Review Article

Aquaculture in Algeria: Current Status, Analysis, and Considerations for Commercial Development

Abstract

Aquaculture in Algeriahas developed significantly since the 1920s, primarily focusing on oyster and mussel farming. Establishing the Ministry of Fisheries and Marine Resources (MPRH)in 1999marked a crucial milestone for the industry. Despite challenges in data collection, Algerian aquaculture production reached only 4,779.29 tonnes in 2021, showing a mere 0.2% of African production and 0.0044% of world aquaculture production. More than half of production comes from marine fish cultured in private-sector sea cages. However, shrimp production is almost null. The taxonomic composition of Algerian aquaculture is diverse, with marine and freshwater fish species playing prominent roles. Despite these challenges, the aquaculture fieldin Algeria has demonstrated an impressive annual growth rate of 12.49% and receives continuous government support.Nevertheless, limited infrastructure, a shortage of expertise, and the need for further research pose significant obstacles. Efforts are underway to integrate aquaculture with agriculture in Saharan zones, further facilitated by governmental support. Overcoming challenges and promoting sustainability through strengthening research capacities, fostering collaboration, and providing financial support is crucial for the advancement ofindustry. By addressing challenges and embracing sustainability, the aquaculture branch in Algeria can unlock its full potential, ensuring food security, economic growth, and environmental sustainability.

Keywords: Aquaculture growth,aquaculture integration,fish cultivation, food security,shrimp farming

1 Introduction

Aquaculture, farming aquatic animals and plants, has emerged as a rapidly growing sector in the global food industry, providing a solution to the increasing demand for food as the world population continues to rise. The production limits of land-based protein sources have been reached in some regions, necessitating the expansion of marine production as an alternative protein source. However, manyfisheries in the world face significant challenges, with overfishing pushing them beyond their sustainable limits and leading to the collapse of some populations. This often stems from inadequate fisheries management and the widespread occurrence of illicit, unreported, and unregulated fishing practices. Embracing environmentally responsible fishing techniques, enforcing effective fisheries management, and combating unlawful fishing are vital for ensuring the sustained viability of our marine resources and the continuation of sustainable practices while meeting the demand for protein.The global fishing fleet exceeds sustainable limits by 2.5 times, with 85% of global fish stocks at risk of illegal fishing [1]. Approximately 24% fish species confront challenges related to overexploitation, depletion, or recovery, while more than half (i.e., 52%)of fisheries cannot produce greater harvests. In 2020, global fishing production declined by 4.0%, with marine capture at 78.8 million tonnes and inland capture at 11.5 million tonnes[2].In Algeria, capture fisheries production in 2020 was 81,456 tonnes, with marine fish comprising 97.1% of the total.The 2.9
% share of shellfish, with a primary 2.2% share belonging to crustaceans, was below the averages for Northern Africa and the world, while molluscsaccounted for 0.6%. Surprisingly, the capture fisheries in Algeria were 100% from marine areas; inland fisheries had no contribution to the sector production, as opposed to a 17.8% share in Northern Africa and a 12.5% share in global production n [3].

Over the past 50 years, aquaculture has made significant advancements, providing over 49% of the global seafood supply. This marks a substantial increase from its share of 4% in the 1950s; it accounted for 5% in the 1970s, it rose to 20%, and by the 1990s, it reached 44% in the 2010s. In terms of

aquaculture production, 73.54% originated from marine waters, and 62.40% came from inland water sources. In the same year, worldwide aquaculture production exceeded a record 122 million tonnes, comprising 87.5 million tonnes of aquatic animals and 35.1 million tonnes of algae [2]. Consequently, the average annual growth rate of global aquaculture production is expected to slow over the next decade, dropping to 2.0% in 2020-2030 from 4.2% in 2010-2020. Except for Egypt and Nigeria, Africa experienced a 14.5% growth in aquaculture production in 2019. However, total African aquaculture witnessed a slight contraction in 2020, mainly due to the decline in production in Egypt, the primary producer in the region. Aquatic husbandryin Algeria in 2020contributed 0.0045% to the global volume, 0.33% of the African production volume, and 0.53% of the total national fishery production [4]

In Algeria, the program initiated in 2000, spanning from 2000 to 2025 for the advancement of fisheries and aquaculture initiatives, has set strategic goals to produce approximately221,000 tonnesfrom marine fishing and 53,000 tonnes from diverseaquaculture ventures by 2025[5]. This plan is built upon scientific and technical knowledge and aims to establish a resource management mechanism for fisheries and aquaculture. It involves the active participation of productive and academic sectors and the collaboration of all levels of government to identify and evaluate opportunities for developing these sectors.However, the current status of fishery and aquaculture in Algeria is far from achieving the outlined objectives. This review paper is intended to offer a comprehensive perspective on the current condition of aquaculture in Algeria, relying on FAO statistics. It will analyse production per environment and categories, emphasising the significant species cultured and critical components of the aquaculture industry in the country. Additionally, the paper will explore the barriers and considerations associated with the transition from traditional to commercial aquaculture, offering a comprehensive analysis of the challenges and potential solutions. By examining the growth trajectory and initiatives undertaken thus far, this review aims to shed light on the development and potential of aquaculture in Algeria.

