



## Making marine biotechnology work for people and nature

Robert Blasiak, Jean-Baptiste Jouffray, Diva Amon, Joachim Claudet, Paul Dunshirn, Peter Søgaaard Jørgensen, Agnes Pranindita, Colette Wabnitz, Erik Zhivkopljas, Henrik Österblom

### ► To cite this version:

Robert Blasiak, Jean-Baptiste Jouffray, Diva Amon, Joachim Claudet, Paul Dunshirn, et al.. Making marine biotechnology work for people and nature. Nature Ecology & Evolution, In press, 10.1038/s41559-022-01976-9 . hal-03956421

**HAL Id: hal-03956421**

**<https://hal.science/hal-03956421>**

Submitted on 16 Feb 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Making marine biotechnology work for people and nature

Robert Blasiak<sup>1,2\*</sup>, Jean-Baptiste Jouffray<sup>1</sup>, Diva J. Amon<sup>3,4</sup>, Joachim Claudet<sup>5</sup>, Paul Dunshirn<sup>6</sup>, Peter Sogaard Jørgensen<sup>1,7</sup>, Agnes Pranindita<sup>1,8</sup>, Colette C.C. Wabnitz<sup>9,10</sup>, Erik Zhivkoplías<sup>1</sup>, Henrik Österblom<sup>1,2,11</sup>

\* Corresponding author: [robert.blasiak@su.se](mailto:robert.blasiak@su.se)

<sup>1</sup> Stockholm Resilience Centre, Stockholm University, 106 91, Stockholm, Sweden

<sup>2</sup> Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo, 113-8657, Japan

<sup>3</sup> SpeSeas, D'Abadie, Trinidad and Tobago

<sup>4</sup> Marine Science Institute, University of California, Santa Barbara, Santa Barbara, CA, USA

<sup>5</sup> National Center for Scientific Research, PSL Université Paris, CRIOBE, CNRS-EPHE-UPVD, Maison de l'Océan, 195 rue Saint-Jacques, 75005 Paris, France

<sup>6</sup> Research Platform Governance of Digital Practices, University of Vienna, Universitätsstraße 7, Vienna, Austria

<sup>7</sup> The Global Economic Dynamics and the Biosphere Academy Program, Royal Swedish Academy of Science, 104 05, Stockholm, Sweden

<sup>8</sup> Bolin Centre for Climate Research, Stockholm University, SE-106 91 Stockholm, Sweden

<sup>9</sup> Stanford Centre for Ocean Solutions, Stanford University, 473 Via Ortega, Stanford, CA, 94305, USA

<sup>10</sup> Institute for the Oceans and Fisheries, The University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T1Z4, Canada

<sup>11</sup> South American Institute for Resilience and Sustainability Studies, Maldonado, Uruguay

*Transforming the rapidly growing ocean economy into a “blue economy” based on principles of sustainability, equity and inclusivity is crucial. We contend that marine biotechnology is not currently on this trajectory, and that a more holistic approach for people and nature is needed to bring marine biotechnology into the blue economy.*

---

The ocean economy encompasses economic sectors as diverse as shipping, tourism and aquaculture, with a collective export value estimated at USD 2.5 trillion. Its global scale and rapid growth have triggered concerns due to the benefits remaining heavily concentrated within a handful of countries and companies, while degradation of ocean ecosystems affects all<sup>1</sup>. This reality has spurred growing calls to transform the ocean economy into a “blue economy”, one that ensures ocean sectors are aligned with principles of sustainability, equity and inclusivity<sup>2</sup>.

Marine biotechnology – the use of marine organisms to solve problems and make useful products – is one important sector of the ocean economy. It has generated a diverse and growing suite of innovations of central importance to multiple industries (Figure 1)<sup>3</sup> and has great potential to become part of the blue economy<sup>3</sup>. Indeed, an inclusive and equitable marine biotechnology sector could also result in significant benefits to low and middle-income countries, which contain within their jurisdictions some of the world’s most biodiverse marine ecosystems. Likewise, the deep sea is a frontier of marine biotechnology interest found predominantly in areas beyond national jurisdiction, a vast global commons covering two-thirds of the ocean<sup>4</sup>.

Despite this great potential, marine biotechnology has been almost exclusively driven by highly-industrialized countries and remains misaligned with blue economy principles of equity and inclusivity<sup>5</sup>. Efforts to eliminate such inequities have relied on protracted international negotiations that have yielded mixed outcomes, not least due to rapid advances in biotechnology that dramatically outpace the development of appropriate regulatory frameworks<sup>6</sup>. Here we argue that a singular focus on regulatory solutions could result in the marine biotechnology industry remaining misaligned with the aspirations of a blue economy, and that a more holistic approach for people and nature is crucial.

