SUSTAINABLE
DEVELOPMENT
GOAL
**14**

# LIFE BELOW WATER

## CONTRIBUTIONS OF EMBRAPA

Fabíola Helena dos Santos Fogaça
Angela Aparecida Lemos Furtado
Carlos Alberto da Silva
Marcos Tavares-Dias
Eric Arthur Bastos Routledge

Technical Editors


Embrapa

***Brazilian Agricultural Research Corporation***
***Ministry of Agriculture, Livestock and Food Supply***

## Sustainable Development Goal 14

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# Foreword

Launched by the United Nations (UN) in 2015, 2030 Agenda for Sustainable Development is powerful and mobilizing. Its 17 goals and 169 targets seek to identify problems and overcome challenges that affect every country in the world. The Sustainable Development Goals (SDG), for their interdependent and indivisible character, clearly reflect the steps towards sustainability.

Reflecting and acting on this agenda is an obligation and an opportunity for the Brazilian Agricultural Research Corporation (Embrapa). The incessant search for sustainable agriculture is at the core of this institution dedicated to agricultural research and innovation. Moreover, sustainable agriculture is one of the most crosscutting themes of the 17 goals. This collection of books, one for each SDG, helps society realize the importance of agriculture and food in five priority dimensions – people, planet, prosperity, peace and partnerships –, the so-called 5 Ps of 2030 Agenda.

This collection is part of the effort to disseminate 2030 Agenda at Embrapa while presenting to the global society some contributions by Embrapa and partners with potential to affect the realities expressed in the SDG. Knowledge, practices, technologies, models, processes, and services that are already available can be used and replicated in other contexts to support the achievement of goals and the advancement of 2030 Agenda indicators.

The content presented is a sample of the solutions generated by agricultural research at Embrapa, although nothing that has been compiled in these books is the result of the work of a single institution. Many other partners joined in – universities, research institutes, state agricultural research organizations, rural technical and extension agencies, the Legislative Power, the agricultural and industrial productive sector, research promotion agencies, in the federal, state and municipal ranges.

This collection of books is the result of collaborative work within the SDG Embrapa Network, which comprised, for 6 months, around 400 people, among editors, authors, reviewers and support group. The objective of this initial work was to demonstrate, according to Embrapa, how agricultural research could contribute to achieve SDGs.

It is an example of collective production and a manner of acting that should become increasingly present in the life of organizations, in the relationships between public, private, and civil society. As such, this collection brings diverse views on the potential contributions to different objectives and their interfaces. This vision is not homogeneous; sometimes it can be conflicting, just as is society's vision about its problems and respective solutions, a wealth which is captured and reflected in the construction of 2030 Agenda.

These are only the first steps in the resolute trajectory that Embrapa and partner institutions draw towards the future we want.

*Maurício Antônio Lopes*
President of Embrapa

# Preface

This book aims to present research carried out by the Brazilian Agricultural Research Corporation (Embrapa) and its partners regarding United Nations' Sustainable Development Goal 14 (SDG 14), whose title is *Life below water*. This goal is part of a set of 17 goals agreed upon in 2015 by the UN member states, as part of a plan of action to eradicate poverty, protect the planet and ensure that people achieve peace and prosperity: the 2030 Sustainable Development Agenda.

This book has been divided into six chapters. The first chapter addresses the context in which this Agenda was created, the problems that SDG 14 intends to solve by 2030 and its 11 agreed targets, which include reducing marine pollution and sustainably managing marine and coastal ecosystems through conservation of coastal areas, regarded as nurseries of marine life. In addition, a brief description of the Brazilian context and the history of contributions of Embrapa to the targets of this SDG are presented.

In Chapter 2, whose title is *Current situation of the seas*, oceans and coastal regions, problems for the sustainability of oceans and seas in the world and, more specifically, in Brazil are analyzed, including disordered settlement, pollution, deforestation that impact life under water. It describes how several marine species are disappearing in seas, rivers and mangroves, even after the establishment of conservation areas and programs aimed at environmental conservation in Brazil.

Chapter 3, *Conservation, use and management of marine resources and ecosystems*, addresses the work of Embrapa, in partnership with domestic and foreign research, development and innovation institutions, for advancing scientific knowledge and technology transfer in order to improve ocean health and increase the contribution of marine biodiversity to sustainability of developing countries (targets 14.a, 14.1, 14.2, 14.4 and 14.5).

Chapter 4, *Sustainable use of the seas for food sovereignty*, shows how marine aquaculture could contribute to increased food supply for the world's population. It describes actions, projects and research results of Embrapa and its partners to achieve the target 14.7 – Increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism[1].

Chapter 5, *Sustainable development of fisheries*, describes how Embrapa, in partnership with several institutions, has been working on the development of projects and actions to improve scientific knowledge and ocean health and increase the contribution of marine biodiversity to socioeconomic development of Brazil by means of artisanal fishing and related topics. In addition, actions aimed at raising awareness of small-scale artisanal fishermen on sustainable use of marine resources are mentioned.

Chapter 6, *Advances and future challenges*, present a summary of problems raised throughout this book and solutions presented: what is the role of Embrapa in the conservation and use of seas and oceans and how this commitment is presented in the Company's Master Plan.

*Technical Editors*

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[1] Available at: https://sustainabledevelopment.un.org/sdg14

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Chapter 1

# Life below water: conservation and responsible use of seas, oceans and coastal environments

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## Introduction

Oceans cover three quarters of the planet surface, connect populations through ports and markets; are, thus, an important natural and cultural heritage for humanity. Marine environments offer important environmental services: they provide approximately half of the oxygen we breathe, absorb more than a quarter of the carbon dioxide ($CO_2$) we produce, play an important role in water cycle and climate system, and are an essential source of biodiversity. All this contributes to marine and continental ecosystem sustainability, to economic development, to poverty eradication, to food security, to transportation and maritime traffic, to decent work opportunities and means of survival (United Nations, 2017).

Despite the many benefits that life in water brings us, the adverse effects of global changes aggravated by human action can be perceived in ocean temperature rising, acidification of seas and coastal zones, deoxygenation of marine environments, rising sea level, polar ice caps melting, erosion of coastal zones, silting of river mouths, extreme winds, pollution, disorderly exploitation of oil resources, reduction of fish stocks, changes in physiology and metabolism of aquatic species as a result of harmful substance bioaccumulation in the environment, overfishing, illegal fishing, conflicts, among many other.

In order to organize a forum for discussing and aligning decisions on the sustainability of the oceans, in 1982 in Montego Bay, Jamaica, the *United Nations Convention on the Law of the Sea* (UNCLOS) was signed, which has standardized numerous actions, such as maritime transit, border delimitation, environmental regulations, scientific research, trade and international conflict resolution. Brazil ratified its participation in UNCLOS on December 22nd, 1988 (United Nations, 2017). In 2012, the *United Nations Conference on Sustainable Development* (*Rio+20*) considered the oceans and coastal waters as fundamental for the planet survival, emphasizing the importance of their conservation and responsible use, also for poverty eradication, food security and decent work, while protecting biodiversity, the marine environment and populations and countries dependent on marine fishery resources, and proposing reduction and remediation of climate change impacts on these ecosystems (Beirão; Pereira, 2014).

Faced with this worrying scenario, in September 2015, 193 United Nations (UN) member states gathered to discuss a new global agenda committed to people, the planet and peace. The 2030 Agenda for Sustainable Development presents 17 sustainable development goals (SDG) and 169 targets designed to foster a better world (Machado Filho, 2017). Among these goals, Goal 14, entitled Life Below Water, was created to promote, in general terms, the conservation and sustainable use of oceans, seas, other fishery resources and coastal zones.

## SDG 14 and its relation with the world

The movement of the oceans, through marine currents, distributes nutrients and heat to coastal areas (Figure 1), being the energy that moves life on the planet, the motor that regulates various natural processes that generate our food, renew the water and air we breathe. Throughout history and to the present day, oceans and seas are vital for trade, transportation, energy and wealth generation and food (United Nations, 2016).

Oceans contain 97% of the planet's water and cover three quarters of the Earth's surface. It is not by chance that more than 3 billion people depend on the seas and oceans for their livelihood, generating about 5% of the world's gross domestic product (GDP) or approximately US$ 3 trillion per year as a result of use, trade and other activities related to marine resources and industries. However, the potential value of these resources can never be estimated, since there are millions of unidentified marine species and only 200,000 known (United Nations, 2017).

Among the many biological functions seaweed species perform, they absorb atmospheric carbon dioxide from greenhouse gas emissions, whose main side effects have been acidification of the seas and oceans and global temperature rise. These same species that help regulate the planet's climate join the food chain that feeds billions of people who depend solely on the oceans. Indirectly,

Photo: Fabíola Helena dos Santos Fogaça

**Figure 1.** Detail of the coastal area of Piauí, Brazil.

marine fisheries employ 200 million people worldwide. Besides offering jobs and food to the world's populations, fisheries, if managed irresponsibly, contribute to the depletion of many fish species and hamper organized and sustainable management of global fisheries, leading to immeasurable social, environmental and economic losses. It is therefore estimated that up to 40% of the oceans are affected by human activities, such as pollution, depleted fisheries and loss of coastal habitats (United Nations, 2017).

The problem with the oceans sustainability is so serious that, in 2017, an article published in the scientific journal *BioScience*, signed by 15 thousand scientists from 184 countries and entitled *World Scientists' Warning to Humanity: A Second Notice*, describes that the 1992 forecasts disseminated at the *United Nations Conference on Environment and Development,* also known as *Eco 92*, were exceeded due to the rapid world population growth (35% increase), and, consequently, there were increased carbon dioxide emissions from fossil fuel use, high impact agriculture, deforestation, drought, loss of marine life and increased so-called dead zones in the oceans (Ripple et al., 2017).

Careful management of this resource is essential for sustainable development. In addition, coastal and marine resources are extremely vulnerable to the impacts of environmental degradation, pollution, overfishing and global climate change. In this sense, the following are some important concepts related to such impacts, which are also particularly relevant to Brazil, and have based the 11 sustainable development targets proposed in the 2030 Agenda (Brasil, 2017).

The proposed targets include avoiding and significantly reducing, by 2025, all types of marine pollution, particularly those from land-based activities, which cause the dispersion of debris and pollution by nutrients, and lead actions mainly related to disposal, management and treatment of solid wastes, such as sewers and effluents. Targets also include sustainably managing and protecting marine and coastal ecosystems, thus strengthening their resilience and taking action for their restoration, in order to achieve healthy and productive oceans by means of conservation of coastal zones, regarded as marine life nurseries. In the same path, by 2020, conserving at least 10% of coastal and marine areas, in accordance with national and international laws and based on the best available scientific research is also a target (United Nations, 2017).

In order to control and monitor climate change in these environments, one of the targets is to minimize and address the impacts of ocean acidification through improved scientific cooperation at all levels. Accordingly, the European calls for submissions to Horizon 2020 (European funding program for research and innovation) are already creating inter-institutional and multidisciplinary networks with the same research focus to broaden knowledge, prioritize and plan actions for coexistence and climate change effect reduction on marine ecosystems. The relation between environment, people and fisheries, in all its aspects, is included in specific targets. Some of them are, by 2020: to regulate harvesting and end overfishing, illegal, unreported and unregulated fishing, as well as to extinguish destructive fishing practices; to implement science-based management plans in order to restore fish stocks in the shortest time feasible, at least to levels that can produce sustainable fisheries development for exploited species; and to provide access for small-scale artisanal fishers to marine resources and markets. Targets also seek to prohibit certain forms of fisheries subsidies that contribute to overcapacity, overfishing, illegal, unreported and unregulated fishing, and the negotiation of fishing subsidies should be dealt with in the World Trade Organization (WTO), prioritizing actions that also benefit the developing and least developed countries (United Nations, 2017).

