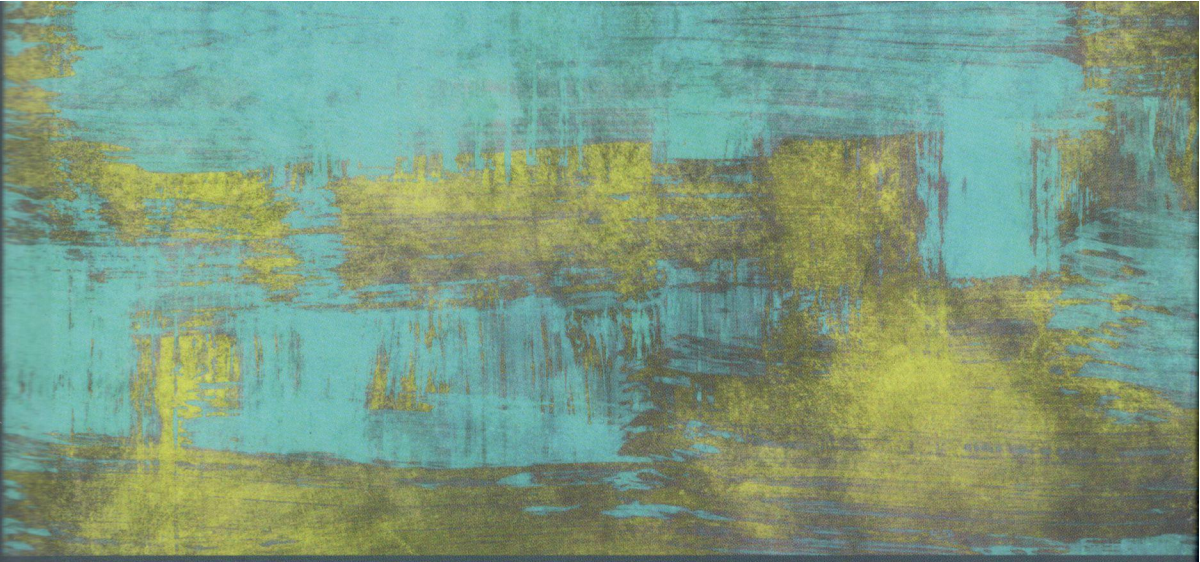

Earthscan Oceans

MARINE AND FISHERIES POLICIES IN LATIN AMERICA

A COMPARISON OF SELECTED COUNTRIES

Edited by
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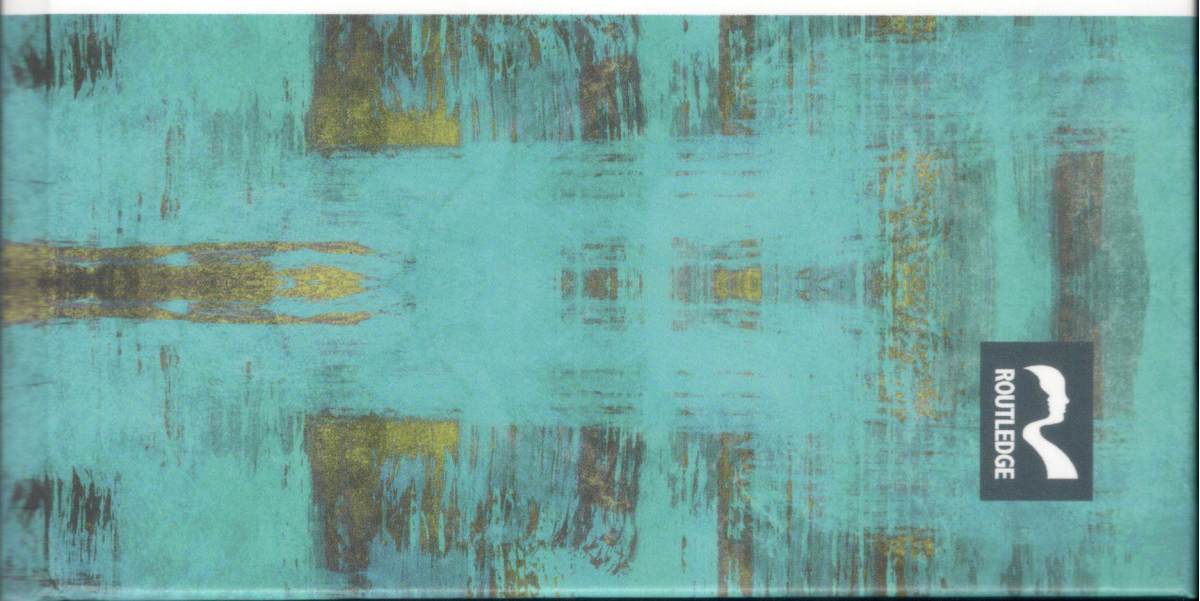
and Bruno Monteferri



ROUTLEDGE

1 Marine, coastal and fisheries issues in Chile, Mexico and Peru

An initial institutional and policy review

Bruno Monteferri and Manuel Ruiz Muller

Introduction

What do Chile, Mexico and Peru share with regard to their marine and coastal realities and fisheries and their relevant institutional and legal architectures? This chapter explores some common elements that marine and coastal areas and fisheries of these three countries have and the legal and institutional challenges they face for their sustainable development.