2 Brief History

Aquaculture in Algeria has a rich and evolving history that spans several decades. The industry has undergone significant developments and milestones, shaping its current status. Algerian aquaculture has a history that dates back to the early 20th century. The establishment of the Bou-Ismail station in 1921 marked the inception of the national oyster industry (*Crassostrea gigas*) and mussel (*Mytilus galloprovincialis*) farming. In 1937, a freshwater fish breeding station focused on species like largemouth Bass *(Micropterus salmoides)* and rainbow trout *(Oncorhynchus mykiss).* The aim was to stock impoundments and wadis with these fish species. However, the station was later closed. During the 1940s, efforts were made to exploit the lakes in Eastern Algeria, which encompass Mellah, Oubeira, and Tonga.This entailed the set-up of fish weirs, the initiation of both fisheries, and the cultivation of shellfish of species such as *M. galloprovincialis*, *C. gigas*, and grooved carpet shell(*Ruditapesdecussatus*). In the following decades, the aquaculture industry in Algeria experienced further developments. Cooperation programs were initiated with China, focusing on carp reproduction techniques and restocking activities. Private producers also played a role in aquaculture, exporting significant produce to Italy.From 1982 to the present, the industry has seen continued growth and government support. The National Dams Agency initiated dam restocking operations, introducing species such as common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodonidellus*), Silver carp (*Hypophthalmichthys molitrix*), and bighead carp (*Hypophthalmichthys nobilis*). The government has provided subsidies to promote and develop the aquaculture sector, establishing maritime aquaculture enterprises, freshwater aquaculture stations, and open-sea shellfish culture [6].

Today, sea impoundment fisheries dominate aquaculture production in Algeria, with a focus on marine species such as European seabass (*Dicentrarchuslabrax*) and githead seabream (*Sparus aurata*).In addition, efforts are being made to integrate aquaculture with agriculture in Saharan zones, and the government continues to support the growth and development of the industry. Algerian aquaculture production is now in a phase of rapid expansion and development, signalling significant growth potential for the industry.

3 Data Collection

The primary source of data for this review is the FAO. 2023. Fishery and Aquaculture Statistics. Global aquaculture production 1950-2021 (FishStatJ; www.fao.org/fishery/ statistics/software/FishStatJ/en). However, it is essential to note that aquaculture production data is not readily available or formally reported for Algeria due to the absence of a national statistics system dedicated to collecting and reporting such data. As a result, FAO relies on alternative resources and estimation methods to approximate aquaculture production figures for Algeria. Information was gathered through various personal communications, from multiple institutions and organisations websites,and available literature to overcome the data limitations used. The production data discussed in this review pertain to aquatic animal species, excluding plants, and are measured in tonnage.

4 Current situation of aquaculture in Algeria

Aquaculture in Algeria encompasses various aspects[6]:

1. In the eastern part of the country, fisheries within brackish and freshwater lake basins contribute to a diverse array of fish species. These species encompass mullet, eels, sole, European bass, common carp, gilthead seabream, sand steenbras, clams, oysters, Caramote prawns, white seabream, and Chinese carp.Inland impoundments play a significant role in supporting aquaculture production. They are utilisedto cultivate common carp, Chinese carp, tilapia,barbel species, shrimps, and other crustacean species such as crayfish (R. Bilal, pers. comm. 2023), contributing to developing inland commercial fisheries.

2. Private operators engage in marine fish farmingby using floating cages. This method produces species of European seabass, Meagre, and gilthead seabream. The reproduction of these two species takes place at the sole marine farm in the regionunder the supervision of the National Center for Research and Development in Fisheries and Aquaculture (CNRDPA).
3. Shellfish culture is also conducted by private business operators, leading to the production of significant quantities of Mediterranean mussels and Pacific-cupped oysters.

These diverse aquaculture practices showcase the efforts to enhance its domestic aquaculture production and contribute to the sustainable development of the fisheries and aquaculture industry.

5 Aquaculture production in Algeria

Aquafarmingin Algeria has shown significant growth and fluctuations over the years. From around 450 tonnes two decades ago, it expanded to 4,779.29 tonnes in 2021, with a value of USD 20.733 thousand. Nonetheless, Aquatic farming in the country remainsrelatively low compared to the top 10 African countries, constituting just 0.21% of the total aquaculture production on the continent. (**Fig. 1**). Despite this, Algeria has experienced a relatively high annual growth rate of 12.49%, surpassing sub-regional, regional, and global averages. Except for Tunisia, it also has the highest growth rate among its neighbouring countries (**Tab. 1**).

Table 1: Status and trends of aquaculture production, 2001-2021

Country/area	Aquaculture production of total species (tonnes)		Annual growth (%)
	2001	2021	
World	34617654.72	90863706.34	4.94
Africa	405675	2322023.3	9.11

Northern Africa	348629	1638558.1	8.05
Algeria and selected neighbouring countries			
Egypt	342864	1576189.4	7.93
Spain	311591	279880.43	-0.54
Italy	218330	145861.9	-2.00
France	251620	198505.7	-1.18
France	251620	198505.7	-1.18
Greece	97512	143863.47	1.96
Türkiye	67244	471686	10.23
Tunisia	1868	25957.2	14.06
Morocco	1403	1922.18	1.59
Sudan	1000	9900	12.15
Algeria	**454**	**4779.29**	**12.49**