A number of targets show a great deal of concern about small island developing states and least developed countries. This is because, in the UNCLOS treaty, these countries are already a priority in order to guarantee their sovereignty over their exclusive economic zone (EEZ) and territorial sea. As a result, by 2030, these states could have more economic benefits from the sustainable use of marine resources, including sustainable fisheries management, aquaculture and tourism. For this reason, there will be worldwide investment in broadening scientific knowledge, research capacity and transfer of marine technology in order to improve ocean health and increase the contribution of marine biodiversity to the development of these countries. And finally, it is expected to improve the conservation and sustainable use of oceans and their resources through the implementation of international law, as reflected in the final declaration of the *Rio+20: The Future We Want* (United Nations, 2012).

## Important data and facts about SDG 14 in Brazil

Brazil has a coastal area with over 500,000 km$^2$, home to 19 Brazilian metropolises where 45.7 million people (24% of the country's population) live (IBGE, 2017). This urban concentration, which places pressure on coastal natural resources, is interspersed with low population density areas, inhabited by fishermen populations and traditional peoples with close relation with marine biodiversity (Brasil, 2017). Because of that and of the economic potential of seas and oceans, Brazil has been focusing on commitments ratified in international conventions and treaties to guarantee its sovereignty over its EEZ by means of designing national policies for the sustainability of seas and oceans.

First, Brazil committed itself to participate in discussions on the Law of the Sea by formulating a proposal for setting the ocean limits of Brazil in order to protect our interests in relation to the so-called Blue Amazonia territory, because of its scale and rich diversity; interest grew after the Pre-Salt layer (Lima, 2015) was discovered. Since then, in addition to its active participation in the *United Nations Convention on the Law of the Sea,* Brazil also became a signatory to conventions on biological diversity and climate change (Machado Filho, 2017).

Subsequently, other programs and projects were developed. The main objectives of Programa Oceanos, Zona Costeira e Antártica (Oceans, Coastal Zone and Antarctic Program) are personnel training, carrying out scientific research to promote environmental conservation and learning about mineral and biological potential of international areas and the Brazilian continental shelf, and shaping the Política Nacional para os Recursos do Mar (National Policy for Sea Resources – NPRS), which provides for the shared marine environment use and coastal zone management, including its exploitation rights (Brasil, 2017).

Another marine coastline integrated management project, named Projeto Orla (Coastline Project), focuses on the Brazilian coastline (Figure 2), whose goal is to scan 100% of the coastal zone by 2019. Based on gathered information, it will be possible to assist coastal municipalities in sustainably using and occupying terrestrial space and preventing erosive processes, contamination of water bodies and social conflicts between fishing, tourism, aquaculture and space occupancy (Brasil, 2017).

Photo: Luiz Eduardo Lima de Freitas

**Figure 2.** Detail of the occupancy on the coast of Santa Catarina, Brazil.

In 2016, the Plano Nacional de Adaptação à Mudança do Clima (National Adaptation to Climate Change Plan – NAP) was implemented to promote Brazil's adaptation to climate effects in coastal and marine areas. Also aiming at the conservation of coastal areas, in addition to funding federal conservation units, the government plans to create other 11 units and expand protected areas to reach 5% of the Brazilian territory by 2019 (Brasil, 2017).

With regard to fisheries and aquaculture, in addition to funding through research agencies and the Plano de Desenvolvimento da Aquicultura Brasileira (Brazilian Aquaculture Development Plan – ADP) – with over BRL 500 million available for investment in the area –, in recent years, the Ministry of the Environment (MMA) and its partners (universities, institutes, non-governmental organizations – NGOs, Brazilian Agricultural Research Corporation – Embrapa, Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – Ibama and Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio) fostered plan formulations for managing fishery resources for relevant species under risk of overfishing (lobsters, sardines, soft crabs, crabs, prawns, mullets, elasmobranchii, seahorses, groupers, snooks, sea basses, etc.) with emphasis on regulations for fishing and satellite monitoring of vessels in order to reduce marine fauna vulnerability (Machado Filho, 2017).

## Embrapa actions for SDG 14 targets

Embrapa participation in research related to marine fishery resources began with the work of Embrapa Food Technology, located in Rio de Janeiro, which started developing studies on more than 27 years ago (Rebelatto Junior et al., 2014). According to a survey on the performance of Embrapa in research, development and technology transfer in the areas of fisheries and aquaculture, there are only four Embrapa Units dealing with marine and estuarine ecosystems: Embrapa Amapá, in the state of Amapá, Embrapa Food Technology, in the state of Rio de Janeiro, Embrapa Mid-North, in the state of Piauí, and Embrapa Coastal Tablelands, in the state of Sergipe (Rebelatto Junior et al., 2013).

Since 2002, Embrapa Mid-North has been carrying out research, development and technology transfer for conservation and management of estuarine and marine aquaculture resources. As of 2009, Embrapa Coastal Tablelands joined a research network with over 20 institutions and made official its participation in discussions related to marine aquaculture. There are also several both finished or ongoing actions and local projects led by other Embrapa Units throughout Brazil, mainly focused on fishing, some of which to encourage its sustainable development and others to investigate marine biotechnology, genetic resources and food processing. These projects related to marine and estuarine fishery resources will be described in the following chapters.

Thus, it is clear that Embrapa already participates in actions that coincide with SDG 14 targets. The fact that this theme is embedded in several goals of Embrapa

Master Plan (PDE), which establishes its strategic map for 2014 to 2034 (Embrapa, 2014) is a proof of this. Among these goals, the following can be mentioned: 1) developing new sciences, because of the enormous demand for knowledge and technologies in this area; 2) researching natural resources and climate change: fully aligned with targets set by UN; 3) developing production systems: developing possibilities for producing quality food in the seas, avoiding overexploitation of marine resources or even freshwater sources; and 4) generating technologies to ensure food security, nutrition and health: the importance of quality marine fish for export, for the human diet and for the subsistence of numerous Brazilian families.

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Chapter 2

# Current situation of seas, oceans and coastal regions

Marcos Tavares-Dias

## Introduction

Marine environments, which include oceans, seas and adjacent coastal areas, are an essential component that enables the existence of life on Earth and whose richness opens numerous possibilities for sustainable development. They house a wide variety of living organisms, providing products and services essential to man's survival, such as food, climate maintenance, water purification, flood control and coastal protection, along with the possibility of recreational and spiritual use. Well-conserved coastal and marine areas have much greater biological diversity than converted areas, and their ecosystems provide much more diverse and effective services (United Nations, 2016).

Despite countless efforts of many countries to promote the sustainable management and use of seas and oceans, fostered by the institutional action of the United Nations (UN), there is no global, joint, delimited, and specifically targeted plan for all users of marine and coastal resources. In practice, many actions are taken, but there is no global consensus on anticipation approach, precautionary measures, systematic assessments of environmental impacts in all parts of the planet, mandatory use of clean technologies, recycling, control and reduction of sewage emission, construction and/or improvement of sewage treatment plants, qualitative criteria for the proper management of hazardous substances and comprehensive approach to harmful impacts from air, land and water. Therefore, there is no management structure, including integrated coastal zone management and development. Proof of this is that the main polluting countries did not sign the Kyoto Protocol (global agreement to reduce carbon dioxide emissions). There are still many economic barriers to be discussed in the United Nations Convention on the Law of the Sea (UNCLOS). Japan continues to engage in predatory fishing, and the United States has recently officially left the Paris Convention, showing that they have no interest in contributing to reducing global warming.

## Aspects of the Brazilian coast

In Brazil, the survival of several ecosystems present along our 10,800-km-long coastline is threatened by disordered occupancy, pollution, deforestation, among other problems. The beaches, environments well known by the population, are deposits of sand accumulated by fluvial or marine transportation agents and have variable width by reason of the tide. They are often associated with other coastal ecosystems, such as estuaries, deltas, *restingas*, mangroves, dunes, rivers and intertidal marshes, and occur along the entire coast, from the state of Amapá to Rio Grande do Sul, making up 82,778 ha. They are threatened by real estate speculation, uncontrolled tourism, expansion of marinas and urban and industrial pollution.

The beaches closest to ports and urban centers, especially those in more sheltered places and with less water renovation (estuaries and bays), have poorer water quality, with very high annual mean values of bacteria and very low of oxygen (hypoxia) (Machado Filho, 2017). This situation reflects the low percentage of sewage and effluent treatment, which end up being collected and dumped into bodies of water, thus generating, in the case of Brazil, six dead zones in the states of Pernambuco, Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul (Simcock et al., 2016).

The mangrove is another coastal ecosystem of equal importance for sea and ocean conservation. It is estimated that 8.5% of the world's mangrove areas (Spalding et al., 2010) and the largest continuous mangrove forest, of about 6,500 $km^2$ (United Nations, 2016), are located in Brazil. Mangroves are areas with fine sediments that undergo tidal action and present typical vegetation such as *Rhizophora mangle*, *Avicennia schaueriana* and *Laguncularia racemosa*, which stabilize sediments between their roots and trunks, a process in which pollutants are also trapped, thus preventing them from contaminating adjacent coastal waters. Mangrove sediments are inhabited by numerous benthic fauna, especially crustaceans, which are exploited by local communities.

Mangroves are also an important primary producer of the marine environment, transforming mineral nutrients into organic plant matter (phytomass), which, in addition to supporting the base of coastal food webs, generate ecosystem goods and services that include carbon sequestration, climate regulation and protection of coastal zones from silting. Mangroves are threatened by real estate speculation, pollution, silting of river beds that cause their salinization, high impact agriculture and aquaculture development in inappropriate areas (United Nations, 2016).

## Agriculture and its effects on coastal regions

Embrapa has made an effort to generate technologies for rational input use. However, the agricultural model adopted by Brazil (monoculture based on heavy use of fertilizers and agricultural pesticides) is still considered as one of the main forms of environmental degradation. Brazil is the world's largest consumer of agrochemicals, with over 1,000 tons per year. Soy, corn, citrus and sugarcane account for about 70% of agrochemical use. Agrochemical consumption reached 6.7 kg $ha^{-1}$ in 2014 (IBGE, 2016). In 2001, a survey carried out by Companhia Ambiental do Estado de São Paulo (Environmental Company of the State of São Paulo – Cetesb) in samples of water, sediments and living organisms from the estuary system of Santos and São Vicente, on the coast of the state of São Paulo, showed the presence of persistent contaminants and organochlorine pesticides, such as BHC (Hexachlorobenzene), in concentrations above the limit (Companhia de Tecnologia de Saneamento Ambiental, 2001). These substances cause mortality of aquatic organisms, coastal zone's food chain unbalance, and serious health problems to people who eat food and drink water from these places. Because they are bioaccumulated, many of those substances remain in organisms and water and end up being release throughout the ocean; therefore, pesticide residues have already been found in Polar Regions, where there has never been agriculture (United Nations, 2016).

## Mining and its effects on coastal regions

Mining tailings are another source of pollution. Brazil is rich in minerals, and its exploitation is essential for wealth creation and consumer good manufacturing in Brazil; however, residues are almost always not cared for. This fact was proven in November 2015, when the iron ore mining tailings containment dam at Fundão, in Mariana, state of Minas Gerais, owned by Samarco Mineração S.A. (Vale S.A. and BHP Billiton), bursted, releasing 60 million cubic meters of tailings into the environment. Mud reached the Rio Doce river basin, which covers 230 municipalities in the states of Minas Gerais and Espírito Santo, many of which supplied its population with river water.

Sludge from tailings with high amounts of arsenic, lead and mercury (originating from mines) reached the Atlantic Ocean and spread over 10 km of the Espírito Santo coast, thus affecting many marine fauna and flora species. One of these is *Kishinouyea corbini*, a not very much studied and extremely rare cnidarian, whose geographical distribution is restricted and overlaps with the area affected by this environmental disaster (Miranda; Marques, 2016). Studies conducted by the Serviço Autônomo de Água e Esgoto (Autonomous Water and Sewage Service – SAAE) of Baixo Guandu, in the state of Espírito Santo, in 2015, proved that Rio Doce is dead because of the sediment transport to its bed which caused mortality of its fauna and flora, and little is known about what will happen to the affected adjacent ecosystems (Baixo Guandu, 2015). Brazil has not yet developed any mitigation plan for the effects caused by the dam failure, nor has it designed precautionary policies in case of these events.