Chile, Mexico and Peru have large extensions of coastlines (Chile 6,400km, Peru 3,100km and Mexico 11,200km approximately) and seas (120,000km^2 Chile, 1,140,000km^2 Peru and 231,800km^2 Mexico, approximately). They share a historic tradition of use and occupation of coastal areas, with important urban centers developing rapidly on their shores. These areas contribute significantly to their economies including through small- and large-scale exploitation of fisheries, the presence of a massive off-shore oil industry in Mexico and to a lesser extent Peru and increasingly multifaceted and growing tourism activity in marine and coastal spaces. A large share of urban populations is concentrated on the coastal zones of these countries, especially in Chile and Peru.

These interrelated land and marine areas are equally critical from an ecologic point of view and the services they provide at local, national and global levels. The Humboldt (cold) and Niño (warm) currents that converge in the north of Peru and south of Ecuador are causing climate events with global repercussions. The presence of a type of plankton in marine zones in Chile and Peru makes their seas particularly rich for pelagic fishing. The potential of this resource is still being explored in laboratory conditions (Adiba, *et al.*, 2013). Tourism directed towards the coasts is also growing with large-scale tourist centers and enclaves in each country, mainly Mexico (i.e. Acapulco, Cancun). Even sports such as surfing, wind surfing, underwater spearfishing and body boarding, among others, have grown exponentially over the last two decades and have become an economic support for many local communities in the three countries (Thomas, 2014).

Although archeological evidence shows that fisheries in these countries have been locally relevant long before the Inca, Maya and Aztec periods, it was from the middle of the twentieth century that industrialization gained national and international importance in trade flows (Mann, 2006), and it is

only recently that the national political, institutional and legal agendas began to reflect concern for the viability of fisheries in these countries in general, given the intensification in activities.

In the context of marine and coastal zones and the seas, these national agendas in Chile, Mexico and Peru mirror growing international concern for the state of these spaces. In terms of conservation and sustainability, the last two decades, more or less, have seen a sudden reaction from the national and international community concerning the accumulated problems of fisheries overexploitation, coastal pollution, unplanned development of marine and coastal spaces and the effects of climate change on the seas, among others. The Brundtland Report of 1980 marked a milestone in this regard, by calling attention to the state of the global environment around the world (including the oceans) from a multi-sectorial and multidisciplinary approach.[1]

As a result, a number of international conventions (in some cases regional agreements) have been developed and present complex legal architectures that seek to protect ecosystems and marine and coastal species, as well as to prohibit and regulate conducts that are harmful for the marine environment. These conducts include waste disposal, transport of dangerous substances, migratory species, bycatch, etc.[2]

In this context, Chile, Mexico and Peru have privileged coasts and seas which face similar challenges. A look into their realities may offer alternatives and responses potentially scalable to similar realities in each country and beyond. This chapter attempts to identify these challenges and present a few notable examples of legal, policy and institutional experiences and constructs from each country, targeted at sustainably conserving and developing adjacent coasts and seas, as well as fisheries.

Some socioeconomic and environmental achievements

When analyzed quantitatively, the importance of coastal and marine areas and fisheries in Chile, Mexico and Peru is self-evident. Chile is a coastal country due to its geography. The capital Santiago de Chile, less than 120 km away from the Pacific Ocean, concentrates 40 percent of the country's population that amounts to 17.3 million.[3] In the case of Mexico, it is estimated that more than 50 million people live in coastal states. This represents approximately 40 percent of the total population of Mexico.[4] At least 60 percent of the population in Peru lives in large cities on the strip of land along the Pacific. Lima alone, the capital, has 10 million inhabitants, 30 percent of the country's population.[5] The tendency is growing and the phenomenon of populations concentrating in coastline cities is global (Creel, 2003).

All this inevitably implies a direct effect and continuous pressure on the environments and marine and coastal areas of these countries. The impacts from this concentration of population are expressed in numerous ways, from the disposal of wastewater and debris from urban centers into the sea, to the

effects of coastal edge infrastructure developments (i.e. piers, housing, highways) on marine biodiversity.

Fisheries for their part are a major contribution to the socioeconomic well-being of Chilean, Mexican and Peruvian societies and to food security for hundreds of thousands of people in local areas. These fisheries, both small/artisanal and industrial, have developed differently in each country. In general terms and concerning catch volumes Chile occupies sixth place in the world, Peru fourth and Mexico sixteenth.[6] Around these numbers there are certainly significant nuances that vary year to year. For example, historically Peru has the largest fishery of a single species on the planet, Peruvian anchoveta (*Engraulis ringens*), mainly used to produce fishmeal and fish oil and is the first worldwide producer. This fishery alone represents nearly 10 percent of catches of *all* the worlds' fisheries (Heck, 2015).

On the other hand, the population that depends directly and indirectly on fishing and associated activities (i.e. repair services for vessels, restaurants, boat owners, etc.) is equally important. In broad terms, fisheries activities generate 350,000 direct jobs and 2,000 indirect ones in Mexico[7]; 200,000 direct and 800,000 indirect in Peru[8]; while in Chile, 90,000 workers are employed directly and 95,000 indirectly. Despite this, fisheries contributions to the Gross Domestic Product (GDP) continue to be relatively low. In Peru, this contribution fluctuates between 1.5 percent and 2 percent (SNP, 2017); in Mexico the contribution is 0.3 percent (GBC, 2013) while in Chile it reaches 0.4 percent (AQUA, 2019). In general, these are relative low figures when contrasted against contribution to employment and food security.

