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

Sustainable Development Goal **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 14th 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

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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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