## Oil exploitation and its effects on coastal regions

In addition to ores, it is from the sea floor that Brazil withdraws most of its oil and natural gas. Oil industry, especially in deep marine waters, has been significantly growing in recent years and undergoing a profound transformation. Platform and pipeline installation and operation, vessel traffic and land installations directly interfere with the coastal zone, affects the growth of cities and modifies local populations socioeconomic activities, including the Amazon River Basin region.

Oil industry activities begin with remote surveys that, later, lead to seismic activities and well drilling, which may cause disruption to marine organisms; atmospheric emissions from ships' engines and discharges of organic and inorganic waste from seismic and its auxiliary vessels (Silva Junior; Magrini, 2014; United Nations Environment Programme – Finance Initiative, 2017); as well as conflicts such as sea fishing. Drilling can directly impact the biota due to the discharge of mud from this procedure in the ocean (United Nations Environment Programme – Finance Initiative, 2017).

## Fishing and environmental conservation

All these factors have led to the loss of biodiversity because measures to prevent degradation and promote compromised environments recovery have not been adopted. Fishing is added to this worrying picture. Over-exploitation of fishery resources (mainly fish, shellfish and crustaceans) at rates higher than reproduction and/or target population recruitment rates is frequent due to lacking or few activity regulations and local and regional management and planning measures, as established by environmental authorities, especially because economic and social parties rarely engage in and participate.

An analysis of the main marine fishing resources in Brazil in South Atlantic areas revealed that fish such as albacore (*Thunnus albacares*, *T. alalunga* and *T. atlanticus*), swordfish (*Xiphias gladius*), dolphinfish (*Coryphaena hyppurus*), mackerel (*Scomberomorus cavalla* and *Scomberomorus brasiliensis*), sailfish (*Istiophorus albicans*, *Makaira nigricans* and *Tetrapterus albidus*) are under full exploitation or overfishing. Demersal fish such as whitemouth croaker (*Micropogonias furnieri*), argentine croaker (*Umbrina canosai*), striped weakfish (*Cynoscion guatucupa*) and king weakfish (*Macrodon ancylodon*) are fully exploited or even overfished (Dias Neto; Marrul Filho, 2003). There are signs of reduced stocks of mangrove crab (*Ucides cordatus*) in 10 states of Brazil, and of blue land crab (*Cardisoma guanhumi*), the largest brackish of mangrove/*restinga* areas in Brazil, and, therefore, economically important, is already on the list of endangered animals (Dias Neto, 2011).

In this same situation of declining population is the Brazilian sardine (*Sardinella brasiliensis*), the most caught fish in the Southern and Southeastern coast of Brazil, where both artisanal and industrial fishing take place. Industrial fishing developed due to governmental tax incentives in the 1960s, resulting in high production related to increased fishing effort. Over the last decade, Brazilian sardine fishing has declined, leading to a decrease in sardine sector activities (Silva; Flores, 2016). The same occurs in the Northern region between the coast and the platform of the states of Amapá and Pará, where there are many mangroves and the strong influence of the Amazon River continental discharge. There, about 40 marine fish species, 4 crustacean species and 2 shellfish species are (artisanally and industrially) explored (Castello, 2010), but it fishery management and stock management are still incipient.

## The Amazon in the context of conservation

The importance of conservation, management and sustainable use of natural resources in the Amazon region has increased over a year ago, when the existence of a coral area at the Amazon River mouth was reported; it ranges for over 700 km on the coast from the border of the state of Maranhão in Brazil to French Guiana. It is estimated that these corals occupied an area of approximately 40,000 km$^2$, reaching more than 200 m in depth. It is interesting to note that the Amazonian corals are in a river mouth region, where fresh and salt water are mixed and much sediment is brought by the Amazon River, thus hindering the passage of light and altering water salinity and pH levels.

This environment is home to endangered species and not-yet-described-by-science species, as well as a large concentration of rhodoliths (set of calcareous red algae), which absorb carbon diluted in sea water to produce calcium carbonate with which they build their skeleton. This helps to remove carbon from the atmosphere, which gets accumulated in the seabed for thousands of years, thus contributing to the planet's climatic balance.

There is also evidence that this complex set of rhodoliths, corals, and sponges work as a biodiversity corridor that allows species to move between the Caribbean and the Atlantic Ocean (Moura et al., 2016). This Amazon River mouth region is threatened by oil exploration. Conserving this peculiar environment is crucial for maintaining ocean biodiversity, and its destruction can trigger economic and social problems for local traditional populations who rely on marine resources. As the coastal regions of Brazil, Guianas (Guyana, French Guiana and Suriname) and the Caribbean are connected by the coral biodiversity corridor, impacts in this region could also affect the biodiversity of several other countries.

## How Brazil can enhance SGD 14

Although Brazil has created most conservation areas in the world over the last 10 years, its marine region is poorly protected. Only 1.57% of the 3.5 million km$^2$ of its sea is under protection in conservation areas (Machado Filho, 2017). Brazil has committed to protect 10% of its marine area by 2020, according to targets of UN's Sustainable Development Goals. However, only 2% of its coast and coastline are protected under some form of conservation unit.

In addition, the marine biodiversity of the Brazilian coastal zone is little known. Many regions, ecosystems and environments still need to be properly inventoried. In 2010, a survey conducted by the Ministry of Environment (MMA) selected 239 different conservation targets: 85 in coastal ecosystems, 55 in marine ecosystems and 99 coastal and marine species (Table 1) (Prates et al., 2012). Based on these conservation targets, the Instituto Chico Mendes de Conservação da Biodiversidade (Chico Mendes Institute for Biodiversity Conservation – ICMBio) identified threatened species under risk of extinction in order to design plans to recover them; however, these plans are still being drafted and have not yet been implemented in practice.

The Agenda 21 Global Program, of which Brazil is a member, recommends adhering countries to protect and conserve the marine environment based on

**Table 1.** Regions and their conservation targets for the coastal and marine areas.

| Region | Territorial space | Number of defined conservation targets | Total conservation targets |
|---|---|---|---|
| South | Arroio do Chuí (state of Rio Grande do Sul) to Cabo de Santa Marta (state of Santa Catarina) | 27 ecosystem targets<br>23 species targets | 50 |
| Southeast-South | Cabo de Santa Marta (state of Santa Catarina) to the limit between the states of Espírito Santo and Bahia, including the islands of Trindade and Martim Vaz | 26 coastal targets<br>17 oceanic targets | 43 |
| Northeast | Limit between the states of Espírito Santo and Bahia to the limit between Maranhão and Piauí, including the Archipelago of Fernando de Noronha and Atol das Rocas | 22 coastal targets<br>17 marine life targets<br>33 species targets | 72 |
| North | Limit between Maranhão and Piauí to Rio Oiapoque (state of Amapá) | 17 coastal ecosystem targets<br>13 coastal species targets<br>14 marine ecosystem targets<br>30 marine species targets | 74 |

Source: Prates et al. (2012).

regional and global cooperation, adopt laws and regulations to try to reduce marine pollution, mainly from land-based sources, and protect oceans, seas and coastal zones for the rational use and development of their living resources in order to achieve sustainable development. It also recommends the integrated management for the development of coastal zone and exclusive economic zones and for the sustainable development of small islands. It also lists the methods and mechanisms for coordinating and implementing integrated programs to manage these resources by establishing measures for maintaining biodiversity and increasing productivity (United Nations Conference on Environment and Development, 1992). However, in recent years, few actions have been taken for marine conservation in Brazil, despite commitments made 25 years ago.

Urgent action is needed to reduce land pollution, which accounts for 80% of marine pollution, including reduction of agricultural waste that eventually drains into the oceans and causes dead zones. Actions to stop excessive, illegal and destructive marine fishing practices, measures for the sustainable management, protection and conservation of marine and coastal ecosystems and community-based conservation measures and environmental education to increase people's awareness are needed.

Implementing the Paris Agreement on Climate Change is essential to reduce emissions that are causing changes in our oceans and to adopt measures to promote resilience to the impacts of ocean acidification and climate change, such as rising sea levels. In Brazil, effective mechanisms are lacking for regulations to be effectively enforced. In the specific case of coastal ecosystems degradation, integrated coastal management should be the ultimate goal. However, it is also very difficult to get local parties involved in integrated management and to integrate river basin management with coastal zone management. In addition, there is a lack of information about occupancy and impacts on the coastal zone and marine ecosystems that is reliable, updated and detailed enough for planning needed actions.

Therefore, the chapters of this book will be important to set a starting point based on the actions already carried out by Embrapa that contributed to ocean and sea conservation, to provide relevant information for Brazil to plan its future actions within 2030 Agenda.

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Chapter 3

# Conservation, use and management of marine resources and ecosystems

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## Introduction

Brazil has an important marine biodiversity heritage, distributed over sandy beaches, rocky shores, mangroves, estuaries, coastal lagoons, limestone algae reefs and endemic corals, islands and oceanic banks, and the only atoll in the South Atlantic Ocean (Rocas). This physiographic complexity is home to a stock of invaluable and under-exploited genetic resources (Mar..., 2008). The use of resources focuses on fishing activities, oil and gas exploration, marine aquaculture, tourism and leisure. Other potential uses include deep-water mineral exploration and prospecting for biodiversity active ingredients in tropical regions and inhospitable habitats for medical-pharmacological, cosmetic and food industries (Mar..., 2008). Biotechnology potential is promising, but initiatives are still experimental and fragmented (Caracterização..., 2010). In order to protect and rationally use its marine resources and ecosystems, Brazil has been improving its laws, creating conservation units (UC) and implementing management plans based on applied scientific studies of biodiversity and environmental, ecological and socioeconomic processes (Frighetto; Queiroz, 2005).

Within this context, the present chapter addresses the actions of Embrapa, in partnership with national and international research, development and innovation institutions (PD&I), to advance scientific knowledge and technology transfer in order to improve the health of oceans and increase the contribution of marine biodiversity for developing countries sustainability (target 14.a). Here, studies, assessments and management tools for marine resources conservation and use (target 14.1) are presented as inputs to avoid significant adverse impacts of human activities and to take measures to protect, restore and regulate coastal and marine areas, in accordance with national and international laws (targets 14.2, 14.4 and 14.5).

## Actions of Embrapa for marine resources conservation

Actions of Embrapa to promote marine and estuarine resources conservation are very recent; they date back to 2003, when Embrapa Mid-North launched projects focused on the mangrove crab (*Ucides cordatus*) in the Environmental Protection Area (APA) of the Parnaíba River Delta, between the states of Maranhão, Piauí and Ceará (Ivo et al., 1999). As a scientific basis for the management of this important fishing resource in the Northern and Northeastern regions of Brazil, Embrapa Mid-North and Embrapa Amapá, with the collaboration of the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute of Environment and Renewable Natural Resources – Ibama), of the Instituto Chico Mendes de Conservação da Biodiversidade (Chico Mendes Institute for Biodiversity Conservation – ICMBio), of the Federal University of Piauí (UFPI), the State University of Piauí, the State University of Amapá and the Instituto de Pesquisas Científicas e Tecnológicas do Estado do Amapá (Institute of Scientific and Technological Research of the State of Amapá – Iepa), have conducted studies on reproductive biology, distribution, abundance, ecdysis period and population composition in different mangrove ecosystems (Góes et al., 2005; Legat et al., 2007; Amaral et al., 2014; Santos et al., 2018). Embrapa Mid-North, in partnership with UFPI, Federal University of Ceará (UFC), Federal Rural University of Pará (UFRPA) and Dalhousie University (Canada), also developed molecular tools to investigate diversity and genetic structure; they found that a single population of mangrove crab exists in the Northern and Northeastern regions (Mendes et al., 2007; Britto et al., 2009, 2011a, 2011b, 2018; Araújo et al., 2015; Diniz, 2015).