### **Complexities and tradeoffs in marine biotechnology**

Marine biotechnology has frequently resulted in innovations that can contribute to achieving sustainability goals, for example improvements in aquaculture production. Genetically-engineered salmon grows twice as quickly and can thrive in near-freezing conditions due to insertion of genes from two other fish species<sup>3</sup>. While such advances are improving food yield, they can also encourage over-reliance on monocultures, and spatial expansion of salmon pens into more coastal areas, potentially harming local and Indigenous communities who rely on integrity of wild salmon populations<sup>3</sup>.

Another example of the complex trade-offs arising from marine biotechnology is the recent development of transgenic canola plants with genes from a variety of marine and freshwater algae<sup>9</sup>. Transgenic canola produces high levels of omega-3 fatty acids and could become a key agrofeed ingredient, potentially reducing the need for fishmeal production and relieving fishing pressure in low-income coastal regions, where fish is nutritionally vital for local communities. Yet a trade-off would remain if increased demand results in further conversion of land for monoculture canola production.

### **A regulatory landscape struggling to keep up**

Substantial effort has been focused on regulatory instruments to address sustainability and equity issues. Perhaps the most significant milestone for the biotechnology community was the entry into force of the Nagoya Protocol in 2014, intended to eliminate inequitable and unethical practices. These include biopiracy, which involves the appropriation of genetic resources (and often associated traditional knowledge) from Indigenous peoples and local communities and subsequent commercialization without sharing of benefits. The Nagoya Protocol established a framework for “source” and “user” countries to regulate access to genetic resources and subsequent benefit sharing according to mutually agreed terms.

The Nagoya Protocol, however, follows an overall pattern of policymaking being far outpaced by scientific and technological advances<sup>5</sup>. During the 12 years that it was being negotiated, for instance, the first synthetic life form was created, the CRISPR gene editing technique was introduced, and cultivation of genetically modified organisms had spread to over 10% of the world’s farmland<sup>5</sup>. As a tool most effective at regulating the movement of physical samples across national boundaries, the Nagoya Protocol came into effect at the same time that the industry was growing less reliant on physical samples and increasingly working directly with genetic sequence data. Today, the industry applies a growing suite of bioinformatics and omics technologies to analyze vast databases such as the GenBank

Sequence Read Archive. Since 1982, this database has been doubling in size roughly every 18 months<sup>10</sup> as a result of the average cost of sequencing a base pair of DNA falling by six orders of magnitude within two decades from over USD 6,000 in 2001 to less than USD 0.01 in 2020<sup>3</sup>.

Multiple negotiations are currently underway to better regulate access, use and transparency requirements associated with marine genetic resources and genetic sequence data, including in areas beyond national jurisdiction<sup>11</sup>. While progressive regulatory frameworks can help to clarify and level the playing field for all, sluggish regulatory responses can result in a widening gap between those with the capacity to engage in marine biotechnology and everyone else.

## **Bringing marine biotechnology into the blue economy**

We contend that successfully transforming marine biotechnology into an element of the blue economy will depend on coordinated actions by diverse actors, including scientists, local communities, and companies. We suggest four interrelated pathways to accelerate this transformation.

### *1. Strengthen capacity in lower income countries*

An aspiration of the blue economy is that it can drive greater equity and inclusivity in the ocean economy<sup>9</sup>. However, just ten countries account for 98% of filed patent sequences from marine life<sup>5</sup>. This relates to capacity limitations, which are a particular barrier in the case of the most lucrative biotechnology products. For example, it costs an estimated USD 1 billion<sup>3</sup> to bring a new drug from development to market, and all marine drugs that have been brought to market were developed by companies in Europe, Japan and North America. For low and middle-income countries to fully benefit from marine biotechnology, efforts at multiple levels are needed to develop capacity and close resource gaps. First, research groups can contribute with efforts to strengthen human and technical capacity, and to provide research and product development infrastructure that builds lasting ability to develop solutions and foster change that aligns with national interests and priorities. Second, the handful of companies driving innovations in the marine biotechnology sector<sup>5</sup>, which are currently benefitting most from the ocean's genetic resources, should play a similarly disproportionate role in ensuring that global sustainability goals and ocean equity is achieved by advancing capacity building and transfer of marine technology. Third, providers of development finance and philanthropies should dedicate more resources to drive equitable outcomes, noting that SDG14 ("Life Below Water"), which includes Target 14.8 on increasing scientific knowledge, research and technology, receives the least development funding of any of the Goals<sup>10</sup>. Finally, the international community should elevate capacity building and the transfer of marine technology within the UN Decade of Ocean Science for Sustainable Development 2021-2030 as well as the negotiations on a treaty for biodiversity in areas beyond national jurisdiction to generate further institutional support.

