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Oreochromis niloticus is a blue economy alternative for the Papaloapan region of the state of Oaxaca, Mexico

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1 Introduction

Food insecurity is steadily increasing in many countries across the world, reversing years of progress and jeopardizing the ability to achieve the Sustainable Development Goals (SDGs) by 2030. According to the FAO, IFAD, WHO, WFP, and UNICEF report, "The State of Food Security and Nutrition in the World 2021" (FAO et al., 2021), before the onset of the global health crisis, the countries of the world were lagging behind in achieving the goal of eradicating hunger by 2030 (FAO et al., 2022). In the early 2020s, the combination of the onset of the COVID-19 pandemic with declining incomes and disruptions in supply networks led to an increase in the number of people affected by chronic and acute hunger. This increase is due to a variety of variables, such as social conflicts, socioeconomic conditions, pests, climate change, and the effects of extreme weather events. The pandemic only exacerbated these problems, resulting in a significant and widespread increase in global food insecurity, affecting vulnerable populations in almost all countries in the Western Hemisphere. Although economies are slowly recovering from COVID-19, uncertainty and disruptions persist as fiscal capacity and food and nutrition security prospects deteriorate in many low-income and middle-income countries, which remains a serious concern. Although the outlook for global food supply remains positive, food prices have risen dramatically due to high input prices, which, combined with high transportation costs and further trade disruptions caused by armed conflicts, are driving up import costs. Poor and emerging countries are the most affected in this scenario, as they are the most dependent on food imports (FAO, 2022). Blue transformation is the vision and process by which FAO can use current knowledge, tools, and practices to ensure and maximize the contribution of aquatic food systems to food security; through blue transformation, aquatic food systems can support the provision of sufficient aquatic food for a growing population in an environmentally, socially, and economically sustainable manner, ensuring the availability and accessibility of nutritious aquatic foods for all, especially vulnerable populations, and reducing food losses and food wastage, contributing to improving the rights and incomes of communities that depend on the sector for equitable livelihoods (FAO, 2023). Many studies describe the nutritional and economic importance of fisheries and aquaculture worldwide (Okoye et al., 2014; Adugna, 2020; Chibwana et al., 2020). These activities produce more than 179 million tons of fish per year (FAO, 2021), and one of the most produced is the fish called "tilapia," a term used to refer to cichlid fish of the genera *Oreochromis*, *Sarotherodon*, and *Tilapia*. In Mexico, during the last 10 years, an increase in the production of tilapia has been reported, with an average annual growth of 3.1% (Huerta and Oyadener, 2019; UN, 2021). The objective of this study is to present an opinion on the importance of the aquaculture sector in the sustainable development of rural communities in the state of Oaxaca, Mexico, using the blue economy model, strengthen the state food security, and improve the level of use of tilapia as a fishery resource, for which adequate aquaculture management of this resource can generate significant direct benefits in the socioeconomy of the different regions of the state where it is grown because it is a source of high-protein food, jobs, and economic spillover. The production of Nile tilapia can be considered an integral part of the blue economy, which refers to the sustainable exploitation of marine and aquatic resources, including aquaculture, fishing, and other water-related activities. Aquaculture is a crucial practice for feeding the growing human population, and tilapia culture in rustic ponds has become an important alternative to small-scale aquaculture development (Betanzos-Torres et al., 2020). This form of aquaculture production offers a significant source of income for many families, contributing to the socioeconomic development of rural and peri-urban areas (Vega-Villasante et al., 2010) and providing a low-cost source of protein for human consumption (Toriz-Roldan et al., 2019; Pomares and Velázquez, 2022). The main states producing tilapia in Mexico are Jalisco, Chiapas, Sinaloa, Nayarit, Michoacán, Veracruz, Tabasco, Guerrero, and Hidalgo, and these states use their harvest for local sales and, to a lesser extent, regional sales, at the farm gate, markets, and restaurants, with fresh presentations of (a) whole gutted tilapia (62.2%), (b) live whole tilapia (24.3%), and (c) tilapia filet (13.5%).