In addition to this quantitative overview, the value of marine-coastal zones has yet to be calculated in terms of ecosystem services from natural infrastructure and the non-consumptive or material benefits they provide through contemplation, and spiritual, recreational and aesthetic values (Millennium Ecosystem Assessment, 2003). In this respect, Chile, Mexico and Peru have a cultural wealth yet to be enjoyed and benefitted from sustainably.

Legal and policy frameworks

Just as Chile has a National Policy for the Use of the Coastal Border,[9] Peru approved its Guidelines on Integrated Coastal Zone Management,[10] which are in essence, public policies that seek to give these spaces a sustainable treatment. Mexico does not have a general and comprehensive policy or legal framework for its marine and coastal zones but does have focalized policies for specific fisheries and their management. For Chile, Mexico and Peru, infrastructure development, exploitation of non-renewable resources, waste disposal and marine protected areas, among others, as well as fisheries in particular, are governed by specific and sectorial legislation which entails a complex web of interrelations, overlaps and, sometimes, conflicts of competences at different government levels (i.e. central or federal government, municipalities, specialized units, etc.). In other words, the creation and

management of marine and coastal protected areas is governed by legislation on protected areas, infrastructure development responds to relevant legislation (i.e. development of roads and highways, or ports and piers, or urban development in general), waste disposal is regulated by an environmental or industrial framework, and so forth. Inter-sectorial coordination among the different levels of government to implement the National Policy in Chile and the Guidelines in Peru, continues to be a challenge and pending matter.

Although there is not a comprehensive and systematic policy or law to address or integrate the different dimensions of fisheries with marine and coastal related issues, it is important to emphasize that in the biodiversity strategies and action plans of Chile, Mexico and Peru, references to biodiversity conservation and marine and coastal ecosystems have been made either at the species or ecosystem levels. These policy instruments are an important, albeit often overlooked, references to inform both regulatory actions as well as specific interventions in these areas. For example, Chile has developed a National Biodiversity Strategy 2017–2030 (2016) that includes a detailed assessment on the situation of marine and coastal ecosystems and oceanic islands; it proposes measures to integrate marine biodiversity in sectorial policies, plans and programs and develops a thematic approach to marine biodiversity and islands.[11] In the case of Mexico, the National Biodiversity Strategy and Action Plan 2016–2030 (2016)[12] also has explicit references and actions aimed at restoring vulnerable marine and coastal ecosystems; ensuring the continuity of ecosystem biogeochemical processes in infrastructure planning in coastal and island areas, and generating incentives for community participation in the restoration of marine-coastal ecosystems in terms of their environmental services. Finally, in the case of Peru, the National Strategy for Biological Diversity 2021 and Action Plan 2014–2018,[13] does not include major references to marine and coastal areas, except with regards to the need of establishing a type of sustainable management and operating modality for at least 10 percent of the biodiversity in marine areas and some action in terms of valuation, education and awareness on marine and coastal biodiversity. The focus of these strategic instruments is, primarily, on better understood continental and terrestrial biodiversity. None of the three countries has a specific strategy dedicated to marine and coastal biodiversity. The exception may be Chile to some extent due to its location and particular geography.

In terms of marine and coastal protected areas, advances in Chile, Mexico and Peru are quite dissimilar. Nearly 42 percent of the marine territory in Chile is under a form of special protection or management. It has 33 recognized protected areas in marine zones.[14] Chile has also developed the Marine and Coastal Areas for Indigenous Peoples, a new category, different to a protected area but with similar features, that proposes exclusiveness in the management and administration of marine-coastal ecosystems where ancestral communities of fishers have historically developed.[15] Mexico for its part has 37 marine-coastal protected areas that cover 22 percent of the marine territorial surface, protected under some specific category.[16] Both Mexico and Chile have considerably exceeded their commitments to the Aichi Biodiversity Targets to protect

10 percent of their sea territory. Beyond the forever-existing limitations to guarantee management and monitoring mechanisms for the protection given to these spaces, there is evidence of political commitment, mainly in recent years. Peru is still far behind in terms of marine protected areas, with only 0.5 percent of its marine territorial extension protected through four natural areas dedicated to the conservation of marine and coastal spaces and biodiversity.[17]

In the case of fisheries, unlike Mexico and Peru, Chile has a National Fisheries Policy (2007)[18] and a National Aquaculture Policy (2003)[19] which despite the time lapsed, show certain clarity in relation to the order in which the activities must be approached in national development agendas. Additionally, Chile has a General Fisheries and Aquaculture Law (updated and modified in 2017) and complementary regulations, which include modern and innovative approaches related to inspection, fisheries quotas and protected zones, among others.[20] Mexico has a General Law for Sustainable Fisheries and Aquaculture from 2007 (modified in 2018) that also includes innovative aspects such as a National Fisheries Chart, a national fund for sustainable fishery and aquaculture, differentiated instruments for small and large operators, a detailed sanctions regime and a National Fishery Council as a multi-sectorial counseling space for fisheries and aquaculture. Finally, Peru has a General Law on Fisheries from 1992, that has been modified over time on specific aspects, such as creating subsequent regulations with regard to fisheries quotas, differentiated regimes for artisanal and industrial fisheries. One of the advances made over time under the Law was the adoption of a framework for fisheries quotas.[21] Due to the time passed, the General Law on Fisheries requires a reformulation in order to adapt to the modern realities of fishery resources management, conservation and sustainability at all levels.

