Chapter 5

Science, society and industry: Working together for sustainability

This chapter looks at some of the broader social challenges and opportunities relating to the conservation and sustainable development of marine bio-resources. It examines the interactions of science, industry and society that will affect this development. It focuses particularly on social issues requiring particular attention: those originating from the complexity of developing marine bioresources and from the shared and dynamic nature of the marine environment.

Science and society: Towards sustainable development

Access and sharing of benefits

Marine biotechnology raises a number of ethical, legal and social issues (ELSI). Many relate to the harvesting of marine bioresources[1] which may be widely, variably and fluidly distributed. Their harvesting, or appropriation, for biotechnological applications therefore raises questions of national sovereignty and the sharing of benefits and intellectual property rights. Many of these issues are addressed in various international instruments,[2] which seek a balance between the industrial drive for innovation and profitability and the need to ensure the sustainable use, and an equitable sharing of the benefits of, marine bioresources (Box 5.1).

It is increasingly recognised that there is a vast market for marine bio-resources (both as biomass and as a genetic resource). As a result, many companies, governments, researchers and other actors wish to have access to these resources. While there is general agreement on broad principles of prior informed consent as a basis for equitable sharing of benefits, views differ on what is equitable, the nature of benefits, and the mechanism(s) for capturing them.

What is equitable?

The 1993 Convention on Biological Diversity (CBD) is an international legal framework, which is strengthened by the Nagoya Protocol (2010)[3] (see Box 5.1), for the acquisition and use of genetic resources and associated traditional knowledge, innovations and practices of local and indigenous peoples. The CBD's Access and Benefit Sharing (ABS) negotiations resulted in a legal obligation for CBD parties to ensure fair and equitable sharing of the benefits accruing from the utilisation of genetic resources with the country that provided the terrestrial or marine genetic resources.

The principle was also extended to "local" providers or custodians of biodiversity that may have traditional knowledge associated with genetic resources or an established right to provide access to genetic resources. While further clarity is needed regarding who may constitute a "local" provider or custodian, sharing benefits with such providers is important for the equitable development of marine genetic resources, particularly as it may encourage conservation and sustainable use.

Box 5.1. The Convention on Biological Diversity's benefit sharing provisions relating to marine genetic resources

Convention on Biological Diversity (1993)

CBD-ABS negotiations were driven primarily by equity and the aim to redirect benefits back to provider(s) of genetic resources. Directing benefits back to providers was expected to create incentives to conserve biodiversity

The CBD's ABS provisions

Three fundamental access-related principles (Article 15):

- Sovereign rights over natural resources: Art.15(1)
- Prior informed consent (PIC): Art. 15(5)
- Mutually agreed terms (MATs), including the sharing of benefits arising from the commercial and other utilisation of genetic resources: Art. 15(4) and (7)

Six fundamental benefit-sharing obligations:

- Research and development results: Art. 15(7)
- Commercial or other benefits derived from use: Art. 15(7)
- Access/transfer of technology using genetic resources: Art. 16(3)
- Participation in biotechnological research on genetic resources: Art. 19(1)
- Priority access to results/benefits arising from biotechnological use: Art. 19(2)
- Traditional knowledge associated with genetic resources: Art. 8(j)

Nagoya Protocol (adopted 2010)

Addresses ABS implementation challenges not fully addressed by CBD by providing a legal framework to operationalise the CBD's third objective and Article 15.

