ENVIRONMENTAL STUDIES

Corporate control and global governance of marine genetic resources

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Who owns ocean biodiversity? This is an increasingly relevant question, given the legal uncertainties associated with the use of genetic resources from areas beyond national jurisdiction, which cover half of the Earth's surface. We accessed 38 million records of genetic sequences associated with patents and created a database of 12,998 sequences extracted from 862 marine species. We identified >1600 sequences from 91 species associated with deep-sea and hydrothermal vent systems, reflecting commercial interest in organisms from remote ocean areas, as well as a capacity to collect and use the genes of such species. A single corporation registered 47% of all marine sequences included in gene patents, exceeding the combined share of 220 other companies (37%). Universities and their commercialization partners registered 12%. Actors located or headquartered in 10 countries registered 98% of all patent sequences, and 165 countries were unrepresented. Our findings highlight the importance of inclusive participation by all states in international negotiations and the urgency of clarifying the legal regime around access and benefit sharing of marine genetic resources. We identify a need for greater transparency regarding species provenance, transfer of patent ownership, and activities of corporations with a disproportionate influence over the patenting of marine biodiversity. We suggest that identifying these key actors is a critical step toward encouraging innovation, fostering greater equity, and promoting better ocean stewardship.

INTRODUCTION

The prospect of the ocean generating a new era of "blue growth" is increasingly finding its way into national and international policy documents around the world and has spurred a rush to claim ocean space and resources (*1*, *2*). If economic activities in coastal and offshore areas are to expand in an equitable and sustainable manner, in line with the Sustainable Development Goals (SDGs), progress is needed toward addressing multiple and potentially conflicting uses of ocean space within national jurisdictions, in addition to developing a consistent and transparent legal framework for the vast areas beyond national jurisdiction (ABNJ) (*3*, *4*). These areas cover 64% of the world's ocean and 47% of the Earth's surface yet remain poorly understood or described (*5*).

Marine organisms have evolved to thrive in the extremes of pressure, temperature, chemistry, and darkness found in the ocean, resulting in unique adaptations that make them the object of commercial interest, particularly for biomedical and industrial applications (*6*–*8*). By 2025, the global market for marine biotechnology is projected to reach $6.4 billion, spanning a broad range of commercial purposes for the pharmaceutical, biofuel, and chemical industries (*9*, *10*). One way to ensure exclusive access to these potential economic benefits is through patents associated with "marine genetic resources" (MGRs). Although the term MGRs has never been formally described (*10*), it suggests a subset of "genetic resources," which have been defined under the Convention on Biological Diversity (CBD) as "genetic material of actual or potential value" (*11*). The registration of patent claims involving MGRs constitutes an opaque and rapidly evolving frontier where the worlds of science, policy, and industry meet (*12*). The adoption of the Nagoya Protocol in 2010 represented an important step within the international policy arena to define obligations associated with monetary and nonmonetary benefit sharing of genetic resources and their products sourced from within national jurisdictions (*13*). No such mechanism currently exists for ABNJ.

Transnational corporations have a unique ability to capitalize on and monopolize markets characterized by global scope and complexity. The recent identification of "keystone actors" in the seafood industry, for instance, illustrates how a handful of transnational corporations and their subsidiaries have a disproportionate influence on production volumes and revenues, as well as on governance processes and institutions (*14*). The global scope of the marine biotechnology sector and its expanding size seem conducive to the emergence of a similar pattern of dominance by a small number of transnational corporations. Their substantial financial resources enable them to develop commercial applications despite uncertain timelines and returns on investment while also facilitating the acquisition or collection of samples (for example, chartering vessels for a week-long sampling cruise of deep-water corals was estimated in 2013 at $455,000) (*15*). Past research has focused on countries where patents have been registered (*16*) rather than the individual actors registering them. Identifying the entities in control of MGRs, however, is of crucial importance, given the rapidly evolving legal and political landscapes associated with marine biodiversity.

Here, we investigate how many and what types of marine species are being included in patent claims, by whom, and when. We suggest that identifying the key actors registering patents involving MGRs is a critical step toward ensuring more equitable ocean stewardship, whether through regulation, voluntary industry action, or other mechanisms. These findings are discussed in relation to global governance of MGRs, in particular in light of the Nagoya Protocol and the ongoing international negotiations on the conservation and sustainable use of biodiversity in areas beyond national jurisdiction (BBNJ).

