Yet, open-net fish farming at a large scale, in particular, has serious environmental impacts that include the spread of disease and parasites to wild stocks, spreading of chemotherapeutants such as antibiotics to non-target organisms, negative interactions with

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[15] *Ibid*, Arts 2, 56, 60 and 77.
[16] *Ibid*, Arts 192, 194.
[17] For an overview and discussion see, eg, Nikolaos Giannopoulos, 'Global Environmental Regulation of Offshore Energy Production: Searching for Legal Standards in Ocean Governance' (2019) 28 *Review of European, Comparative and International Environmental Law* 289; Angelica Bonfanti and Francesca R Jacur, 'Energy from the Sea and the Protection of the Marine Environment: Treaty-Based Regimes and Ocean Corporate Social Responsibility' (2014) 29 *International Journal of Marine and Coastal Law* 622.
[18] See extensively, Giannopoulos (n 17).
[19] See, *eg*, 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic (opened for signature 22 September 1992, entered into force 25 March 1998) 2354 UNTS 67, Appendix I, paras 2 and 6 (OSPAR Convention).
[20] Giannopoulos (n 17) 301.
[21] Seline Trevisanut, 'Is There Something Wrong with the Increasing Role of Private Actors? The Case of the Offshore Energy Sector' in Cedric Ryngaert et al (eds), *What's Wrong with International Law?* (Brill | Nijhoff 2015).
[22] Michael J Phillips, 'Mariculture Overview' in John H Steele (ed), *Encyclopedia of Ocean Sciences (Second Edition)* (Academic Press 2009).

wild predators, genetic modification and mixing with wild species, and organic enrichment and habitat modification in the area of operation.[23] Escaped farmed salmon and the spread of sea lice and other parasites are the two main threats causing Norwegian wild salmon populations to be halved in recent years.[24] Fish farming systems are primarily deployed in coastal waters and thus licenced and regulated at the discretion of the coastal State, which is also responsible for setting environmental and technical standards. In 2021, Argentina became the first country to ban salmon farming in the coastal waters of its southernmost province altogether due to the environmental impacts,[25] whereas in Scotland, for example, the industry is still expanding despite serious concerns.[26] In addition to the general obligation to protect the marine environment and the obligation to manage interactions with other uses of the (territorial) sea, the LOSC contains no obligations on the coastal State that are directly applicable to mariculture. The general obligation of due diligence is supported by other general obligations under other environmental agreements, notably the Convention on Biological Diversity (CBD),[27] which requires States to protect (marine) biodiversity, including through the prevention and control of alien species that threaten ecosystems, habitats or other species.[28] There is currently no dedicated international regulation on technical or environmental standards for mariculture, only industry practices and certification standards for farms,[29] and some non-binding international and regional standards and guidelines applicable to the development of mariculture.[30]

The authorisation and use of new technologies in the context of offshore renewable energy production and mariculture have in common that – for now – they mainly take place in areas within national jurisdiction, particularly in coastal waters. As a result of the nature of these

[23] Thomas A Wilding et al, 'Mariculture' in Markus Salomon and Till Markus (eds), *Handbook on Marine Environment Protection: Science, Impacts and Sustainable Management* (Springer 2018).
[24] Norwegian Scientific Advisory Committee for Atlantic Salmon, 'Status of Wild Atlantic Salmon in Norway 2020' (Vitenskapelig Rad for Lakseforvaltning 2020) <https://www.vitenskapsradet.no/Portals/vitenskapsradet/Pdf/Status%20of%20wild%20Atlantic%20salmon%20in%20Norway%202020T.pdf>.
[25] Harry Cockburn, 'Argentina Becomes First Country to Ban Open-Net Salmon Farming Due to Impact on Environment' *The Independent* (8 July 2021) <https://www.independent.co.uk/climate-change/news/argentina-salmon-farming-ban-environment-b1880503.html>.
[26] Martin Williams, 'Scotland's Fish Farms Expansion Alarm: Concern over Premature Deaths and Sea Lice Risk' *The Herald* (17 January 2021) <https://www.heraldscotland.com/news/19017511.scotlands-fish-farms-expansion-alarm-concern-premature-deaths-sea-lice-risk/>.
[27] Convention on Biological Diversity (adopted 5 June 1992, entry into force 29 December 1993) 1760 UNTS 79 (CBD).
[28] CBD, Art. 6 sub h.
[29] *Eg*, by Aquaculture Stewardship Council, see <https://www.asc-aqua.org/what-we-do/our-standards/>.
[30] *Eg*, FAO, 'Code of Conduct for Responsible Fisheries' (31 October 1995) <www.fao.org/3/v9878e/V9878E.pdf>, Art. 9; Council Communication COM (2021)236 of 12 May 2021, Strategic Guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030 [2021].

activities and their close connection to the traditional exploitation rights that coastal States enjoy, a considerable measure of discretion remains in how to weigh and regulate the environmental impacts of these activities. The general obligation of due diligence is an obligation of conduct and not of result, which relies on external norms and standards to provide it with normative content, and the example of mariculture illustrates that these may be sparse. Given the specialist nature of the technologies, the industries that possess the relevant expertise furthermore have a key role to play in (co-) developing their own standards and practices, which may be(come) widely accepted by States when they incorporate them into their contracts and licencing practice.[31]

3. NEW TECHNOLOGIES INTENDED TO MITIGATE ENVIRONMENTAL HARM

While technological developments are often seen as part of the problem in many persistent pressures on the marine environment, technology also has a role to play as a potential part of the 'solution'. In the most conventional sense, the use of certain technologies may be directly or indirectly prescribed by law to mitigate the environmental impacts of ongoing activities. Examples can be found in the evolving international technical standards for commercial shipping adopted by the International Maritime Organization (IMO): from double hulls to reduce the risk of oil spills from tanker accidents;[32] to the fitting of scrubbers as a means to comply with the IMO's 2020 global fuel sulphur oxide emission cap;[33] or requirements for ballast water management systems to reduce the risk of pathogens and invasive species.[34]

In addition to the use of technology to mitigate impacts from ongoing activities at the source, technological interventions are also being explored as a means to 'fix' marine environmental damage that has already occurred.[35] The remainder of this section will focus on this novel and

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[31] This process of standard-setting may be contrasted with, for example, the context of deep seabed mining, where the ISA is the international organisation with a dedicated regulatory mandate to adopt regulations before activities take place, see Chapters XX-XX of this volume.

[32] International Convention for the Prevention of Pollution from Ships (as Modified by the Protocol of 1978 Relating Thereto) (adopted 2 November 1973, entered into force 2 October 1983) 1340 UNTS 184, Annex I as amended, (MARPOL).