2 Blue economy and *Oreochromis niloticus*

The blue economy refers to the sustainable use of marine and aquatic ecosystems while promoting human wellbeing in economic (production) and social (improved livelihoods and source of employment) terms, preserving the ecosystem base on which economic activity and human wellbeing rest (Phang et al., 2023). The positioning on sustainability is based on the origin of the concept of the blue economy at the Rio+20 Conference, which was to think of the finite nature of coastal, marine and ocean resources, and thus sustain not only tourism, port, fishing, and hydrocarbon economic activities, but also the livelihoods of coastal communities (UNEP, 2012; UNECA, 2016; UNDP, 2018). Due to the recognition of the implementation of environmental policies to boost the blue economy from the approach of ecosystem conservation, beyond the productive capacity and economic dimension (Cisneros-Montemayor et al., 2021), it is of the utmost importance to know and analyze, in general terms, the behavior of Mexican fisheries (Santander-Monsalvo et al., 2018). The National Water Program 2020–2024 recognizes that the country's surface water is polluted by untreated wastewater, municipal and industrial discharges, and agrochemicals. Pollution has strongly affected rural communities and indigenous peoples, who observed the benefits they obtained from nature diminish (DOF, 2020). In Mexico, the National Commission for Aquaculture and Fisheries (CONAPESCA) designates "controlled systems" as aquaculture activities and culture-based fisheries as "aquaculture fisheries." The controlled systems comprise production in facilities created for the cultivation of aquaculture species through the application of technological models based on work routines (water pumping, animal feeding, fertilization, and density control). Culture-based fisheries are referred to as "aquaculture fisheries" and fishery exploitation in epicontinental reservoirs, where sustained commercial fishing is practiced, both in the systematic planting of fry produced in official aquaculture facilities, as well as those derived from the management of wild stocks of fish fry, and this would be the case of Nile tilapia (CONAPESCA, 2020).

After rice, forest products, milk, and wheat, fish are the fifth most important agricultural product and the largest animal protein resource available to humans, providing 25% of animal protein in developed countries and more than 75% in developing countries (FAO, 2019). In addition to its contribution to economic activity, employment, and foreign exchange generation, aquaculture production plays an important role in contributing to food security by meeting the demand for fish and fish products for human consumption, which has increased from 14% in 1996 to 50% in 2014, with an expected increase of 62% by 2030 (FAO, 2019). Nile tilapia is the second most widely farmed group of fish worldwide, with aquaculture production reaching 4.4 million tons in 2020 (FAO, 2022). This made a significant contribution to global food security, since this fishery resource has contributed 5% of the world's aquaculture production. In Mexico, fishing and aquaculture production amounted to 1,950,011 tons in 2020, of which 82% corresponded to fishing, while 18% came from aquaculture. The most abundant fishery resources are sardines, shrimp, and tuna, while in the domestic aquaculture industry, the most representative species in terms of production volume are white shrimp (*Penaeus vannamei*) and tilapia (*Oreochromis niloticus*) (INAPESCA, 2023). Data presented in the sectoral strategic plan 2016–2022 of the Rural Development program for the agricultural, livestock, fisheries, and aquaculture subsectors of the State of Oaxaca government; aquaculture production increased from 409 to 779 production units of aquaculture species in 2016, totaling a surface area of 2,020 hectares of cultivation, of which 170 are specifically for tilapia production.

The Papaloapan region has an important water infrastructure represented by the Miguel Alemán and Miguel de la Madrid Hurtado (Cerro de oro) dams, which generate electricity that supplies the same region, as well as part of Veracruz and Puebla. The different bodies of water in the Papaloapan region, due to their climatic conditions, present great potential for the production of Nile tilapia (FAO, 2019). This activity is practiced in dam reservoirs, whose surfaces reach up to 70,000 hectares, of which ∼2% are used for cultivation; so, there is still an opportunity to expand the current production area, increasing production and economic income, which currently amounts to 45 million pesos per year in the state. With the construction of the Temascal Aquaculture Center, a new activity was launched that would benefit the ethnic groups of Chinanteca and Mazateca in the Papaloapan region, which reveals how fishing activity began in that region. Today, the current relationship between aquaculture and food security has led to the promotion of the development of this activity in Oaxaca, as it is a state with great potential for the development of aquaculture due to its water resources.