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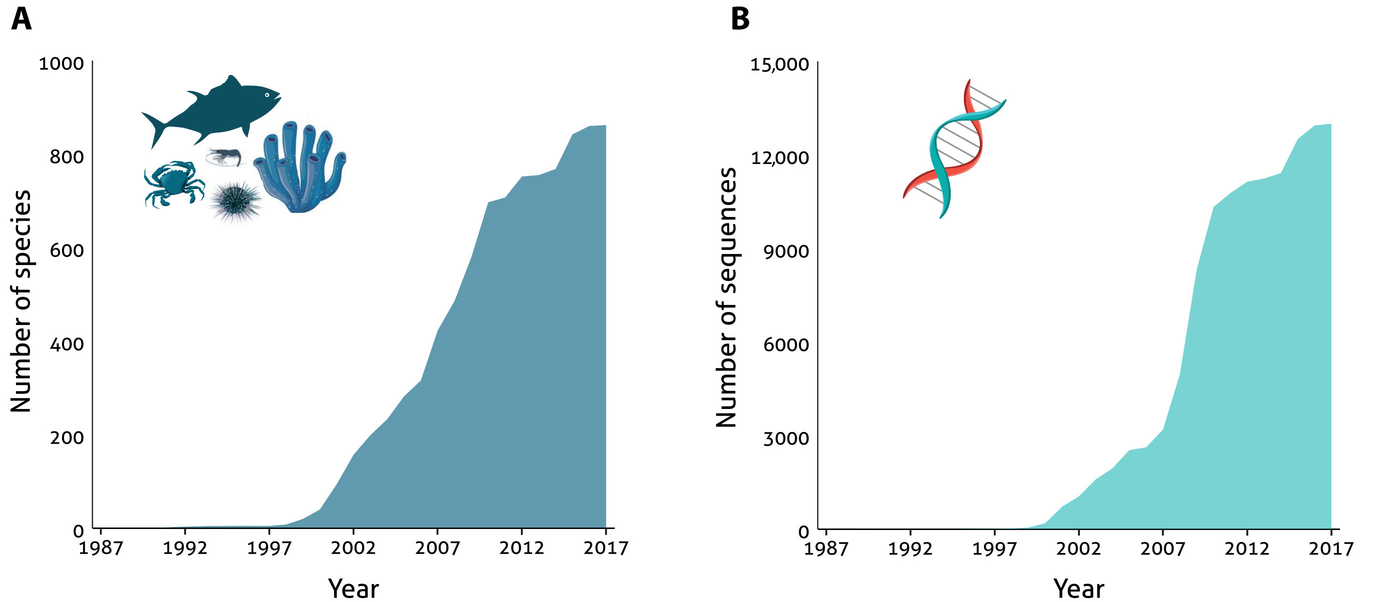

Fig. 1. Growing commercial interest in MGRs. Cumulative number over time (1988–2017) of (A) marine species with patent sequences and (B) patent sequences from marine species.

RESULTS

We identified 862 marine species, with a total of 12,998 genetic sequences (see the Supplementary Materials) associated to patents with international protection filed under the Patent Cooperation Treaty (see the Supplementary Materials), as of October 2017. The first such patent related to a marine species was traced to 1988, resulting in a database spanning 30 years. The vast majority of patents were registered in the last 15 years, in terms of both the number of marine species used as a source for gene patents (Fig. 1A) and the actual number of genetic sequences included in patent claims (Fig. 1B).

What is being patented?

Sequences from a wide range of species have been the focus of patents, extending from the sperm whale (*Physeter macrocephalus*) and giant oceanic manta ray (*Manta birostris*) to microscopic archaea and plankton (fig. S1). The majority of patents are associated with microbial species, which constitute 19% of named species in the World Register of Marine Species (WoRMS), yet account for more than 73% of all patent sequences in our database. Fish and mollusks represent 16 and 3%, respectively (fig. S1B). Other forms of ocean life have drawn less commercial interest. For instance, of the 3057 tunicate (sea squirt) species in WoRMS, only 6 have been the subject of patents (*5*). A considerable portion of all patent sequences (11%) are derived from species associated with deep-sea and hydrothermal vent ecosystems (91 species, 1650 sequences), many of which are found in ABNJ.

Who is registering the patents?

We found that 221 companies had registered 84% of all patents. Public and private universities accounted for another 12%, while entities such as governmental bodies, individuals, hospitals, and nonprofit research institutes registered the remaining 4% (Fig. 2). A single transnational corporation had registered 47% of all patent sequences: BASF, the world's largest chemical manufacturer, headquartered in Germany. With posted sales exceeding $79 billion in 2017 and a network of 633 subsidiaries and offices in 94 countries, BASF is a truly global actor. Not only did BASF register more patent sequences than the other 220 companies combined (37%), but it also exceeded the second and third companies by an order of magnitude: Japanese biotechnology firm Kyowa Hakko Kirin Co. Ltd. (5.3%) and U.S.-based biofuel company Butamax Advanced Biofuels LLC (3.4%) (fig. S2). More than half (56%) of all university patents were registered by the Yeda Research and Development Co. Ltd., the commercial arm of the Weizmann Institute of Science (Israel), exceeding the combined claims of the 77 other universities.

Entities located or headquartered in three countries registered more than 74% of all patents associated with MGR sequences: Germany (49%), United States (13%), and Japan (12%). This figure rises to more than 98% when one considers the top 10 countries (see the Supplementary Materials). In total, international patent claims have been made by entities in 30 countries and the European Union (EU), while the remaining 165 countries are unrepresented.

Trends over time

The annual record of published patents reveals a striking temporal pattern (Fig. 3). Following an extended period of negligible growth from 1988 to 1998, patent claims gradually increased to a plateau of roughly 500 patent sequences annually until 2006, before abruptly peaking in 2009 at 3354 claims and declining just as sharply to 367 in 2012. More than half of the sequences registered to date were included in claims during the period 2007–2010. This peak in activity appears to coincide with key stages in the negotiations and adoption of the Nagoya Protocol (Fig. 3).

