Ortega-Mejía M, et al., J Aquac Fisheries 2023, 7: 057
DOI: 10.24966/AAF-5523/100057

HSOA Journal of Aquaculture & Fisheries

Review Article

Fresh Water Fish Farming In Mexico: Its Current Status and Factors Associated With Its Production Levels

Mariana Ortega-Mejía, Cesar Ortega[1]*, Soledad Delgadillo[2], Simón Martínez-Castañeda[1], Linda Bautista-Gómez[3] and Benjamín Valladares-Carranza[1]

[1]Centro de Investigación y Estudios Avanzados en Salud Animal (CIESA), Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma del Estado de, México

[2]Acuaculture independent consultant, Boca del Río, Veracruz, México

[3]Centro Universitario UAEM Amecameca, Km 2.5 Carretera Amecameca-Ayapango, Amecameca de Juárez, México

Abstract

This study analyzes Mexico's farming production of tilapia (*Oreochromis spp.*), carp (*Cyprinus spp.*), rainbow trout (*Oncorhynchus mykiss*), and channel catfish (*Ictalurus punctatus*) as the only freshwater fish species cultured for human consumption in the country. The analysis was based on production data from 2009 to 2020 issued by the country's fishing sector and shows that the production of trout, carp, and catfish in 2020 was lower than that obtained in 2009; tilapia production was the only one that showed moderate growth during the period. Here, we discuss the factors that the authorities and other sector members have detected as deficiencies and/or requirements to increase production and take advantage of the country's fish farming potential. We highlight that aquaculture within the fishing sector has historically been at a lower hierarchical level than fishing. Additionally, the fishing sector has been under the responsibility of multiple government agencies. Although these agencies have been instructed and intend to promote and increase aquaculture, they have not understood the importance of aquaculture as a primary activity for the country, and there has been a lack of professionals necessary to deal with the different aquaculture specialities. Lastly, we will present other proposals that the official sector has not considered. Finally, we conclude that it is necessary to include fish farming as a primary activity, supported by infrastructure and the participation of specialists in all sectors of the production chain, including the managerial level.

Keywords: Aquaculture; Fisheries; Fish farming; Fishing; Pisciculture

***Corresponding author:** Cesar Ortega, Centro de Investigación y Estudios Avanzados en Salud Animal (CIESA), Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma del Estado de México, Km. 15.5 Carretera Toluca-Atlacomulco, Toluca, Estado de, México. Código Postal 5029, Tel: +52 (722) 2898220; Email: cortegas@uaemex.mx; cos_mx@hotmail.com

Citation: Ortega-Mejía M, Ortega C, Delgadillo-Tiburcio S, Martínez-Castañeda S, Bautista Gómez L, et al. (2023) Fresh water fish farming in Mexico: its current status and factors associated with its production levels. J Aquac Fisheries 7: 57.

Received: March 02, 2023; **Accepted:** March 13, 2023; **Published:** March 20, 2023

Introduction

Aquaculture is the fastest-growing food-producing sector in the global food economy. The highest annual growth rates of aquatic animal production were in the 1980s and 1990s, with averages of 10.8% and 9.5%, respectively. The trends have gradually decreased; between 2001 and 2010, growth was 5.8% and 4.5% from 2011 to 2018, in 2019 - 2020 was 2.6% [1].

In 2020, total fish production was 178 million t in live weight, valued at 406,000 million USD; 87.5 million t (49%) were obtained from aquaculture and generated 265,000 million USD [1]. In contrast, aquaculture production during 2000 represented 25.7% of world fishery production.

Multiple factors have allowed increased fish production worldwide; better knowledge of the characteristics and basic needs of fish, the use of "new species" adapted to farming conditions, health management, the technification of the activity, and the availability of better food and supplies, including vaccines and medications [2]. Aquaculture has also been strengthened by providing products obtained with established safety standards and offering alternatives to overexploitation and deterioration of fishing resources; It is also of great socioeconomic importance for developing areas and countries [1,3]. However, this growth has been accompanied by complications such as disease and environmental deterioration [4,5].

Inland aquaculture produces the majority of farmed aquatic animals, mainly fish. In 2018, freshwater production systems produced 54.3 million t, corresponding to 62.1% of farmed fish, while in 2000 it was 57.9% [1].