[33] MARPOL, Annex VI as amended.

[34] International Convention for the Control and Management of Ships' Ballast Water and Sediments (adopted 13 February 2004, entered into force 8 September 2017) IMO Doc BWM/CONF/36. Similarly, IMO, *Guidelines for the Control and Management of Ships' Biofouling to minimize the transfer of invasive Aquatic Species*, IMO Doc Res MEPC.207(62), 15 July 2011. For an extensive discussion, see, *eg* Alexander Proelss and Valentin J Schatz, *Regulating Vessel Discharges on the International and EU Level: The Examples of Scrubber Washwater, Sewage and Ballast Water* (Brill 2021); Nishatabbas Rehmatulla et al, 'The Implementation of Technical Energy Efficiency and CO2 Emission Reduction Measures in Shipping' (2017) 139 *Ocean Engineering* 187.

[35] Another context in which technological interventions are explored as a potential "quick fix" or "bridging technology" is geo-engineering, see Chapter XX of this volume.

potentially more controversial application of new technology, namely: technological interventions for environmental restoration purposes. The term 'restoration' is generally used to describe positive measures that aim to improve the degraded condition of the environment affected by past activities, and can thus be distinguished from 'remediation' or 're-instalment' action to repair damage for which there is legal liability.[36] While restoration is a relatively novel concept in the marine environment,[37] a variety of restoration activities are already taking place, primarily on a local scale within territorial seas, such as revegetating seagrass meadows or coral farming to re-plant and restore natural reefs. The success of such restoration projects relies on continuous advances in a range of different technologies, from genetic sequencing to camera and image processing technology that enables the creation of photomosaics.[38] These digital photomosaics can be used to monitor growth, health and changes in several thousand square meters of reef, reducing the number of human-hours needed on site and offering the potential to collect previously unattainable underwater data.[39] The application of these technologies thereby simultaneously serves to enhance scientific knowledge, a function to which we will return in more detail in Section 4 below.

Legally speaking, the application of technology for restoration purposes becomes more complicated when the technology itself may have impacts on the marine environment in addition to or other than the 'target risk' it is designed to tackle. A further layer of legal complexity is added when the deployment of the technology or its impacts span across multiple jurisdictions. For example, in the Baltic Sea, engineering measures are being investigated to combat the serious threat posed by eutrophication and oxygen depletion, due to which large parts of the seabed have become dead zones.[40] Proposed technological 'solutions' include dredging phosphorus-rich sediments, or chemically treating these sediments, but these

[36] This distinction is, for example, made under Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage [2004] OJ L143. See also Ronan Long, 'Restoring Marine Environmental Damage: Can the "Costa Rica v Nicaragua" Compensation Case Influence the BBNJ Negotiations?' (2019) 28 *Review of European, Comparative and International Environmental Law* 244, 252.
[37] See more extensively Rozemarijn Roland Holst, 'Restoration Activities in the Marine Environment: Balancing Diverging Perceptions of "Risk"' in Alla Pozdnakova and Froukje M Platjouw (eds), *The Environmental Rule of Law for Oceans: Designing Legal Solutions* (Cambridge University Press 2022).
[38] A high-resolution image that is digitally created out of multiple individual and overlapping images, see *eg* Coral Restoration Foundation <https://www.coralrestoration.org/science>.
[39] Alexander M Neufeld and Garrett Fundakowski, 'White Paper: Coral Restoration Foundation™ Photomosaic Manual' (9 November 2020) <https://www.coralrestoration.org/white-paper-photomosaic-manual >.
[40] This is caused by excessive nutrient runoff from land into this semi-enclosed sea. See, extensively, Henrik Ringbom et al, *Combatting Eutrophication in the Baltic Sea: Legal Aspects of Sea-Based Engineering Measures* (Brill 2019).

interventions are controversial. There are concerns not only about the environmental risks involved in the new technologies themselves, including sediment turbidity or harmful chemical reactions, but also about the implications of technological interventions for the overall governance approach to eutrophication in the region.[41] The Baltic Sea is one of the most densely regulated seas on the planet, yet the absence of a dedicated legal framework to govern the proposed technological interventions and the resultant questions of legal qualification under the different layers of law, make it a very complex activity from a regulatory point of view.[42]

An altogether different set of questions in terms of applicable law comes to the fore when technological interventions for restoration purposes take place entirely in areas beyond national jurisdiction. Interestingly, private actors appear to be leading the way here, an example of which is The Ocean Cleanup (TOC). This Dutch private entity has taken to the high seas on a mission to develop a technology that can systematically clean up plastic pollution. System 001 consisted of a 600-metre-long U-shaped passively floating boom with a 3-metre underwater curtain to retain plastics within the system.[43] The latest iteration of the system, 002, uses a similar contraption, but with a closed retention net and the system is actively towed by two vessels.[44] Similar to the sea-based engineering measures in the Baltic, operating TOC's envisaged fleet of cleanup systems may pose potential risks to the marine environment that are different from the target risk (plastic pollution) it seeks to address. Experts and indeed TOC's latest EIA have flagged potentially high risks of bycatch and impacts of the cleanup on a fragile and understudied floating sea-surface ecosystem called 'neuston' that coexists with the plastics in the area of operation and that plays an important role in the wider ecosystem.[45]

[41] Most Baltic countries strongly emphasise the potential of (enhanced) land-based measures. Only Sweden and Finland are openly positive towards exploring sea-based measures further. *Ibid* 3-4.
[42] Applicable laws include national laws, regional rules under the Convention on the Protection of the Marine Environment of the Baltic Sea Area (opened for signature 9 April 1992, entered into force 17 January 2000) 2099 UNTS 195 (Helsinki Convention) and EU law, as well as international law under the LOSC, the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter (opened for signature 29 December 1972, entered into force 30 August 1975) 1046 UNTS 120 (London Convention), the Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (opened for signature 7 November 1996, entered into force 24 March 2006) 36 ILM 1 (London Protocol), and the CBD. For an extensive and comprehensive legal analysis of all these aspects, see Ringbom et al, *Combatting Eutrophication in the Baltic Sea* (n 40).
[43] See The Ocean Cleanup <https://theoceancleanup.com/oceans/>.
[44] *Ibid*.
[45] Rebecca R Helm, 'How Plastic Cleanup Threatens the Ocean's Living Islands' *The Atlantic* (22 January 2019) <https://www.theatlantic.com/science/archive/2019/01/ocean-cleanup-project-could-destroy-neuston/580693/>. CSA Ocean Sciences, 'The Ocean Cleanup: Final Environmental Impact Assessment' (12 July 2021) <https://assets.theoceancleanup.com/app/uploads/2021/07/TOC_FL_21_3648_EIA_FINREV01_12July2021.pdf>.