Focusing on the production chain in the states of Maranhão, Piauí and Ceará, Embrapa Mid-North also developed methods to catch, store and transport that reduced the mortality rate of live marketed crabs from 50% to 3% (Legat et al., 2005, 2006; Legat; Legat, 2009). Research results helped keeping natural stocks and designing the management plan for mangrove crab in the APA of Parnaíba River Delta; it also served as input for Normative Instruction number 9, of July 2, 2013 (Brasil, 2013), on standards and methods mangrove crab transportation in the states of Pará, Maranhão, Piauí and Ceará (Figure 1), and for Ordinance number 725, of November 6$^{th}$, 2017, which approves rules for the sustainable use of mangrove resources in the APA (Instituto Chico Mendes de Conservação da Biodiversidade, 2017).

Photos: Francisco das Chagas Machado Brandão

**Figure 1.** Detail of crab transportation on boats and trucks according to regulations.

Since 2004, Embrapa has expanded its research activities on marine genetic resources in order to support designing public policies on sustainable use for fishing and marine aquaculture. In terms fishery resources conservation, Embrapa Mid-North coordinated studies on genetic diversity and population structure of lobsters (*Panulirus argus* and *Panulirus echinatus*), in partnership with UFC, UFRPA, Dalhousie University (Canada), University of Southampton (UK) and University of Central Lancashire (UK) (Diniz et al., 2004, 2005a, 2005b, 2007, 2010; Quadros et al., 2007a, 2007b; Soares et al., 2010; Santos et al., 2018); of croaker (*Micropogonias furnieri*) (Puchnick-Legat; Levy, 2006; Chaguri et al., 2014), with the Federal University of Rio Grande (Furg) and Federal University of Pará (UFPA); and of the blue land crab (*Cardisoma guanhumi*), with UFPI, University of Nebraska (USA) and the National Park Service (USA) (Amaral et al., 2015).

Regarding the conservation of genetic resources with aquaculture potential, Embrapa has joined three national research networks: 1) Rede de Ostras Nativas (Native Oysters Network), coordinated by the Federal University of Santa Catarina (UFSC), in which Embrapa Mid-North, in partnership with the Federal University of Rio de Janeiro (UFRJ) and the Federal Rural University of Pernambuco (UFRPE), took part in the molecular identification of native oyster species of the genus *Crassostrea*, distributed in the Brazilian coast from Maranhão to Santa Catarina; this provided input to differentiate and separate species for aquaculture (Legat et al., 2009; Puchnick-Legat et al., 2010); 2) Rede de Recursos Genéticos Animais (Animal Genetic Resources Network), under the coordination of Embrapa Genetic Resources and Biotechnology, Embrapa Mid-North standardized morphological descriptors with the aid of molecular markers and created tissue and DNA banks for native oyster species (*Crassostrea gasar* and *Crassostrea rhizophorae*) and shrimps (*Farfantepenaeus subtilis*, *Farfantepenaeus brasiliensis*, *Litopenaeus schmitti*) in the Northeastern region of Brazil; 3) Rede de Piscicultura Marinha (Marine Fisheries Network), coordinated by Embrapa Coastal Tablelands, Embrapa Genetic Resources carried out the phylogeographic study of cobia (*Rachycentron canadum*), in partnership with Embrapa Coastal Tablelands, Embrapa Mid-North and the Instituto de Pesca de São Paulo (São Paulo Fisheries Institute), in order to understand the species genetic diversity distribution in Brazil for the creation of a germplasm bank (Nepomuceno et al., 2013). Embrapa Mid-North, UFSC and UFRJ also assessed the risk of natural hybridization between the invasive oyster (*Crassostrea gigas*) and native oyster species (*C. rhizophorae* and *C. gasar*) on the coast of Santa Catarina. Experimental results in laboratory demonstrated that interspecific hybrid larvae do not complete their development and die, which means that current genome incompatibilities between species prevent natural hybridization and the genetic integrity of native oysters is not threatened so far by the invasive exotic species (Legat, 2015).

## Actions of Embrapa in marine biotechnology

In the areas of biotechnology and nanotechnology, since 2005, Embrapa has been conducting research studies on bioactive substances produced mainly by algae, sessile invertebrates and bacteria with great potential for the food, pharmaceutical, cosmetics, agriculture and bioremediation industries. Embrapa Genetic Resources and Biotechnology, in partnership with the National Institute of Health of the United States and the University of London, has been conducting studies on cyanovirin, a protein produced by blue-green seaweed (*Nostoc ellipsosporum*) that can prevent the HIV virus (human immunodeficiency virus) multiplication in the human body (Diniz et al., 2015). The research involved introducing the substance into genetically modified soybeans for large-scale production. The next phase after seed production will isolate cyanovirin and start clinical trials, in collaboration with the Council for Scientific and Industrial Research of South Africa.

Embrapa Genetic Resources and Biotechnology also conducted, in collaboration with UFSC and the University of Brasilia (UnB), the cloning and characterization of the gene involved in the synthesis pathway of omega-3 polyunsaturated fatty acids in the marine microalga *Thalassiosira fluviatilis*, thus creating a molecular tool to help increase the concentrations of these fatty acids in oil seeds that are important food sources for human health (Caracterização..., 2010).

As of 2007, Embrapa joined expeditions to the Antarctic continent to collect and prospect marine biodiversity active molecules from extreme environments. Embrapa Genetic Resources and Biotechnology collected biological resources of notothenioid fish to learn about the molecular mechanisms they developed to resist extremely low temperatures; the aim was to develop prototypes for frozen semen and embryos preservation or for cold tolerance selection programs (Costa et al., 2012). Embrapa Environment studied ultraviolet-C ray resistant bacteria by performing the genome sequencing of *Rhodococcusery thropolis* P27, with greater biotechnological potential; and analyzed the genome of bacterial species of the genus *Bacillus* that are more environmental stress resistant, in partnership with the State University of Campinas (Unicamp) and the University of São Paulo (USP), revealing its potential for producing antibiotics (Souza et al., 2011).

Among the Brazilian biodiversity resources, Embrapa Environment, Unicamp and USP studied active compounds present in the extract produced by M137 fungus, isolated from the marine sponge *Aplysina fulva*, against the pathogen *Staphylococcus aureus*, which is methicillin resistant (MRSA) (Martins et al., 2016), and also tested the inhibitory efficiency of extracts obtained from marine sponges *Kocuria palustres* against fish bacteria and considered them a potential source for aquaculture (Schinke et al., 2014). Researchers from Embrapa Eastern Amazon, State University of Amazonas, State University of Rio de Janeiro and Federal Fluminense University analyzed the use of extracts from red marine seaweed *Asparagopsis taxiformis* on inhibiting weeds growth in the Amazon and evidenced their potential as a bioherbicide (Diniz et al., 2011). Finally, Embrapa Tropical Agroindustry has been developing biodegradable packages based on seaweed polysaccharides, among other natural polymers, to wrap food in biodegradable materials that are as efficient and inexpensive as plastic, in order to reduce environmental damage (Sociedade Nacional de Agricultura, 2014).

## Environmental contamination impacts on seas and oceans

Because of growing concern about pollution by debris (mainly plastic ones), organic pollutants, heavy metals and nitrogen compounds discarded by various marine and terrestrial sources, Embrapa has been conducting impact analysis studies on marine biodiversity and coastal ecosystems (target 14.2). Embrapa contributed with the Federal University of Rio Grande (Furg) and the Southern Cross University (Australia) in assessing pollution by debris along the most important sea turtle nesting beaches of Bahia coast. Debris rates observed shows that pollution control agreements are not being followed in the Brazilian coast (Sul et al., 2011).

Embrapa Coastal Tablelands and UFPA investigated the effect of metabisulphite, used in the marine shrimp aquaculture, on the mortality of mangrove crabs. Results revealed that it is a significantly toxic substance and that crabs can be used as a bioindicator in monitoring Brazilian mangroves (Pedale et al., 2012). Embrapa Environment, USP and the Northern State Fluminense University investigated the amount of carbon and nitrogen discharged by the Paraíba do Sul River into the Atlantic Ocean by assessing biogeochemical processes along the river basin. Observed patterns reveal changes in land use due to increasing sugarcane production, which led to increased C and N concentrations in estuarine and marine ecosystems (Figueiredo et al., 2011).

Research conducted by Embrapa Environment, in partnership with USP and the Pontificia Universidad Javeriana (Colombia), identified mangrove fungi and bacteria responsible for the metabolism of methane, nitrogen and sulfur; thus, they revealed possible transformations promoted by microbial organisms in mangrove sediments. These results are important to encourage policies for conserving these areas and bioremediation and climate change control programs, as these organisms act as consumers of gases and debris from pollution (Andreote et al., 2012).

Studies on climate change in coastal and marine areas are recent at Embrapa. Among studies carried out in recent years, Embrapa Environment joined a research in partnership with USP, Unicamp, Federal University of Sergipe (UFS), Federal University of Pernambuco (UFPE), Rural University of Pernambuco (UFRPE), University of Waterloo (Canada) and Institut de Recherche por le Développement (France) that reconstructed vegetation changes (with climatic inferences) during the Holocene on the Fernando de Noronha island, in the state of Pernambuco, based on geochemical, carbon isotopes and pollen analyses in soils and sediments (Pessenda et al., 2008). The study concluded that there were no significant vegetation changes, but observed variations in mangrove ecosystem vegetation that may be associated with climatic events, sea level oscillations and also anthropogenic events over the last 500 years.

Embrapa Coastal Tablelands, in partnership with UFS and the Federal University of Campina Grande (UFCG), evaluated the trends in rainfall changes along the coast of the following states: Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. The study presented important information for the understanding of the rainfall regime and for the assessment of most critical rate spots, thus contributing to decision making regarding public policies (Cruz et al., 2017). Another study, conducted by Embrapa Eastern Amazon, UFPA and Sistema de Proteção da Amazônia (Amazon Protection System – Sipam), analyzed sea surface temperature change and its consequences on oscillating maximum daily rainfall volume over the Tomé-Açu region in Pará's Northeastern area (Bezerra et al., 2013)

## Actions of Embrapa for coastal zones conservation

In agreement with target (14.5) for conserving, by 2020, at least 10% of coastal and marine areas, in addition to the aforementioned actions of Embrapa

Mid-North in the APA of Parnaíba River Delta, Embrapa Environment and Ibama carried out joint studies to promote the environmental management of rural activities developed in the APA of Mamanguape River Mouth in the state of Paraíba. These studies supported the assessment of these activities sustainability and impacts on estuarine water resources and the implementation of the APA management plan (Rodrigues et al., 2005).

Embrapa Coastal Tablelands transformed part of its Experimental Field at Itaporanga into the Private Natural Heritage Reserve (RPPN) of Caju, comprising *restinga*, mangrove and *apicum* (hypersaline tidal flats) ecosystems associated to the Atlantic Forest biome. Subsequently, it designed and implemented the RPPN of Caju management plan including various programs and projects to be developed within 5 years to contribute to the natural resources and biodiversity conservation through environmental education actions and scientific research on sustainable use of renewable resources and environmental processes for the region's rural development (Nogueira Júnior et al., 2015).

Embrapa has become one of the Brazilian leaders in data management and in environmental modeling studies. One of the main products developed is the Agropensa database, created by the Embrapa Strategic Intelligence System, based on information from the Brazilian Institute of Geography and Statistics (IBGE). The platform is based on a large database collected since the 1990s and presents information about Brazilian agricultural production, and national aquaculture important information since 2013. It is possible to know where 20 different fish species and other seafood, such as oysters and shrimps, are being produced.