In Mexico, fish farming mainly involves freshwater fish; tilapia (*Oreochromis* spp.), carp (*Cyprinus* spp.), rainbow trout (*Oncorhynchus mykiss*) and catfish (*Ictalurus* spp.) are the only species considered in official fish farming statistics [3,5-8], all included in the national aquaculture charter (Carta Nacional Acuícola) as commercial aquaculture species [9]. There is also small-scale cultivation of native mojarras *Chiclasoma urophthalmus, C. fenestratum* and the lizardfish (*Atractosteus tropicus*), as well as pike silverside (*Chirostoma estor*) [10]; however, there are no official data on their production; native mojarras can be included in total tilapia production [11]. Despite the successful reproduction of marine species such as the Pacific Snook (*Centropomus viridis*), Gulf of Mexico Snook (*C. undecimalis*), Snappers (*Lutjanus*), Pufferfish (*Sphaeroides annulatus*),

Totoaba (*Totoaba mcdonaldi*), Corvina pinta (*Cynoscion nebulusos*), and Rubia or Rabirubia (*Ocynus chrysurus*), their cultivation is minimal; official statistics [12] only refer to these species as catch-fish [5,7,8].

Official statements estimate that Mexico is ranked 17th globally for fishing and aquaculture production. However, statistics show that in the last 10 years the country's fish farming sector has had discreet increases, and production rates of farmed species in freshwater have been irregular with an overall negative trend [7,8,13,14]. An analysis of the Mexican fisheries and aquaculture sector indicated that the sector has low productivity, referring to some factors that influence it, and proposing general actions to favor production in the medium term [13]. However, the analysis did not present an in-depth diagnosis of the situation. It did not specify how to deal with aspects such as health problems, technical-scientific participation, and aquaculture training at all production levels, including managerial levels of the sector.

Despite the above, the country's extension and geography offer the potential to be a global leader in fish production [13,15], either by increasing production in established areas with "known" species, by exploiting unused or underutilized places for fish farming, and strengthening the cultivation of other freshwater and marine species [2,12]. However, the industry needs defined objectives and priorities, as well as know and analyze the factors that influence production chain development or delays in order to improve current and future conditions. Here we provide an analysis of fish farming production based on information from publications and official declarations of the sector.

Fish Farming in Mexico

The consumption, trade, and exchange of fish were common and important practices in pre-Hispanic Mexico [3], but in 1883 fish farming was linked to the Ministry of Development (Secretaría de Fomento), an institution responsible for stimulating economic, industrial, and agricultural activities in the country. This inclusion promoted the creation of aquaculture centers to reproduce rainbow trout and imported carp, and to create the first Regulation to Propagate Fish Farming in the Mexican Republic [16]. The hatchlings produced were stocked mainly for fishing purposes in permanent or temporary water bodies [5]. Additionally, the authorities encouraged farmers with water availability to convert to fish farming as their primary activity and help reduce deforestation [17]. However, during the process there was no support from professionals in the different areas of fish farming, some farms failed due to lack of advice on farm design, management, fish care, and marketing [17,18].

The most important economically farmed fish species in the country are exotic [3,5,6,9]. While there are no precise records, it is estimated that the carp of the genera *Cyprinus* spp., and *Carassius auratus* were introduced between 1876 and 1889 [9]. Tilapia (*Oreochromis aureus, O. mossambicus*, and *Tilapia melanopleura*) were officially imported in 1964 [14,19]. Although the rainbow trout and catfish of the *Ictaluridae* family are native to North America, including certain states of Mexico, those species that are currently farmed have been re-introduced; the trout between 1839 and 1888, and the blue catfish (*Ictalurus furcatus*) in 1933 [6]; *I. punctatus* is the most cultivated species in the country [20].

Since the first attempts to promote the fishing sector as an economic activity in Mexico, aquaculture has been lower in the hierarchy than fisheries [13,15-17]. In 1884, fishing, aquaculture and other livestock activities were formalized with the intention of developing and modernizing the country. However, it soon became only a complementary and a support activity by propagating the offspring of imported species in rural communities to increase animal protein consumption [9,15,18]. After this intention to promote the activity, only extensive production practices with low consumption rates were registered [5], due to discontinuous promotion actions or policies [16], associated, among other factors, with frequent changes in the institutions responsible for the sector and the lack of objective development plans.

Since the 1960s and until the mid-1990s, official fish farms produced and distributed hatchlings to repopulate the so-called "aquacultural fisheries" in dams and reservoirs. However, according to the National Aquaculture Charter, these species have passed into commercial production [9]. The first private companies emerged in 1996 to produce tilapia hatchlings for self-consumption culture, public sale, and to import and incubate rainbow trout eggs for culture and/or sale [3].

The first fishery production records in inland waters in Mexico were published in 1976, and were included as fisheries-derived only data [21]. The Statistical Yearbook of Aquaculture and Fisheries (Anuario Estadístico de Acuicultura y Pesca) was published in 2004, and despite the fact that aquaculture production data was incorporated, recent reports do not include objective production records [5], nor information on situations that could positively or negatively affect these activities, such as the availability of hatchlings or the occurrence of diseases, which are factors that have affected the development of fish farming in other countries [22].