Objective: Ensure benefits arising from utilisation of genetic resources are shared fairly and equitably

Nagoya Protocol Innovations Scope and Access Measures

Scope

- Genetic resources within scope of CBD and benefits arising from their utilisation
- Clear application to biochemical compounds: utilisation of genetic resources; derivatives

Access-related measures

- Legal certainty, clarity and transparency
- Permit or equivalent

Nagoya Protocol innovations: benefit-sharing measures

Benefits to be shared on MATs: Art. 5:

- Utilisation, subsequent applications and commercialisation

Monetary and non-monetary benefits (Annex)

- Access fees
- Milestone payments, licence fees, royalties
- Technology transfer
- Sharing research results
- Effective research participation

Box 5.1. The Convention on Biological Diversity's benefit sharing provisions relating to marine genetic resources (cont'd)

Nagoya Protocol innovations: compliance measures

Supporting compliance with provider country's domestic ABS requirements: Art. 15

Facilitating dispute resolution when non-compliance with MATs (contractual terms): Art. 18

Monitoring use: Art. 17:

- Designate "check points" to collect information at any stage of value chain (research, development, innovation, pre-commercialisation or commercialisation)
- Internationally recognised certificate of compliance
- Encouraging model contractual clauses and codes of conduct: Arts. 19 & 20

Source: CBD Secretariat (2012), www.cbd.int/.

Many parts of the world have bodies of knowledge, practices and beliefs regarding the use of biological natural resources, e.g. for curing ailments, which have evolved and been passed down through generations. Demunshi and Chugh (2010) cite examples from various countries and indigenous peoples. This knowledge, such as the use of snail flesh in curing asthma, tuberculosis, stomach disorders and eye-related problems by the tribes of Nagaland, India, could provide important starting points or development opportunities for marine biodiscovery (Box 5.2).

Marine biodiscovery is already taking place in the open ocean and the international seabed, marine areas beyond the limits of national jurisdiction, and is expected to increase. The CBD and Nagoya Protocol only apply to the continental shelves and exclusive economic zones (EEZs) of their contracting parties, and therefore do not address marine genetic resources obtained from these areas. At present, such resources are accessible to anyone for any purpose. There is no formal obligation to share benefits with the international community, although the United Nations Convention on the Law of the Sea (UNCLOS) does have provisions on international co-operation and the exchange of results with respect to marine scientific research in these areas (Glowka, 2010). While it is important to reach a shared understanding of "countries providing genetic resources" and "local" providers and a better understanding of the role and value of traditional knowledge, particularly to ensure legal certainty in the discovery and development of marine bioresources, the equitable development of marine genetic resources in areas beyond national jurisdictions may provide event greater challenges.

Box 5.2. Involvement of traditional knowledge in access and sharing of benefits

The Suriname project

This project is concerned with the medicinal qualities of the coastal forest plants of Suriname. The US government relies on access and sharing of benefits between companies and the Maroon tribes of the region of Samaraka in South America (Guerin-McManus et al., 1998).

Unilever's Best Food

This project includes an agreement (a kind of bioprospecting contract) between Unilever's Best Food and the local people of Vietnam. According to the agreement nuoc mam (fish sauce) is produced from anchovies by the Phu-Quoc islanders in a traditional manner and the finished sauce is bottled, packed and marketed by Unilever. The islanders are free to sell their product in the wholesale market at Unilever's equivalent market price (Kazmin, 2003).

Bioprospecting in the South Pacific

The University of South Pacific, along with what is now Glaxo SmithKline and the Fijian Affairs and Fisheries Department, developed a draft ''biodiversity access and benefit sharing policy'' which resulted in the establishment of a successful bioprospecting enterprise. The enterprise has provided licensing fees of USD 30 000 to a trust fund established by the community.

National Biodiversity Institute (INBio)

Through an agreement between the National Biodiversity Institute (INBio), a non-profit scientific organisation in Costa Rica, and Merck, INBio will provide 10 000 samples of plants, animals and soil to Merck, which will have the exclusive right to study these samples for two years. Merck will retain the patents to any drugs developed using the samples but will pay royalty fees for those patents to INBio. Merck will also pay INBio USD USD 1 million up front and will give the institute an additional USD 130 000 worth of laboratory equipment (Coughlin, 1993).

Source: Demunshi and Chugh (2010).