In institutional terms, there are some similarities and differences between Chile, Mexico and Peru. Chile has a Sub-Secretariat of Fisheries and Aquaculture, which depends on the Ministry of Economy, Development and Tourism, as the maximum authority responsible for determining public policies in the context of fisheries and aquaculture. In Mexico, this responsibility falls at the federal level, on the Secretariat of Agriculture, Livestock, Rural Development, Fishing and Food. In Peru, the Ministry of Production, through the Vice-Ministry of Fisheries, determines fisheries public policies. These are the policy-setting bodies that set the direction for countries in terms of fisheries and aquaculture policies. However, within the fisheries sector in general, there are many other public institutions with competences regarding funding, promotion, inspection and research, etc.

With regards to fisheries innovation and research to inform policy making, the Institute of the Sea of Peru is responsible for generating and providing the Vice-Ministry of Fisheries and other actors, data and technical and scientific information on the status of the country's fisheries. The National Institute of Fisheries and Aquaculture of Mexico is a decentralized and public body which is in charge of directing, coordinating and guiding scientific and technological research in terms of fisheries and aquaculture, as well as the

3 Marine bioprospecting

Liliana Pardo López

Introduction

The oceans cover more than 70 percent of the Earth's surface. Over 30 of the 36 known animal phyla inhabit the oceans and sea. It is estimated that the total number of marine species is 1 million, together with hundreds of millions of microbial species. Marine genetic resources are becoming an important input to biotechnology and bioprospecting, given marine organisms can survive environments with high atmospheric pressures, extremely high and low temperatures, low oxygen levels, high salt concentrations and even lack of light. Their metabolisms have adapted to contend with extreme environmental pressures. As a result, expectations for finding novel and useful industrial organisms or natural products derived thereof, are very high and on the rise (Skropeta and Wei, 2014).

This chapter will reflect briefly on the international environmental policies and laws related to biodiversity and marine bioprospecting in particular. Examples of marine bioprospecting will be described to provide an overall picture of advances in the field. It will also address issues of national and international jurisdiction or the lack thereof, regarding marine genetic resources (MGR). Although there has been a recent increase in the number of papers and publications regarding marine bioprospecting, the issue is relatively new in Latin America. Its technology, financial and knowledge-intensive features have made marine bioprospecting a field closed almost exclusively for developed countries. Understanding some of the social and economic implications of this activity will hopefully offer decision makers, scholars and interested actors an avenue for further and more detailed analysis of marine bioprospecting. A section on conclusions and challenges closes this overview and reflection of a potentially useful and lucrative activity, with considerable implications on sustainable development.

Conceptual issues: genetic resources, biotechnology and bioprospecting

What are genetic resources?

The most popular and widely accepted legal definition for genetic resources in that of the Convention on Biological Diversity (CBD) of 1992, which

defines "genetic resources" as "any material of plant, animal, microbial or other origin containing functional units of heredity." "Biological resources" on the other hand, include "genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity."

What is biotechnology?

The CBD also defines biotechnology as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." As with any other technological tool, biotechnology should be deployed to solve problems in the environmental, health, food and agricultural sectors in a respectful and sustainable manner.

It is difficult to specify the exact birth date of biotechnology given the long history of manipulation of biological systems. Examples of biotechnology include the development of the first smallpox vaccine by Alexander Fleming in the early 20th century and the creation of the first transgenic organisms that allowed the synthesis of a human hormone in bacteria in 1979. The discovery in 1953 of the double helix of deoxyribonucleic acid (DNA) by James Watson and Francis Crick, paved the way for genetic engineering and *modern* biotechnology which includes fields such as molecular biology, microbiology, genomics, gene editing and biochemical engineering (Bolivar-Zapata, 2017).[1]

Marine microorganisms (bacteria, viruses, phytoplankton, zooplankton), as well as their derivatives (DNA, enzymes, secondary metabolites) are a valuable source of inputs for modern biotechnology. In the past, access to marine microorganisms or genetic material was possible mostly through laboratory cultures. However, it is estimated that researchers have only managed to cultivate less than 1 percent of all bacteria living on the planet. Recently, independent cultivation techniques have been developed, allowing for genetic material from microorganisms living in the sea to be obtained, including from abyssal zones.[2] Metagenomics is one such technique which allows access to previously unexplored resources.[3]

What is bioprospecting?

Bioprospecting can be defined as the systematic search for new sources of useful and potentially commercially valuable chemical compounds, genes, proteins, secondary metabolites, microorganisms, etc., from nature and biodiversity. This search demands responsible management of resources (e.g. plants, animals, fungi and microorganisms) and environmentally responsible conducts and practices. Marine bioprospecting, as the name suggests, utilizes marine compounds and organisms from a variety of ecosystems such as the seabed, hydrothermal vents, seamounts and coral reefs.

For bioprospecting to take place, research must first be undertaken on new organisms and biological sources which may provide useful compounds.

A biotechnology intermediate step then takes place and, finally, a move towards commercializing the possible product/process. Coordinated work among scientists, business and the government is essential for these steps to happen fluidly. Strategic alliances should be established to formulate bioprospecting plans which contribute to national development. Ethical considerations and recognition of the value of nature and its contribution to sustainable livelihoods should be part of these strategies and plans (Gómez-Madrigal *et al.*, 2014).