The Importance of Fishing and Aquaculture in Mexico

Mexico's fisheries and aquaculture sector significantly contributes to the country's economy. In 2018 the industry contributed 2.5% of the agricultural Gross Domestic Product (GDP), equivalent to 0.08% of the national GDP; of the 295,033 people dedicated to the sector, 238,783 participate in fishing activities and 56,250 in aquaculture [7]. In coastal or rural areas, fisheries and aquaculture are the main sources of animal protein and an important livelihood source [7,11,13,23]. In some places, the sector is essential for local gastronomic development or for regional production and commercialization [18,23]. In this sense, the country's 6,500 km^2 of inland water surfaces offer diverse climates and ecosystems to produce different species [13].

In Latin America, Mexico is the fourth largest aquaculture producer after Ecuador, Brazil, and Chile. In 2018, 247,000 t of aquaculture-derived products were produced, which only contributed 0.22% to world aquaculture production [14]. The production of the species included in this study is not enough to cover the national demand; none of the species are significantly exported. Additionally, in 2020, 140,393 t of tilapia were imported [14].

In 2020, Mexico's per capita fish consumption was approximately 14.0 kg. Sardine was the most consumed fish, with an average of 2.5 kg, while tilapia was 1.97 kg, carp was 0.15 kg, and catfish was 0.03 kg [7]. The projection is that by 2028 the general per capita consumption will reach 6.03 kg. The potential consumption of these freshwater species for the country is enormous and represents an excellent opportunity to increase local production [7], although there are few export possibilities for now.

Year Specie	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Tilapia	77,009	81,250	75,927	77,547	102,039	128,866	135,129	182,952	179,919	168,359	113,149	114,769
Annual growth rate		5.2	< 6.5	2.1	24	20.8	4.6	26	< 1.6	< 6.4	< 32.8	1.4
Rainbow trout	7,969	9,212	10,486	9,781	9,757	19,123	11,527	11,132	14,197	13,454	4,572	3,871
Annual growth rate		13.5	1.2	< 6.7	< 0.24	49	< 40	< 3.4	21.6	< 5.2	< 66	< 15.3
Catfish	5,186	5,466	4,434	4,481	6,754	8,806	9,306	7,812	8,274	6,589	3,883	3,827
Annual growth rate		5.1	< 19	1.0	33.6	23.3	5.4	< 16	5.6	< 20	< 41	< 1.4
Carp	26,659	30,241	23,507	26,920	33,003	43,053	43,716	48,400	53,421	48,126	18,253	18,979
Annual growth rate		12	< 22.2	12.7	18.4	23.3	1.5	9.7	9.4	< 9.9	< 62	4.0

Table 1: Production data of freshwater fish species farmed in Mexico and the annual growth rates between 2009 and 2020.

Source. Own elaboration, adapted from Statistical Yearbooks of Aquaculture and Fisheries [7,8,24].

Fish Production Data from Mexico

The official statistics summarized in Table 1 indicate the aquaculture production values of freshwater fish in the last 12 years. During 2020 the main fish species produced in Mexico were tilapia (*Oreochromis* spp.) with 114,769 t; carp (*Cyprinus* spp.), 18,979 t; rainbow trout (*Oncorhynchus mykiss*), 3,871 t and catfish (*Ictalurus* spp.) with 3,827 t [7].

According to official data, between 2009 and 2018, the average annual growth rate in general tilapia production (farming and capture) was 9.08% (8), a value higher than the world report of 7.6% observed for the same period in farmed and wild tilapias [1]. However, in the last 10 years, the average annual growth in Mexico decreased to 4.7%. In the period analyzed (Table 1), there were notable increases in tilapia growth rate in 2013, 2014, and 2016, the years with the highest historical production. However, there has been a decline since 2017, and the negative trends registered until 2020 (7) deserve attention and deep analysis.

Rainbow trout production values were relatively constant between 2010 and 2013. According to official data, in 2013, 9757 t were produced; 2014 was the year with the highest annual growth rate with 19,123 t (49%); however, in 2015, production fell by 40% compared to the previous year. This downward trend continued until 2020, when rainbow trout production barely reached 3,871 t [7,8].

Catfish production also had highs and lows during the analyzed period; it began at -19% in 2011 compared to 2010; in 2013, it increased 33.6%, 23.3% in 2014, reaching its maximum level in 2015 with 9,306 t. However, since then (except for 2017), there has been a decrease, which in 2020 reached 3,827 t [7,8].

Until 2018, the annual growth for carp was 6.78% [8]. In 2011, it had negative growth -22% compared to 2010. Its highest growth was recorded in 2017 with 53,421 t, and between 2014 and 2018, there was a relatively stable production with a positive trend. However, in 2019 there was a 62% decline compared to 2018 [7,24], a similar trend to the other species included in this analysis.