### *2. Equitable and inclusive research collaborations*

Although industry is seen as the main commercial driver of marine biotechnology, academic institutions are central players<sup>11</sup>. Not only are they driving the exponential growth of databases like GenBank by depositing sequence data from research expeditions, but many universities also own and operate their own commercialization centers – private companies established to monetize university research<sup>11</sup>. Nearly one-third of patent applications associated with marine genetic resources have been filed by universities or their commercialization centers<sup>11</sup>. The transboundary nature of many marine science topics has spurred international collaboration, but may be strengthening imbalances rather than challenging them<sup>12</sup> unless these collaborations ensure representative inclusion, rely on working openly and in a transparent manner with a broad range of stakeholders in developing solutions, and ensure that stakeholders from low and middle income countries have an active voice and role in study design<sup>13</sup>. More explicit requirements from research funders and scientific journals to disclose sample origin and acknowledge collaborators may help shift existing norms<sup>14</sup> toward more equitable collaborations.

### *3. Commit to responsible data sharing*

While a broad landscape of environmental and genetic sequence databases already exists, interoperability and access issues limit the potential for diverse groups to fully utilize these resources. The UN Decade of Ocean Science for Sustainable Development aims to address this issue, and acknowledges that data infrastructures need to be co-designed with stakeholders to achieve the desired social and political impact<sup>15</sup>. Local authorities as well as private companies can play crucial roles in supporting the flow of data through targeted partnerships and investment focused on ensuring data accessibility and development of technical capacity. Protracted and unresolved negotiations under the auspices of the World Trade Organization have focused on new regulatory obligations to disclose the origin of genetic samples being commercialized, which would add a layer of transparency and accountability to such activities. Scientists involved in filing marine biotechnology patents could advance best practices by disclosing origin of marine genetic resources throughout all academic and commercial activities<sup>11,16</sup>. While commitments to sharing marine genetic sequence and origin data are crucial for transparency and can facilitate access and engagement by as broad a set of constituents as possible, there is a tension between such commitments and the protection of Indigenous rights and data sovereignty. In such cases, attention should be paid to the International Indigenous Data Sovereignty Interest Group who developed the ‘CARE Principles for Indigenous Data Governance’<sup>17</sup> based around the principles of Collective Benefit, Authority to Control, Responsibility, and Ethics. These people- and purpose-oriented principles build on earlier data-centered work represented in the ‘FAIR Guiding Principles for scientific data management and stewardship’ (Findable, Accessible, Interoperable, Reusable) and represent a cornerstone of responsible data sharing highly relevant in the context of genetic resources and marine biotechnology.

### *4. Connect marine biotechnology to marine conservation*

Marine biotechnology can support local to global conservation efforts in multiple ways. Examples include bioremediation and ecosystem monitoring, where the collection and sequencing of samples from marine ecosystems can provide a baseline for taxonomic and conservation efforts<sup>3</sup>. Biotechnology and genomic research are increasingly being used to

design ecosystem adaptation strategies, most prominently perhaps in efforts to create bionic corals, including through CRISPR gene editing<sup>18</sup>. Better connecting biotechnology to local conservation planning and outcomes can broaden the range of beneficiaries from this industry and highlight the existential reliance of the marine biotechnology community on intact and functioning marine ecosystems.

While the environmental impacts of sample collection can be minimal<sup>19</sup> – marine natural products are increasingly sampled through analytical chemistry rather than collection of physical samples – an analysis of genetic sequences referenced in patents identified multiple endangered and critically endangered marine species (Figure 2). Importantly, the vast majority of species associated with marine biotechnology have not been assessed by the IUCN (1,191 of 1,488 species). Responsible practice within such contexts of uncertainty requires precautionary efforts, and provides further incentive to conserve entire ecosystems, which can result in living repositories of genetic information with potential future biotechnological potential.