DISCUSSION

Corporate control over MGRs

The dramatic asymmetries in patent registration resemble trends in resource use and industry dominance that have been observed in multiple sectors, where high levels of consolidation have resulted in

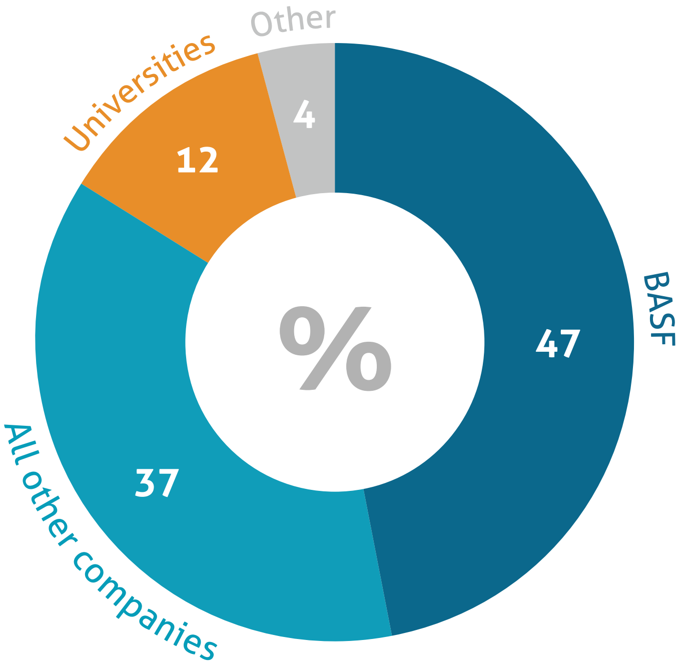

Fig. 2. Percentage of patents with international protection associated with MGRs that were registered over the period 1988–2017 by BASF, all other companies (*n* = 220), universities (*n* = 78), and other actors (*n* = 26; including governmental bodies, individuals, hospitals, and nonprofit research institutes).

the emergence of a handful of keystone actors (*14*, *17*). In the seeds industry, for instance, the so-called Big Six (BASF, Bayer, Dow, DuPont, Monsanto, and Syngenta) have dominated the sector for years (*18*). The merging of Dow and DuPont (in 2015) and current (2018) negotiations by Bayer to acquire Monsanto illustrate a pattern of further consolidation and have increased concerns about an emerging oligopoly characterized by reduced competition, forms of collusion, and inflated prices for consumers (*18*, *19*). Our findings show that the corporate landscape with regard to MGRs is already far more consolidated than the seeds industry, although this development has not drawn public attention or scrutiny. BASF is a keystone actor with 5701 MGR patent sequences (fig. S2), while the participation of the remaining Big Six companies is remarkably modest: DuPont (180), Bayer (34), Monsanto (17), Syngenta (4), and Dow (1). The existence of large transnational corporations with global networks of subsidiaries increases the complexity and difficulty of keeping track of patent contracts (*20*). Large corporations are known to acquire smaller companies for the primary purpose of claiming ownership of their patent portfolios (*21*) while also taking advantage of branches located in countries with weaker institutions and limited monitoring or enforcement capacity (*20*). The full extent of consolidation in ownership of patents related to MGRs will likely not be known until the disclosure of transfers in patent ownership becomes a legal obligation.

Many patents associated with MGRs have been registered by public and private universities, or by their commercialization centers. Existing for the primary purpose of monetizing university innovations and discoveries, commercialization centers operate as companies owned by the respective universities. A keystone pattern is evident here as well, with the Yeda Research and Development Co. Ltd. (the commercial arm of the Weizmann Institute of Science) exceeding the combined claims of all the other universities. Commercialization centers, particularly those associated with publicly funded universities, operate in an ethically ambiguous area, as they are under no legal obligation to disclose how they are monetizing these patents (for example, through transfer of ownership).

The Nagoya Protocol and its obligations

The prospect of the Nagoya Protocol and its obligations heralding a new set of international regulations governing access and benefit sharing appears to have spurred a rush to patent marine biodiversity (Fig. 3). Registering patents through the Patent Cooperation Treaty takes around 30 months from the date of application filing (*22*). In 2004, the seventh Conference of the Parties to the CBD defined the scope of an ad hoc open-ended working group "to elaborate and negotiate the nature, scope and elements of an international regime on access and benefit-sharing" (*23*). Negotiations started in February 2005. Patent registration had peaked by 2009 when a draft text emerged, and fell within 3 years by an order of magnitude. This trend is primarily driven by the activities of BASF and may or may not have been associated with the timing of the Nagoya Protocol. In an interview, a BASF contact suggested that this trend could be linked to patent applications on algae sequences for a research project on cultivating canola plants fortified with polyunsaturated omega-3 fatty acids and consequently unrelated to the Nagoya Protocol negotiations. Moreover, this contact suspected that while the Nagoya Protocol created an obvious regulatory burden, it would not have altered the scope or extent of BASF's patenting activities during this period. Its annual corporate and financial reports underscore a strategic focus on patents and innovation, which suggests continuity and long-term planning, with 2006 research and development investments already being tied to expectations of two- to fourfold returns in annual sales starting in 2015. Since 2004, BASF has continuously expanded its investments in research and development, reaching a new record of €1.9 billion in 2017 (*24*). BASF has also highlighted the fact within its annual reports that it has consistently occupied the top position on the Patent Asset Index since it was launched in 2009 to identify the comparative value of corporate patent portfolios (*24*, *25*).