The data in Table 1 show that between the first and last year analyzed, tilapia production was the only one of the 4 species with overall growth. However, as of 2017, its production shows a clear decline [7,8,24]. There was a shocking setback in the other three species; in the 12 years analyzed, production levels for 2009 were greater than those in 2020 [7,8]. It is interesting to note that for the analyzed period, the annual production values do not have a regular trend, there are ups and downs [13], and in the four species, there was a drastic productive drop in 2017 [7]. In a national context, the obtained values are aligned with previous decades' trends that have shown production stagnation. In 1980 the national aquaculture production was higher than the production levels of Norway and Chile. These countries are among the world leaders thanks to the vision of opportunity and implementation of actions to overcome fishing restrictions, use of technologies and export prospects, meanwhile in recent years Mexico is not considered within the top ten producing countries [13,16]. Although the species included in this analysis are incorporated within commercial aquaculture [9], there is officially no explanation for the decline in production, nor actions to amend it or any justification for not doing so.

Factors Associated with Current Fish Production in Mexico

At the international level, production statistics reported by each country generally explain situations or facts that affect production trends [4,22], such as low availability of eggs and/or offspring to populate farms, scarcity of water, presence of diseases and their consequences, higher production costs either due to high input prices or

due to mandated sanitary restrictions [22]. In this sense, the factors that influence the production values registered in Mexico have been partially commented on in official [13] and unofficial [15] documents. However, they have not been fully addressed and/or explained in the statistical yearbook of aquaculture and fisheries [7] nor in the National Aquaculture Charter [9], which refers to the country's production state of aquatic species.

Aquaculture success in several countries has been based on implementing real support policies, where governments have proposed realistic regulations based on the characteristics and conditions of each region, production organization is strengthened at different levels, which generate confidence in the producers, and favors the development of global production and trade chains. It also allows the specialization of technological services, including relevant technical assistance [18]. Regarding the above, aquaculture in Mexico has been developed based on production models from other countries at the proposal of official bodies or the initiative of producers. However, growth has been slow and unable to adapt copied practices or technologies, with a lack of planning in site selection, production, demand, and profitability [11, 15]. Some production units in Mexico have unused or underutilized infrastructure, either due to lack of water or not planning production objectives, considering the characteristics and actual needs of the farms [18].

Previous to and during the beginning of Mexico's independence, the officials responsible for the fishing sector did not considered aquaculture a primary agricultural activity [13,15,16]. Aquaculture has remained hierarchically immersed within fisheries and has not been included in benefit programs that favour other livestock activities, receiving little recognition. The specific and crucial importance has not been provided to stand out as a primary productive activity. It is important to remember that these are different activities, both essential for the sector but requiring specific actions. While fisheries are extractive and take advantage of available natural resources, aquaculture is a productive activity and requires investment and resource management [15]. In this sense, the success of Norwegian aquaculture is associated with the creation of a Ministry of Fisheries and Aquaculture in 1940, which positioned aquaculture at the same level as other primary agricultural activities [16].

Administratively, aquaculture in Mexico has been regulated by several government agencies, which has caused gaps, instability, little continuity, and a lack of strategic planning in the development policies for the sector, regardless of the economic model of the government in turn [15, 16]. At the beginning of this century, the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), an official agency in charge of animal health and production, included fish as animals under its jurisdiction. Despite this administrative transition, the lack of planning to differentiate and direct aquaculture and fisheries activities is evident, as well as the need to have qualified human resources to address them, both at a technical and managerial level.

The information in Table 1 corresponds to data from the Statistical Yearbook of Aquaculture and Fisheries [7,8], published by the central administration with information collected by the fishing sub-delegations of each State. Therefore, the quality and integrity of the data reported depend on the information provided by each State and may not necessarily reflect the real production state and activity trends [3]. Although the delivery of information is constant and the information for 2021 was collected and reported, the corresponding yearbook has not been published; 2020 [7] is the latest version available.

Producers and people related to fish farming have identified situations that hinder the delivery of information or its frequency, leading to inconsistencies in the reported data. A requirement to carry out formal aquaculture is to have a National Registry of Fisheries and Aquaculture (RNPA). However, this may limit data collection since less than 50% of producers are associated with an RNPA, and unregistered units do not declare their production [15,23]. Another scenario is that, despite being registered at RNPA, the farms are too far from the government office to declare production. Although the process could be done online, it must be stamped and validated by the state Fisheries office. In this sense, the authorities responsible for the sector have detected that overregulation to develop legal aquaculture in the country predisposes informality [13].