## Conclusion

While marine biotechnology has resulted in diverse benefits, more effort is needed to ensure this sector does not perpetuate systemic injustices through stark discrepancies in access, capacity and opportunities. The four interrelated pathways highlighted in this commentary present opportunities to build lasting capacity where it is needed, to leverage existing advances, and to accelerate progress towards ensuring the marine biotechnology sector espouses the principles at the core of the blue economy. Crucially, these pathways are viable irrespective of whether key international negotiations have stalled, or result in regulatory frameworks that are easily sidestepped by bad actors. A status quo approach may result in a marine biotechnology industry that remains profitable and continues to deliver impressive scientific advances that benefit human well-being, but at its core, it would be at odds with the larger aspirations of equity, sustainability and inclusivity inherent to a blue economy, to the UN Decade of Ocean Science for Sustainable Development, and to the Sustainable Development Agenda.

## Acknowledgments:

*RB, AP and EZ are funded by FORMAS, project number 2020-01048. AP is funded by FORMAS, project number 2019-01220.*

## Author contributions statement

*All authors contributed to the writing and revision of the manuscript.*

## Competing interests statement

*The authors declare no competing interests.*

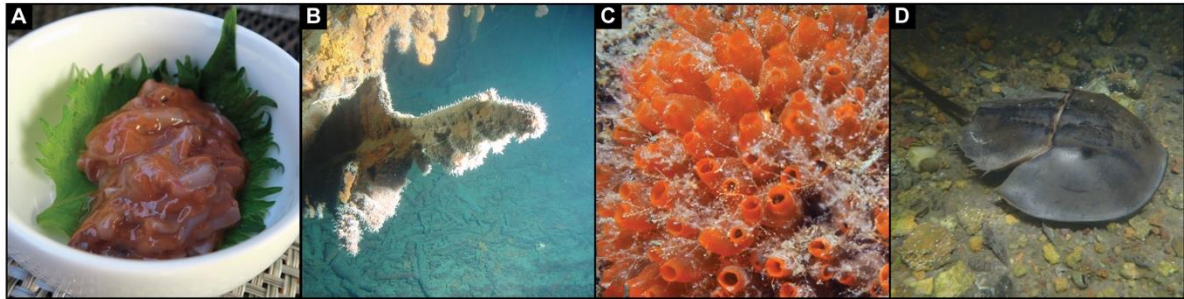
## REFERENCES

1. Virdin, J. *et al.* The Ocean 100: Transnational corporations in the ocean economy. *Sci. Adv.* **7**, eabc8041 (2021).
2. Satizábal, P., Dressler, W. H., Fabinyi, M. & Pido, M. D. Blue economy discourses and practices: reconfiguring ocean spaces in the Philippines. *Marit. Stud.* **19**, 207–221 (2020).
3. Blasiak, R. *et al.* The ocean genome and future prospects for conservation and equity. *Nat. Sustain.* **3**, 588–596 (2020).
4. Claudet, J., Amon, D. J. & Blasiak, R. Transformational opportunities for an equitable ocean commons. *Proc. Natl. Acad. Sci.* **118**, e2117033118 (2021).
5. Blasiak, R., Jouffray, J.-B., Wabnitz, C. C. C., Sundström, E. & Österblom, H. Corporate control and global governance of marine genetic resources. *Sci. Adv.* **4**, eaar5237 (2018).
6. Wynberg, R. & Laird, S. A. Fast Science and Sluggish Policy: The Herculean Task of Regulating Biodiscovery. *Trends Biotechnol.* **36**, 1–3 (2018).
7. Yang, D. Strain capable of efficiently removing inorganic phosphorus in water bodies and application of strain. (2020).
8. Strandwitz, P. & Lewis, K. Modulation of the Gut Microbiome to Treat Mental Disorders or Diseases of the Central Nervous System. (2022).
9. Stuchtey, M. *et al.* Ocean solutions that benefit people, nature and the economy. *High Level Panel Sustain. Ocean Econ.* (2020).
10. OECD. The SDG Financing Lab. <https://sdg-financing-lab.oecd.org/explore> (2022).
11. Blasiak, R., Jouffray, J.-B., Wabnitz, C. C. C. & Österblom, H. Scientists Should Disclose Origin in Marine Gene Patents. *Trends Ecol. Evol.* **34**, 392–395 (2019).