Given the pioneering nature of this activity, there is no dedicated international regulation in place on the operation of plastic catching devices on the high seas. The legal classification of the cleanup system is not entirely clear, it is not currently listed as a 'vessel' on any flag registry, but this is not directly problematic because as an 'installation' it falls under the (non-exhaustive) freedoms of the high seas.[46] Because TOC is a legal entity incorporated under Dutch law, the Dutch Government has an obligation of due diligence under the LOSC and general international law to ensure that activities under its jurisdiction and control do not cause harm to other States or to the marine environment.[47] In order to ensure that TOC's activities are at least conducted in accordance with general international law on maritime safety, the protection of the marine environment, and other legitimate uses of the high seas, the Dutch government entered into an agreement with TOC on 8 June 2018 (hereafter 'the Agreement') that translates these general obligations of the Netherlands under the LOSC into equally generally phrased obligations on TOC that reiterate the precautionary approach.[48] Yet, general obligations of due diligence and precaution do not inform precisely what standard of care is required from the Netherlands, nor how potential benefits and risks of the cleanup are to be weighed. This is where extra-legal knowledge about a technology, its risks and possible alternatives is required to give content to legal standards and obligations. If neuston, for example, can be considered a 'rare and fragile ecosystem', or even the habitat of 'depleted, threated or endangered species' this classification would raise the standard of care and precautionary measures required in accordance with the LOSC,[49] but also, for example, the CBD,[50] and potentially also a future Agreement on Biodiversity Beyond National Jurisdiction (BBNJ).[51] Tools of environmental law, such as BAT, BEP, and 'best available science' that are commonly used to give content to general obligations

[46] LOSC Art. 87(1)(d). For a detailed discussion, see Rozemarijn Roland Holst, 'The 2018 Agreement between The Ocean Cleanup and the Netherlands' (2019) 34 *International Journal of Marine and Coastal Law* 351.
[47] LOSC Art. 194(2). In the Matter of the *South China Sea Arbitration (Philippines v China*) (Award of 12 July 2016) PCA Case No 2013-19, para. 944 (South China Sea Award).
[48] *Agreement between the State of the Netherlands and The Ocean Cleanup concerning the deployment of systems designed to clean up plastic floating in the upper surface layer of the high seas* (The Hague, 8 June 2018) Staatscourant 2018 nr. 31907, 6 July 2018, reproduced in Roland Holst, 'The 2018 Agreement between The Ocean Cleanup and the Netherlands' (n 46).
[49] See LOSC, Art. 194(5).
[50] See also South China Sea Award, paras 945, 956.
[51] The future Implementing Agreement is likely to contain more specific obligations on environmental impact assessment vis-à-vis biodiversity beyond national jurisdiction, see, *eg, Revised Draft Text of an Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction*, Intergovernmental conference on an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (fourth session, New York, 23 March–3 April 2020)', UN Doc A/CONF.232/2020/3, 18 November 2019, Part IV.

of due diligence and precaution are of little help when there is no practice or science to compare a completely novel technological intervention with in the first place.

What the technology-driven 'solutions' to environmental problems discussed in this section have in common is that the technological intervention aimed at reducing the target environmental risk (potentially) poses other risks. The regulator is thus confronted with a 'risk/risk trade-off',[52] and striking this balance is particularly difficult in the face of uncertainty as to both the environmental risks and benefits of the technology.

4. NEW TECHNOLOGIES THAT ENHANCE SCIENTIFIC KNOWLEDGE

Protection and preservation of the marine environment is inextricably linked to and dependent upon scientific knowledge. Only if we have knowledge of the state of the marine environment, and of the impacts of human activities on the marine environment as well as the factors influencing how humans use the marine environment, can we adequately protect and preserve the marine environment.[53] In addition to advances in marine resource exploitation and the mitigation of environmental harm, technological developments have considerably advanced the ways in which humans obtain and use scientific knowledge.[54]

Some technological advances within this third category help or improve manual labour – these technologies simply do better what we as human beings can already do ourselves. An example in this regard is artificial intelligence helping to process research results. In addition to the example of photomosaics in coral reef monitoring and restoration described above, another example is a recent research product led by the Danish meteorological office that has used artificial intelligence to help meteorologists in their task to process satellite imagery and draw up ice charts.[55] Artificial intelligence has not only shortened the time it takes to create an ice

[52] Floor M Fleurke, 'Catastrophic Climate Change, Precaution, and the Risk/Risk Dilemma' in Monika Ambrus et al (eds), *Risk and the Regulation of Uncertainty in International Law* (Oxford University Press 2017).

[53] The Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO) adopts a broad definition of ocean science: 'it encompasses natural and social science disciplines, local and indigenous knowledge; it includes the science-policy and science-innovation interfaces, as well as technology and infrastructure.' IOC-UNESCO, 'The United Nations Decade of Ocean Science for Sustainable Development (2021-2030) Implementation Plan', *IOC Ocean Decade Series* 20 4, July 2020.

[54] [cross-reference Hubert's chapter on MSR in the book]. Of course, new technology does not automatically lead to improvements for people or the planet unless social, economic and other conditions are conducive thereto.

[55] Kevin McGwin, 'How Artificial Intelligence Could Help Get Better Ice Charts to Mariners Faster' *Arctic Today* (27 July 2021) <https://www.arctictoday.com/how-artificial-intelligence-could-help-get-better-ice-charts-to-mariners-faster/>.

chart to 15 minutes, but the charts also have a higher resolution than charts produced by human hands alone.[56] Other technological advances, however, change the type of data we obtain, the ways in which we obtain scientific data, or how we use scientific data. For these technologies, more complicated legal questions arise that are further elaborated below, namely in relation to equity issues, the balancing of environmental risk against scientific gain as well as the adequacy of the current legal regime to regulate these new technologies.

Advances in technology within the field of marine scientific research (MSR) have witnessed the use of new technologies changing the ways in which we obtain scientific data. Two examples are discussed here: the deployment of (semi-)autonomous research equipment and citizen science projects. What these examples have in common is that they illustrate the growing number of ways of collecting scientific data, and the increasing number and variety of actors who could play a role in acquiring scientific knowledge. Part XIII of the LOSC sets out the legal framework for MSR. Negotiated in the 1970s, the question remains whether Part XIII is sufficient to regulate the use of these new research technologies or whether additional regulations or guidelines are needed.