Marine gene patents (even if they do not result in exploitation of bioresources) provide an indication of access to marine bioresources and illustrate the challenge. A search of the patent division of GenBank from 1999-2009 identified 677 international claims of marine gene patents. These patents originated from only 31 of the world's 194 countries. Some 90% of these patents belonged to just ten countries[4] which account for only 20% of the world coastline (Arnaud-Haond et al., 2011). These ten countries have the scientific and technological capacity to explore and develop resources, which many other countries, especially developing coastal countries, lack. If this issue is not addressed, successful biodiscovery, of which patents are one indicator, may spur further investment by capacity-rich countries and create further inequities.

In discussions under the auspices of the United Nations General Assembly,[5] some countries argue that marine genetic resources in areas beyond the limits of national jurisdiction should be viewed as a common heritage of humankind. Other countries take a different view, considering the international legal situation as settled. Ongoing discussions would benefit from identification of the actual or potential scientific/economic/ commercial value of marine genetic resources in areas beyond national jurisdictions, the profiling of the sectors involved (including their practices of exchange and use), an assessment of the accessibility of marine genetic resources (*in situ*, *ex situ* and *in silica*) and related data, and an assessment of the ability of developing countries to access and utilise marine genetic resources and related data (Glowka, 2010).

As work proceeds to identify situations in which sharing of benefits is required or might be desirable, questions arise concerning the basis for determining the sharing of particular benefits in particular situations. While the Convention on Biological Diversity emphasises sharing of benefits, none of the international and national legal instruments determines the extent of the sharing of profits or defines benefits for the indigenous communities that provide traditional knowledge to companies interested in product commercialisation. It seems that one of the first questions regarding access and sharing of benefits is how to value the contributions of different stakeholders in the discovery and development process.

Understanding benefits

The CBD and the Nagoya Protocol embody a broad international consensus that the sharing of benefits is a necessary part of the equitable development of bioresources. However, as such benefits can be defined in different ways, it will be important to specify what kinds of benefits marine biotechnology can offer. The Nagoya Protocol and the FAO International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)[6] may provide a basis for addressing this issue. The Nagoya Protocol reproduces, in an annex, an indicative list of monetary and non-monetary benefits derived from the CBD (Secretariat of the Convention on Biological Diversity Guidelines, 2002), and the FAO International Treaty (which was negotiated to be consistent with the CBD) identifies four main forms of benefits: *i*) the exchange of information; *ii*) access to and transfer of technology; *iii*) capacity building; and *iv*) financial and commercial flows.

Financial benefits, which relate to commercialisation (e.g. royalties or cash exchanges), are often the first type considered. While equitable sharing of financial benefits is important, it can be short-sighted to focus solely on these, since commercial applications of marine bioresources are typically not immediately apparent and achieving a commercialisable product may take

many years. Therefore, financial considerations should not overshadow aspects such as the sharing of genomic or taxonomic information, capacity-building or technology transfer. In some cases, access to and transfer of technology or capacity building may confer greater net benefits in the short to medium term by enabling provider countries and local communities to take advantage of marine bioresources and may allow them to negotiate fair and balanced deals over the longer term.

The focus on access and sharing of benefits should not overshadow the importance of conservation and sustainable use of marine bioresources, as this may determine the possibility of deriving future benefits. The CBD clearly recognised the importance of this. It requires its contracting parties to facilitate access to genetic resources for environmentally sound uses [Art. 15(2)]. For example, Costa Rica has realised monetary and non-monetary benefits from access to its genetic resources while supporting programmes aimed at conserving its biodiversity. It benefits financially through a direct contribution to research budgets and royalties, in addition to transfers to public universities, research infrastructure and research funding. Of these benefits, 10% of research budgets and 50% of royalties are channelled to conservation work. Non-monetary benefits include the development of scientific networks for R&D programmes, sharing of results, technology transfer, capacity building, publication and dissemination of data relevant to conservation and sustainable use of biodiversity and establishment of *ex-situ* collections.