The Nagoya Protocol's drafting and adoption were driven by an international interest in "levelling the playing field," and the agreement was never meant to stifle innovation. However, concerns have been raised that the lack of user guidance on how to adequately exercise the obligations of legislation to implement the Nagoya Protocol at the national level (*26*) and the consequences of failure to comply with these obligations may be indirectly restricting access to biological material for research purposes (*27*, *28*). Since 2012, patent claims have remained at comparable levels to those seen before the drafting of the Nagoya Protocol, suggesting a damper effect on innovation or a rush to register patents before signatories to the Nagoya Protocol established corresponding compliance mechanisms. The outcome has been a reduced pool of benefits to share, as the Nagoya Protocol does not apply retroactively.

The Nagoya Protocol, like all international agreements, represents a compromise among diverse interests. The African Group, for instance, lobbied unsuccessfully for retroactive application of benefit-sharing provisions and legally mandatory disclosure of the country of origin of the genetic resources. The final language associated with the latter issue references the Bonn Guidelines: "countries could consider, *inter alia*, the following: [...] measures to encourage the disclosure of the country of origin of the genetic resources" (*29*). The origin requirement specified within Article 4 of the EU implementing regulation (no. 511/2014) is currently a nonmandatory provision. Consequently,

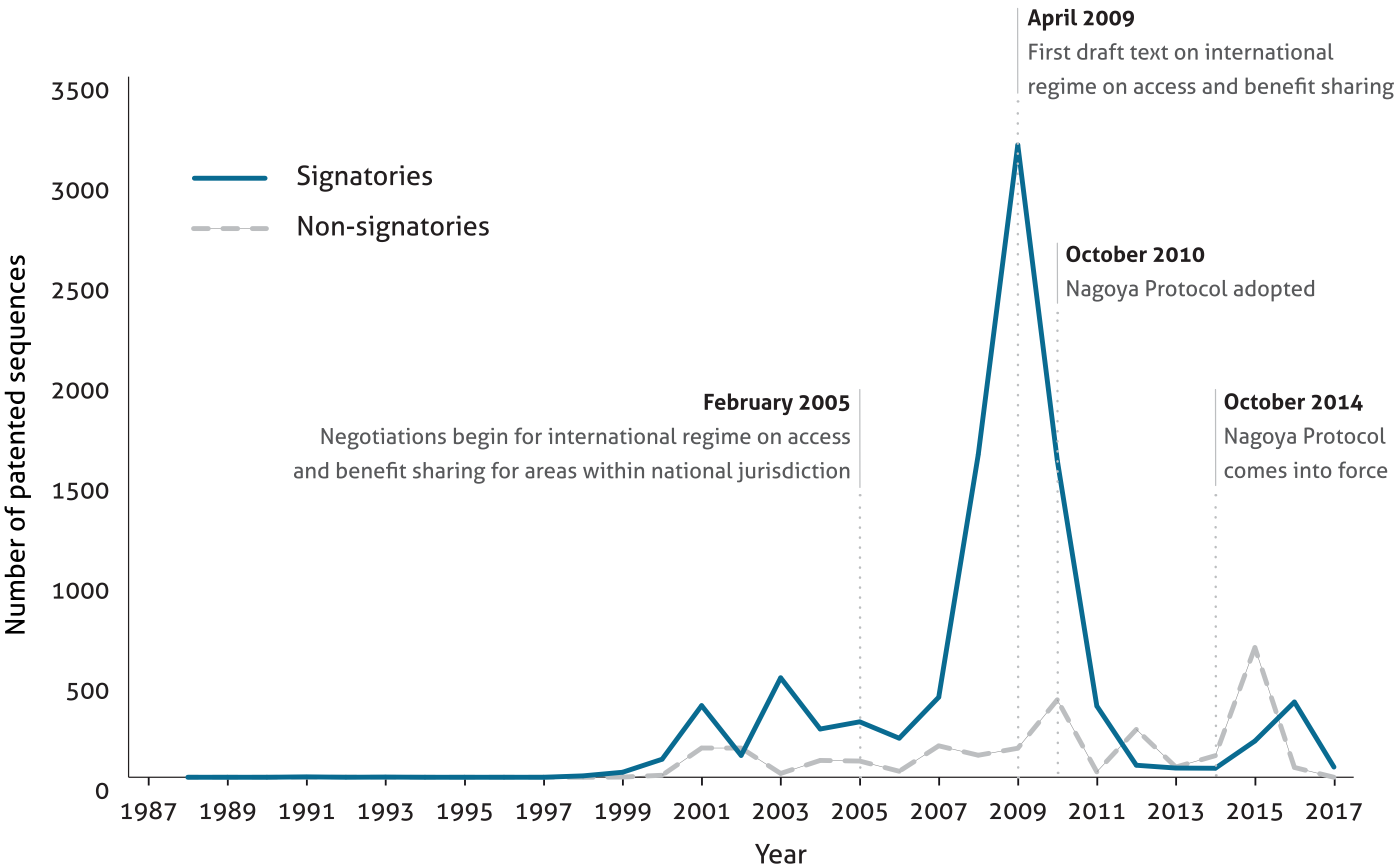

Fig. 3. Timeline of the number of marine genetic sequences associated with claims for international patent protection. Note that registering patents through the Patent Cooperation Treaty entails a roughly 3-year process from the date of filing. A distinction is made between contracting parties to the Nagoya Protocol (n = 20; solid blue line) and non-signatories (n = 10; dashed gray line). Key stages in the negotiations, adoption, and entry into force of the Nagoya Protocol are also included. The protocol remained opened for signature between February 2011 and February 2012 but mostly was not passed into law in national parliaments until 2015 (for example, EU, UK, and Germany).