The use of floats and gliders and other (semi-)autonomous devices represents a novel way to collect data throughout a large geographical area without the need for ships or a research crew on location. The use of (semi-)autonomous research equipment makes it possible to conduct research in the oceans and on the seabed with fewer costs involved, fewer safety hazards, and they are often more environmentally friendly than ships (although they may need to be deployed from ships). This equipment can take the form of floats and gliders that either traverse across the surface of the oceans[57] or may change their depth throughout deployment;[58] of autonomous vehicles that span across the entire water column; of underwater robots that move along the seabed; or of 'soft' robots that can travel down to the deepest point in the ocean.[59] For legal purposes, the 'problem' of this type of technology is that it is often hard to predict the precise course the device will travel. Many of these devices cross jurisdictional boundaries and/or

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[56] *Ibid*.

[57] See *eg* 'Saildrone: Any Sensor. Anytime. Anywhere' <https://www.saildrone.com/>; Jørgen Berge et al, 'Ice-Tethered Observational Platforms in the Arctic Ocean Pack Ice' (2016) 49 *IFAC-PapersOnLine* 494; Hilde Woker et al, 'The Law of the Sea and Current Practices of Marine Scientific Research in the Arctic' (2020) 115 *Marine Policy* 103850.

[58] Katharina Bork et al, 'The Legal Regulation of Floats and Gliders—In Quest of a New Regime?' (2008) 39 *Ocean Development & International Law* 298, 299; 'Argo' (*Argo*) <https://argo.ucsd.edu>.

[59] Guorui Li et al, 'Self-Powered Soft Robot in the Mariana Trench' (2021) 591 *Nature* 66.

follow weather or ice patterns, making it hard to provide accurate information when applying for consent pursuant to Part XIII of the LOSC. Other legal questions that arise from this technology are the legal status these devices enjoy, how they can be protected, the corresponding legal obligations and how to balance obligations of due diligence and due regard in the deployment of these devices.[60] The Advisory Body of Experts on the Law of the Sea of the Intergovernmental Oceanographic Commission (IOC/ABE-LOS) issued Draft Guidelines for the Implementation of Resolution XX-6 of the IOC Assembly regarding the Deployment of Floats in the High Seas within the Framework of the ARGO Program in 2008 in an attempt to crystallise the legal framework.[61] However, these Guidelines have faced a lot of opposition due to the provision of new notification and information duties they impose, and thus the debate about the legal regime applicable to such (semi-) autonomous research devices has yet to be resolved.[62]

A second example in this regard is citizen science, through which members of the general public collect and/or analyse data in collaboration with professional scientists.[63] Ocean-focused initiatives range from collecting marine mammal sightings by members of the public, to cooperation with diving associations to report on ghost fishing gear, and to getting the general public involved in the identification of certain flora and fauna species in photographs.[64] One specific example of citizen science is crowd-sourced bathymetry (CSB). CSB refers to the sharing of depth measurements from navigation instruments by private entities while out at sea or obtained during surveys.[65] The International Hydrographic Organization (IHO) has published the Guidelines for Crowdsourced Bathymetry,[66] which are continuously reviewed and

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[60] For further discussion on these questions, see Bork et al, 'The Legal Regulation of Floats and Gliders' (n 58); Tobias Hofmann and Alexander Proelss, 'The Operation of Gliders Under the International Law of the Sea' (2015) 46 *Ocean Development & International Law* 167; Woker et al, 'The Law of the Sea and Current Practices of Marine Scientific Research in the Arctic' (n 57).
[61] IOC/ABE-LOS, *Draft Guidelines for the Implementation of Resolution XX-6 of the IOC Assembly regarding the Deployment of Floats in the High Seas within the Framework of the ARGO Program (2008)*, Res EC-XLI.4, 5 June 2018.
[62] Tara Davenport, 'Submarine Communications Cables and Science: A New Frontier in Ocean Governance?' in Harry N Scheiber, James Kraska and Moon-Sang Kwon (eds), *Science, Technology, and New Challenges to Ocean Law* (Brill Nijhoff 2015) 236.
[63] Carlos Garcia-Soto et al, 'Advancing Citizen Science for Coastal and Ocean Research' (2017) *Position Paper 23 of the European Marine Board*, 9 <https://www.marineboard.eu/sites/marineboard.eu/files/public/publication/EMB_PP23__Citizen_Science_web.pdf>.
[64] For an overview of citizen science initiatives in Europe, see *ibid* 105–109, Annex III.
[65] International Hydrographic Organization, 'Crowdsourced Bathymetry' (14 January 2021) <https://iho.int/en/crowdsourced-bathymetry>.
[66] International Hydrographic Organization, *B-12 - IHO Guidelines for Crowdsourced Bathymetry*, B-12 Edition 2.0.3, 20 January 2020 <https://iho.int/uploads/user/pubs/bathy/B_12_Ed2.0.3_2020.pdf>.

maintained by the IHO's Crowdsourced Bathymetry Working Group. The increased gathering and sharing of bathymetric data could help meet the objectives of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030)[67] as well as the Nippon Foundation-GEBCO Seabed 2030 project, which aims to map all of the ocean floor by 2030 using largely crowd-sourced data from research vessels, corporations and privately owned ships around the world.[68] At the same time, some legal uncertainties still exist. What is the legal framework applicable to CSB? Should it be classified as MSR or (rather) as hydrographic surveying? Can private yachts take depth measurements anywhere or could that be considered illegal surveying?[69] Is it even citizen science if privately funded vessels are being used? Furthermore, CSB depends on the willingness of coastal States to participate and commit to data-sharing, but according to an IHO questionnaire, coastal States have worries about the detection of apparent deficiencies in their official charts (and liability issues related thereto), concerns because of national security issues, and concerns about the legal status of CSB in the context of the LOSC.[70] It is the ambition of the IHO to initiate a discourse about the status of CSB in terms of the LOSC, arguing that CSB is not illegal surveying but rather provides a great contribution to advancing knowledge of the seabed topography for the benefit of all who use the seas and oceans.[71]

Advances in technology to enhance scientific knowledge may cause environmental impacts, such as physical, acoustic, chemical, or accidental environmental impacts;[72] and numerous ocean sensor-carrying platforms are deployed without any plans for recovery.[73] Some research technologies may come with a high environmental cost in terms of emissions and waste, and some research activities deliberately manipulate the marine environment to understand the