By official instruction, production reports must be delivered monthly. This situation requires collecting and maintaining Production Unit records; however, many fish farmers carry out rural aquaculture (repopulation or subsistence) [3,13,23], making it difficult to keep accurate information records. This shows the need for a closer producer-authority approach. Likewise, producers often do not declare their actual production for fear of tax collection or withdrawal of government support; in other cases, the fear is that their information will be exposed to criminals.

A reality that contravenes official declarations to promote and support aquaculture [13] is an insufficient rapprochement between authorities and producers to make surveillance, advisory, or extension visits. For central policy reasons, the fishing sub-delegations have disappeared in recent years, and the resulting reduction or absence of field and office technical personnel to verify the information provided is evident. Although the aquaculture health committees (Comités de Sanidad Acuicola) attend the farms and know their production rates [9], reporting production is not their responsibility. The role of the committees is to provide advice and technical assistance in aquatic animal health aspects; however, most of them are not made up of veterinary professionals [17], and they show deficiencies in job security and technical-scientific training.

In addition to the above, production statistics are not adequately reviewed and analyzed to objectively determine the limiting factors or conditions and detect errors and inconsistencies in the reported data. For example, the National Aquaculture Charter [9] presents different production numbers based on data from the 2018 Yearbook. Previously, Ortega and Valladares [18] described a striking inconsistency in the production values of rainbow trout in the State of Tamaulipas. While the specie are not farmed, the 2018 Yearbook [8] placed this State in third place for national production, and in first place in 2020 [7].

The foregoing could also be associated with a set of inconsistencies in the report or database that make it impossible to objectively determine the production values of these species in the States. Thus, the lack of control and surveillance has caused some States to report acquired fishery products from other states as their own. Additionally, while official statistics indicate that fish farming shows trends of increased production [13], it is unclear whether the increase is due to an actual rise in production or an increase in the number of farms. A critical situation in official statistics is the lack of reports on fish farming production of native and marine species [5,10, 11,12].

Sanitary Aspects

The increase in world fish production has been accompanied by diseases, dissemination and invasion of exotic species, and negative environmental impacts, among others [18,22,25]. Although fish diseases of different etiologies have been reported in Mexico [2,26], there is no official information on the diseases identified, and their possible impacts are unknown. Given this, it is clear that the variations in production cannot be attributed to the occurrence of certain diseases.

The periodic registration of the health situation helps analyze the characteristics and trends of diseases or pathogens. It shows whether the number of cases has decreased or if a disease has spread to previously unaffected regions. Although the authorities consider aquaculture health and safety a priority and coordinate diagnostic activities through aquaculture health committees and official laboratories [9], the results of such actions are unknown, which could be key in explaining the observed production rates in the years analyzed. The lack of information or its unreliability creates uncertainty; lack of data is often the key to not applying surveillance measures [18]. Having this information is necessary to face challenges such as climate change, anthropogenic pressure, limited sources of good-quality water, and the inherent growth of aquaculture.

A fundamental part of successful fish production is having a health diagnosis service capable of detecting infectious agents or causes of disease [22,25]. In this sense, the health authorities of the sector have an incomplete vision. In Mexico, health diagnosis is mainly aimed at detecting some diseases on the OIE list and others that the authority considers important. This does not cover the need to detect any health threats since they focus on detecting exotic diseases that have not affected national fish production [18,27]. This mentality makes it difficult to detect new or non-infectious diseases that could influence the registered production values.

Success stories in disease control have shown that the health system must have sufficient human and financial resources that are managed and coordinated transparently, with broad participation and scientific-based decision-making. In this context, Chile's Infectious Salmon Anemia (ISA) emergency allowed the national aquatic animal health services to strengthen their capacities and helped sustain the salmon industry [22]. In México, the National Aquaculture Charter [9,13] has proposed that part of the solution is to create health programs or strategies based on the reality of the country's regions, considering cultivated species and health history. However, these proposals are general and ambiguous for the four key species as it proposes to carry out epidemiological studies and standardize diagnostic techniques only for high-risk diseases, without addressing endemic diseases or others that are not consider important. Likewise, it lists unreported diseases in the country and omits other documented ones. The preceding reflects ignorance and the absence of specialists at the decision-making level in the aquaculture sector.

Understanding the types of Aquaculture Production in Mexico

The policies and strategies for developing fish farming in the countries must be designed considering aspects such as the product type and whether production has a social or commercial vision. An important aspect associated with the production trends observed in this analysis is related to the fact that about 50% of the production units are dedicated to rural aquaculture [13,23]. This represents enormous social importance for supporting rural sectors or marginalized communities by producing and harvesting fish in lagoons, dams, rivers, and reservoirs without managing and/or supplying food [3]. Despite their importance and social contribution, these farms face production problems since most depend on the distribution or contribution of offspring by government institutions, subject to the availability of offspring and inputs and the producer's disposition [13,18,23].