International environmental law: relevant milestones

United Nations Convention on the Law of the Sea (UNCLOS)

The first United Nations Conference on the Law of the Sea was held in 1956. In 1994 the United Nations Convention on the Law of the Sea (UNCLOS)[4] was adopted and is now considered analogous to a "Constitution for the Oceans" which is binding to 168 parties. UNCLOS recognizes the right of states to establish a territorial sea (12 nautical miles), an adjacent area (12 nautical miles) and an Exclusive Economic Zone (EEZ) (200 nautical miles). Within the EEZ each state has sovereign rights for exploration and exploitation purposes, conservation and management of natural resources, as well as for marine research and protection and preservation of the marine environment. Although UNCLOS did not originally refer to biological or genetic resources, there is at present a move within the agreement to develop a specific legal regime which addresses genetic resources and related digital sequence genetic information and aligns its principles with the CBD and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing Arising from their Utilization (2010).

Convention on Biological Diversity (CBD)

The CBD was signed on June 5, 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro (UNCED or "Earth Summit") and entered into force on December 29, 1993, after its ratification by 193 Parties.[5] It has three main goals including: the conservation of biological diversity; the sustainable use of its components; and the fair and equitable sharing of benefits arising from the use of genetic resources (Glowka *et al.*, 1994). The CBD covers biotechnology extensively, recognizing its critical potential in the sustainable use of genetic resources – both marine and terrestrial. Articles 15, 16 and 19 specifically address issues related to the rules of access to genetic resources and benefit sharing, access to and transfer of biotechnology and its handling, and the distribution of its benefits, respectively. It is within these principles that bioprospecting develops. The CBD specifies that ecosystems, species and genetic resources must be utilized for the benefit of humans, without undermining biological diversity. Its binding, albeit often qualified, provisions also address principles of cooperation, awareness raising, *in situ* and *ex situ* conservation, sustainable use, among others.

Cartagena Protocol on Biosafety

The UNCED Declaration on Environment and Development, refers to the precautionary approach in the transfer and manipulation of living modified organisms (i.e. genetically modified organisms produced through modern biotechnology).[6] This specific principle and the CBD references to the safe use and handling of biotechnological products, paved the way for the Cartagena Protocol on Biosafety (2000).[7] The Cartagena Protocol contributes to ensure an adequate protection in the transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, also taking into account risks to human health. Its emphasis is international or transboundary movements of these organisms.

Mexico was one of 170 countries to sign the Cartagena Protocol and according to its monitoring and reporting obligations, the Secretariat for the Environment and Natural Resources, the Secretariat for Health,[8] the Secretariat for Cattle, Rural Development, Fishing and Food,[9] the National Commission for the Knowledge and Use of Biodiversity and Inter-Secretarial Commission on Biosafety of Genetically Modified Organisms have submitted periodic reports on monitoring and implementation of the Protocol to the CBD's Secretariat. The Biosafety Law on Genetically Modified Organisms (2005) and the regulation on the functions of the Inter-Secretarial Commission on Biosafety of Genetically Modified Organisms are two reflections of advances made in this field.[10] Chile and Peru have also signed the Cartagena Protocol[11] and together with Colombia have been working on a multinational project – OEA-CONICYT – focused on the evaluation of policies and national regulatory systems for biosafety at the national level to facilitate the implementation of the Protocol.

Nagoya Protocol on Access to Genetic Resources

The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization was adopted in 2010 in Nagoya, Japan, after several years of arduous negotiations.[12] It includes a series of provisions to promote benefit sharing through, for example, transfer of biotechnology, streamlining access and benefit-sharing procedures, developing monitoring mechanisms and check points to very movements and uses of genetic resources, etc. One key goal of the Nagoya Protocol is to create legal certainty for and transparency between users and providers of genetic resources and related traditional knowledge of indigenous peoples.

Mexico ratified the Nagoya Protocol on May 16, 2012 and it is now in the process of being implemented through a Global Environmental Facility and United Nations Development Program project. The key principle underlying the implementation process is the recognition that states have the sovereign right to exploit their own natural resources pursuant to environmental safeguards and to ensure that these activities do not undermine other

states or zones situated outside national jurisdiction.[13] The project seeks to contribute to the construction of sensible laws and regulations to facilitate and control access to and use of genetic resources. The project is conducted by the Secretariat for the Environment and Natural Resources and involves key actors related to research in genetic resources, including universities, civil society and indigenous and local communities. To consolidate and ensure appropriate participation, an interagency working group has been created and includes the Secretariat for the Environment and Natural Resources, the Secretariat for Cattle, Rural Development, Fishing and Food, the Secretariat for Foreign Relations, the National Commission for the Development of Indigenous Peoples and the Secretariat for Economy.