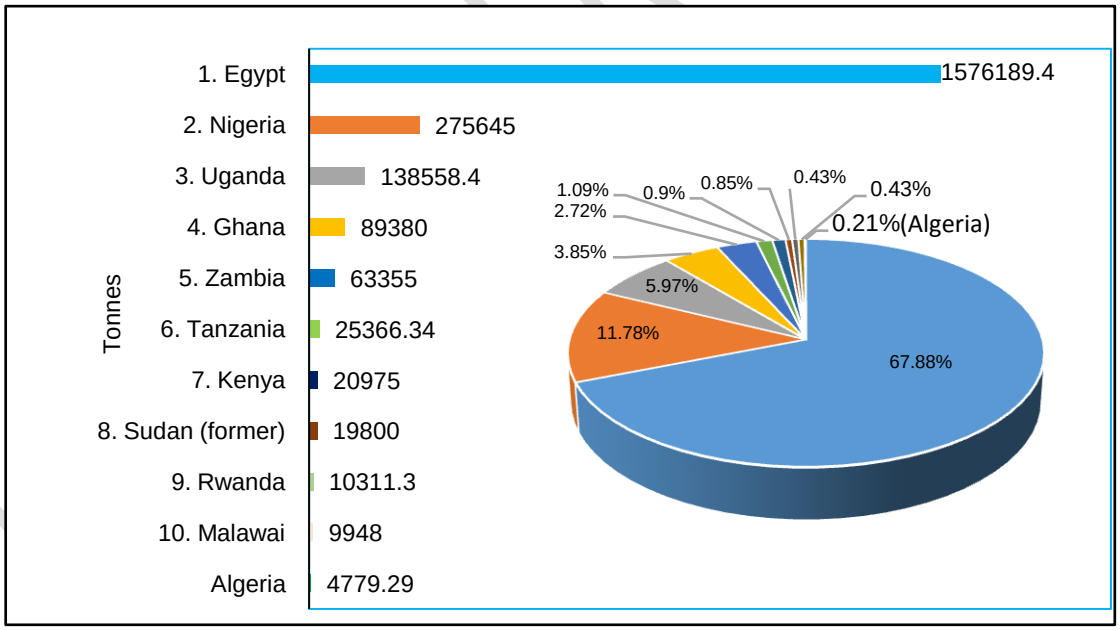

Fig. 1. Top 10 Aquaculture production quantities in Africa, including Algeria (2021). Source of data: (FishStatJ; 2023)

The production volume from commercial farming has been modest and highly variable. Over the years, aquaculture production in Algeria has witnessed fluctuations. It decreased from 407 tonnes in 1990 to 368 tonnes in 2005, then surged to 2,779.91 tonnes in 200. However, there was a significant decrease to 1,759 tonnes in 2010, followed by a further decline to 1,332 tonnes in 2015. The production then

experienced a jump to 5,436 tonnes in 2020 but decreased again to 4,779.29 tonnes in 2021. Despite these fluctuations, there has been a steady increase in the portion of aquaculture in the total fisheries production of Algeria. It has grown from less than 05% before 2005 to nearly 6% in 2021. (**Fig. 2**).

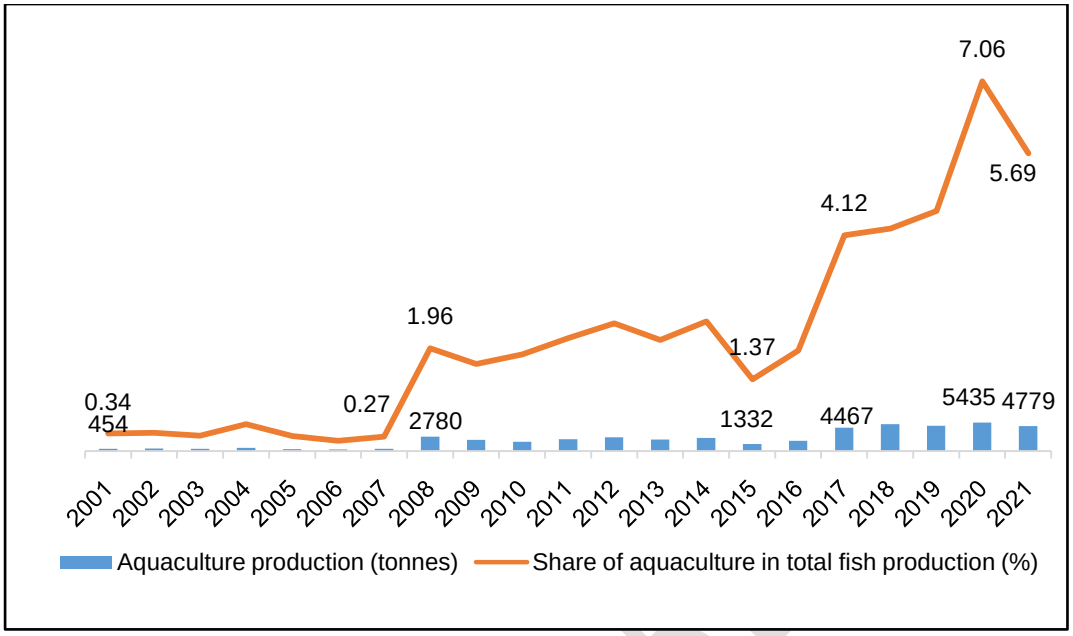

Fig. 2.share of Algerian aquaculture in total fishery production. Source of data: (FishStatJ; 2023)

5.1 Aquaculture production inAlgeria by farming area

From 2001 to 2021, aquaculture production in Algeria experienced a significant increase,rising from 454 tonnes to 4,779.29 tonnes. The expansion of aquaculture in marine and coastal environments mainly drives this growth. The expansion of finfish mariculture.The expansion of finfish mariculture played a significant role in this growth, with the share of finfish rising from 7.05% to 53.33%. In contrast, aquaculture production in freshwater environments witnessed a notable decrease. The outcomes of freshwater aquaculture decreased from 71.81% to 35.66%, indicating a decline in freshwater fish production attributed to various factors, including drought and certain impoundments within the country (**Fig. 3**).Likewise, the share of brackish water aquaculture also declined from 14.10% to 9.82%. This trend was consistent with the decline in fish production in freshwater and brackish areas.