close to 90% of patent applications do not provide such information—nondisclosure rates being the highest among private corporations (95%) (*30*). This opacity constitutes a serious hurdle to access and benefit sharing of MGRs from ABNJ and would render any potential future retroactive application of such mechanisms largely unfeasible (*16*). The extent to which organisms collected in ABNJ are the subject of gene patents will remain unclear until patent authorities require and verify the MGR origin or until voluntary disclosure becomes an industry norm.

Negotiations on biological diversity beyond areas of national jurisdiction

The nondisclosure of species provenance in patents associated with MGRs has implications for international governance. The United Nations Convention on the Law of the Sea (UNCLOS) distinguishes between two geographical zones in ABNJ: the water column (the High Seas) and the seabed, ocean floor, and subsoil thereof (the Area). An international legal regime exists to govern the exploitation and benefit sharing of mineral resources in the Area, which are considered the common heritage of mankind. While the Nagoya Protocol addresses access and benefit sharing for genetic resources within national waters (*31*), no such mechanism currently exists for MGRs in ABNJ (as of June 2018). Addressing this gap was the focus of one of four "package" issues addressed by a BBNJ Working Group (2006–2015) and Preparatory Committee (2016–2017) (*32*) and will be a key element of the BBNJ treaty negotiations set to start in September 2018. A challenge in these negotiations has been the insistence by some states that MGRs in the Area should, like mineral resources, fall under the common heritage of mankind principle, which would require that their exploitation be subject to some form of benefit sharing. Other states interpret the corresponding articles in UNCLOS to exclude biological resources, resulting in application of the principle of freedom of the High Seas, implying that no legal obligation exists to share the benefits of their exploitation (*10*, *33*).

Developing states have identified MGRs sourced from ABNJ as a top priority within the BBNJ negotiations (*34*). The lack of participation and continuity among delegations of developing countries, however—particularly small island developing states—hampers equitable engagement by these states (*34*). Coupled with a comparatively low level of legal and technical expertise with regard to MGRs, this situation has represented a serious obstacle to progress and has delayed the BBNJ negotiations (*35*). To ensure that the process moves forward in an inclusive manner, states need to increase their commitments to capacity building, including scientific training and collaboration, and make greater use of mechanisms like a voluntary fund that was established to support participation of delegates during the BBNJ Preparatory Committee (*36*). Likewise, greater focus on UNCLOS Part XIV on the development and transfer of marine technology could lay the foundations for more equitable participation by states in efforts to explore and exploit MGRs found in ABNJ (*37*). The findings of this paper, along with the creation of a publicly accessible database (see the Supplementary Materials), represent a practical tool for negotiators engaged in the BBNJ process.

Transformative capacity for ocean stewardship

The existence of keystone actors involved in the patenting of MGRs suggests not only the need to track corresponding lobbying efforts within the BBNJ process but also an opening for more direct engagement with corporations for ocean stewardship (*38*). As private entities, participation by major patent holders like BASF, Kyowa Hakko Kirin Co. Ltd., Butamax Advanced Biofuels LLC, and Yeda Research and Development Co. Ltd. has likely been limited to opaque intersessional engagement with national delegations or trade associations like the International Chamber of Commerce (*22*). Formal participation by major patent holders would render their influence more transparent, enable direct industry reaction to potential rule changes, help outline steps to realistically comply with obligations, and foster greater accountability. Such entities are likewise in a unique position to discuss the implications of various potential monetary and nonmonetary benefit-sharing mechanisms or the practical consequences of regulatory changes.

In addition to the BBNJ process, other mechanisms could also influence change in business standards and practice. Examples include informal governance mechanisms such as advocacy campaigns, changes in consumer and employee interest, engagement with the scientific community, and shareholder activism (*39*). BASF, for instance, is among the world's largest publicly owned companies (ranked 127 on the Fortune 500 list in 2017), with >500,000 individual shareholders, >100,000 employees, and private investors holding some 28% of the company's share capital (*40*). BASF is also participating in the World Business Council for Sustainable Development, is a member of the UN Global Compact, and follows the Global Reporting Initiative guidelines. These are just three of a growing landscape of "voluntary environmental programs," which bring together companies that voluntarily go beyond what is required by government regulation, for instance, with regard to transparency or accounting for externalities (*38*, *41*). There is a possibility that major patent holders would see open engagement with the BBNJ process as purely a risk or liability. Yet, such engagement could also help companies distinguish themselves through their proactive behavior and contribute to providing new norms and standards associated with transparency, capacity building, and benefit sharing (*41*).