The aquaculture activity that takes place in the upper Papaloapan region in the state of Oaxaca, groups more than 1,000 integrated producers such as the Comité Estatal de Sistema Producto Tilapia de Oaxaca, A.C. (CESPTO, A. C.), and is considered one of the economic activities with the highest expectations for the growth and development of the region and the state (SAGARPA, 2017; INAPESCA, 2023). According to the National Commission of Aquaculture and Fisheries (CONAPESCA), in 2014, Oaxaca produced 571 tons of tilapia per year and ranked fifth in the production of this species among the southeast states of the country with 29,603 tons, a region that contributed 40% of the 73,500 tons nationwide (CONAPESCA, 2014). The producers of the Comité Estatal de Sistema Producto Tilapia de Oaxaca, A.C. (CESPTO, A. C.), have, as their main objective, the technological development of the four links of the production chain [this chain is made up of the following four links: (1) raw materials; (2) typology of producers according to their production and target market; (3) processing; and (4) marketing], and they have chosen the processing link as their strategy to develop derivative products that are free of preservatives and also preserve the nutritional characteristics of this raw material. The objective is to generate greater added value to increase profit rates, diversify aquaculture activity, and expand marketing lines. The Nile tilapia has a great adaptation to environmental conditions and the wide range of food it can consume, it has been one of the most cultivated species worldwide, using fresh water for its culture and in some varieties brackish water and can even be adapted for culture in seawater (FAO, 2022). It is important to note that aquaculture products and their by-products are an excellent source of nutrients; the proteins they contain are of high biological value, in addition to minerals, vitamins and minerals (Ca^{2+}, Mg^{2+}, and P^{+}), trace elements, and vitamins. It has polyunsaturated lipids (n-3). Nile tilapia is a fish that stands out for its high protein content of high biological value; 100 g of this species, provides, on average, 18–23 g of protein, 70 g of water, and 2–4 g of total lipids, of which saturated fatty acids represent 6.5% (monounsaturated fatty acids 13.9%, polyunsaturated fatty acids 80.4%, and unsaturated fatty acids 94.3%), 128 Kcal of energy, 191–285 mg of P^{+}, 15–33 mg of Ca^{2+}, 1–3 mg of Fe^{+}, and 302 mg of K^{+} (Crespo, 2009; Cardiles-Guerrero and Contreras Tirado, 2013; Mera, 2015).

In addition to the above, it is important to consider the availability of food or food insufficiency that varies according to the region, and this refers to the fact that Mexico has wealth of soils and crop species of different botanical families that are an important source of nutrients. However, many places are not used for food production due to a lack of technology and infrastructure appropriate for the terrain and the type of crop. Some of the factors that most influence food intake are emotional, social, cultural, and economic, the latter being the most influential of all (Mundo-Rosas et al., 2019; Ramírez-Maces et al., 2023). The economic aspect is a determining factor in the purchase and, consequently, the availability of food, particularly in the state of Oaxaca, where there are still areas where men are the sole responsible for family income and women are not allowed to carry out professional growth activities, resulting in low family income and a decrease in the purchasing power of food; however, aquaculture activity favors equal and constant participation of the family members who are responsible for feeding in the cages and for all phases of cultivation.

3 Conclusion

In conclusion, we can say that the blue economy not only supports economic growth based on the premise of conservation and sustainable management of coastal and oceanic ecosystems but also the need to keep them healthy to maintain their productivity and thus sustain human needs and activities. Aquaculture in the upper Papaloapan region is mainly practiced by men of 40–49 years of age, although there are also younger aquaculturists between 20 and 39 years of age. Most of these aquaculturists belong to the ethnic groups of Chinanteca and Mazateca, and this activity has become a family activity in these communities in the last 10–15 years. Aquaculture presents challenges related to food security, such as the need to address environmental and health concerns, water pollution, fish diseases, and responsible use of natural resources. In terms of production, producers in this region should consider generating control logs to better identify the needs in practice and the possible optimization of their resources. In post-harvest handling, knowledge of sanitary quality, and value addition for tilapia, can benefit the processing link, allowing producers to identify the necessary treatments to apply, which is an option to preserve it to increase its shelf life. The generation of a tilapia by-product can increase the lines of commercialization, placing the region's producers as pioneers in the industrialization of tilapia; diversifying aquaculture in the region represents a healthy option for consumers of possible by-products, such as sausages. There are still more studies to be conducted, such as technology transfer, the search for alternatives for the use of waste generated by aquaculture, the creation of cooperatives dedicated to the integration of production in the region, and avoiding unfair sales, among other things. To promote the consumption of fish and aquaculture products, these actions are in line with the first two of the 17 Sustainable Development Goals (SDG) of the 2030 Agenda of the United Nations. A strategy should be implemented to reduce and control pollution to prevent the deterioration of water bodies and their impact on the health of the population through actions such as identifying priority areas for attention in terms of the quality of water bodies, monitoring compliance with maximum permissible limits for pollutants in discharges, promoting the reduction of diffuse pollution associated with agrochemicals, and strengthening mechanisms to control pollution derived from extractive activities and the final disposal of solid waste, promoting the reduction in diffuse contamination associated with agrochemicals and reinforcing mechanisms to control contamination derived from extractive activities and the final disposal of solid waste, in addition to monitoring the levels of parasites present in fish products and the use of all fish components (the Skeleton, viscera, and head).

Author contributions

CA-E: Conceptualization, Investigation, Writing—original draft. EC-D: Conceptualization, Investigation, Methodology, Writing—original draft. MM-L: Conceptualization, Investigation, Methodology, Supervision, Writing—original draft. DM-P: Conceptualization, Investigation, Methodology, Resources, Writing—original draft. IG-M: Conceptualization, Investigation, Supervision, Visualization, Writing—review & editing.

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Conflict of interest

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