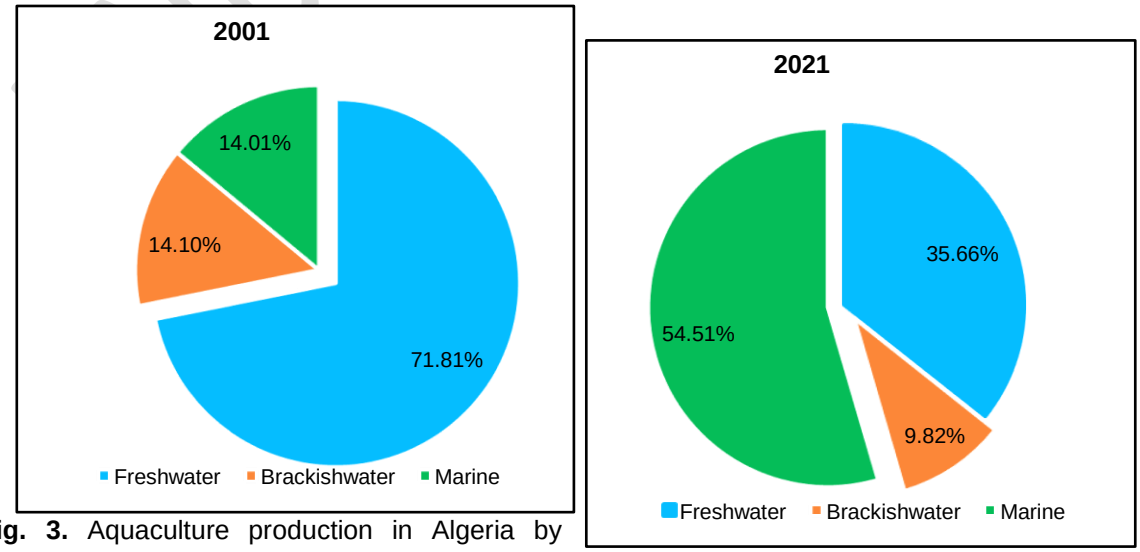

Fig. 3. Aquaculture production in Algeria by

farming environment (2000 versus 2020). Source of data: (FishStatJ; 2023)

5.2Taxonomic composition aquacultureproduction in Algeria

The distribution of aquaculture production in Algeria is diverse, with contributions from various fish species (**Fig.4 and5**). Out of the total production of 4,779.29 tonnes, marine fishes, specifically Githead seabream and European seabass, accounted for over 53% of production, with shares of 45.85% and 7.85%, respectively. Two carp species, common carp, and crucian carp, contributed over 28% to the aquaculture production in the country. Freshwater fisheries, represented by various unidentified fish species (Freshwater fishes nei), comprised almost 6% of total production. Other significant contributors to the production included barbel (3.28%), Pike-perch (2.80%), tilapia nei (tilapia spp., 2.20%), muletnei (*mulet* spp., 1.35%), and Mediterranean mussel (1.09%). The remaining species collectively represented 1.60% of total production. These species include roach, freshwater bream, European eel, tench, pacific cupped oyster, gilthead seabream, European seabass, common sole, north African catfish, Penaeus shrimps nei (*Penaeus* sp.), largemouth black bass, bleak, bighead carp, cyprinids nei (*cyprinids* spp.), grass carp (white amur), long-finned charr, caramote prawn, grooved carpet shell, and meagre. This highlights the wide range of species contributing to aquaculture production in Algeria, with marine fishes and carp species playing significant roles in the industry.

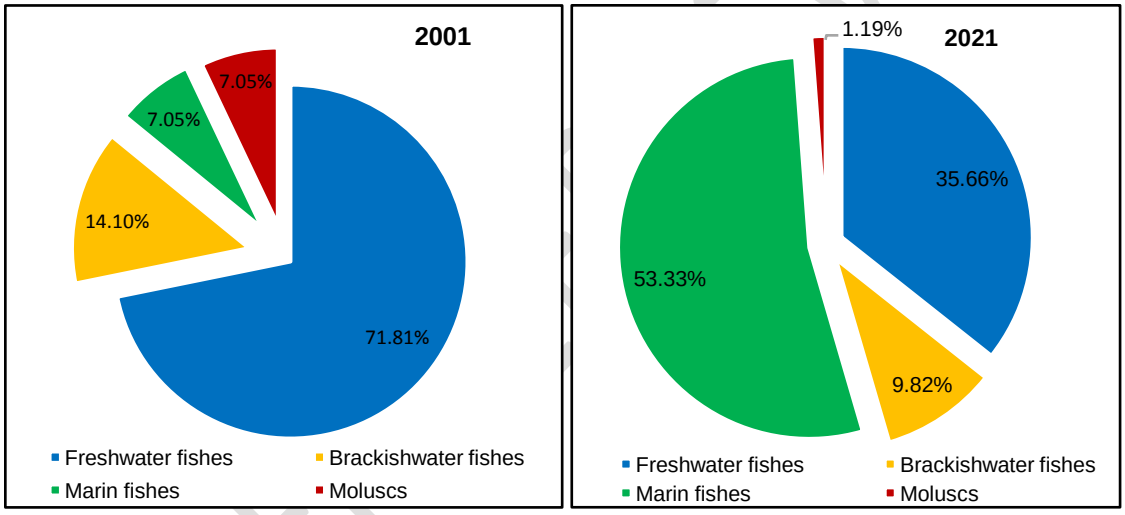

Fig. 4. Composition of taxa in Algerian aquaculture production (2000 versus 2020): Species groups less than 1 per cent of total production may not be Labelle. Source of data: (FishStatJ; 2023)