Mechanisms for sharing benefits

Two broad approaches to sharing benefits have emerged: case-by-case and multilateral agreements. A case-by-case approach involves negotiations and agreement between parties concerning access to genetic resources and the fair and equitable sharing of benefits derived from their utilisation. As countries implement the CBD, many have taken this approach. They are likely to continue to do so as they implement the Nagoya Protocol, although neither instrument precludes multilateral approaches.

A multilateral approach is attractive when negotiating benefit-sharing arrangements that may involve high transaction costs, e.g. when it is difficult to identify the source(s) of genetic resources or when a resulting product implies contributions from many sources over time. This may be the case for genetic resources for food and agriculture and may have important implications for food security. The FAO ITPGRFA has used a multilateral approach to facilitate access to an internationally agreed group of plant crops important for food security (e.g. wheat) which are in the public domain and managed by governments. The ITPGRFA creates a common pool of plant genetic resources located *ex-situ* for the purposes of research,

conservation and breeding. Access to the pool is governed by a standard material transfer agreement (sMTA). Both the treaty and the sMTA provide for the possibility of monetary and non-monetary sharing of benefits, with facilitated access to the common pool considered an important benefit. A multilateral approach to access and benefit sharing may be useful for non-sedentary marine genetic resources which are not within the exclusive domain of any one country. For these resources, a "commons" approach that recognises collective interests of access and sharing may be more useful.

Multilateral approaches may also be useful when there is a disparity between activities in exclusive economic zones (EEZ) and the geographic distribution of resources in the region. This situation may arise for regional seas. For the Mediterranean basin, for example, targeting marine genetic resources as a common resource, perhaps via the development of the Mediterranean Science Commission (CIESM) Marine Peace Parks, has been suggested as a possibility. Beyond the limits of national jurisdictions, marine genetic resources might be considered a common pool; this would call for consideration of multilateral approaches to access and benefit sharing. Such approaches will need to take into account a multiplicity of stakeholders with different interests and levels of technological and economic development. They will likely require new types of legal instruments that capture direct and indirect benefits at societal level, while creating incentives for research and development.

When developing mechanisms for sharing benefits, information on the spatial distribution of marine genetic resources and on the geographic location of sampling activities will be needed to help identify the applicable legal regime. The maritime zones delineated by UNCLOS will need to be kept in mind. This will help to identify who should benefit. For example, there is the question of whether a geographic region can be considered a stakeholder for purposes of benefit sharing. If so, it will be important to understand how the marine genetic resources can be shared, how the countries of the region interact and whether appropriate governance mechanisms are in place to capture benefits at regional or national levels. It will also be important to identify the major stakeholders in each of the relevant states.

Finally, sharing of the benefits of marine genetic resources from areas beyond national jurisdictions raises questions about the governance of such areas and about the overall authority for access and sharing of benefits. The treatment of marine genetic resources may be influenced by geopolitical or economic conditions in individual countries and there may be a need for some common benchmarks for governance of these resources. UNCLOS can provide a framework, but its provisions may be insufficient to resolve all relevant issues and it may require further elaboration.

Social engagement

Many of the ocean's beneficial functions and services stem from the interconnected ecosystems of marine bioresources distributed across an immense shared environment that can be positively or negatively affected by the actions of countries and stakeholders. It is increasingly evident that stakeholders need a common understanding of the ocean and of the economic, social and environmental aspects of the sustainable development of its resources. This will involve dialogue and diverse forms of engagement by all stakeholders, including developers and users of innovations and those relying on the ocean for other purposes. There is already considerable evidence of the convergence of the views of the international community on several aspects of protection of the marine environment. A first indication was the entry into force of UNCLOS in 1994. Its general provisions provide a foundation for marine environmental protection. These have been complemented and deepened by those of the CBD.[7] The Convention recognises the conservation of biodiversity as a "common concern of humankind".