[67] IOC Ocean Decade Series 20 4 (n 53).
[68] 'Crowd Sourced Bathymetry' (*The Nippon Foundation-GEBCO Seabed 2030 Project*, 2020) <https://seabed2030.org/crowd-sourced-bathymetry>.
[69] Andrew Schofield, 'Crowd Sourced Bathymetry', 9th ABLOS Conference: UNCLOS: Pushing the Limits of UNCLOS (Monaco, October 2017).
[70] Mathias Jonas, 'Crowd Sourced Bathymetry - How Can a Grass Root Movement Be Legally Framed?', '10th ABLOS Conference: Opportunities and Challenges in the Governance of the Planet Ocean' (Monaco, October 2019).
[71] *Ibid*.
[72] Anna-Maria Hubert, 'The New Paradox in Marine Scientific Research: Regulating the Potential Environmental Impacts of Conducting Ocean Science' (2011) 42 *Ocean Development & International Law* 329, 330.
[73] Linwood Pendleton and Asgeir J Sørensen, 'The Hidden Downside to Ocean Data and How to Make It More Sustainable' (*World Economic Forum*, 14 April 2021) <https://www.weforum.org/agenda/2021/04/10-ways-to-make-ocean-data-more-sustainable/>.

effects of those manipulations.[74] Many ocean sensors and platforms are made from minerals mined from the Earth, as with other sensors and indeed all computers and mobile phones. The LOSC provides that MSR shall be conducted in compliance with all relevant regulations for the protection and preservation of the marine environment.[75] At the same time, the LOSC also provides the general obligation to promote and facilitate the conduct of MSR,[76] calling for a balance to be struck between environmental risk and scientific gain, which has been referred to as the 'paradox of marine scientific research'.[77]

New technologies not only change the way in which we obtain scientific data, but they also change the type of scientific data we are able to collect and how we use that data. The development of genetic research technologies, combined with marine biological sampling tools, open up new opportunities to gather scientific information from the oceans that can be used for the protection of the marine environment. One example is environmental DNA (eDNA), whereby genetic residue left behind by organisms (such as cells shed from skin, or body waste) in the ocean, can be detected and analysed using molecular biology tools.[78] By providing information on the presence/absence of marine species, eDNA can be used in monitoring marine biodiversity, identifying endangered species, assessing environmental impacts of human activities and in fisheries management.[79] Genomic technologies are a growing area of research and innovation and are used to complement traditional marine biological research techniques. For example, eDNA has been used in combination with visual observations to understand the distribution of lionfish, an invasive species in parts of the Caribbean.[80] A further example is real-time gene sequencing, which can support law enforcement efforts to tackle illegal wildlife trade and fisheries, for example by enabling the identification of endangered shark and ray species from dried fins and gill plates.[81]

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[74] Philomène A Verlaan, 'Experimental Activities That Intentionally Perturb the Marine Environment: Implications for the Marine Environmental Protection and Marine Scientific Research Provisions of the 1982 United Nations Convention on the Law of the Sea' (2007) 31 *Marine Policy* 210, 211.
[75] LOSC, Art. 240(d).
[76] *Ibid*, Art. 239.
[77] Hubert 'The New Paradox in Marine Scientific Research' (n 72).
[78] National Oceanic and Atmospheric Administration, 'Omics Strategy: Strategic Application of Transformational Tools' (*NOAA*, February 2020) <https://nrc.noaa.gov/LinkClick.aspx?fileticket=RReWVFNjr5I%3D&tabid=92&portalid=0>.
[79] Bradley R Moore et al 'Defining the stock structures of key commercial tunas in the Pacific Ocean I: Current knowledge and main uncertainties' (2020) 230 *Fisheries Research* 105525.
[80] Haley Erickson et al, 'Using Environmental DNA (eDNA) to Improve the Accuracy and Efficiency of Managing the Invasive Pacific Red Lionfish in the Caribbean' (*Dutch Caribbean Biodiversity Database*, 2019) <https://www.dcbd.nl/sites/default/files/documents/article%20lionfish.docx>.
[81] Dirk Steinke et al, 'DNA analysis of traded shark fins and mobulid gill plates reveals a high proportion of species of conservation concern' (2017) 7 *Scientific Reports* 9505.

The negotiations for the new BBNJ Agreement highlight the many legal questions raised by the development of new technologies to collect and use ocean data.[82] On the one hand, States are seeking to promote scientific research, recognising that scientific knowledge and technological tools associated with genetic information are useful for the conservation and sustainable use of marine biodiversity. On the other hand, States are also seeking to ensure that there are measures in place to share benefits from the use of MGR (which include the development of new biotechnologies, biomaterials, and products for industry sectors spanning cosmetics and pharmaceuticals to industrial processes[83]), recognising that few are capable of accessing and using MGR from the deep and remote areas beyond national jurisdiction. Attempting to achieve these two objectives requires States to tackle a complex mix of legal questions relating to the rights and responsibilities of States associated with MSR and the development and transfer of marine technology.[84] A further challenge is that most access and benefit-sharing attempts applied to information have tried to replicate systems used for physical materials without recognising the fundamental differences between information and materials.[85] The issue of MGR has been one of the more contentious issues in the negotiations to date, and it remains unclear the extent to which the BBNJ agreement will improve the accessibility of scientific data and the capacity of all States to use it.[86]

5. NEW TECHNOLOGIES FOR MONITORING AND ENFORCEMENT

A final category of technological advances discussed here comprises new technologies for monitoring and enforcement, whereby advances in science and technology are used to better

[82] Harriet Harden-Davies and Kristina Gjerde, 'Building scientific and technological capacity: a role for benefit-sharing in the conservation and sustainable use of marine biodiversity beyond national jurisdiction' (2019) 33(1) *Ocean Yearbook* 377.

[83] A central issue is thus the 'blurring between non-commercial and commercial research', as the academic community partners with industry. See Robert Blasiak et al, 'The Ocean Genome: Conservation and the Fair, Equitable and Sustainable Use of Marine Genetic Resources' (B*lue Paper Commissioned by High Level Panel for a Sustainable Ocean Economy*, 2020) 27 <https://oceanpanel.org/sites/default/files/2020-09/The%20Ocean%20Genome%20Conservation%20and%20the%20Fair%20Equitable%20and%20Sustainable%20Use%20of%20Marine%20Genetic%20Resources.pdf>.

[84] The LOSC establishes the framework for marine scientific research in Part XIII, and for the development and transfer of marine technology in Part XIV.

[85] Deep Ocean Stewardship Initiative, 'Digital Sequence Information – Clarifying Concepts', *DOSI Policy Brief* (March 2020) 2 <https://www.dosi-project.org/wp-content/uploads/070-DSI-Policy-brief-V4-WEB.pdf>.