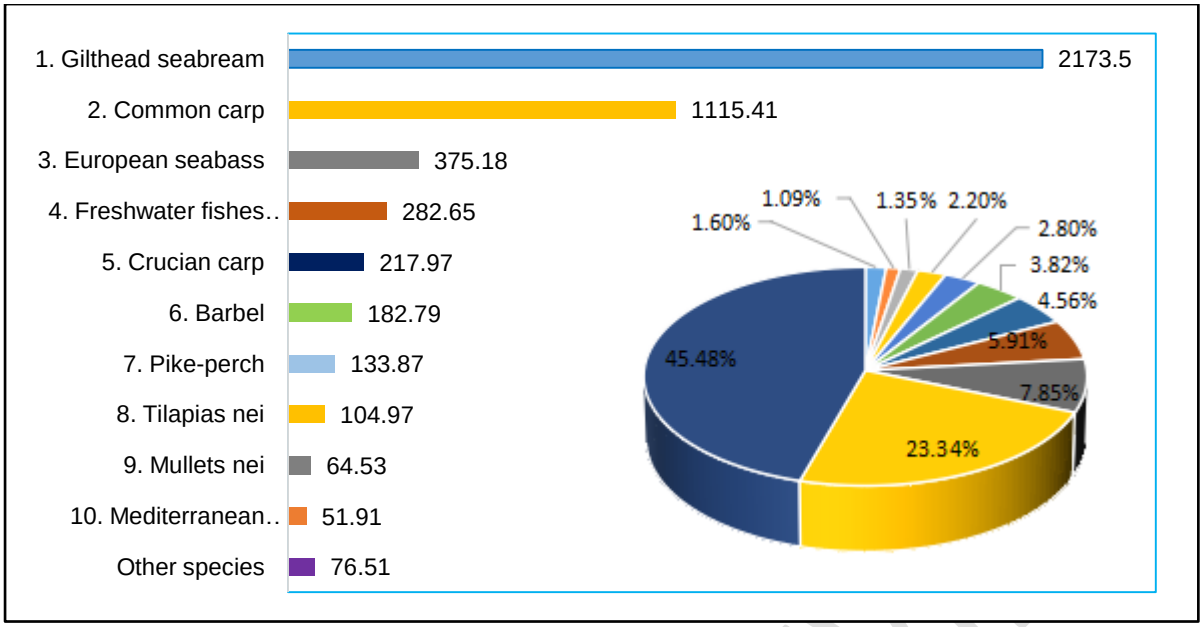

Fig. 5. Top 10 ASFIS species items in a quantity of aquaculture production in Algeria(2020).Source of data: (FishStatJ; 2023)

6Main species cultured

6.1 Cyprinids

The "Cyprinids nei" production, including various species within the Cyprinids family, was zero in 2021. However, common carp and crucian carp were reported sportily, andwhether they are included in the group is unknown. Unlike what is reported here, that common carp and crucian carp are major Cyprinids fish produced, this group, predominantly consisting of common and Chinese carp, dominated the aquaculture industry in previous years. The production was 250 tonnes in 1999, 454 tonnes in 2001, and 368 tonnes in 2005 [7]. There were fluctuations in the following years, with almost zero production in 2016, an increase to 816.09 tonnes in 2019, and zero production in the last two years as shown in **Table 2** [4]. These Cyprinids species were mainly introduced from Hungary and stocked across lakes, dams, and small reservoirs throughout the country, totalling seven species: *C.carpio, H. molitrix, Aristichthys nobilis, C.idella, M.salmoides, S.lucioperca,* and *Silurusglanis*. The production fluctuations over the years could be attributed to drought and the drying up of some impoundments in the country. The introduction of these species also resulted in accidental introductions of nine additional fish species through live fish transfers: *Alburnusalburnus, Abramis brama, Carassius gibelio, C.carassius, Lepomis gibbosus, Gymnocephaluscernua, Percafluviatilis, Pseudorasbora parva,* and *Scardinius erythrophthalmus*. Artificial spawnings were successfully carried out for *C.carpio, H.molitrix, A. nobilis, S.lucioperca,* and *C. gariepinus* [8], [9] and [10].

6.2 Tilapia

The group referred to as "Tilapia nei" is assumed to represent red tilapia (*Oreochromis mossambicus* x *O. niloticus*), and its yield accounted for 194.97 tonnes in 2021. However, it is worth noting that *O.niloticus*, the most commonly cultured tilapia worldwide, has been specifically targeted for its adaptability to the unique climatic circumstances within the Algerian Sahara. These tilapia species demonstrate resilience to unfavourable physicochemical conditions and exhibit excellent growth rates when provided with artificial feed.In order to foster the growth of tilapia cultivation in Algeria, tilapia fingerlings and adult fish were imported from Egypt in 2002. These imports were then distributed to fish farmers equipped with the necessary infrastructure and water supplies [11]. Several intensive farming areas were established for *O. niloticus* and red tilapia, including locations such as Fatstep in the

Saida district with a production target of 100 tonnes per year, Pesca de da Duna in the Ouargla district with a total capacity of 14,400 $m^{3,}$ and an expected production of 1,000 tonnes per year, and Ezzahra in the Ghardaia district with a semi-extensive breeding system and an anticipated production of 490 tonnes per year. These farming areas obtain water supply through drilling, with a capacity of 200 litres per second [12]. Furthermore, several ongoing projects in the private sector are focused on extensive, semi-extensive, or intensive tilapia breeding, underscoring the significance of tilapia farming in various regions of the country (B. Hamza pers. comm, 2023).

6.3 Catfish

Despite being considered a well-adapted species for freshwater farming in theSaharan region, the production of the North African catfish *C.gariepinus* (Clariidae) inAlgeria has not been substantial, and the reasons for this decline remain unclear. The recorded output for this speciesdeclined from 30.28 tonnes in 2016 to 0.42 tonnes in 2021 (**Table 2**), with no reported production between 2001 and 2015. However, *C. gariepinus* possesses ideal characteristics for aquaculture, including a high growth rate, tolerance to high stocking densities, efficient food conversion, good flesh quality, and the potential for high profitability on an annual basis. Successful experiments conducted by Zouakh and Meddour [10] have demonstrated the feasibility of inducing artificial reproduction in *C. gariepinus*. These advancements hold significant potential for reducing the cost of importing fingerlings and mitigating the emergence of opportunistic pathogens. Additionally, they pave the way for thriving and intensive catfish culture in the area. By leveraging the knowledge gained from these experiments, there is an opportunity to promote the growth of the North African catfish industry in Algeria and further enhance the aquaculture sector in the country.