The CBD, its programme of work on marine and coastal biodiversity and, more recently, the adoption of the Biodiversity Strategic Plan (2011-20), which includes the 20 Aichi Biodiversity Targets, provide a strong framework for the conservation and sustainable use of marine biodiversity. The CBD's work on the biodiversity of the deep seas and open oceans, particularly the adoption by its Conference of the Parties in 2008 of scientific criteria for identifying ecologically or biologically significant areas in the global marine realm, has spawned the Global Ocean Biodiversity Initiative (GOBI). Established in 2008, GOBI is an international partnership for advancing the scientific basis for the conservation of biological diversity in the deep seas and open oceans. It aims to support countries, as well as regional and global organisations, use and develop data, tools and methodologies to identify ecologically or biologically significant areas, building on the CBD's scientific criteria for ecologically or biologically significant areas. The initial focus of GOBI is on areas beyond national jurisdiction.

Marine protected areas can conserve and make sustainable use of marine biodiversity. They can help protect the contributions of marine biodiversity to human well-being either directly or in the form of ecosystem goods and services (e.g. cultural, recreational). The management of such areas typically places restrictions on human activities in certain regions to safeguard the natural environment and conserve biodiversity. In 2010, when marine protected areas were first included in the World Database on Protected Areas (WDPA) they numbered more than 5 880 in 1.17% of the ocean. By mid-2012, their number reached 7 354, as nations and regions designated more areas for protection.[8] The Aichi Target[9] is conservation of 10% of coastal and

marine areas, especially those of particular importance for biodiversity and ecosystem services, by 2020.

Marine protected areas can be designated and managed at different scales. For example, local fishermen in Cabo Pulmo, Mexico, faced with declining catches and the possibility of losing their livelihood, lobbied to have the area designated a national park. In 1999, four years after the establishment of the nature reserve, and with little change in biomass, the community declared and enforced no-catch zones in the park. Over the next decade, fish biomass increased by over 460%, whereas there was little or no change in other protected or open access areas (Aburto-Oropeza et al., 2011). This increase in biomass is the largest measured increase in a marine reserve worldwide and is attributed to a combination of social (strong community leadership, social cohesion, effective enforcement) and ecological factors. The recovery of fish biomass has brought significant economic benefits to the community and indicates that a bottom-up approach may be a viable response to unsustainable coastal development and fisheries collapse.

Because the ocean provides a range of critical functions and services (e.g. food, nutrient cycling and oxygen generation), diverse strategies will be needed to sustain marine biodiversity. Clearly, well-managed marine protected areas can restore or conserve endangered or threatened species. However, in many places, restrictions are poorly enforced, and work is needed to improve the effectiveness of this approach.

The appropriateness of this approach for marine microbes, or for species of which little is known, is uncertain. Protecting the habitat of marine microbes would undoubtedly require quite large reservoirs, although it is difficult to suggest the most appropriate size given the limited understanding of marine microbes and associated ecosystems. Similarly, as the roles that species play in this global system are not clear, and because of the immense difficulties of a species-focused strategy, strategies for biodiversity preservation might best focus on protection of habitat.

Stakeholders have adopted bottom-up and top-down approaches with considerable success. However, because the vast majority of the ocean, especially the open ocean, is beyond the jurisdiction of any one state, it is not clear how marine protected areas could be established or who would enforce them. This is presently being discussed by a working group of the United Nations General Assembly, which is also discussing benefit sharing as it relates to the utilisation of marine genetic resources from areas beyond national jurisdictions.

Priority setting and special social issues

The shared nature of marine bioresources will create particular challenges for setting priorities for their use and development. Consideration should be given to how priority setting can encourage the use of marine biotechnology for the national and global good. The alignment of research policy with national bioresource policy can help achieve an appropriate balance between development and sustainability. A number of governance issues from the laboratory to commercialisation (e.g. biosecurity, biosafety, public perception) are also likely to require policy attention.