Regulating marine genetic resources (MGR) within or beyond national jurisdictions

Marine genetic resources include plants, animals and microorganisms, either complete organisms or groups of organisms such as plankton or samples partially contained in water and sediment.[14] Genomics data covers deoxyribonucleic acid (DNA) sequences obtained through different methodologies such as Sanger sequencing or new massive sequencing techniques (illumine, PacBio, Oxford Nanopore). Marine samples are used to classify organisms or microorganisms for 16S or 18S ribosomal gene sequencing. Metagenomics has revolutionized the way in which marine microorganisms are classified. Beginning in the 21st century important contributions have been made in this field.[15] For instance, the ocean exploration genome project – Global Ocean Sampling Expedition (GOS) – conducted by the Craig Venter Institute, whose goal is to assess genetic diversity in marine microbial communities, has visited 23 countries spanning four continents, reporting millions of new genes and nearly 1,000 genomes for uncultivated microbial lineages, as well as a wider understanding of marine microbiology. In Mexico, the Consortium for the Research of the Gulf of Mexico (2015–2020)[16] conducts a similar project of oceanographic expeditions seeking to obtain a regional baseline for marine genetic resources, using metagenomics techniques (Escobar-Zepeda *et al.*, 2018; Godoy-Lozano *et al.*, 2018). Hand-in-hand with the development of genomics and metagenomics, bioinformatics is having a key role in analyzing and classifying large amounts of data generated on a daily basis. However, the oceanographic community is not immune to problems with regards to unloading, classifying and analyzing metadata about genome sequences or associated to them. This community faces storage limitations for samples (genetic resources) obtained from the sea. Clear and definitive international and national regulations are nonexistent to date, therefore each university, gene bank or company stores genetic resources according to different protocols and only a few actually report to countries in whose jurisdictions these marine genetic resources were obtained.

Deep-sea marine areas, especially Areas Beyond National Jurisdiction (ABNJ), are particularly challenging from an institutional and policy perspective.

These areas comprise 64 percent of the ocean's surface around the world and 47 percent of the earth's surface (Costello *et al.*, 2017). There are no international instruments or national laws to govern collection and storage of samples and related data, let alone addressing property and control dimensions, particularly in the context of increasing enclosures through patents over innovations based on these resources. It is important to take into account that the majority of species found in these areas have yet to be taxonomically described and genomically deciphered. Transnational corporations and northern hemisphere research institutions with technological capacities have a large advantage in exploring and making use of marine genetic resources.

Some efforts have been undertaken recently to compile international registers of sample collections including through the Global Genome Biodiversity Network (GGBN) that saves genomic collections for research purposes[17] and the Global Registry of Biodiversity Repositories (Schindel *et al.*, 2016).[18] These international initiatives are supported as a means to improve storage capacities and create standardized principles and best practices regarding collecting, storing and analyzing marine genetic resources. Open data repositories can improve access to data and information and strengthen opportunities for collaboration.

Whilst bioprospecting is a technically complex and challenging endeavor, sensible policies and legal frameworks to address it are still in the making. More than two decades since the CBD was adopted, countries and the international community are still grappling with how to develop appropriate rules, even in the light of advancements with the FAO International Treaty and Nagoya Protocol (Wright *et al.*, 2016). One looming question is how to regulate marine genetic resources and digital sequence information derived thereof. Quite a few people advocate that marine genetic resources, particularly beyond national jurisdiction, should be considered part of the world heritage and freely accessible for research and development, in practice moving away from the sovereignty principles in the CBD and Nagoya Protocol. However, especially developing countries, some consider this may be unfair given capacities to access and use these resources are concentrated in very few countries and institutions. They also call for bioprospecting or marine genetic resources to be aligned with the CBD and Nagoya Protocol benefit sharing principles.

The challenge for developing countries to participate in world biotechnology markets

Governments around the world are seeking opportunities for sustainable economic growth. Most acknowledge that development and success cannot place an additional cost on the planet's already endangered ecosystems. Many countries see in the "bioeconomy" – parts of the economy that use renewable biological resources from land and sea, to produce food, materials and energy – a key conceptual framework under which to plan their development. For instance, it is estimated that the global market for marine biotechnology has the potential to reach US$4.8 billion by 2020 and US $6.4 billion by 2025. The

identification of new applications for enzymes derived from the sea and uses of bacteria, marine algae and microalgae in the production of biofuels can become key drivers for market growth and a dimension of development (Hurst *et al.*, 2016).

Unfortunately for the interests of developing countries, access to and use of marine resources, particularly outside their jurisdiction and in the deep-sea bed, are disproportionately concentrated in companies, research centers and transnational corporations with the financial clout and technical capacities to undertake these high-risk projects. The literature reviewed shows that 84 percent of patents derived from marine products are owned by a small group of companies. The chemical company BASF, headquartered in Germany, is the largest chemical producer in the world. It owns 47 percent of all marine sequences, including patented gene sequences. In 2017, the company surpassed US$79 billion in registered sales, with a network of 633 subsidiaries worldwide. Germany (49 percent), United States (13 percent) and Japan (12 percent) are the three countries with most patent applications – and granted patents – associated to innovations derived from marine genetic resources (Blasiak *et al.*, 2018). Most patents are under company control, with universities in contrast holding only 12 percent of registered patents. These figures open at least two important considerations. First, bioprospecting is not only technically complex, but it often also involves very complex relationships between multiple actors; second, patents over biological materials immediately call into the analysis whether samples and genetic resources were accessed in accordance with the CBD and Nagoya Protocol principles on benefit sharing and whether these have been fairly and equitably shared.

Mexico, Chile and Peru have very rich marine environments and some of the most important fisheries in the world. Except for a few well documented cases, there is little information available as to exactly what is happening in terms of bioprospecting of marine resources. For instance, in Mexico, the technology company Nova Proteins produces shark antibodies to generate various medical applications.[19] In Peru, Peruvian Seaweed (PSW) is a successful technology company discreetly producing biotechnological products based on marine resources, especially algae. Many of its products are already protected by trademark and patents associated to their products and processes – which is quite exceptional for most developing countries.[20] However, Chile, Mexico and Peru, as do most developing and biodiversity endowed countries, act as providers of biological and genetic resources which then feed into technological processes in industrialized nations. Nuances are warranted with regards to this scenario, but it describes quite correctly a historic pattern.