Marine fishes

Marine fishes, specifically European seabass and Githead seabream, are cultured in open systems known as "cage systems" along the Algerian coast (**Fig 6**). The private sector predominantly owns these farms. According to the Center for Development of Advanced Technologies (CDAT), 116 marine fish farming concessions along the Algerian coast [13]. Out of these, 17 farms are in the production phase with a capacity of over 10,000 tonnes per year, while 10 farms have ceased operations (**Table 2, Fig. 9**). The remaining 87 farms are either in progress or in the administrative and financial set-up process. However, there is a notable discrepancy between the production data reported by CDAT and the figures reported by the FAO regarding aquaculture production from the marine environment or marine fishes. This inconsistency could potentially be attributed to the lack of accurate statistics delivered to the FAO, as the data is not readily available or formally reported

Figure 6. Harvesting European seabass from floating cage (Photo courtesy of B. Hamza)

Molluscs

Mollusc culture in Algeria primarily involves the cultivation of Mediterranean mussels, Pacific cupped oysters, and Grooved carpet shells.These molluscs are cultured in the sub-surface sector at sea along the Algerian coast. Currently, 13 farms are engaged in mollusc culture, with a combined production capacity of approximately 1.8 thousand tonnes. Notably, out of these 13 farms, 5 are currently inactive or ceased operations, while 41 farms are either in progress or undergoing administrative and financial set-up(**Table. 2, Fig. 9)**. This indicates the ongoing development and expansion of mollusc culture activities in Algeria.

6.6Shrimps

According to CDAT [13], there are two inland shrimp farm projects in Algeria, one in Skikdaand the other in Boumerdes(**Fig. 9)**.The project in Boumerdes, located in the north of the country, was planned to enter the production phase in 2018. It is a private intensive shrimp culture project covering a 3-hectare area, including preservation and transformation units. Although the estimated production capacity is 80 tonnes, no production has been recorded as of now. However, CDTA states that the project is still in progress and has yet to complete administrative and financial installations. The total projected production capacity of the enterprise is 600 tonnes.

The pilot-scale shrimp farm in Skikda (**Fig.7**) is a small-scale or experimental shrimp farming operation conducted to test and evaluate various aspects of shrimp production. It results from Algerian-South Korean cooperation and extends throughout a 15-hectare area. The farm initiated its activities by establishing a hatchery, a laboratory, and 8 breeding ponds, including 2 settling ponds, with a production capacity of 5 tonnes. 2011, they began breeding *P. japonicus*shrimp using Egyptian broodstock. This marked a significant milestone as Algerian professionals received training in South Korea, guided by Korean experts. Following this achievement, a second phase was initiated, introducing the local species *P. kerathurus*, or imperial shrimp. The experiment involved capturing fertilised females locally and placing them in the hatchery. The post-larval stage has been reached, with shrimp around 2 cm in length. They will soon be transferred to ponds for further growth. The complete breeding cycle is expected to take 6 months, with the first harvest projected for November 2012. This experience positions Algerian professionals with valuable expertise, and the hatcheries have 10 million fingerlings for restocking the bays of Skikda and Annaba to replenish a highly valued resource that is becoming increasingly scarce. After a period of inactivity, a budget of 22 million dinars has been allocated to revitalise the operations of the experimental shrimp farming station. The funds will be used to conduct a technical study on a seawater pumping station and procure necessary equipment and materials. The expected arrival of the equipment and establishment of the hatchery is scheduled for early December 2023.

Figure 7. Pilot-Scale Shrimp Farm in Skikda - Cultivation Ponds (Left) and Repopulated Shrimps (Right)

Another important project was initiated in July 2016 in Ouargla (**Fig. 8**), focusing on cultivating *P.vannamei*(white leg shrimp) in a dedicated shrimp farm. This project, conducted under the Algerian-South Korean collaboration, received funding from the Korean side, with an investment of approximately USD 5 million. The main goal of the project is to secure the sustainable growth of industries related to shrimp aquaculture and impart Korean expertise and knowledge to professionals in Algeria. This includes the establishment of farming infrastructure, the execution of management and marketing strategies, as well as the exchange of expertise. The shrimp farm in Ouargla covers a total surface area of 10 hectares; the facility comprises various units, including ponds, breeding raceways, a

food processing facility, and a laboratory.The farm aims to produce 5 tonnes of shrimp annually in the initial experimental phase. Subsequently, after extension works were completed in 2017, production is expected to reach 10-20 tonnes per year [12]. Unfortunately, no specific data was reported on these shrimp projectsor freshwater fish production.

Fig. 8. Whiteleg shrimp farming pond at Ouargla shrimp farm **(**Source**:** Zouakh and Meddour, 2010)

Table 2. Aquaculture production per species in Algeria 2016-2021

	ASFIS species (Name)*	2016	2017	2018	2019	2020	2021
Brackish water	Caramote prawn	0.2	0.25	0	0	0	0
	Common sole	0	0	0	1.76	2.2	2.2
	European eel	0	7.7	27	27.69	48.35	6.8
	European seabass	0	0	0	0	0	3.67
	Freshwater fishes nei	4.2	7.73	15	39.09	1009.96	282.65
	Gilthead seabream	0	0	0	0	0	4.4
	Mullets nei	2.38	34.76	10.58	40.86	37.67	64.53
	Penaeus shrimps nei	0	5	0.05	0	1.8	0.33
	Tilapias nei	87.18	464	10.36	376.97	421.36	104.97
	Total	**93.96**	**519.44**	**62.99**	**486.37**	**1521.34**	**469.55**
Freshwater	Barbel	110.77	95.58	78.57	178.35	90.02	182.79
	Bighead carp	0	0.55	0	1.8	0	0
	Bleak	0	0	0	1.8	0	0.03
	Common carp	978	1452.35	2549	536.61	11.54	1115.41
	Crucian carp	58	63	30	201.44	178.58	217.97

	Cyprinids nei	2.7	0	0	816.09	0	0

Continued

	Freshwater bream	0	0	0	0	6.92	7.29
	Grass carp (=Whiteamur)	0	0	0	0	0	0
	Largemouth black bass	2.76	1.37	0.81	1.44	6.92	0.21
	Long-finned charr	0	0	0	103.39	0	0
	North African catfish	302.8	300	310.5	238.28	60.38	0.42
	Pike-perch	9.1	28.9	1.8	50.13	72.88	133.87
	Roach	0	0	0	0	0	41.45
	Tench	0	0	0	0	0	4.9
	Total	**1464.13**	**1941.75**	**2970.68**	**2129.33**	**427.24**	**1704.34**
Marine water	European seabass	69.7	445.71	126.04	56.5	311.5	375.18
	Gilthead seabream	225.7	1352.22	1689.11	1600.22	3043.2	2173.5
	Mediterranean mussel	99.7	166	217	550.47	113.48	51.91
	Pacific cupped oyster	6.3	42.19	42.6	12.58	19.23	4.81
	Total	**401.5**	**2006.12**	**2074.75**	**2219.77**	**3487.41**	**2605.4**

*ASFIS = Aquatic Sciences and Fisheries Information System; additional insights regarding ASFIS species items can be located on www.fao.org/fishery/collection/asfis/en.