Aquaculture-specific data management stands out among actions led by Embrapa. Created by the Ministry of Agriculture, Livestock and Food Supply (Mapa) and coordinated by Embrapa Environment, the Rede Nacional de Pesquisa e Monitoramento Ambiental da Aquicultura em Águas da União (Aquaculture Research and Environmental Monitoring in Governmental Waters National Network) gathers over 15 institutions to generate and provide data, information and knowledge about aquaculture sustainability in reservoirs and in the Brazilian coast. The main objective of the network is to provide input for the federal government to design policies for aquaculture development based on possible impacts assessment and indicators for the monitoring and orderly and sustainable growth of this productive activity (Vicente, 2016).

Another project focused on information management is Aquapesquisa, coordinated by Embrapa Fisheries and Aquaculture, which has built an information database on information from public and private institutions, and non-governmental organizations dealing with fisheries and aquaculture research, development, teaching and outreach programs. Data also include technologies and knowledge supplied for and demanded by aquaculture and fisheries sectors, so that relevant demands for the development of fisheries and aquaculture can be identified and improved (Rebelatto Junior et al., 2013).

To assist in the biodiversity data management, Embrapa Agricultural Informatics analyzed the information system used by Unicamp in the theme project Biota Gradiente Funcional (Biota Functional Gradient), conducted at the Parque Estadual da Serra do Mar (Serra do Mar State Park), in the state of São Paulo. The analysis took into account environmental and biodiversity data integration and system applications and limitations for environmental conservation and management. Results lead to the conclusion that advancing the use of digital tools make data collected in individual surveys even more valuable to manage information on biodiversity and ecosystems (Drucker, 2012).

Embrapa Territorial, previously named Embrapa Satellite Monitoring, joins the DevCoCast international project and got a receiver installed that allows accessing the western component of the GEONETCast system. This system was created to access and disseminate geospatial information supplied by various providers around the globe, so that surface and atmosphere can be viewed and satellite image historical series can be obtained. Products based on analyzing these data can support technical and political decision making, productive sector planning, land use, access to federal waters and vegetation, extreme events and oceanographic data monitoring (Scussel, 2012).

In another study in partnership with Unicamp, Embrapa Territorial and the National Institute for Space Research (Inpe) assessed conflicts, uses, natural risks and vulnerabilities in the coastal zone of the state of São Paulo. The study was based on geospatial indicators and on the modeling of debris flows and flood events. Results indicated priority river basins for risk control, different analysis processes for different scales and suggested land use and coverage analysis to review coastal and urban management plans and to plan strategies to respond to natural disasters (Iwama et al., 2014).

In view of the above, one can clearly see Embrapa initiatives in several Brazilian regions by means of its Decentralized Units. All studies, projects and results are the basis for Embrapa abilities to promote the management, use and conservation of the seas, oceans and related areas, and contribute to achieving SDG 14, Life Below Water.

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Chapter 4

# Sustainable use of seas for food sovereignty

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## Introduction

The seas and oceans contribute to the nations' food sovereignty through fishing and aquaculture, and to maintaining freshwater sources and Earth's climate. There is a growing demand for fish for human consumption in most producing countries (FAO, 2016), and estimates of the Food and Agriculture Organization of the United Nations (FAO) indicate that global demand for these products will increase by 70% over the next 30 years. Today, the largest share of this demand (71%) is supplied by natural stocks; thus, aquaculture emerges as an activity with potential to sustainably provide fish in the long term (Boletim de Estudos & Pesquisas, 2015).

As the world's human population continues to expand beyond 8 billion, dependence on aquaculture products as important protein sources will increase. World aquaculture fish output more than doubled from 32.4 million tons in 2000 to 73.8 million tons in 2014. Brazil occupies the 14$^{th}$ position in the world ranking, with a total of 562,500 tons of fisheries (1.1% of the world total), of which 474,300 tons are of freshwater fish; 65,100 tons are of crustaceans and 22,100 tons are of shellfish (FAO, 2016). Brazilian marine aquaculture is concentrated on shrimp and shellfish, however, marine fish farming can be developed because of the country's enormous natural resources and adequate climatic conditions (Schwarz et al., 2007; Cavalli; Hamilton, 2009; Cavalli et al., 2011; Collaço et al., 2015), especially considering that Brazil has an over-8,500-km-long vast coastline and large estuary areas of about 2.5 million hectares (Barroso et al., 2007).

Considering that, Embrapa, together with partners, has been running projects to increase scientific knowledge, develop research abilities and transfer marine technologies in order to improve the contribution of marine biodiversity to Brazil's development, and results described here may be replicated in countries with similar environmental conditions within Latin America (target 14.a). This chapter will describe actions, projects and research results focused on aquaculture development and sustainability in order to promote Brazil's economic and social development (target 14.7).

## Marine shrimp farming at Embrapa

The first research studies conducted by Embrapa on marine aquaculture were related to shrimp farming in the Northeastern region. The first study, published in 2001, in partnership between Embrapa Mid-North and the Federal University of Ceará (UFC), evaluated shrimp (*Litopenaeus vannamei*) quality (Diniz et al., 2001). The second was carried out in 2003, by Embrapa Tropical Agroindustry, and described research challenges for shrimp farming environmental sustainability in Brazil by relating local environmental aspects to negative and positive impacts of shrimp farming (Figuerêdo et al., 2003).

Between 2003 and 2006, Embrapa Mid-North conducted two projects, funded by the Financiadora de Estudos e Projetos (Studies and Projects Funding Agency – Finep) and the Brazilian National Council for Scientific and Technological Development (CNPq), to support for shrimp farming development on the Piauí coast. The study evaluated the genetic variability of breeding animals in maturation and hatchery laboratories (Maggioni et al., 2006) and monitored estuaries and shrimp ponds water quality (Arzabe et al., 2006). In 2004, Embrapa Mid-North published a manual on biosecurity for shrimp farms to prevent the spread of diseases among producing states (Pereira et al., 2004). In the same year, a research to replace animal protein sources with plant ones in marine shrimp feeds in order to reduce the rate of nutrients (N and P) in nursery water, was funded by Banco do Nordeste.

However, because of performance and economic losses in Brazilian shrimp production caused by the spread of viral and bacterial diseases in the nursering grow and grow-out phases, partnerships were established and expanded with other Embrapa units and universities for developing technologies to improve sanitary conditions of shrimp lots. Thus, research and studies were funded by Finep, CNPq, Banco do Nordeste, by the former Ministry of Fisheries and Aquaculture

(MPA), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Higher Level Personnel Improvement Coordination – Capes) and Embrapa to identify the main diseases in Brazil, their signs and effects on production, to prevent sanitary problems , and to encourage immunostimulant use in diets and breeding programs.

Because of these joint initiatives gathering academia, private partners and Embrapa, national networks were established: Rede de Pesquisa em Carcinicultura do Nordeste (Northeastern Shrimp Farming Research Network – Recarcine), Bases Tecnológicas para o Desenvolvimento Sustentável da Aquicultura no Brasil (Technological Bases for the Sustainable Development of Aquaculture in Brazil – Aquabrasil) and Rede de Carcinicultura Nacional (National Shrimp Farming Network – Recarcina). These networks advanced knowledge in the areas of genetics (Legat et al., 2005, 2008; Maggioni et al., 2013) and aquaculture safety (Pereira et al., 2010; Morales-Covarrubias et al., 2011), and also developed technologies for: a) producing native species, such as *Farfantepenaeus subtilis* (Buarque et al., 2009, 2010); b) formulating environmentally friendly diets for marine shrimp farming; c) standardizing sustainability indicators based on actual production parameters; d) processing shrimp residues to produce flour, fertilizer and silage, aiming to add value to products and to reduce impacts caused by this waste (Fogaça, 2008; Vieira et al., 2011, 2013; Fogaça et al., 2014; Savay-da-Silva et al., 2016); e) obtaining high market value products such as chitosan and chitin from shrimp processing residues; and f) obtaining protein hydrolysate from shrimp residues (Leal et al., 2010). In 2013, Embrapa Genetic Resources and Biotechnology organized the research network to search for genomic information and to generate innovative molecular tools for new species and shrimp pre-breeding.

In 2014, Embrapa Coastal Tablelands in partnership with the Federal University of Sergipe (UFS) drafted a document on the practice and management of family shrimp farming in the state of Sergipe (Lima; Silva, 2014), which presents contributions to consolidate the activity's sustainability; improve the use of Sergipe estuarine areas that are under intense anthropic pressure; directly benefit local populations with income generation and food security.

## Oyster farming at Embrapa

Another activity developed by Embrapa projects is oyster farming. In Brazil, about 90% of oyster national production is concentrated in the state of Santa Catarina, specially the exotic species *Crassostrea gigas*. However, because the growth and survival of *C. gigas* is limited in warmer water temperatures, the native oyster *Crassostrea gasar* is the species with the greatest potential for oyster farming development in Brazil's Northern and Northeastern regions.

Since 2003, Embrapa Mid-North started doing research on native oyster production (*C. gasar* and *C. rhizophorae*) as a bioremediator in pre-treating shrimp farming effluents, in order to reduce nutrient discharge into estuaries (Pereira et al., 2007a). In the following years, the project included developing native oysters culture with the rack-and-bag system in artisanal fishermen communities of the states of Piauí and Maranhão, as a productive unit model for family farming (Pereira et al., 2007b).

In 2008, Embrapa Mid-North joined the Rede Nacional de Pesquisa em Ostras Nativas (National Native Oyster Research Network), along with eight universities (Federal University of Santa Catarina – UFSC, Federal University of Rio de Janeiro – UFRJ, Federal University of Rio Grande do Norte – UFRN, Federal Rural University of Pernambuco – UFRPE, Federal University of Bahia – Ufba, Federal University of Espírito Santo – Ufes, Federal University of Paraná – UFPR, Regional University of Joinville – Univille, the Instituto de Pesca de São Paulo (São Paulo Fisheries Institute) and the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Agricultural Research and Rural Extension Company of Santa Catarina – Epagri). As of 2011, research studies concluded that: a) the use of anesthetics helps selecting animals apt for reproduction in the laboratory (Legat, 2015a); b) the best *C. gasar* larval performance in the laboratory was observed at salinity of 28 PSU (practical salinity unit); c) the reproductive cycle of native oyster *C. gasar* in the Northeast is intermittent, whereas in the South, gamete maturation is concentrated in spring and summer; d) the growth and survival of *C. gasar* cultivated in the South are better as compared to those in the Northeast, and 8 months was considered the ideal period for this oyster species to reach commercial size (Legat, 2015b). In 2017, Embrapa Fisheries and Aquaculture has described oyster producing units in Santa Catarina in order to foster this productive chain within Embrapa research studies (Mataveli et al., 2017).

## Marine fish farming at Embrapa

Within marine aquaculture activities promoted by Embrapa, marine fish farming is included, as one of the great alternatives for Brazil to increase its fish production. For this reason, Embrapa Coastal Tablelands created the Rede de Pesquisa e Desenvolvimento em Piscicultura Marinha (Marine Fish Farming

Research and Development Network – Repimar), joining researchers from Federal Rural University of Pernambuco (UFRPE), Federal University of Recôncavo Baiano (UFRB), Federal University of Pernambuco (UFPE), Federal University of Santa Catarina (UFSC), Federal University of Rio Grande (Furg), Fundação Instituto de Pesca do Estado do Rio de Janeiro (Fisheries Institute of the State of Rio de Janeiro – FIPERJ), Federal University of Lavras (Ufla), São Paulo University (USP), Instituto de Pesca (Fisheries Institute) and Embrapa Genetic Resources and Biotechnology and Embrapa Mid-North, which had already been working in partnership since 2007.