In Mexico, these repopulation and subsistence systems were traditionally based on producers (farmers) inducted into aquaculture through government support programs or policies [3,18,23]. However, these programs have created a dependency on government agencies and have led to little interest from producers to participate actively in production processes and associated responsibilities, resulting in inconsistent production.

Since rural aquaculture is extremely important for a sector of the country's population, a system that offers real support for each situation, establishes a clear separation between fisheries and aquaculture, and obtains reliable production data is required. Although official documents have highlighted the importance of fish farming in Mexico, the priorities are not defined. In this sense, if the main objective was to provide low-cost protein for underprivileged human sectors through rural fish farming, its production should also be efficient and productive.

Conclusion

In Mexico, several species of native and exotic fish are cultivated; however, official statistics only record freshwater aquaculture production of tilapia, carp, rainbow trout, and channel catfish. In recent years, the annual growth rates of the production of these species have shown an inexplicable decline. Until now, the official sector has no explanation for these production trends. Given the national fishing and pisciculture production numbers observed in this analysis and the international aquaculture growth scenario, there is a real urgency for the Mexican aquaculture sector to identify and integrate alternatives that trigger aquaculture production.

Since the beginning of the fishing industry (fishery and aquaculture) in México, aquaculture has remained at a lower hierarchical level than fishery since the agencies responsible for the fishing industry have not understood the differences between these two sub-categories. The analysis shows that there is currently no comprehensive planning for the aquaculture sector, which contrasts with statements that announce aquaculture as a national security activity with constant support. Evidently, the decrease in production rates is not derived from policies or instructions to reduce the environmental impact or focused solely on providing quality protein for disadvantaged rural sectors. Instead, it lacks planning and management and specific objectives and development plans for rural and commercial fish farming must be proposed.

Rural fish farming in Mexico makes a significant social contribution, but its participation in production is unknown. This production mode has depended on government programs as a provider of inputs and/or animals, consultancies of different types, technology transfer, organization, etc. For this, the institutions must have sufficient resources to meet all the needs; however, the sector presents deficiencies such as the lack of adequate personnel and capacity in the different production links, sometimes extending to managerial levels.

Although there are successful cases of rural and commercial producers, in other cases, dependency (paternalism) has limited the technical improvement of producers. The reduction of technical personnel in government agencies and the disappearance of offices associated with the country's livestock sector represent obstacles for overcoming production trends when, on the contrary, it is necessary to have sufficient and trained personnel in fish production and management.

Finally, collecting information is important to the country's fishing sector. Both rural and commercial fish farming must generate information and data to prepare reliable production records and reports, which allow actions to be taken to favor the development of the activity. Recording all production statistics, no matter how minimal, could further evidence the deficiencies in the production systems since, regardless of the form of production, the sector must show growth and evidence development. They must find a way to integrate producers from all sectors to formalize production. Experience shows that tripartite participation is necessary: industry-academia and government.

Acknowledgement

This work was part of the research project Ciencia Básica CONACY- México: reference 287537 (4489/2018/CI from SIEA-UAEM). The authors thank the fish farmers and people from the official sector who provided information.

Conflict of interest

The authors declare no competing conflicts of interest.