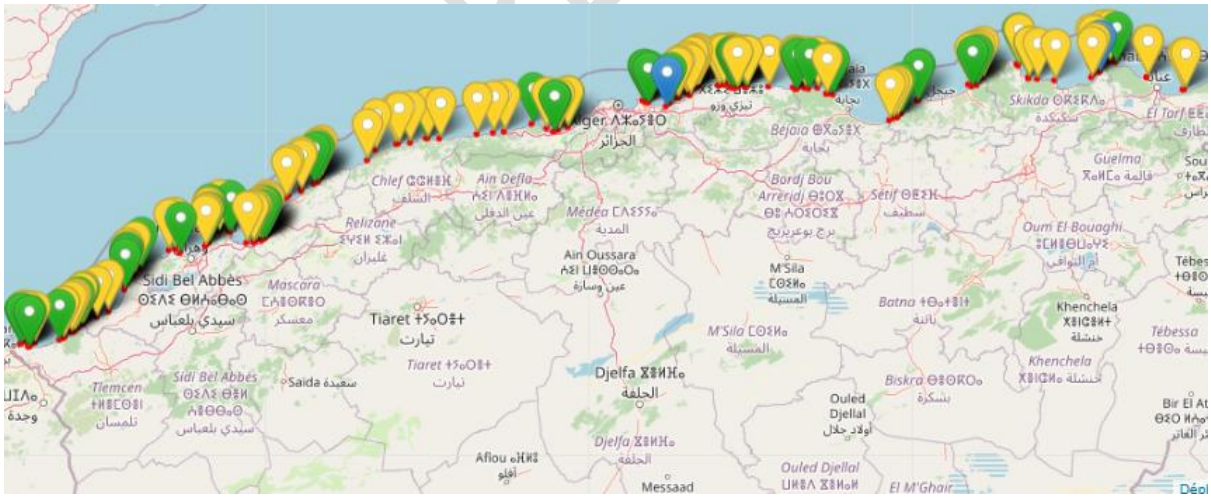

Figure 9. The location of the main marine farming along the coast of Algeria. Yellow: fish farms, green: shellfish farms, blue: shrimp farms (Source: CDTA 2023).

7. Integrated aquaculture

Integrated aquaculture**(Fig. 10**), specifically the cultivation of tilapia and carp within agricultural systems, has emerged as a promising approach. These species possess unique traits that contribute to the overall productivity and sustainability of the integrated system. Their efficient feed conversion,

tolerance to poor water quality, and adaptability to fluctuating temperatures make them well-suited for this approach. One key aspect of integrated aquaculture is the utilisation of tilapia and carp waste as a nutrient source for plants. Through aquaponics, the nutrient-rich water from the fish is used to irrigate crops, providing essential nutrients for their growth. This symbiotic relationship between fish and plants creates a closed-loop system where both species benefit from the presence of one another. Although integrated aquaculture has gained attention and government support, our research could not obtain specific production data, species utilised, labour, water exchange rates, or other relevant information.

Nevertheless, it is evident that integrated aquaculture offers a cost-effective and environmentallyfriendly production method for small-scale farmers, enabling them to produce multiple products within limited space and water resources. Further efforts and collaborations are needed to expand knowledge and understanding of integrated aquaculture, improve production efficiency, and promote its adoption among farmers. With continued research and support, integrated aquaculture has the potential to contribute significantly to sustainable food production and rural livelihoods.

Figure 10. Integration of red tilapia farming into agriculture: Farms in Mohamadia, Mascara (Left) and in Khenchela (Right).

8.Discussion: efforts, barriers, and recommendations

8.1 Efforts

Since the establishment of the MPRH in Algeria, significant efforts have been made to develop and promote aquaculture in the country. These efforts are supported by various actions and measures to enhance production and improve food security. The 2020-2025 Orientation Plan for the Advancement of Fisheries and Aquaculture Activities outlines strategic objectives aimed at achieving a production target of approximately 221,000 tonnes from sea fishing and 53,000 tonnes from various aquaculture projects by the year 2025.Institutional, legal, and financial instruments have been implemented as part of the upstream measures to lay a solid foundation for aquaculture development. Additionally, research, development, and training initiatives have been undertaken to provide comprehensive support to the growth of the aquaculture sector.

The National Center for Fisheries and Aquaculture Research and Development (CNRDPA) is a prominent research institution in Algeria that specialises in fisheries and aquaculture. Established in 2008 through the reorganisation of the National Center for Studies and Documentation for Fisheries and Aquaculture (CNDPA), CNRDPA is a public institution with a scientific and technological focus (EPST). Its primary objective is to generate scientific knowledge and provide decision-support tools to facilitate the sustainable development of fisheries and aquaculture while ensuring the preservation of natural resources and the environment. CNRDPA has a national presence through aresearch network spanning

multiple sectors comprising research centres and laboratories with teams of researchers. These research centres include both inland and marine aquaculture facilities, which enhance their capacity to contribute to the advancement of aquaculture in Algeria. The sectoral research policy of CNRDPA focuses on various areas of aquaculture development.
Inland aquaculture stations in Algeria include Ecloserie d'El Ouricia in Sétif, station de Hareza in Ain Defla, statiode Tabia in Sidi Bel Abbès, station de Bechar, Station de développement de l'aquaculture saharienne in Ouargla, and station de développement de la crevetticulture in Ouargla. These stations target species such as carp, sander, black bass, perch, tilapia, catfish, and *vannamei* shrimp. CNRDPA operates the station de pisciculture marine for marine aquaculture in Bou Ismail, which focuses on seabass and seabream. There is also the station de conchyliculture in Bou Ismail, specialised in mussel and oyster farming, and the station de shrimp farming in El Marsa, Skikda, which cultivates marine shrimp species like *P. japonicus* and Kerathérus. These research stations play a crucial role in conducting research, experimentation, and development in the field of aquaculture in Algeria. However, the fingerlings raised in these stations are currently utilised mainly for reviving natural stocks, as such stocks are scarce.