In 2009, as a result of its initiatives, Repimar approved the Projeto Bijupirá: Desenvolvimento de tecnologias sustentáveis para a criação do bijupirá no Brasil (Cobia Project: Development of sustainable technologies for cobia farming in Brazil), funded by Embrapa, CNPq, MPA and Capes. It supports a network with over 70 specialists from 12 Brazilian and 2 foreign research institutions. The management and funding for the project were strengthened by the creation of two subnetworks: Nutrição, Sanidade e Recursos Genéticos (Nutrition, Health and Genetic Resources) and Sistemas de Produção, Qualidade Ambiental e Processamento (Production Systems, Environmental Quality and Processing), coordinated by UFRPE and Furg, respectively. Their results were relevant to the areas of processing, production systems, environmental management, genetic resources, health and nutrition.

In diets for marine fish, most of the animal protein usually comes from fish meal because of its nutritional quality. In 2006, previous studies on nutrition and feeding of cobia (*Rachycentron canadum*), conducted by Embrapa in partnership with UFRB, Ufba, State University of Santa Catarina (Uesc) and Bahia Pesca S.A., assessed the digestibility of some commonly used ingredients of feedstuff in Brazil, such as fish meal, blood meal, meat and bone meal, poultry by-product meal, soybean meal and corn gluten (Portz et al., 2008).

The Cobia Project continued this research and established rates for substituting fish meal for by-products from other industries, such as shrimp (protein hydrolysate) and poultry (chicken offal), ingredients which are available in large quantities in the national market at lower cost. Additionally, they do not jeopardize fish performance and quality, being extremely important for cobia farming economic and environmental sustainability, and reduce pressure on forage fish species such as anchovies and sardines, among others used in industrial fish meal manufacture, causing overfishing and even stock depletion. For processing, technologies were created for cobia slaughtering, and new cuts and products were developed in order to promote the species' integral use; protocol for sensory evaluation of fresh cobia was created; shelf life under cold storage was determined; smart photochromic indicators to monitor their expiry date were established; traceability parameters were identified; modified atmosphere packaging for fillets was developed; and collagen from cobia skin was extracted (Cavalli et al., 2016).

In relation to production systems, three systems were assessed: 1) offshore production on the coast of the state of Pernambuco, 2) nearshore production along the coast of the states of Rio de Janeiro and São Paulo, in family farms (Figure 1 , model of cage), and 3) production in closed water recirculation system at Furg, in the state of Rio Grande do Sul. All systems were technically viable, with indicators for animal performance, storage rates, production time, feed rates and sanitary protocols. In terms of environmental management, water parameters of deep-sea cobia production were monitored, and a low impact in cage areas and their surroundings was observed, in addition to increased local benthic fauna.

In terms of genetic resources, genetic diversity of wild (in Bahia, Ceará and Piauí) and farmed (in São Paulo and Pernambuco) specimens were assessed; a low variability between wild and farmed specimens was observed, which indicates that eggs released by free-living females can be fertilized by a small number of

Photo: Fabíola Helena dos Santos Fogaça

**Figure 1.** Nearshore cobia production in marine cage system.

breeders and that, in captivity, mating was random. The characterization of semen, coupled with the genetic characterization of wild and farmed populations, makes it possible to establish germplasm banks of great importance for future breeding and conservation programs (Araújo et al., 2013).

In terms of health, the main problems affecting the species, both in captivity and in the natural environment, were identified. Among them, *Amyloodinium ocellatum* is a parasite that sets in the gills and causes great mortality among farmed fish. In terms of controlling *Amyloodinium ocellatum* infestations in cobia, the use of almond and neem aqueous extracts had promising effects after 48 hours (86% of parasite elimination and 95% of juvenile survival) and of copper sulphate had effects after 24 hours.

All these results will serve to establish cobia sustainable production systems in Brazil, thus contributing for better marine fish quality. In addition to these results, the main developments of Cobia Project were the articulation and establishment of a research and innovation network in marine fish farming, the integration of work teams from different institutions in different Brazilian regions, the involvement of Embrapa in marine fish farming and new partnerships for future projects.

## Technologies for marine fish better use

Many Embrapa marine technologies are related to processing and integral use of fish. Embrapa Western-Region Agriculture, in partnership with Ufba and UFRB, studied omega-3 incorporation in muscular tissue of Nile tilapia fed with shrimp head silage. Including 16% of silage in tilapia diet significantly increased tilapia fillet EPA (eicosapentaenoic) and DHA (docosahexanoic) levels, thus improving its nutritional value; in addition, it opens an opportunity for using marine aquaculture by-products in inland fish industry (Costa et al., 2012). Embrapa Food Technology developed a process for better using salmon filleting residues and reducing waste (Góes et al., 2014). Embrapa Fisheries and Aquaculture studied alternatives to replace Brazilian sardines (*Sardinella brasiliensis*) for others fishes in the canning industry.

Embrapa also focuses on assessing fish quality in terms of contamination by pesticide residues, metals, polycyclic aromatic hydrocarbons (PAHs) and other substances. In 2010, a network coordinated by Embrapa Environment standardized the identification of these compounds in fish and optimized, in 2014, the technique for detecting multi-residues of organochlorines in marine shrimp (Ferracini et al., 2014). In 2011, the analysis of the presence of phycotoxins, produced by marine algae, was also standardized (Bobeda; Godoy, 2011).

In 2015, Embrapa Mid-North, in an international partnership with the Portuguese Institute for Sea and Atmosphere (Lisbon/Portugal) and the Engineering Higher Institute of Porto (Porto/Portugal), determined bioaccessibility (part of a compound that is available for absorption after human digestion) of biotoxins in marine bivalves, of metals and PAHs in bivalves, marine shrimps and seaweed (Fogaça et al., 2016; Alves et al., 2017; Manita et al., 2017). In this project, the effects of climate change (increase in temperature and acidification of seas and oceans) on contaminant bioaccumulation in aquaculture species were also determined. A 4 °C temperature rise, combined or not with a 0.4 point reduction in water pH level, resulted in higher bioaccumulation of compounds known as persistent organic pollutants, thus demonstrating a cumulative effect over time (Maulvault et al., 2017).

## Native marine species prospecting

In searching for native species for aquaculture, Embrapa Mid-North, in partnership with the Federal University of Maranhão (Ufma), carried out a preliminary study on farmed tarpon (*Megalops atlanticus*) and simulated fattening systems developed for the species by local fishermen. The study showed that fish has difficulty in accepting commercial feed because of their carnivorous habit, but it grows at different stocking densities. Other studies focused on the commercial production of seaweed (micro and macroalgae). The nutritional composition of marine algae (*Asparagopsis taxiformis*, *Centroceras clavulatum*, *Chaetomorpha aerea*, *Sargassum filipendula* and *Spyridia hypnoides*) was studied for its use in human diet (Diniz et al., 2011). The sustainability of *Gracilaria birdiae* seaweed production in the coast of Flecheiras, in the state of Ceará, is being assessed by Embrapa Mid-North. Embrapa Agroenergy described the biomass chemical composition of microalgae *Nannochloropsis oculata* grown in raceways for food and clean energy production purposes (Ribeiro et al., 2016).

## Institutional actions

Regarding institutional action, in 2015, Embrapa created its Aquaculture Portfolio to organize demands and select priority research areas; to promote and monitor final results, taking in consideration Embrapa strategic objectives. Currently, Embrapa approved projects on marine aquaculture in the following areas:

oyster farming, developing multitrophic systems with marine shrimp and marine fish farming. Within the latter, the construction of the Laboratório de Pesquisa e Inovação em Piscicultura Marinha (Marine Fisheries Research and Innovation Laboratory) at Embrapa Coastal Tablelands was approved with funds from the Technology Fund of the Brazilian Development Bank (Funtec/BNDES); this laboratory will focus on developing technologies for marine native fish species farming.

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Chapter 5

# Sustainable development of fisheries

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## Introduction

Marine and estuarine fishery in Brazil is performed by millions of fishermen and produces almost 500 thousand tons of fish per year (FAO, 2017), thus being an important source of food, employment and income for people and the country (Haimovici et al., 2014). However, since the 1990s, it remained stagnant and its stocks are overexploited. For this reason, Embrapa, in partnership with several institutions, has been carrying out projects and intervention actions to increase scientific knowledge, improve ocean health and enhance the contribution of marine biodiversity to Brazil's socioeconomic development, according to the target already described in Chapter 4 (14a). The Company has also developed projects to provide access for small-scale artisanal fishermen to marine resources and markets (Figure 1) (target 14.b).

Among the actions already carried out, many aim to meet target 14.7: by 2030, increase the economic benefits to Small Island developing States and least developed countries, from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism (United Nations, 2017).

## Crustacean fisheries

Studies on estuarine fishery began with projects related to mangrove crab (*Ucides cordatus*) because of its important role both in nutrient recycling on trophic structure of mangroves (Christofoletti et al., 2013; Santos et al., 2016a) and in securing the livelihoods of thousands of people in Brazilian coastal areas (Alves; Nishida, 2002, 2003; Nascimento et al., 2012, 2017). In the Parnaíba River

Photo: Fabíola Helena dos Santos Fogaça

**Figure 1.** Detail of artisanal estuary fishing in the state of Piauí, Brazil.

Delta, mangrove crab catching represents 30% of fish landed in the state of Piauí (Fogaça et al., 2015).

Therefore, in 2003, Embrapa Mid-North addressed crab catching in the region, funded by Banco do Nordeste. The work involved production chain diagnosis, identifying fisheries sites, fishing gears, loading and unloading places, transportation methods, and marketing price. A socioeconomic diagnosis of crab catchers, by identifying family composition and income, age group, schooling status and living conditions, was also made (Legat; Puchnick, 2011). Results allowed to identify the sector reality and served to rank priority research actions of Embrapa Mid-North, priority training actions of the Brazilian Micro and Small Business Support Service (Sebrae), and social actions of the Piauí and Maranhão governments for this production chain. The project also estimated the Capture per Effort Unit (CPUE), which is the amount of collected crabs per person per day; it ranged between 14.6 and 22.6. It was verified that only crab males were caught and that their average size was higher than that of crab females.

Between 2009 and 2010, the team assessed the population composition and density (individuals per square meter), the reproductive and ecdysis periods. This information was presented to environmental authorities and was input for drafting the mangrove crab management plan in 2017, prepared by the Instituto Chico Mendes de Conservação da Biodiversidade (Chico Mendes Institute for Biodiversity Conservation – ICMBio). In 2014, the Embrapa Unit – in partnership with the Comissão Ilha Ativa (Active Ilha Commission), State University of Piauí (Uespi), Federal University of Piauí (UFPI), ICMBio and City Hall of Ilha Grande, with funding from the Fundo Brasileiro para a Biodiversidade (Brazilian Biodiversity Fund – Funbio) – monitored the mangrove crab unloading in the ports of Ilha Grande, the largest island of the Parnaíba River Delta. The study concluded that 12,000 crab ropes are unloaded monthly (each rope contains four individuals), totaling 576,000 crabs unloaded between 2014 and 2015 (Fogaça et al., 2015).

Actions focused on the production chain of mangrove crab were also carried out by Embrapa Amapá. Between 2009 and 2010, information on the catch size and its compliance with the law (which requires a carapace width of more than 60 mm in order to guarantee crab reproduction, fishing sites and sales), as well as crab price in the market, were collected. It was found that animals were collected all over Amapá, except in the closed season (during which capture is forbidden), when crab from the state of Pará was sold. Carapace size was within the allowed limit and sale price depended on product demand and supply. In 2014, the same team carried out a study on the mangrove crab bio-ecology in the state of Amapá. Findings included higher crab densities per burrow, a greater number of individuals per square meter during summer, higher male/female ratio (1: 38/1), larger catch size compared to those found in other studies, higher frequency of females with eggs and mature females with carapace width between 59.8 mm and 67.5 mm, and highest reproductive peak in May to August (Amaral et al., 2014). This information was (and is) important for establishing regional management programs for crab.