Conclusion

Of the 30 countries involved in patenting MGRs, 27 are Parties to UNCLOS and have thereby committed to promoting the development and transfer of marine technology "for the benefit of all parties concerned on an equitable basis" (*42*). The promotion of equity is also deeply embedded within the language of the SDGs. BBNJ negotiations surrounding a new legal regime for MGRs sourced from ABNJ provide countries with an opportunity to follow through on commitments, to increase transparency by requiring disclosure of the geographic origin of MGRs, and to promote greater international participation toward discovering and using the benefits of marine biodiversity (*34*). The scale of patenting to date suggests the need for a greater sense of urgency to ensure a successful conclusion to the negotiation of a new legal regime. Regardless of whether monetary or nonmonetary benefit-sharing mechanisms ultimately emerge through formal agreement or voluntary commitments, it is clear that the potential for commercialization of the genetic diversity in the ocean currently rests in the hands of a few corporations and universities, primarily located or headquartered in the world's most highly industrialized countries. Constructive cooperation among scientists, policymakers, and industry actors is needed to develop appropriate access and benefit-sharing mechanisms for MGRs that serve the triple purpose of encouraging innovation, fostering greater equity, and promoting better ocean stewardship.

MATERIALS AND METHODS

We first created a database of 38 million records of sequences of genetic material associated with patents by accessing the publicly available records of the patent division of GenBank from the National Center for Biotechnology Information on 10 October 2017 (ftp://ftp.ncbi.nih.gov/genbank/). Drawing on a previously described process (*16*), all files (gbpat1.seq.gz to gbpat294.seq.gz) were downloaded and processed to create individual database entries with information on species name, patent number, patent data, and the party (parties) registering the patent. This was done by splitting each file into individual sequences and by extracting the data in the ORGANISM field (species name) and JOURNAL field (patent type, year, and registering party) for each sequence. Data processing was done using the Anaconda Python distribution (version 2.4.1 for Python 2.7). Jupyter notebooks with the data extraction code as well as an SQLite database with the 38 million records are both available on request.

Only those patents issued through international patent applications (those marked "WO") were considered in the analysis that we report on here (7.3 million records). Such applications can facilitate patent recognition throughout some or all of the 152 contracting states to the Patent Cooperation Treaty of the World Intellectual Property Organization (see the Supplementary Materials) (*43*).

The majority of patent sequences relate to identified species (59.3%) and synthetic constructs (39.5%), while a small number are associated with unidentified species (1.2%). Sequences from a total of 8032 different species are included in the database (see the Supplementary Materials). To determine the marine origin of named species, the taxon match tool of the WoRMS, which is estimated to include 98% of described species (*5*), was used for all database hits (*44*), resulting in a conservative filtered list of 1720 species (see the Supplementary Materials). Web searches were conducted for each of these 1720 species to verify the marine origin and to collect further information about the nature of each species. Nearly half of the matched species were subsequently excluded, resulting in a final list of 862 marine species (see the Supplementary Materials). Species were excluded if a literature search revealed that they were associated with freshwater or terrestrial environments; seabirds were also excluded. A final filtering process was carried out to remove a small number of cosmopolitan microbes found in diverse environments, including marine systems. This is due to the high costs typically associated with the collection of genetic resources from marine environments, meaning that cosmopolitan microbes would more likely have been isolated from other more easily accessible sources. In some cases, it was possible to collect information about whether microbes had been isolated from sediments or seawater, and whether this signified a likely deep-sea or hydrothermal vent provenance (see the Supplementary Materials for list and references).

Records of patent sequences from the 862 marine species were extracted from our database and analyzed with regard to patent applicants, resulting in 12,998 relevant sequences. A total of 12,169 (94%)

sequences were registered to a sole entity and formed the basis for the ownership analysis. Analysis of species provenance, date of patent, and number of patent sequences was carried out on the full sample (see the Supplementary Materials). A total of 559 entities were recorded as sole or joint applicants on patents, and web searches were used to collect information about each, including their web presence and the type of entity that they represent, leading to the subsequent definition and classification into three broad categories: companies, universities and their commercialization centers, and others (national institute or agency or government body, individuals, hospitals, nonprofit research institutes) (see the Supplementary Materials).

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/4/6/eaar5237/DC1
Basics of gene patents
fig. S1. Number of marine species and marine sequences associated with patents.
fig. S2. Top 30 largest patent holders.
data file S1. Raw data, species data, patent registration data, owner data, and data aggregations section (Excel file).
References (*45*–*61*)