[86] See for example Muriel Rabone et al, 'Access to Marine Genetic Resources (MGR), Raising Awareness of Best-Practice Through a New Agreement for Biodiversity Beyond National Jurisdiction (BBNJ)' (2019) 6 *Frontiers in Marine Science* 520; Arianna. Broggiato et al, 'Mare Geneticum: Balancing governance of marine genetic resources in international waters' (2018) 33 *International Journal of Marine and Coastal Law* 3; 'International legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction' UNGA Res 72/249 (24 December 2017) A/RES/72/249 (BBNJ Agreement).

implement and enforce the legal framework. In addition to the example of real-time gene sequencing discussed above, monitoring and enforcement is usually done by using data collected by satellites orbiting the Earth, which can monitor human activities at sea, detect oil spills and other sources of pollution, contribute to port inspections, and contribute to the fight against illegal, unreported or unregulated (IUU) fishing.[87] Satellite remote sensing can be an effective tool in the assessment and mitigation of a disaster impact, the monitoring of compliance with and enforcement of international treaties, and the verification of facts and evidence.[88]

One example of using satellite remote sensing for monitoring and enforcement purposes is the not-for-profit organisation Global Fishing Watch. Thanks to advances in satellite technology and machine learning, Global Fishing Watch has been able to build an open-access picture of global fishing activity.[89] Its mission is to ‘advance ocean governance through increased transparency of human activity at sea’.[90] The Global Fishing Watch map is the ‘first open-access online platform for the visualization and analysis of vessel-based human activity at sea’.[91] Global Fishing Watch combines publicly available tracking data from automatic identification systems (AIS) with information acquired through vessel monitoring systems (VMS) operated by governments, whilst also incorporating satellite imagery for a more complete picture of global fishing activity. These satellite imaging systems can use infrared technology – such as the ‘Visible Infrared Imaging Radiometer Suite’ (VIIRS); optical imagery – such as the satellite images on Google Earth; or radar technology – such as synthetic aperture radar (SAR) technology. This data is then processed and made publicly available. The map thus provides a view of human activity at sea, including apparent fishing activity, vessel encounters, night light vessel detection and vessel presence. Anyone using the map – including governments – can monitor apparent fishing activity by searching for vessels or downloading reports of activity from custom areas. Governments can thus use this data to identify and take action against

[87] For a discussion on the potential of remote sensing in the fight against IUU fishing, see Denzil GM Miller, ‘Occupying the High Ground: Technology and the War on IUU Fishing’ in Davor Vidas (ed), *Law, Technology and Science for Oceans in Globalisation: IUU Fishing, Oil Pollution, Bioprospecting, Outer Continental Shelf* (Brill Nijhoff 2010); Michele Kuruc, ‘Monitoring, Control and Surveillance Tools to Detect IUU Fishing and Related Activities’ in Davor Vidas (ed), *Law, Technology and Science for Oceans in Globalisation: IUU Fishing, Oil Pollution, Bioprospecting, Outer Continental Shelf* (Brill Nijhoff 2010). See also Group on Earth Observations, ‘Global Earth Observation System of Systems (GEOSS)’ <https://earthobservations.org/geoss.php>.
[88] Atsuyo Ito, *Legal Aspects of Satellite Remote Sensing* (Martinus Nijhoff Publishers 2011) 3, 100.
[89] Global Fishing Watch, ‘About Us’ <https://globalfishingwatch.org/about-us/>.
[90] *Ibid*.
[91] Global Fishing Watch, ‘Our Map’ <https://globalfishingwatch.org/about-us/>.

vessels that are not authorised to fish in certain areas whereas fishers can show they are operating transparently and responsibly, increasing their market value. While there are limitations[92] on the use of satellite remote sensing for the protection of the marine environment, it is fast gaining traction in international ocean governance.

Another illustrative example of technology used for monitoring and enforcement is satellite remote sensing technology to detect oil spills. Aerial observation of marine oil spills is an important element of an effective response to oil spills, by determining the location and extent of oil contamination as well as verifying predictions of the movement and fate of oil slicks at sea.[93] Kongsberg Satellite Services (KSAT), for example, uses optical sensors and SAR technology to extract oil thickness.[94] Classifying oil thickness within an oil spill allows responders to directly target the oil that can be cleaned up. Oil spill detection by satellite remote sensing can be complemented by other technologies mounted on aircraft (such as Side-Looking Airborne Radar, Infrared and Ultraviolet Scanner, Microwave Radiometer or Laser Fluorescence Sensor), as well as human visual inspections.[95]

These initiatives use data collected by satellites orbiting the Earth. The legal framework applicable to this type of activity includes the 1967 Outer Space Treaty[96] (and its principle of the freedom of outer space), the 1986 Principles Relating to Remote Sensing of the Earth from Space,[97] and possibly also the LOSC (its provisions on development and transfer of marine technology, and if the activity for enforcement purposes is deemed to be MSR and if one accepts that Part XIII also applies to research activities that do not take place in, on, or below the water

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[92] For example, AIS may be switched off or locations falsified, and there are variable legal requirements for the use of AIS, see Solene Guggisberg, 'The roles of nongovernmental actors in improving compliance with fisheries regulations' (2019) 28 *Review of European, Comparative and International Environmental Law* 314.

[93] International Tanker Owners Pollution Federation Limited (ITOPF), 'Aerial Observation of Marine Oil Spills', *Technical Information Paper No. 1* (2011) 2 <https://www.itopf.org/fileadmin/uploads/itopf/data/Documents/TIPS_TAPS_new/TIP_1_Aerial_Observation_of_Marine_Oil_Spills.pdf>.

[94] 'KSAT Extracts Oil Thickness from Satellite Images' (*Kongsberg Satellite Services*, 15 May 2020) <https://www.ksat.no/news/news-archive/2020/ksat-extracts-oil-thickness-from-satellite-images-providing-important-information-for-effective-oil-spill-response/>.

[95] Olaf Trieschmann, 'Illegal Oil Spills from Ships: Monitoring by Remote Sensing' in Davor Vidas (ed), *Law, Technology and Science for Oceans in Globalisation: IUU Fishing, Oil Pollution, Bioprospecting, Outer Continental Shelf* (Brill Nijhoff 2010) 216–220.

[96] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (opened for signature 27 January 1967, entered into force 10 October 1967) 610 UNTS 205.