Public engagement will be necessary to stimulate development of the field and to advance the policy agenda. It will be important to have an ongoing, inclusive dialogue on the opportunities offered by marine biotechnology and their environmental implications, and for this dialogue to take place at regional, national and international levels. The goals of economic productivity and wealth creation need to be seen in terms of the cultural and social well-being not only of coastal populations but of the entire world.

Specific applications of marine biotechnology may be associated with social issues that should be addressed in a particular context. For example, *Aquaculture, Innovation, Social Transformation* (Culver and Castle, 2008) looked at issues associated with modern aquaculture, such as animal welfare, intellectual property, environmental sustainability and the interactions between traditional and local knowledge and modern aquaculture as they relate to the social effects of intensified fish farming and production, food security, environmental sustainability and global competitiveness.

Issues such as these need to be considered in relation to other areas of marine biotechnology and its application and to other uses of the marine environment (e.g. oil and gas extraction, transport, recreation, aquaculture, culture, etc.) which affect the extent to which marine biotechnology contributes to the bioeconomy and economic growth.

Climate change and many of the ensuing ecosystem changes, such as habitat loss, the rise of invasive species and population decline, are all likely to raise the profile of many of the ethical issues surrounding the sustainable development and exploitation of marine resources.

Collaboration with industry for knowledge co-creation and translation

The last two decades have seen an opening up of the innovation process. It is increasingly recognised that many actors participate in innovation processes and organisations increasingly rely on external sources of knowledge or innovation via inter-organisational network relationships. As the OECD observed in 2008:

> Globalisation has changed the location and way in which knowledge is generated. Confronted with increasing global competition and rising research and development (R&D) costs, companies can no longer survive on their own R&D efforts but look for new, more open, modes of innovation. Companies' innovation activities are increasingly international, and they are embracing "open innovation" – collaborating with external partners, whether suppliers, customers or universities, to keep ahead of the game and get new products or services to market before their competitors. At the same time, innovation is being "democratised" as users of products and services, both firms and individual consumers, increasingly become involved in innovation themselves. (OECD, 2008)

As in other fields, effective partnerships will play a large role in developing marine biotechnology and in translating new scientific and technological knowledge into social and economic benefits. Successful innovation will require partnership with stakeholders throughout the innovation cycle: suppliers, consumers, competitors, private R&D firms, universities and higher education institutions, and government and public research institutes. It will be important to understand the types of partnerships that facilitate innovation and the mechanisms that are effective for initiating and supporting them.

Many organisations have recognised the benefits of viewing the relation between research and industry as a partnership in which contacts between researchers and industry accelerate the creation and application of knowledge. Industry-university partnerships now take a range of forms: collaborative research, university-industry research centres, contract research and academic consulting (Perkmann, 2007). Governments have also recognised the benefits of linking organisations and external researchers earlier in the innovation process and provide a range of financial and other incentives. In Canada, federal funding agencies for science and engineering and social science have specific funding programmes for university-industry partnerships.[10] These programmes require 30-50% matching support from industry or other research partners. In Canada and elsewhere, knowledge exchange meetings foster constructive dialogue with industry and earlier engagement.[11] Further work to specify incentives for involvement and to ensure all partners benefit from the collaboration would be valuable.

In marine biotechnology also, interaction between researchers and industry can provide opportunities for co-development or sharing of databases and other infrastructure to support basic research. Currently, a number of databases or culture collections developed with public funding are shared with industry. Established in 1995 and housed in the Department of Aquaculture, Pukyong National University, Korea, the Marine Microalgae Culture Centre maintains cultures from microalgal species collected from Korean coastal waters which are shared with researchers in universities, research institutes and industry. The European Marine Biological Resource Centre (EMBRC), discussed in Chapter 4, provides small- and medium-sized enterprises (SMEs), academia and industry with access to marine biodiversity, associated metadata and extractable products, for their marine biotechnology projects. Platforms such as databases and biobanks provide an excellent focus for collaboration and the open sharing of data and data products. Yet, while industry has access to databases developed with public, and sometimes private, funding, the converse may not always be true. Consideration should be given to incentives for industry and scientists to work together in this area.