REFERENCES AND NOTES

1. OECD, *The Ocean Economy in 2030* (OECD Publishing, 2016).
2. M. Barbesgaard, Blue growth: Savior or ocean grabbing? *J. Peasant Stud.* **45**, 130–149 (2018).
3. J. S. Golden, J. Virdin, D. Nowacek, P. Halpin, L. Bennear, P. G. Patil, Making sure the blue economy is green. *Nat. Ecol. Evol.* **1**, 0017 (2017).
4. D. H. Klinger, A. M. Eikeset, B. Davíðsdóttir, A.-M. Winter, J. R. Watson, The mechanics of blue growth: Management of oceanic natural resource use with multiple, interacting sectors. *Mar. Policy* **87**, 356–362 (2018).
5. M. J. Costello, C. Chaudhary, Marine biodiversity, biogeography, deep-sea gradients, and conservation. *Curr. Biol.* **27**, R511–R527 (2017).
6. A. Poli, G. Anzelmo, B. Nicolaus, Bacterial exopolysaccharides from extreme marine habitats: Production, characterization and biological activities. *Mar. Drugs* **8**, 1779–1802 (2010).
7. D. Skropeta, L. Wei, Recent advances in deep-sea natural products. *Nat. Prod. Rep.* **31**, 999–1025 (2014).
8. S. K. Sinha, S. Datta, β-Glucosidase from the hyperthermophilic archaeon *Thermococcus* sp. is a salt-tolerant enzyme that is stabilized by its reaction product glucose. *Appl. Microbiol. Biotechnol.* **100**, 8399–8409 (2016).
9. D. Hurst, T. Børresen, L. Almesjö, F. De Raedemaecker, S. Bergseth, *Marine Biotechnology Strategic Research and Innovation Roadmap: Insights to the Future Direction of European Marine Biotechnology* (Marine Biotechnology ERA-NET, 2016).
10. M. Vierros, C. A. Suttle, H. Harden-Davies, G. Burton, Who owns the ocean? Policy issues surrounding marine genetic resources. *Limnol. Oceanogr. Bull.* **25**, 29–35 (2016).
11. Convention on Biological Diversity, Rio de Janeiro, 5 June 1992 (entered into force 29 December 1993), 1760 United Nations Treaty Series 2; www.cbd.int/doc/legal/cbd-en.pdf.
12. J. M. Arrieta, S. Arnaud-Haond, C. M. Duarte, What lies underneath: Conserving the oceans' genetic resources. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 18318–18324 (2010).
13. Convention on Biological Diversity, *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity (Text and Annex)* (Secretariat of the Convention on Biological Diversity, 2011).
14. H. Österblom, J.-B. Jouffray, C. Folke, B. Crona, M. Troell, A. Merrie, J. Rockström, Transnational corporations as 'keystone actors' in marine ecosystems. *PLOS ONE* **10**, e0127533 (2015).
15. C. L. Van Dover, J. Aronson, L. Pendleton, S. Smith, S. Arnaud-Haond, D. Moreno-Mateos, E. Barbier, D. Billett, K. Bowers, R. Danovaro, A. Edwards, S. Kellert, T. Morato, E. Pollard, A. Rogers, R. Warner, Ecological restoration in the deep sea: Desiderata. *Mar. Policy* **44**, 98–106 (2014).
16. S. Arnaud-Haond, J. M. Arrieta, C. M. Duarte, Marine biodiversity and gene patents. *Science* **331**, 1521–1522 (2011).
17. J. Jacquet, D. Frank, C. Schlottmann, Asymmetrical contributions to the tragedy of the commons and some implications for conservation. *Sustainability* **5**, 1036–1048 (2013).
18. O. A. Jefferson, D. Köllhofer, T. H. Ehrich, R. A. Jefferson, The ownership question of plant gene and genome intellectual properties. *Nat. Biotechnol.* **33**, 1138–1143 (2015).
19. K. Head, B. J. Spencer, Oligopoly in international trade: Rise, fall and resurgence. *Can. J. Econ.* **50**, 1414–1444 (2017).
20. T. R. Young, M. W. Tvedt, *Drafting Successful Access and Benefit-Sharing Contracts* (Brill Nijhoff, 2017).
21. N. Pauchard, Access and benefit sharing under the Convention on Biological Diversity and its protocol: What can some numbers tell us about the effectiveness of the regulatory regime? *Resources* **6**, 11 (2017).
22. P. Oldham, S. Hall, O. Forero, Biological diversity in the patent system. *PLOS ONE* **8**, e78737 (2013).
23. Convention on Biological Diversity, Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its seventh meeting. VII/19. Access and benefit-sharing as related to genetic resources (Article 15) (Kuala Lumpur, 9 to 20 and 27 February 2004. Agenda item 19.11, 2004)
24. BASF, *BASF Report 2017: Economic, Environmental and Social Performance* (BASF, 2017); http://report.basf.com/2017/en/servicepages/downloads/files/BASF_Report_2017.pdf.
25. H. Ernst, N. Omland, The Patent Asset Index—A new approach to benchmark patent portfolios. *World Pat. Inf.* **33**, 34–41 (2011).
26. European Parliament, Council of the European Union, *Regulation (EU) No. 511/2014 on Compliance Measures for Users From the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization in the Union* (Official Journal of the European Union, L 150/59, 2014).
27. D. Cressey, Biopiracy ban stirs red-tape fears. *Nature* **514**, 14–15 (2014).
28. G. Vogel, A plea for open science on Zika. *Science* (2016).
29. Convention on Biological Diversity, *Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of Their Utilization* (Secretariat of the Convention on Biological Diversity, 2002).
30. E. Hammond, *More Patent Claims on Genetic Resources of Secret Origin: An Update on Disclosure of Origin in Patent Applications Under the Budapest Treaty* (Biodiversity, Knowledge and Rights Series No. 4, Third World Network, 2016).
31. L. Glowka, Evolving perspectives on the international seabed area's genetic resources: Fifteen years after the deepest of ironies, in *Law, Technology and Science for Oceans in Globalisation: IUU Fishing, Oil Pollution, Bioprospecting, Outer Continental Shelf*, D. Vidas, Ed. (Martinus Nijhoff, 2010), pp. 397–423.
32. G. Wright, J. Rochette, E. Druel, K. Gjerde, *The Long and Winding Road Continues: Towards a New Agreement on High Seas Governance* (IDDRI, 2016).
33. A. Broggiato, S. Arnaud-Haond, C. Chiarolla, T. Greiber, Fair and equitable sharing of benefits from the utilization of marine genetic resources in areas beyond national jurisdiction: Bridging the gaps between science and policy. *Mar. Policy* **49**, 176–185 (2014).
34. R. Blasiak, J. Pittman, N. Yagi, H. Sugino, Negotiating the use of biodiversity in marine areas beyond national jurisdiction. *Front. Mar. Sci.* **3**, 224 (2016).
35. R. Blasiak, C. Durussel, J. Pittman, C.-A. Sénit, M. Petersson, N. Yagi, The role of NGOs in negotiating the use of biodiversity in marine areas beyond national jurisdiction. *Mar. Policy* **81**, 1–8 (2017).
36. UN General Assembly Resolution 69/292, *Development of 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* (United Nations, 2015).
37. H. Harden-Davies, Marine science and technology transfer: Can the Intergovernmental Oceanographic Commission advance governance of biodiversity beyond national jurisdiction? *Mar. Policy* **74**, 260–267 (2016).
38. H. Österblom, J.-B. Jouffray, C. Folke, J. Rockström, Emergence of a global science–business initiative for ocean stewardship. *Proc. Natl. Acad. Sci. U.S.A.* **114**, 9038–9043 (2017).
39. P. Dauvergne, J. Lister, Big brand sustainability: Governance prospects and environmental limits. *Glob. Environ. Change* **22**, 36–45 (2012).
40. BASF, *Shareholder Structure* (BASF, 2017); www.basf.com/en/company/investor-relations/share-and-adrs/shareholder-structure.html.
41. A. Prakash, M. Potoski, Collective action through voluntary environmental programs: A club theory perspective. *Policy Stud. J.* **35**, 773–792 (2007).
42. UNCLOS, Montego Bay, 10 December 1982 (entered into force 16 November 1994), 1833 United Nations Treaty Series 3; www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
43. G. Quinn, *PCT Basics: Understanding the International Filing Process* (2011); www.ipwatchdog.com/2011/11/03/pct-basics-understanding-the-international-filing-process/id=19960/.
44. WoRMS, *WoRMS Taxon Match* (WoRMS, 2017); www.marinespecies.org/aphia.php?p=match.
45. Genetics Home Reference (U.S. National Library of Medicine, 2017); https://ghr.nlm.nih.gov/primer/testing/genepatents [accessed 21 December 2017].
46. O. A. Jefferson, D. Köllhofer, P. Ajjikuttira, R. A. Jefferson, Public disclosure of biological sequences in global patent practice. *World Pat. Inf.* **43**, 12–24 (2015).
47. O. A. Jefferson, D. Köllhofer, T. H. Ehrich, R. A. Jefferson, Transparency tools in gene patenting for informing policy and practice. *Nat. Biotechnol.* **31**, 1086–1093 (2013).
48. OECD, *OECD Patent Statistics Manual* (OECD, 2009); www.oecd.org/sti/inno/oecdpatentstatisticsmanual.htm.