[97] *Principles Relating to Remote Sensing of the Earth from Outer Space*, UNGA Res 41/65, UN GAOR (Supp No 53) at 115, UN Doc A/41/53, 3 December 1986.

column),[98] in addition to a multitude of other instruments such as those established by the IMO and the UN Food and Agricultural Organization. Whenever the data collected by satellite remote sensing is used for enforcement purposes, however, issues relating to liability, reliability and verifiability of the data,[99] and privacy arise.[100] Indeed, there is a difference between using data from satellite remote sensing for monitoring, control and surveillance purposes, and using that data to check compliance with (and violations of) international law. Satellite remote sensing can offer data for the purpose of verifying facts and evidence, but most environmental agreements do not contain specific references to the use of satellite imagery for verification purposes.[101] However, satellite data has in a number of occasions been used to identify vessels responsible for oil spills and other forms of pollution,[102] and has also been used as evidence in a few cases, mostly concerning maritime and territorial delimitation.[103] As soon as data collected by satellite remote sensing may be used to prove liability or violations of public international law, legal issues relating to reliability, verifiability and translatability[104] of the data may be even more pertinent, especially if the data is collected by non-State actors.

6. THE MULTIFACETED RELATIONSHIP BETWEEN NEW TECHNOLOGY, LAW, AND THE PROTECTION OF THE MARINE ENVIRONMENT

The preceding discussion of the four categories has revealed that the relationship between new technology and the protection of the marine environment is not a one-way street. It is a

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[98] For example, Rothwell and Stephens submit that Part XIII does not include scientific research undertaken from 'outside the surface, water column, subsoil or seabed in the marine environment'. Donald R Rothwell and Tim Stephens, *The International Law of the Sea* (2nd edn, Hart Publishing 2016) 348. However, an alternative interpretation exists, submitting that there is no requirement in LOSC that the research activity take place in, on, or below the water column. For further discussion, see Woker et al 'The Law of the Sea and Current Practices of Marine Scientific Research in the Arctic' (n 57).

[99] London Institute of Space Policy and Law, 'ISPL ESA Study: The Use of Satellite-Derived Information as Evidence' (Doc ESA-ISPL/EO 47), ESA Workshop: Evidence from Space (London, October 2010) <https://www.space-institute.org/wp-content/uploads/2010/10/Workshop-Information-Package-Final.pdf>.

[100] Maria Maniadaki et al, 'Reconciling Remote Sensing Technologies with Personal Data and Privacy Protection in the European Union: Recent Developments in Greek Legislation and Application Perspectives in Environmental Law' (2021) 10 *Laws* 33.

[101] Matxalen S Aranzamendi et al (eds), *Current Legal Issues for Satellite Earth Observation: Treaty Verification and Law Enforcement through Satellite Earth Observation and Privacy Conflicts from High Resolution Imaging (Report 25)* (European Space Policy Institute, 2010) 28.

[102] Ito, 'Environmental Law' (n 88) 132. See, *eg*, *Frontier Dispute (Mali v Burkina Faso)* (Judgment) [1986] ICJ Rep 554; *Kasikili/Sedudu Island (Botswana/Namibia)* (Judgment) [1999] ICJ Rep 1045; *Case Concerning Maritime Delimitation and Territorial Questions Between Qatar and Bahrain (Qatar v Bahrain)* (Judgment) [2001] ICJ Rep 40; *Case Concerning the Land and Maritime Boundary between Cameroon and Nigeria (Cameroon v Nigeria; Equatorial Guinea intervening)* (Judgment) [2002] ICJ Rep 303 (in most of these cases, the satellite images were introduced to determine the locations of points relevant for the delimitation process).

[103] Ito, 'Environmental Law' (n 88) 135-143.

[104] See, *eg*, Trieschmann, 'Illegal Oil Spills from Ships' (n 95) 228: 'For successful prosecution, lawyers need to be able to rely on comprehensive, plausible and complete data sets that are also understandable to non-experts.'

multifaceted relationship. Three cross-cutting themes can be identified that characterise this relationship. First of all, it involves a balancing act that depends on a multitude of variables. Secondly, new technology may challenge the applicable legal framework and its adequacy to regulate advancements in technology. A third cross-cutting theme relates to the range of actors and interests involved and raises questions of who uses (new) technology, who benefits, and who carries the burdens and risks. These three cross-cutting themes are not exhaustive; nor are they mutually exclusive. They do, however, demonstrate the different ways in which new technology facilitates, improves, and/or challenges the protection of the marine environment and how this relationship is mediated by law.

6.1 Balancing Act

The relationship between new technology and the protection of the marine environment involves a balancing act that depends on a wide range of variables, including the nature and scale of the technology and its associated environmental risks, the particular application or purpose of the technology, the area of operation (within or beyond national jurisdiction), and the range of actors and interests involved. These variables, rather than the type of technology *per se*, determine the relation with the marine environment, as well as questions of applicable law and the adequacy of the legal regime. We have seen that a single type of technology, for example autonomous devices, can be applied in MSR, but also in a law enforcement context. Similarly, advances in genetic technologies may enhance scientific knowledge, but may also open up new commercial uses of MGR and thereby their exploitation as a resource. For new technologies that open up new or advanced ways of exploiting resources that fall squarely within traditional sovereign rights of coastal States under the territorial sea, EEZ and continental shelf regimes, it is clear that the balance of interests reflected in these regimes leaves coastal States a considerable measure of discretion in authorising and regulating such activities. Their general obligation of due diligence to prevent, reduce and control pollution of the marine environment resulting from such activities depends on further relevant rules and standards to provide it with detailed normative content. The ‘open’ nature of this obligation means that the balancing act is to be conducted on a case-by-case basis, which allows technological and normative developments to be incorporated progressively over time. However, such dedicated international standards do not always exist, as the examples of renewable energy production and mariculture illustrate. Challenges furthermore arise where large measures of uncertainty remain. General obligations of due diligence or precaution do not inform *how* the potential environmental risks versus environmental benefits of a particular technology are to be weighed, as they are dependent on the availability of extra-legal knowledge and data to inform this balancing act.

In addition to the variables identified above, the 'environmental interest' itself is also not a uniform concept within the balancing act. In case of technological interventions for restoration purposes, one environmental interest (in addressing the target risk) is to be balanced against another environmental interest (the risk posed by operating the technology itself). These applications of technology thereby entail a different kind of balancing act than exploitation activities, where an established sovereign right to exploit a particular resource is to be balanced against the obligation to protect the marine environment from the impacts of this activity. MSR straddles these examples as it involves, on the one hand, a right (to conduct MSR) that has to be balanced against the obligation to protect the marine environment. Yet, this balancing act may involve two environmental interests pulling in opposite directions: scientific gain that may benefit environmental protection versus potential environmental harm caused by MSR technologies. This tension underlines the point that within any balancing act, the weight accorded to the 'environmental interest' and the definition thereof are open to different interpretations that in turn rely on extra-legal knowledge.