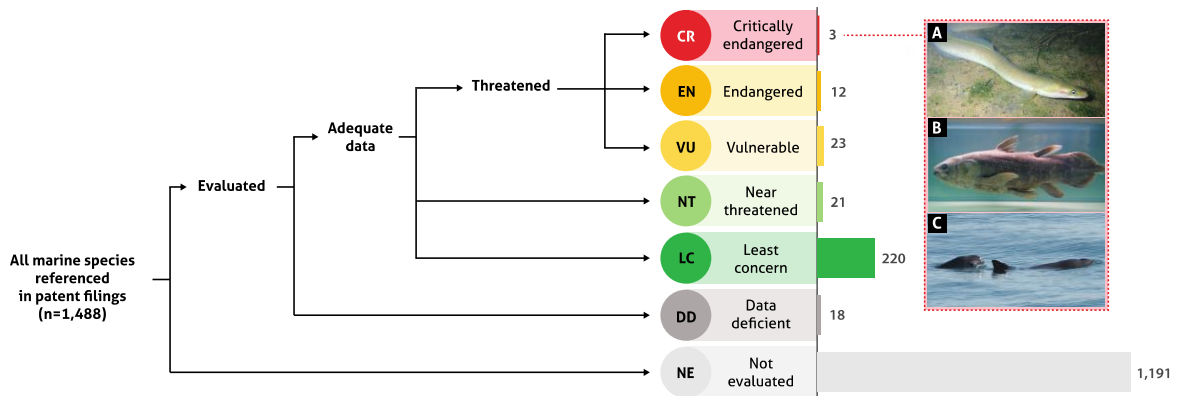
12. Tolochko, P. & Vadrot, A. B. M. Selective world-building: Collaboration and regional specificities in the marine biodiversity field. *Environ. Sci. Policy* **126**, 79–89 (2021).
13. Faure, M. C., Munung, N. S., Ntusi, N. A. B., Pratt, B. & de Vries, J. Mapping experiences and perspectives of equity in international health collaborations: a scoping review. *Int. J. Equity Health* **20**, 28 (2021).
14. Anon. Nature addresses helicopter research and ethics dumping. *Nature* **606**, 7–7 (2022).
15. Muller-Karger, F. E. *et al.* Marine Life 2030: building global knowledge of marine life for local action in the Ocean Decade. *ICES J. Mar. Sci.* fsac084 (2022) doi:10.1093/icesjms/fsac084.
16. Blasiak, R. International regulatory changes poised to reshape access to marine genes. *Nat. Biotechnol.* **37**, 357–358 (2019).
17. Carroll, S. R. *et al.* The CARE Principles for Indigenous Data Governance. *Data Sci. J.* **19**, 43 (2020).
18. van de Water, J. A., Tignat-Perrier, R., Allemand, D. & Ferrier-Pagès, C. Coral holobionts and biotechnology: from Blue Economy to coral reef conservation. *Curr. Opin. Biotechnol.* **74**, 110–121 (2022).
19. Sigwart, J., Blasiak, R., Jaspars, M., Jouffray, J.-B. & Tasdemir, D. Unlocking the potential of marine biodiscovery. *Nat. Prod. Rep.* **38**, 1235–1242 (2021).



FIGURE CAPTIONS



**FIGURE 1: Commercialization of marine genetic resources** (A) *Bacillus jeotgali* was originally isolated from traditional Korean seafood jeotgal, and an associated strain has been identified as a potent bioremediating agent for polluted waterways<sup>7</sup>. (B) *Halomonas titanicae* was isolated from rusticles collected from the wreck of the Titanic and has been identified for its predicted functionality as a neurotransmitter to treat mental disorders<sup>8</sup>, (C) *Ecteinascidia turbinata*, a sea squirt found on mangrove roots in the Caribbean, is the source organism for the active ingredient Ecteinascidin-743 in the drug Yondelis, a treatment for advanced soft tissue sarcoma<sup>3</sup>. (D) *Tachypleus tridentatus*, a horse-shoe crab assessed as “Endangered” in the IUCN Red List, is a source of in vitro diagnostic reagent for invasive fungal infections prevalent in tropical regions. Photo credits: (A) [CC0 Public Domain]; (B) Lori Johnston [NOAA-Public Domain], (C) Pauline Walsh Jacobson [CC BY 4.0]; (D) [CC0 Public Domain].



**Figure 2: Marine biotechnology and conservation.** Updating and expanding a previous analysis (see Supplementary Information), we identified sequences from 1,488 marine species referenced in patent filings. A total of 279 of the species have been assessed by the International Union for Conservation of Nature (IUCN), including species that are Near Threatened (21), Vulnerable (23), Endangered (12) and Critically Endangered (3). The latter category includes the (A) European eel (*Anguilla anguilla*), (B) West Indian Ocean coelacanth (*Latimeria chalumnae*) and (C) vaquita (*Phocoena sinus*). Photo credits: (A) Lara Maleen Beckmann [CC BY 4.0]; (B) Bruce Henderson [CC BY 4.0]; (C) Paula Olson [NOAA-Public Domain]