Partnerships between researchers and industry have had positive results (e.g. sharing of databases) but have also encountered challenges. One is the timing of the engagement between researchers and industry. Engagement with industry is often regarded as incidental to basic R&D or as a post-research, downstream activity. This can leave R&D results stranded, either without a ready market or unable to reach the anticipated market for technical or feasibility reasons. Earlier collaboration with industry can help to ensure that the products of marine biotechnology research are suitable for scaling up to industrial production.

Lessons regarding the timing and possible mechanisms for effective linkages between researchers and industry can be found in programmes of the European Union and activities of OECD member countries. For example, the Algae Technologies (BIOFAT)[12] project, funded in large part by the European Commission's Seventh Framework Programme BIOfuel, involves nine academic, industrial and public-sector partners and aims to demonstrate the economic viability and environmental sustainability of biofuels derived from macroalgae on a large scale.

In France, GREENSTARS is a project that links academic research on microalgae with industrial partners. It targets markets in biofuels and animal food, cosmetics, green chemistry and energy. The initiative is led by the Institut National de la Recherche Agronomique (INRA) in collaboration with 45 partners from the public sector, SMEs, multinationals, local authorities, and competitiveness clusters. Its aim is an integrated biorefinery for biofuels and high value added substances using microalgae fed with industrial emissions and organic wastes. The initiative has a budget of EUR 160 million for 10 years, of

which roughly 20% from public grants. By 2016, the partnership will have industrial prototypes based on state-of-the-art technologies that will enable the building of a viable economic and environmental model.

In industrial biotechnology, including the expanding area of renewable or bio-based fuels, industry is generally involved at an earlier stage of the R&D process than in other sectors. As a result, more commercially significant inventions originate from non-academic research (Mowery and Sampat, 2005). In the biotechnology and pharmaceutical sectors, instead, advances in university research affect industrial innovation more significantly and more directly than in other sectors. In these sectors, industry typically is involved later in the innovation process and a significant portion of the innovation process, and of the related the R&D expenses, is shifted to taxpayers (via universities and public research institutes). Different fields thus have different patterns of engagement. Mechanisms and incentives may need to be adjusted for the emerging organisations that use marine biotechnology in commercial and non-commercial applications.

While marine biotechnology may well follow an innovation path similar to that of other biotechnology sectors, this is not certain. It will be important to plan for the possibility that it will require different partnership approaches and support. As it is a relatively new area, it may be particularly important to support a large amount of basic research (relative to applied research) on marine microbes and the functioning of complex marine ecosystems.

Incentives or other support may be required to encourage academics and other actors in basic research to participate in the full innovation cycle up to commercialisation. To achieve an appropriate balance between basic and applied research in advancing marine biotechnology will also require business models for developing and producing marine biotechnology products and services that ensure the right incentives and support.

Stakeholder engagement for diffusion of innovation

The preceding discussion has shown the importance of engagement and dialogue with a broad range of stakeholders, including local custodians and end-users of marine resources. The role of early links between researchers and private-sector actors in enabling innovation and diffusion in the marketplace has also been explored. Similarly, engagement with other stakeholders is important for removing barriers that may affect how innovations reach end users. Earlier discussions with regulators, for example, may help to reduce the risks of investment in R&D by ensuring that appropriate governance frameworks are in place so that an innovation can reach the market. Such discussion can also contribute to the development of appropriate biosafety, waste disposal or other standards that affect the diffusion of a given innovation. For new products, life-cycle analysis may affect incentives to adopt innovations.

As the marine biotechnology field develops, it will be important to assess the types of stakeholder engagement that facilitate the development and diffusion of innovations. It will be necessary to understand the mechanisms that encourage engagement and to create the appropriate incentives for the various stakeholders.