References

1. FAO (2022) The State of World Fisheries and Aquaculture 2020. Towards Blue Transformation.
2. Alcántara JF, Carranza BV, Ortega C (2022) Enfermedades bacterianas y bacterias obtenidas en peces cultivados de México-Una revisión. Rev MVZ Córdoba 27: 23-35.
3. FAO (2021) National Aquaculture Sector Overview, México. Text by Montero RM. Fisheries and Aquaculture Division.
4. Rodger HD (2016) In: Adams A, eds. Fish Vaccines. Birkhäuser Advances in Infectious Diseases. Springer Base l1-34.
5. Ibáñez AL, Espinosa-Pérez H, García-Calderón JL (2021) Recent data on the distribution of the exotic species used in Mexican freshwater fisheries based on fish stocking. Rev Mex Biodiver 82: 904-914.
6. Arredondo-Figueroa JL (1983) Especies animales acuáticas de importancia nutricional introducidas en México. Biotica 8: 175-199.
7. CONAPESCA (2022) Anuario Estadístico de Acuacultura y Pesca 2022. Comisión Nacional de Pesca, Mexico.
8. CONAPESCA (2018) Anuario Estadístico de Acuacultura y Pesca 2018. Comisión Nacional de Pesca, Mexico.
9. SAGARPA (2018) Acuerdo mediante el cual se aprueba la actualización de la Carta Nacional Acuícola. Secretaria de Agricultura y Desarrollo Rural, Pesca y Alimentación, Mexico.
10. Estrada-Navarrete FD, Soto-Galera E, Hernández-Montaño D, Sandoval-Huerta ER (2015) Actualización de los registros de pescado blanco Chirostoma estor y C. humboldtianum en cinco cuerpos de agua de Michoacán, México. Ciencia Pesquera 23:73-76.
11. Dávila-Camacho A, Galaviz-Villa I, Lango-Reynoso F, Castaneda-Chávez R, Quiroga-Brahms C, et al. (2019) Cultivation of native fish in Mexico: Cases of success. Rev Aquac 11: 816-829.
12. Ibarra-Castro L, Ochoa-Bojórquez MO, Sánchez-Tellez JL, Rojo-Cebreros AH, Álvarez-Lajonchère L (2020) Advances in spotted rose snapper (Lutjanus guttatus, Steindachner, 1869) juvenile's production. Rev Invest 40: 1-14.
13. CONAPESCA (2021) Programa Nacional de Pesca y Acuacultura 2020 -2024. Comisión Nacional de Acuacultura y Pesca, Mexico.
14. Martínez-Cordero FJ, Delgadillo TS, Sánchez-Zazueta E, Cai J (2021) Tilapia Aquaculture In México: Assessment With a Focus On Social and Economic Performance. FAO Fisheries and Aquaculture.
15. Cuéllar-Lugo M, Asiain-Hoyos A, Juárez-Sánchez JP, Reta-Mendiola J, Gallardo-López F (2018) Normative and institutional evolution of aquaculture in Mexico. ASYD 15: 541-564.
16. Celaya TM, Almaraz AA (2018) Historical recount of fishing regulations in Mexico: A long process of growth and crisis. Entreciencias 6: 31-46.
17. Ortega C (2012) Veterinary medical education and veterinary involvement in aquatic-animal health and aquaculture in Mexico. J Vet Med Educ 39: 195-199.
18. Ortega C, Valladares B (2015) Analysis on the development and current situation of rainbow trout (Oncorhynchus mykiss) farming in Mexico. Rev Aquac 09: 194-202.
19. Morales- Díaz A (199) La Tilapia en México. Biología, Cultivo y Pesquerías. AGT Editor.
20. Lara-Rivera AL, Parra-Bracamonte G, Sifuentes-Rincón AM, Gojón-Báez H, Rodríguez-González H, et al. (2015) El bagre de canal (Ictalurus punctatus Rafinesque, 1818): Estado actual y problemática en México. Lat Am J Aquat Res 43: 424-434.
21. Departamento de pesca (2021) Anuario Estadístico Pesquero 1978. Dirección General de Planeación lnformática y Estadística, México.
22. Gallardo LA, Lara M, Gaete A, Montecinos K (2019) Recovering sustainability after a health crisis in aquatic animals. Rev Sci Tech 38: 601-613.
23. García-Mondragón D, Gallego-Alarcón I, García PD, Fonseca C, Cervantes-Zepeda I (2021) Characterization of rural small-scale rainbow trout (Oncorhynchus mykiss) farms in Mexico. Lat Am J Aquat Res 49: 828-835.
24. CONAPESCA (2022) Anuario Estadístico de Acuacultura y Pesca 2017. Comisión Nacional de Pesca. Mexico.
25. Faruk M, Sarker M, Alam M, Kabir MB (2004) Economic Loss from Fish Diseases on Rural Freshwater Aquaculture of Bangladesh. Pak J Biol Sci 7: 2086-2091.
26. Salgado-Miranda C, Palomares E, Jurado M, Marín A, Vega F, et al. (2010) Isolation and distribution of bacterial flora in farmed rainbow trout from México. J Aquat Anim Health 22: 244-247.
27. SAGARPA (2018) ACUERDO mediante el cual se dan a conocer en los Estados Unidos Mexicanos las enfermedades y plagas exóticas y endémicas de notificación obligatoria de los animales terrestres y acuáticos. Secretaria de Agricultura y Desarrollo Rural, Pesca y Alimentación, Mexico.