All these studies aim to increase technical-scientific knowledge on fishing resources and their uses, thus characterizing artisanal fishing. Therefore, in 2010, the Embrapa Amapá team conducted a study to characterize artisanal fishing in the state in order to learn about its reality and propose solutions for its improvement (Silva; Dias, 2010). The region's privileged geographic location makes its fisheries to be under the influence of both the Amazon River and the Atlantic Ocean. The study concluded that the traditional fishing activity is basically artisanal and not very competitive compared to fishing activities by industrial vessels from other Brazilian states and even from other countries in the region. Problems related to the land issue, social organization of fishermen, fishing industries and state fishery production were presented. It was suggested that the sector's development depends on infrastructure improvements, such as: investments in fishing fleets, modernization and construction of modern and adequate unloading ports, reliable knowledge of the statistics of fish unloading, and improvement in methods for processing fish, which is in general sold *in natura* or salted. Therefore, based on this information, appropriate policies for artisanal fisheries in the region could be designed.

## Shellfish harvesting

Another fishing activity investigated by Embrapa Mid-North was shellfish harvesting. In 2010, by interviewing fishermen and monitoring fisheries, Embrapa assessed the main shellfish species collected in the Cardoso and Camurupim rivers estuaries (Legat et al., 2010). Seven species of bivalve shellfish and three harvesting sites along the coast of Piauí were identified, in which 165 fishermen worked throughout the year. Native oyster species (*C. rhizophorae* and *C. gasar*) were harvested in January, February, July and December, when there were more tourists in the region. Occasionally *Mytella charruana* was harvested, depending on its presence in the estuary; it is more abundant from October to December. The *Mytella guyanensis* harvesting occurred throughout the year. The *Anomalocardia brasiliana* stood out as the main harvested species, and was the only one used for both consumption and sale. The species *Iphigenia brasiliana* and *Tagelus plebeius* were characterized as *A. brasiliana* harvest bycatches.

Since 2007, Embrapa Mid-North has been carrying out actions related to seafood processing by supporting the Luís Correia Fishermen Association, the Ilha Grande Shellfish Harvesters Association and shellfish harvester groups in Barra Grande, all located in the state of Piauí. In 2010, the composition and yield (8%) of *A. brasiliana* flesh were determined (Freitas et al., 2010). In 2012, an investigation on the traditional knowledge of shellfish harvesters was performed; conclusions were that they manage the resource guided by harvesting larger animals and alternating harvesting sites, which shows that shellfish harvesting is a traditional local family activity (Freitas et al., 2012). In 2014, in order to improve the microbiological and sensorial quality of shellfish, depuration tests were carried out in partnership with the Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba (São Francisco and Parnaíba Valleys Development Company – Codevasf) and the Active Ilha Commission; results were that a 24-hour-long depuration in potable water in a static system is efficient for eliminating sand and 99% of the microbial content in the product (Santos et al., 2016b).

## Artisanal fisheries

With regard to fishing estuarine, marine and elasmobranch fish, Embrapa Mid-North monitored fish-weir fisheries off the coast of Piauí (Mai et al., 2012). Three fish-weirs were monitored during daytime and nighttime operations between December 2008 and November 2009. A total of 117 fish species belonging to 41 families were recorded. There was no significant difference in average catch weight between rainy and dry seasons, between the daytime and nighttime shifts, and between full moon and new moon phases. The annual catch per fish-weir was estimated at 1.2 ton of fish, of which 79.0% were made up of commercially important fish species for the state of Piauí. In the same vein, the Projeto Sociobiodiversidade da Ilha (Ilha Socio-biodiversity Project, already mentioned above) monitored marine fishery in Pedra do Sal, Parnaíba, state of Piauí. Observations totaled 40 fishing vessels per month, 79 species belonging to 37 families, of which the following were of major commercial importance: *Lutjanus jocu*, *Megalops atlanticus*, *Scomberomorus cavalla*, *Centropomus undecimalis* and *Cynoscion acoupa*, as well as 14 non-commercial species including bycatches of endangered species, such as nurse shark (*Ginglymostoma cirratum*), goliath grouper (*Epinephelus itajara*) and hammerhead (*Sphyrna* sp.). With regard to fishing gears used, nine kinds were observed: hand line, gillnet, casting net, longline and launch, among which gillnet and line represented 74.45% of equipment used in total production.

More recently, in 2015, sponsored by Petrobras through its Petrobras Socioambiental Program, a study was carried out on fishing in the Timonha and Ubatuba rivers estuary (Pereira; Rocha, 2015). It was led by the non-governmental organization (ONG) Active Ilha Commission, in partnership between Embrapa Mid-North, UFPI, Uespi, Federal Institute of Ceará (IFCE), Associação de Pesquisa e Preservação de Ecossistemas Aquáticos (Association for Research and Conservation of Aquatic Ecosystems – Aquasis) and ICMBio. The main project result was drafting and publicly releasing the *Carta-Proposta dos Encontros de Pesca dos rios Timonha e Ubatuba (Timonha and Ubatuba rivers Fishing Meetings Letter-Proposal)*, whose proposals include planning and zoning estuary fishing, increasing the income and enhancing the life quality of community fisherman families located in that region (Pereira; Rocha, 2015). Also, results indicated: a) lower fishing effort in sites closer to coastal zones; b) white mullet (*Mugil curema*) was almost exclusively caught in nets and represented 50% of the amount of species harvested by this system; and c) in terms of environmental diversity, 127 species were identified. Studies have also been carried out on reproduction: catfish (*Sciades herzbergii* and *Aspistor luniscutis*) were able to spawn throughout the whole sampling period (August 2014 to June 2015) and to offer parental care (egg incubation in the mouth), requiring longer closed season time; for white mullets, there are indications that their average size on first maturation is from 23 cm for both males and females. In addition to these fisheries-related studies, physical-chemical and biological parameters of estuarine water were also monitored. This information may contribute to drafting the management plan for the Environmental Protection Area (APA) of the Parnaíba River Delta, where the estuary is located.

## Institutional actions

Despite all these actions carried out since 2003, it was only in 2009, after Law No. 11,958, of June 26 was signed, which created Embrapa Fisheries and Aquaculture, that Embrapa officially joined other Brazilian institutions to directly contribute to the sustainable development of fisheries. This Unit evolved from the Aquapesquisa Project, funded by the former Ministry of Fisheries and Aquaculture (MPA), which was intended to build a significant database containing information from public, private and non-governmental institutions working in scientific research and development, rural education and extension, fisheries and aquaculture. Aquapesquisa final product was a document titled *Diagnóstico Estratégico de Instituições Demandantes e Ofertantes de Tecnologia em Pesca e Aquicultura* (*Strategic Diagnosis of Fisheries and Aquaculture Technology Demanding and Granting Institutions)* (Rebelatto Junior et al., 2013), which identified 3,479 Brazilian institutions working in the area. To better manage the existing socio-technical network, a record of professionals ranked according to their respective areas of activity was organized. The project is intended to be periodically updated, thus allowing its future expansion as the sector evolves. The diagnosis also identified bottlenecks in the fish production chain, which allows better guidance for sector institutions focused on creating (especially sustainable) technologies and proposing interventions, especially on less consolidated areas (Rebelatto Junior et al., 2014).

In this context, in order to better organize information on the Brazilian fishing sector, *Prospesque* was held in June 2012, in Palmas, state of Tocantins, in order to strategically plan the decision making on generating and transferring technologies for the sustainable development of fisheries (Lima et al., 2012).

Fifty experts joined representing proportionally Brazil's regions and four areas of the fishing sector, namely: inland artisanal fishing, marine artisanal fishing, sport fishing and industrial fishing. With such a plural group of specialists, a balanced debate on the main research and technological development demands of the sector was possible. From this technical meeting, the *Relatório técnico do Seminário Nacional de Prospecção de Demandas da Cadeia Produtiva da Pesca PROPESQUE* (*Technical report of the National Seminar on Prospecting Demands of the Fishing Production Chain PROSPESQUE)* (Lima et al., 2012) was released, which, among analytic perspectives, pointed to the main research barriers for the sustainable development of artisanal marine fisheries: a) lack of monitoring and updated production of fisheries statistics to support public policies; b) lack of implementation of a national fisheries monitoring plan and need for developing sustainable management plans; c) need for social, biological, economic, environmental and technological studies on fishing activity (economic analyses and cost-benefit studies on the activity, studies on the socio-environmental aspects and their relation with the concept of sustainability); d) need for obtaining information in regularly predetermined frequency on the production chain for monitoring and input for public policies; e) development of ecosystem approaches to assess the sustainability of exploited stocks; f) need for creating collaborative research and development networks on fishing in the whole country in order to jointly design projects to deeply change the national fisheries context towards a sustainable scenario.

## Including fish in school feeding

Another project that produced a solution for artisanal fishermen to access alternative markets was the one on Technology transfer for including family farmed fish in school feeding. It combined developing a marketing strategy for local fishermen based on acknowledging the value of institutional competences for fostering local development; joining public and private institutions and beneficiaries at all levels to plan and be involved; training parties to adopt technologies, manage cooperative enterprises and assure food security. These actions allowed fishermen to be included in governmental procurement policies, and provided quality food (fish) to beneficiary audiences, such as public schools, nursing homes, rehabilitation centers and other institutions that work with vulnerable populations (Sousa et al., 2016).

## Fisheries management

Still in order to address the demands of artisanal fishing, Embrapa Fisheries and Aquaculture conducted a study in the South of the state of Bahia, in the region of Valença, to assess the fishing dynamics, productivity and harvested species from the five main fishing methods adopted by the region's motorized fleet, according to the fishermen's perception. This survey served as input for actions to broaden the fishing communities knowledge on their reality and to empower them, so that they could play the main role in defining their aspirations and capacities and take part in different stages of designing sector policies (Silva, 2014).

## Fish quality

In order to promote fishermen's access to markets, the product must also be qualified. Therefore, Embrapa Mid-North joined a project for industrializing mangrove crab, thus assuring higher income to catchers and better microbiological quality to the product, which is processed in an industry accredited with the Federal Inspection Service (SIF) seal in the state of Piauí. Still on crab quality, the Unit conducted an assessment of the nutritional composition and sensorial acceptance of crustacean collected in different locations of the APA of the Parnaíba River Delta; conclusions were that crab from sites with higher salinity (> 32) were tastier due to higher mineral content (Silva et al., 2014). The characteristics of crab breaking were evaluated in different places of Parnaíba and Ilha Grande, showing that it is a family activity, performed by both males and females, who earn less than the minimum wage on average; however, the products hygienic-sanitary conditions were within the standards required by Brazilian regulations (Silva et al., 2017).

Another important cause of reduced food quality is the presence of contaminants. Thus, in 2009, Embrapa Coastal Tablelands assessed the presence of methylmercury in zooplankton and phytoplankton and mercury in marine fish from the region of Cabo Frio, in the state of Rio de Janeiro. The highest Hg content was found in tuna muscle and the lowest in sardine. Methyl Hg levels increased according to the trophic levels studied (planktivorous to carnivores), while inorganic mercury (Hg) level was higher at the base of the trophic chain (phytoplankton) (Silva et al., 2009).

The same Embrapa Unit assessed the risk of consuming marine fish traded in Aracaju, Salvador and Maceió focusing on metal contents. Lead and cadmium levels found in the species investigated did not pose risks to consumers of the three cities based on estimates of the risk index used in this study. Zinc contents in all species were below the Tolerable Maximum Limit (TML) by Brazilian regulations. However, in amberjack, tuna, catfish, shark and *dourado*, the highest levels of arsenic were found, thus posing consumers at potential risk (Santos; Silva, 2015; Leite Junior; Silva, 2016).