49. R. Frietsch, U. Schmoch, Transnational patents and international markets. *Scientometrics* **82**, 185–200 (2010).
50. C. Franzoni, G. Scellato, The grace period in international patent law and its effect on the timing of disclosure. *Res. Policy* **39**, 200–213 (2010).
51. P. Webber, Does CRISPR-Cas open new possibilities for patents or present a moral maze? *Nat. Biotechnol.* **32**, 331–333 (2014).
52. S. D. Bergel, Patentability of human genes: The conceptual differences between the industrialised and Latin American countries. *J. Commun. Genet.* **6**, 321–327 (2015).
53. M. Slezak, "Genes can't be patented, rules Australia's High Court," *Daily News*, 2015; www.newscientist.com/article/gene-patents-struck-down-by-australias-high-court/.
54. L. Cartwright-Smith, Patenting genes: What does association for molecular pathology v. Myriad genetics mean for genetic testing and research? *Public Health Rep.* **129**, 289–292 (2014).
55. R. Weinmeyer, T. Klusty, Supreme court to Myriad Genetics: Synthetic DNA is patentable but isolated genes are not. *AMA J. Ethics* **17**, 849–853 (2015).
56. E. R. Gold, J. Carbone, Myriad Genetics: In the eye of the policy storm. *Genet. Med.* **12**, S39–S70 (2010).
57. P. Cole, Patentability of genes: A European Union perspective. *Cold Spring Harb. Perspect. Med.* **5**, a020891 (2014).
58. E. M. Dobrusin, K. E. White, *Intellectual Property Litigation: Pretrial Practice* (Aspen Publishers Online, 2008).
59. G. Dufresne, M. Duval, Genetic sequences: How are they patented? *Nat. Biotechnol.* **22**, 231–232 (2004).
60. M. Bobrow, S. Thomas, Patents in a genetic age. *Nature* **409**, 763–764 (2001).
61. D. Robinson, Towards access and benefit-sharing best practice: Pacific case studies (The Access and Benefit Sharing Capacity Development Initiative. Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), Australia, 2012).

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