HERALD

Advances In Industrial Biotechnology | ISSN: 2639-5665

Advances In Microbiology Research | ISSN: 2689-694X

Archives Of Surgery And Surgical Education | ISSN: 2689-3126

Archives Of Urology

Archives Of Zoological Studies | ISSN: 2640-7779

Current Trends Medical And Biological Engineering

International Journal Of Case Reports And Therapeutic Studies | ISSN: 2689-310X

Journal Of Addiction & Addictive Disorders | ISSN: 2578-7276

Journal Of Agronomy & Agricultural Science | ISSN: 2689-8292

Journal Of AIDS Clinical Research & STDs | ISSN: 2572-7370

Journal Of Alcoholism Drug Abuse & Substance Dependence | ISSN: 2572-9594

Journal Of Allergy Disorders & Therapy | ISSN: 2470-749X

Journal Of Alternative Complementary & Integrative Medicine | ISSN: 2470-7562

Journal Of Alzheimers & Neurodegenerative Diseases | ISSN: 2572-9608

Journal Of Anesthesia & Clinical Care | ISSN: 2378-8879

Journal Of Angiology & Vascular Surgery | ISSN: 2572-7397

Journal Of Animal Research & Veterinary Science | ISSN: 2639-3751

Journal Of Aquaculture & Fisheries | ISSN: 2576-5523

Journal Of Atmospheric & Earth Sciences | ISSN: 2689-8780

Journal Of Biotech Research & Biochemistry

Journal Of Brain & Neuroscience Research

Journal Of Cancer Biology & Treatment | ISSN: 2470-7546

Journal Of Cardiology Study & Research | ISSN: 2640-768X

Journal Of Cell Biology & Cell Metabolism | ISSN: 2381-1943

Journal Of Clinical Dermatology & Therapy | ISSN: 2378-8771

Journal Of Clinical Immunology & Immunotherapy | ISSN: 2378-8844

Journal Of Clinical Studies & Medical Case Reports | ISSN: 2378-8801

Journal Of Community Medicine & Public Health Care | ISSN: 2381-1978

Journal Of Cytology & Tissue Biology | ISSN: 2378-9107

Journal Of Dairy Research & Technology | ISSN: 2688-9315

Journal Of Dentistry Oral Health & Cosmesis | ISSN: 2473-6783

Journal Of Diabetes & Metabolic Disorders | ISSN: 2381-201X

Journal Of Emergency Medicine Trauma & Surgical Care | ISSN: 2378-8798

Journal Of Environmental Science Current Research | ISSN: 2643-5020

Journal Of Food Science & Nutrition | ISSN: 2470-1076

Journal Of Forensic Legal & Investigative Sciences | ISSN: 2473-733X

Journal Of Gastroenterology & Hepatology Research | ISSN: 2574-2566

Journal Of Genetics & Genomic Sciences | ISSN: 2574-2485

Journal Of Gerontology & Geriatric Medicine | ISSN: 2381-8662

Journal Of Hematology Blood Transfusion & Disorders | ISSN: 2572-2999

Journal Of Hospice & Palliative Medical Care

Journal Of Human Endocrinology | ISSN: 2572-9640

Journal Of Infectious & Non Infectious Diseases | ISSN: 2381-8654

Journal Of Internal Medicine & Primary Healthcare | ISSN: 2574-2493

Journal Of Light & Laser Current Trends

Journal Of Medicine Study & Research | ISSN: 2639-5657

Journal Of Modern Chemical Sciences

Journal Of Nanotechnology Nanomedicine & Nanobiotechnology | ISSN: 2381-2044

Journal Of Neonatology & Clinical Pediatrics | ISSN: 2378-878X

Journal Of Nephrology & Renal Therapy | ISSN: 2473-7313

Journal Of Non Invasive Vascular Investigation | ISSN: 2572-7400

Journal Of Nuclear Medicine Radiology & Radiation Therapy | ISSN: 2572-7419

Journal Of Obesity & Weight Loss | ISSN: 2473-7372

Journal Of Ophthalmology & Clinical Research | ISSN: 2378-8887

Journal Of Orthopedic Research & Physiotherapy | ISSN: 2381-2052

Journal Of Otolaryngology Head & Neck Surgery | ISSN: 2573-010X

Journal Of Pathology Clinical & Medical Research

Journal Of Pharmacology Pharmaceutics & Pharmacovigilance | ISSN: 2639-5649

Journal Of Physical Medicine Rehabilitation & Disabilities | ISSN: 2381-8670

Journal Of Plant Science Current Research | ISSN: 2639-3743

Journal Of Practical & Professional Nursing | ISSN: 2639-5681

Journal Of Protein Research & Bioinformatics

Journal Of Psychiatry Depression & Anxiety | ISSN: 2573-0150

Journal Of Pulmonary Medicine & Respiratory Research | ISSN: 2573-0177

Journal Of Reproductive Medicine Gynaecology & Obstetrics | ISSN: 2574-2574

Journal Of Stem Cells Research Development & Therapy | ISSN: 2381-2060

Journal Of Surgery Current Trends & Innovations | ISSN: 2578-7284

Journal Of Toxicology Current Research | ISSN: 2639-3735

Journal Of Translational Science And Research

Journal Of Vaccines Research & Vaccination | ISSN: 2573-0193

Journal Of Virology & Antivirals

Sports Medicine And Injury Care Journal | ISSN: 2689-8829

Trends In Anatomy & Physiology | ISSN: 2640-7752