In 2017, Embrapa Food Technology, in partnership with the Fundação Instituto de Pesca do Estado do Rio de Janeiro (Rio de Janeiro State Fisheries Foundation – Fiperj), assessed chemical contamination levels in fish from Sepetiba Bay, located in the state of Rio de Janeiro; it was focused on residues of organochlorine pesticides (OP), which have great impact because of its environmental persistence, bioaccumulation and high toxicity, and of inorganic contaminants that can occur at high concentrations in aquatic environment and have a high cumulative power in the biota due to intake of food already contaminated with metals or to minerals absorbed from water. Different species were assessed, such as sardines (*Cetengraulis edentulus*), cutlass fish (*Trichiurus lepturus*), mullet (*Mugil liza*), catfish (*Genidens genidens*), bluefish (*Pomatomus saltatrix*), leatherjacket fish (*Oligoplites saurus*) and shrimp (*Farfantepenaeus paulensis* and *Litopenaeus* sp.). Residues of the following were detected: delta-BHC in 77.74% of samples, heptachlor in 56.52% of samples and organochlorine in 71.7% of samples; dichloro-diphenyl-trichloro-ethane (DDT) and its metabolites (dichloro-diphenyl-ethene – DDD and dichloro-diphenyl-dichloro-ethane – DDE) were also found (Castro et al., 2017). Among inorganic contaminants monitored in this study, values for arsenic, lead and cadmium were above those permitted by Brazilian regulations. The following significant values were observed: 1209.04 mg/kg of iron, 2040.02 mg/kg of zinc and 989.95 mg/kg of aluminum and also 9233.58 ng/kg of nickel. This study revealed that the bay is already environmentally degraded due to the presence of contaminants in fish (Freitas et al., 2017).

## Final considerations

These experiences reveal the importance of initiatives of Embrapa and other research, innovation, extension and education institutions to support and enhance the sustainable development of fisheries; they provided solutions that can be replicated in Brazil and abroad to promote the organization of the activity, management of harvesting areas, control of overfishing and improvement of product quality so that fishermen can access the consumer market, thus contributing to Brazil's social and economic development.

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Chapter 6

# Advances and future challenges

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## Introduction

Among the 17 Sustainable Development Goals (SDG) established in 2015 by the United Nations (UN), perhaps one of the most challenging for Brazil and for Embrapa is SDG 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development – Life Below Water. This complex system has undergone several changes caused both locally and globally by human action.

Today, we observe the environmental imbalance caused by greenhouse gas emissions, great part of which (69%) comes from agriculture. In 2015, Brazil's gross emissions reached 1.927 billion tons of $CO_2$, 3.5% more than the 1.861 billion tons emitted in 2014 (Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa, 2017). In Brazil, agriculture based on extensive use of fertilizers and agricultural pesticides is of great concern because it contributes to air pollution and pollutes water streams, rivers and oceans. The environmental crisis over the last decades has not only raised the awareness of how unsustainable traditional production practices are, but has also opened up the possibility of joining nature in search for food security (International Policy Centre for Inclusive Growth, 2017). According to these guidelines, adopting new production methods, improving traditional technologies, fully using fish and keeping environmental quality are fundamental initiatives to ensure sustainable production of healthy and safe food (Barroso; Wiefels, 2010).

It is Embrapa's role to propose changes to current production systems towards a sustainable model guided by eco-systemic integration and appreciation of renewable natural resources. This is why studies and technologies for conserving ecosystems and their biodiversity, developing environmentally friendly aquaculture production systems and encouraging fisheries sustainability are essential.

## Marine resources, impacts and management

Research studies and actions described in Chapter 3 specifically address marine (biological, genetic and biotechnology) resources, anthropogenic impacts and management of biodiversity and coastal marine environmental data as inputs to management plans in conservation units and aquaculture parks. Relevant knowledge advances already made include identifying genetic biodiversity of native crabs, lobsters and shrimps; observing mangrove crab production chain in the Northern and Northeastern regions of Brazil and bio-prospecting active compounds from marine resources.

Among the most significant results are the mangrove crab transportation methodology and the management plan for the crab harvesting reserve area within the Environmental Protection Area (APA) of the Parnaíba River Delta; these are examples of projects conducted by Embrapa that led to the formulation of public policies. These products reveal that Embrapa has already addressed the conservation of marine resources in different domains and as part of portfolios within its project platform. However, there is a need for stronger network projects, such as the proposal to create a National Aquaculture Environmental Monitoring and Research Network in Federal Waters, which would gather different institutions around a single theme, in order to support governmental agendas. Biodiversity data management and environmental management studies, geospatial indicators monitoring, debris flow modeling and flood events should also be addressed in projects to promote the conservation of seas and oceans.

## Aquaculture

As with natural resource management, many environmental problems caused by aquaculture can be identified and minimized by using solutions offered by Embrapa, which imply changing certain management practices or developing new technologies (Tucker; Hargreaves, 2008), such as those described in Chapter 4.

Embrapa took the first step: it fostered the project Bases Tecnológicas para o Desenvolvimento Sustentável da Aquicultura no Brasil (Technological Bases for the Sustainable Development of Aquaculture in Brazil – Aquabrasil) and Rede de Pesquisa e Desenvolvimento em Piscicultura Marinha (Marine Fish Farming Research and Development Network – Repimar), and joined Rede de Pesquisa em Carcinicultura do Nordeste (Northeastern Shrimp Farming Research Network – Recarcine), Rede de Carcinicultura Nacional (National Shrimp Farming Network

– Recarcina) and Rede Ostras Nativas (Native Oysters Network). The projects included in these networks helped strengthening marine shrimp, cobia and native oyster production chains mainly by designing technical production models and identifying problems related to their production, processing and sale.

However, except for shrimp farming, other production chains are not based on a well-structured model, which is technically interesting because it is possible to promote an environmentally friendly system; but more substantial investment and human resources are needed to focus on these species.

Even in terms of fish science and technology based on biotechnology – on which researchers from numerous Embrapa Units work and offer professional training for extracting collagen and organic compounds from fish filleting waste, producing food products from mechanically separated fish meat (MSM) and improving fish quality in terms of contamination with pesticide residues, heavy metals, hydrocarbons and other substances harmful to the species' conservation and to human food safety –, there is still a long way to go if one compares shrimp farming technology development in Brazil with that of other countries.

The first step is conducting basic research, which is fundamental for understanding not only how the aquatic ecosystem in which activities are performed works, but also its connections with the production system, leading to a consolidated marine aquaculture. One of the main points to be studied is the monitoring of environmental parameters, which is essential to improve management practices and reduce the impacts of productive activities (Silva et al., 2015).

Therefore, projects of Embrapa on marine aquaculture should focus on Good Management Practices (GMP) in its original sense, namely: effectively validated practices compliant with sustainable natural resource management goals to reduce environmental impacts (Hairston Junior et al., 1995). In some situations, a single practice can solve the problem, but often environmental monitoring and a set of practices are needed to ensure efficient management. Several production sectors seek management practices as the best way to improve production, reduce external inputs and make more profit, besides serving a market that increasingly demands fish produced in environmentally correct and socially responsible systems, in order to rationally reduce the exploitation of natural fishery resources.

Other paths to be followed in innovating sustainable production methods are: integrated multi-trophic aquaculture (IMTA) and heterotrophic or biofloc technology systems (BFT), which use management techniques for multiple spaces and organisms. IMTA has been recently receiving special attention of the international scientific community as an alternative for mitigating aquaculture effluents and waste. It includes: raising fish or crustaceans that eat feed; inorganic nutrient (C, P and N) absorbing species, such as algae; suspended/dissolved organic matter filtering species, such as shellfish; and benthic detritus eating species, such as polychaetes (Soto, 2009; Troell et al., 2009).

The projects Bases ecológicas para a produção sustentável de ostras nativas no Norte e Nordeste do Brasil (Ecological bases for the sustainable production of native oysters in the North and Northeast of Brazil) and Ações estruturantes e inovação para o fortalecimento das cadeias produtivas da Aquicultura no Brasil (Structuring actions and innovation for strengthening aquaculture production chains in Brazil), approved in 2017, are already aimed at adopting good management practices, environmental monitoring and multitrophic production systems, thus supporting the actions of Embrapa for developing sustainable production systems.

Towards developing more efficient production systems for marine aquaculture in Brazil, one of the major challenges is the need for automated equipment and systems for safer and less workforce-demanding processes of aquaculture production in marine environment. Today, few companies manufacture equipment and other types of structures for breeding at sea, not to mention the lack of boats suitable for management support and ferries that can provide security and logistical support. The potential for developing marine aquaculture in less sheltered places in the open sea will depend on an entire chain still incipient in Brazil.

## Sustainability of fisheries

Sustainability of fisheries, according to results described in Chapter 5, involves activity diagnoses, studies on bio-ecology and fishing, monitoring of boat loading and unloading for fishing statistics, studies on species reproduction, and processing and sale methods aiming at higher food security, integral use of fish and higher profits for fisherman, as well as product quality checks to identify presence of chemical contaminants in fish.

Despite progress made in knowledge and contributions of Embrapa to draft fishery management plans, there are still many gaps to be investigated, among them is the recovery of over-exploited fish stocks by reducing fishing pressure.

Another fundamental challenge is sustainably using existing marine resources while conserving the ecosystem on which they depend, which will require scientific and managerial actions (Dane, 2016).

Another problem is how to manage local marine resources in the face of pressure from developed countries' fishing activities off the coast of developing countries. It is a serious problem because most of these stocks are the basis for small-scale fisheries, which are critical for food security in developing countries. Unfortunately, there are more research studies on biodiversity conservation and maintaining fishing economic profitability than on food security of populations that live by artisanal fishing (La pesca…, 2014). It is necessary to develop efficient management tools for artisanal fisheries and require developing countries to promote sustainable industrial fishing based on assessing fish stocks and conserving marine biodiversity (Hazin, 2015).

## Overview on contributions of Embrapa and potentialities

This overview on results shows that most of them involve advancing knowledge. The lack of technologies generated for marine aquaculture and fisheries is due to their complexity, numerous ecosystem users and lack of public sector involvement with the theme. This is reflected in Embrapa: out of its 42 Units, only 7 presented results to help achieving SDG 14 targets. However, other Embrapa Decentralized Units can and should join to contribute to this theme, either directly in the Aquaculture Portfolio or by establishing partnerships with Units that are already focused on studying the sea.

Among actions that Embrapa can take, are: a) conservation of biodiversity and prospection of bio-molecules of agroindustrial interest; b) data management and geospatial monitoring; c) fisheries monitoring; d) development of marine production systems; e) integral use of fish; f) fish quality and security assessment; and g) national and international institutional connections to guarantee the law of the sea (in its technical-scientific, managerial and territorial aspects) to Brazil. In a scenario of budget cuts and lack of specialist researchers in marine fisheries and aquaculture, Embrapa will need to set a well-structured institutional agenda to meet all these demands and help achieving the targets of SDG 14 – Life Below Water.

In its Sixth Master Plan, which covers the 2014 to 2034 period, Embrapa (2015) showed how its efforts are aligned with the international commitment to SDGs. The five impact axes of the VI Master Plan of Embrapa (namely Advancing in the Quest for Sustainability, Strategic and Competitive Entry in Bio-economy, Contributions to Public Policies, Productive Placement and Poverty Reduction and Being at the Knowledge Frontier) are clearly aligned with all 17 SDGs.

The impact axes are the main transformations that Embrapa expects to leverage in agriculture and in Brazilian society by implementing its Master Plan. In the case of SDG 14, this commitment is clearer in 4 of the 12 Strategic Objectives (SOs) established in the Master Plan, namely: sustainable use of Brazilian biomes (SO1); development of innovative production systems to increase productivity (SO6); concern with public policies (SO9); and generation of knowledge for family agriculture (SO10). By aligning its work with SDGs, Embrapa returns society's investment and shows that it can make a difference in conservation and use of the seas and oceans.

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