Institutional, policy and legal challenges for marine bioprospecting in Mexico

Development and implementation of legal measures in Mexico regarding access and benefit sharing in accordance with the Nagoya Protocol, has been

slow and there are numerous challenges to be overcome. A national plan or bioprospecting strategy demands government leadership and involvement of a wide range of institutions from civil society, academia and universities, private companies and state agencies.

Some countries in Latin America have developed a series of strategies and planning instruments which specifically address bioprospecting. For example, Colombia has approved a National Marine Bioprospecting Plan (Melgarejo *et al.*, 2002)[21]; Peru has in turn approved a Biodiversity Valorization Program which includes specific lines of work and funding for the implementation of bioprospecting activities.[22] General biodiversity strategies in Chile, Mexico and Peru all include specific mandates and describe actions to undertake research and development on genetic resources, with due consideration of the CBD and Nagoya Protocol principles.

Mexico has over the past few years developed a considerable and strong capacity in biotechnology shared among universities, private companies and research institutions. The recent ABS project sponsored by the Global Environmental Facility in Mexico, offers a formidable opportunity to develop a strategy and plan for marine bioprospecting in particular.

A national baseline informed by the business sector, academia and universities, indigenous and local communities and governmental organizations would be a first step to understand the types of marine research being undertaken throughout Mexican territorial seas and support further decisions. The Secretariat of Finance and Public Credit and the National Evaluation Committee define the priorities for GEF and other projects and approve their development and implementation.

This initial step, integrating marine bioprospecting into the national agenda, could be followed by an effort to identify comparative marine bioprospecting cases around the world and best practices in regulatory implementation and institutional development. This could also lead to an analysis of the implications of intellectual property and its effects on stimulating research and development in marine genetic resources. Ultimately, understanding value chains and markets also requires multisectoral and interdisciplinary analysis to identify potential commercial and industrial opportunities.

There is no way bioprospecting and biotechnology development can take place in isolation. The breath of collaboration to strengthen and consolidate successful research and development endeavors in marine genetic resources is very considerable. National and international consortia are common and should be encouraged. Very importantly, science and technology funding agencies such as the National Council for Science and Technology in Mexico or the National Technology Council in Peru, need to increase investments in research and development in marine bioprospecting in particular. Mexico should include a marine bioprospecting section in its recent National Plan for Science and Technology 2018–2024.[23]

Brief bioprospecting cases

It is difficult to estimate the economic value of the different forms of benefits derived from marine bioprospecting activities. There are, however, some useful indicators. Hundreds of patents have been granted during the last 30 years over marine resources derived innovations; as part of these patents, 862 different marine species have been identified; and a total of 12,998 genetic sequences are associated to those patents. Almost 73 percent of patents relate to microorganisms; fish and mollusks represent 16 percent and 3 percent respectively. Approximately 11 percent of patents derive from species living in deep seas and hydrothermal vents, many found beyond national jurisdictions (Blasiak *et al.*, 2018).

There are a group of well-known and documented examples of successful or, at least, persistent bioprospecting efforts around the world. One of the best-known cases refers to the Taq polymerase enzyme from *Thermus aquaticus* bacteria, extracted from the geothermal aquatic ecosystem of Yellowstone National Park in the United States, during the 1960s. Kary Mullis used this enzyme to develop a molecular biology technique called Polymerase Chain Reaction (PCR) that amplifies ADN fragments at high temperatures on the basis of very small quantities. Kary Mullis was granted a Nobel Prize for PCR and profits from the Taq polymerase enzyme exceed US$200 million a year (Doremus, 1999).

Costa Rica was the first Latin American country to allow bioprospecting in its territory through a non-governmental association with close linkages to the state. The National Biodiversity Institute (INBio) was created in 1991 and signed a formal agreement with the Ministry of Environment and Energy to explore existing biodiversity in protected areas, in exchange for 10 percent from the project budget. It was considered, at the time, an international milestone and economic driver for conservation. At present, INBio does not generate enough income to sustain itself, despite multiple bioprospecting contracts signed with about 30 important companies and universities such as Merck & Co., Syngenta, Strachlyde, among others (Hammond, 2015). Unfortunately, its bilateral bioprospecting model to link national scientific research institutions with foreign companies and research centers (large and medium) failed to produce a viable a long-term sustainable product – after 30 years of research and development. Although the reasons that have led to the downfall of INBio are yet to be evaluated in detail, there is speculation that it could have been due to low return rates and negotiation of relatively low monetary benefits, both explained through economic fundamentals that make it impossible to negotiate fair and equitable contracts (Ruiz, 2015).