Conclusions

The marine ecosystem provides a range of services, ranging from modulating climate change to the accumulation of carbon to nutrient recycling. Use or collection of bioresources from the marine environment will affect the marine ecosystem and may in turn affect nations' capacity to derive wealth or to address global challenges. As the field of marine biotechnology develops, it will be important to identify a governance and regulatory environment that fosters the creation of national wealth and global benefits in harmony with the protection of marine biodiversity and ecosystem health.

The Convention on Biological Diversity is evidence of the near universal consensus in the international community that marine biodiversity must be conserved and used sustainably and that the benefits derived from the use of marine genetic resources should be fairly and equitably shared. The use of marine genetic resources will be the basis of new partnerships and approaches to innovation while creating incentives to conserve and use marine biodiversity sustainably.

These efforts, while still in their infancy, show the need for broader and deeper discussions about effective approaches and governance, especially for areas beyond national jurisdictions. While these issues are being addressed,[13] there is no co-ordinated approach to the conservation, sustainable use and sharing of the benefits of marine biodiversity.

Effective earlier links between academic researchers and industry can mobilise knowledge and foster innovation based on marine genetic resources and the development of marine biotechnology. Such engagement may take many forms, from dialogue to large-scale working partnerships, and it is certain that all stakeholders – developers of innovations, those using innovations, those relying on the ocean for other purposes – should be involved. It is important to identify the most effective partnerships and the best ways to support them to enable innovations in and applications of marine biotechnology.

Finally, owing to the breadth of potential applications of marine biotechnology, government actions will affect investment in basic R&D, the development of partnerships, and the diffusion of innovations to end users. Governments will need to consider how policy settings can best enable progress and innovation in this field.

Notes

1. Marine bioresources are understood as the resources derived or originating from biological material from the marine environment. They include both biomass such as algae and fish, and marine genetic resources from these and other biological specimens such as marine microbes. This chapter focuses primarily on marine genetic resources as they relate to marine biodiversity and biodiscovery, but many of the themes explored may also be relevant to marine biomass.
2. Such as the United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Biological Diversity (CBD) and its Cartagena Protocol on Biosafety and its Nagoya Protocol.
3. The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation (ABS) to the Convention on Biological Diversity is a supplementary agreement to the UN Convention on Biological Diversity. It provides a legal framework for the effective implementation of one of the three objectives of the CBD: the fair and equitable sharing of benefits arising from the utilisation of genetic resources.
4. The United States, Japan and Germany account for 70% of the patents.
5. The UNGA Informal Working Group on Biodiversity beyond the Limits of National Jurisdiction was mandated in 2001 to initiate discussion of the legal framework for the conservation and sustainable use of biodiversity in areas beyond the limits of national jurisdiction.
6. See also www.planttreaty.org, accessed August 2012.
7. Marine biodiversity was the theme of the 2012 International Day for Biological Diversity (IDB). Designation of the theme of marine ecosystems provided parties to the CBD and everyone interested in marine life the opportunity to raise awareness of the issue and increase practical action.
8. See www.protectedplanet.net/, accessed August 2012.
9. The Aichi Biodiversity Targets are part of the Convention on Biological Diversity Strategic Plan 2011-20, www.cbd.int/sp/targets/.
10. Canada's National Science and Engineering Research Council (NSERC) and the Social Science and Humanities Research Council (SSHRC) provide funding through Collaborative Research and Development Grants and Partnership Grants (respectively).

11. For example, "Where Industry meets Science", Concarneau, France, 28-29 August 2012, http://concarneau.mnhn.fr/sites/concarneau.mnhn.fr/files/upload/programme_rendez_vous_concarneau_2012.pdf, accessed August 2012.

12. www.biofatproject.eu/, accessed August 2012.

13. The UNGA Informal Working Group on Biodiversity Beyond the Limits of National Jurisdiction.

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