6.2 The Adequacy of the Legal Framework

A second cross-cutting theme characterising the relationship between new technology and the protection of the marine environment is the question of applicable law and the adequacy of the legal framework. In many of the cases discussed above, the law predates (the application of) the technology that was clearly not foreseen during the drafting of the legal instruments. When the applicable legal regime dates from the previous century, questions arise as to how new technology may be classified and how it may 'fit' within the legal regime applicable.

It is widely recognised that the LOSC is to a large extent open enough to be interpreted in an evolutionary manner,[105] thus allowing for changing circumstances and advancements in technology to be taken into account when interpreting certain provisions of the Convention. Indeed, the fact that the list of high seas freedoms is non-exhaustive, facilitates the introduction of new uses of the oceans and technologies. The same is true for new research technologies:

[105] Rozemarijn J. Roland Holst, *Change in the Law of the Sea: Context, Mechanisms and Practice* (Brill 2022); Jill Barrett and Richard Barnes (eds), *Law of the Sea: UNCLOS as a Living Treaty* (BIICL 2016).

due to the absence of a definition of MSR, the right to conduct MSR may be interpreted to include new research technologies.[106] For these examples, the existing legal framework – with an evolutionary interpretation – is thus able to cover such advancements in technology. At the same time, duties of due regard and due diligence remain key to balance such evolving rights with the (existing) rights and obligations of other actors, and thus the balancing act discussed above becomes ever more important.

The examples of TOC, floats and gliders, and citizen science indeed demonstrate how advances in technology may still be included in the existing jurisdictional framework. However, the same examples also demonstrate the need for dedicated rules for the specifics of such advances in technology. For example, although TOC's technology falls within the non-exhaustive freedoms of the high seas, it is still unclear how the technology may be classified. The Agreement between TOC and the Kingdom of the Netherlands reflects the hybrid and/or unclear nature of the technology and its legal status. Furthermore, technologies such as floats and gliders have certainly challenged the traditional image of conducting MSR. Are these devices to be considered ships (with corresponding flag State responsibilities), or installations and structures?[107] What about the requirements for obtaining consent? In these cases, it is often impossible to determine the 'precise geographical areas in which the project is to be conducted'.[108] The LOSC requires MSR to be conducted with 'appropriate scientific method and means'.[109] What does this threshold mean today?[110] Does it include citizen science projects, or the use of floats and gliders? Thus, despite the fact that these activities are governed by the existing legal framework in general terms, the lack of specific norms and standards illustrates how the existing legal framework may not always be fully adequate to regulate new technology.

In other contexts, it is much harder to include new technologies within the existing jurisdictional framework. Here, new legislation altogether may be required to sufficiently regulate the use of and access to new technologies and to prevent any harm to the marine environment. The BBNJ agreement is a case in point. There have been too many legal uncertainties surrounding the

[106] See Nele Matz-Lück, 'Article 238' in Alexander Proelss (ed), *United Nations Convention on the Law of the Sea: A Commentary* (BECK 2017) 1605; Woker et al 'The Law of the Sea and Current Practices of Marine Scientific Research in the Arctic' (n 57).
[107] See Hofmann and Proelss 'The Operation of Gliders Under the International Law of the Sea' (n 60).
[108] LOSC, Art. 248(c).
[109] *Ibid*, Art. 240(b).
[110] See Woker et al 'The Law of the Sea and Current Practices of Marine Scientific Research in the Arctic' (n 57).

harvesting of MGR, the related equity issues, and the rights and obligations in relation to the protection of the marine environment in areas beyond national jurisdiction as such. Hence, the UN initiated the BBNJ process to draft a new implementing agreement to the LOSC, which hopefully will be able to regulate the relationship between new technology and the protection of the marine environment within the BBNJ context.

6.3 Actors and Interests

Thirdly, underpinning the themes explored above are questions about who uses and has access to technology, who benefits, and who carries the burden – regardless of whether technologies are used to exploit marine resources, mitigate environmental harm, or advance knowledge to inform and enable environmental protection. In addition to the example of equity issues surrounding access to and benefit sharing of MGR, remote sensing technology for monitoring and enforcement purposes is expensive and has the potential to be a powerful tool for those who have the means to use it. This requires critical reflection on the actors involved, their interests, and the power relations between them. To a limited extent, these questions were anticipated by the LOSC by providing for the transfer of marine technology. However, today, progress in implementing Part XIV of the LOSC on transfer of marine technology has fallen short of expectations, and questions surrounding technology and equity continue.[111] Meanwhile, the importance of technology for the protection and preservation of the marine environment has been reinforced – including in the UN Sustainable Development Goal 14 Target A,[112] and by the inclusion of 'capacity building and technology transfer' as one of the four key elements of the BBNJ Agreement.[113] As the UN Decade of Ocean Science for Sustainable Development begins in 2021, including the goal to 'leave no-one behind', growing scrutiny on the equity aspects of technology transfer might be expected. Technology alone is not the solution; for example, access to equipment or data will only be useful if there is corresponding, human, institutional and financial capacity to utilise a technology in a socially responsible and sustainable way. This challenge highlights that technology is merely a tool – people will

[111] See, *eg*, IOC-UNESCO, *Global Ocean Science Report 2020: Charting Capacity for Ocean Sustainability* (UNESCO Publishing 2020) highlighting the continuing disparity between States in terms of access to marine science and technology.
[112] *Transforming Our World: the 2030 Agenda for Sustainable Development*, UN Doc A/RES/70/1, 25 September 2015, Goal 14. See also UNESCO-IOC, 'IOC Criteria and Guidelines on the Transfer of Marine Technology' (UNESCO Publishing 2005).
[113] See, *eg*, Harriet Harden-Davies et al, 'Science in Small Island Developing States: Capacity Challenges and Options relating to Marine Genetic Resources of Areas Beyond National Jurisdiction', Report for the Alliance of Small Island States, (University of Wollongong, Australia, 30 October 2020).

determine how it is used and whether it contributes to (or poses a problem for) protection of the marine environment.

7. CONCLUSION

While the focus of this chapter has been on the triangular relationship between new technology, the protection of the marine environment, and the legal framework governing this relationship, we recognise that there are also critical social, political and cultural factors that will determine the efficacy and equitability of technology development and deployment in the marine environment. It is important to note that the current mapping exercise is not exhaustive. Certainly, some of the more familiar examples (such as geoengineering) have been excluded in this discussion as they are discussed elsewhere.[114] However, we hope this overview may help readers understand the different legal issues that arise at the interface between technology and international law, and that it may guide and inspire further research.

[114] [insert cross-reference to Karen Scott's chapter]