Conclusions and final reflections

In Mexico, the fourth most biologically diverse country on the planet, biodiversity is a strategic issue. Approximately 12 percent of the world's species

inhabit its terrestrial and marine environments. Biodiversity has an enormous potential to contribute to biotechnology-based research and development, especially in certain industries such as pharmaceuticals, cosmetics, agroindustry and pollution prevention or remediation. Especially as a result of the Nagoya Protocol, Mexico has started to discuss and develop its own national institutional and legal framework on access and benefit sharing from genetic resources, which is to a great extent the same as describing "bioprospecting." This effort requires not only development of administrative and procedural provisions but due consideration to issues such as safe handling of biotechnology, protection of indigenous peoples' rights, technology transfer and, in the case of marine bioprospecting, due consideration to the highly specialized nature of the activity. After defining their set of needs in sectors such as health, food production, environmental remediation and others, Chile, Mexico and Peru should identify opportunities and openings where marine bioprospecting could play an important role in enhancing development. However, it is important to reflect on the lessons learnt from other countries in this field. A chapter or section in the National Plan for Science and Technology: 2018–2024, incorporating marine bioprospecting, could be an important step in broadening the possibilities for Mexico to move further along the road to sustainable development.

Notes

1 In 1967, an enzyme was isolated that allows the joining of DNA fragments from different sources – DNA ligase; in 1970, the first type of enzyme was isolated, capable of cutting DNA at specific sites – nuclease. Finally, in 1977, DNA nucleotide sequencing was developed.
2 The abyssal zone of the ocean is found at depths of 4,000 metres. This region is characterized by its low temperatures, elevated hydrostatic pressure, lack of nutrients and the total absence of light.
3 Metagenomics is defined as the study of microorganisms through their DNA directly from samples that do not require culturing or microbiological isolation. For more information see, Escobar-Zepeda *et al.*, 2015. See also, www.frontiersin.org/articles/10.3389/fgene.2015.00348/full.
4 See, www.un.org/depts/los/convention_agreements/texts/unclos/convemar_es.pdf.
5 See, www.cbd.int/doc/legal/cbd-es.pdf.
6 See, www.conacyt.gob.mx/cibiogem/images/cibiogem/comunicacion/publicaciones/cartagena-protocol-es.pdf.
7 Report of the Intergovernmental Committee for the Cartagena Protocol in Biosafety on the Work of its Third Meeting, Doc. UNEP/CDB/ICCP/3/10, May 27, 2002.
8 Decentralized health authority with technical, administrative and operational autonomy, with the mission of protecting the population against sanitary risks.
9 Decentralized public entity responsible for developing policies and overseeing agricultural sanitary safeguards, protecting aquatic and livestock resources from pests and diseases of quarantine and economic concern, as well as regulating certification of systems to reduce risks of food contamination and their agricultural quality, and facilitate national and international trade of goods of plant and animal origin.

10 It aims to coordinate policies from the Federal Public Administration of Mexico related to biosafety and the production, import, export, mobilization, propagation, consumption and in general, the use and exploitation of Genetically Modified Organisms, their products and sub-products.
11 See, www2.congreso.gob.pe/sicr/cendocbib/con4_uibd.nsf/A7F5BBC269E1220005257D540063678E/$FILE/RL_28170_ApruebaProtocoloCartagena.pdf.
12 See, www.cbd.int/abs/doc/protocol/nagoya-protocol-es.pdf.
13 The Secretariat of Environment and Natural Resources through the Undersecretary of Development and Environmental Regulation works with indigenous and local communities to strengthen the national implementation of the Nagoya Protocol. Press Release SEMARNAT No. 95/2018 Mexico City, August 28, 2018.See,www.gob.mx/semarnat/prensa/trabaja-semarnat-con-comunidades-indigenas-para-la-implementacion-del-protocolo-de-nagoya?idiom=es.
14 Plankton is a diverse group of free-floating organisms made up of plants, algae, viruses, bacteria and animals. Eighty percent of unicellular organisms that appeared on Earth more than 3 billion years ago were plankton, playing a key role in global climate and biogeochemical cycles.
15 Other similar examples include: TARA Oceans and Tara Oceans Polar Circle (2009–2013), the expedition navigated from the Mediterranean to the Atlantic through the Indian Ocean, Pacific Ocean, Arctic and Antarctic, discovering more than 500,000 new microorganisms – estimating that 95 percent of them continue to be unknown – and 2,600 assembled genomes; and MALASLPINA expedition (2010–2011) where 250 researchers sampled more than 300 stations across the ocean with depths of up to 5,000 metres.
16 The Research Consortium for the Gulf of Mexico was created in 2015 and is formed by approximately 180 researchers from Mexico. Oceanographers, biologists, physicists, chemists and engineers from well-known national research institutions jointly take on the challenge to implement the largest research project in the Gulf of Mexico. The goal is for Mexico to have observation tools, biotechnological development and numerical models to ensure the establishment of contingency plans and mitigation activities in the event of large-scale hydrocarbon spills in the Gulf of Mexico, as well as information to assess environmental impacts.
17 See, www.ggbn.org/.
18 See, http://grbio.org/.
19 See, www.mipatente.com/empresas-spin-off-la-ciencia-tambien-es-negocio/.
20 See, www.pswsa.com/en/.
21 "Bioprospección: Plan Nacional y aproximación al estado actual en Colombia", *Acta Biológica Colombiana*, 2003, Vol. 8, No. 2, p. 73, see, www.invemar.org.co/redcostera1/invemar/docs/3013Plan.pdf.
22 See, https://portal.concytec.gob.pe/index.php/publicaciones/programas-nacionales/item/213-programa-de-valorizacion-de-la-biodiversidad.
23 See, www.smcf.org.mx/avisos/2018/plan-conacyt-ciencia-comprometida-con-la-sociedad.pdf.

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