Aquaculture is also taught at various universities and high schools in Algeria, following the License, Master, and Doctorate (LMD) system institutions like the University of Science and Technology Houari Boumediene (USTHB), University of Annaba, University of Oran, University of Mostaganem, University of Ouargla, and the National Superior School of Sciences of the Sea and Coastal Planning (ENSSMAL) offer aquaculture education and training. In spite of the efforts made, the aquaculture industry in Algeria is still in its early stages rather than being a fully established industry.Furthermore, although experimental, extensive, and intensive production techniques have been implemented, primarily using imported fingerlings from Egypt, South Korea, and Hungary, overall progress has been modest.

Shrimp farming is virtually non-existent in Algeria, with only limited government-owned stations engaging in experimental activities. The development of shrimp farming in the country has not reached significant levels compared to other aquaculture sectors. This is due to various challenges, such as limited infrastructure, lack of specialised expertise, and the need for further research and development in shrimp farming techniques. Even with modest progress, the aquaculture industry in Algeria exhibits a greater taxonomic diversity compared to other countries in Northern Africa. Marine fish production surpasses regional and global averages, indicating the potential for further growth in this sector. However, the production of freshwater fish is relatively lower. The shellfish sector in Algeria performs better than the regional average but remains below the global average. Looking ahead, there are optimistic predictions for the growth of the fish industry in Algeria by 2030. However, several factors may impact the pace and stability of this growth.

8.2 Constraints

In light of the high growth rate of aquaculture in Algeria, there are still significant challenges that impede its further progress.

1. Contradiction in objectives and evaluation of aquaculture programs: The absence of a consistent national statistics system for collecting regular data on aquaculture production hinders progress in the sector.This absence prevents the establishment of a comprehensive assessment of the status of the aquaculture sector and the effectiveness of existing programs. Lacking precise data makes it difficult to implement suitable initiatives and measures as part of the aquaculture development strategy, ultimately leading to inefficient utilisation of efforts, time, and financial resources.

2.Instability in the management of aquaculture institutions:The limited number of research centres and lack of straightforward long-term programs hinder aquaculture development. The sector suffers from backwardness due to the absence of sustained research efforts, mainly caused by inadequate research funds, qualified human resources, and infrastructure. This leads to a lack of continuity and progress in aquaculture development.

3. Inadequate aquaculture research: Insufficient research services provided by the government for supporting aquaculture development is a significant constraint. Experimental stations exist, but they often lack interdisciplinary research teams and the necessary equipment, facilities, and scientific workforce. The limited research conducted is primarily focused on biological aspects and fails to address comprehensive issues related to aquaculture systems.

4. Insufficient aquaculture training: The general fisheries training provided in some institutions includes only a few diploma-level theoretical courses for students ngaging in an aquaculture technician program., which is insufficient to equip fishery officers to effectively engage in production programs or offer sound technical assistance to farmers.

5. Lack of trained personnel: A shortage of trained personnel is available to undertake aquaculture production programs. The existing workforce is mainly engaged in research or administrative work. At the same time, production and extension activities are typically carried out by staff from fisheries, agriculture, or water and forest departments who may not have received proper training or orientation in aquaculture.

6. Absence of an effective extension service: The absence of a well-functioning extension service is a significant handicap for all types of aquacultures in Algeria. An efficient extension service is crucial for disseminating knowledge, providing technical guidance, and supporting farmers in implementing the best practices and improving productivity.

7. Lack of subsidies and bank credit: The aquaculture sector faces a lack of financial support, including subsidies and access to bank credit. Limited financial assistance restricts the growth and expansion of aquaculture operations, making it difficult for farmers to invest in necessary infrastructures, equipment, and technologies.

8. Underdeveloped fish feed industry: Algeria lacks a developed animal feed industry, including fish feed production. The absence of a reliable supply of quality feed hampers the growth and sustainability of aquaculture operations, as adequate nutrition is crucial for the health and productivity of farmed fish.

9. Challenges in desert aquaculture and consumer perceptions: Attempting aquaculture in desert regions of Algeria presents challenges related to climate change, such as reduced rainfall and rising temperatures. Additionally, consumer preferences for fish from the sea pose a barrier to market demand for aquaculture products. Furthermore, the availability of supplies, such as local shrimp larvae, can limit the potential of aquaculture ventures.

These barriers and challenges highlight the need for comprehensive efforts to address the constraints inthe Algerianfish farmingdomain, including improvements in data collection, research capacity, training programs, extension services, financial support, and the development of a sustainable feed industry.

8.3 Prospects

Algerian aquaculture has made significant strides in recent decades and is poised for a promising future, driven by the substantial market demand and the high economic value of the product. Nonetheless, precise strategies are essential to guarantee the robustness of the country and sustainable fish farming development.

1. Broad-based programs for realistic production targets: Developing comprehensive programs focusing on achieving them is crucial. This includes conducting detailed surveys and evaluations of existing rural fish farming activities to determine the precise nature of development activities required. Additionally, priority should be given to surveys of potential areas for aquaculture development, which will provide essential information for adapting programs to changing needs and fostering collaboration between scientists and technicians.
2. Establishment of centres in strategic areas: Centers should be established in strategic locations within each region. These centres can serve multiple functions, including training extension workers, field personnel, and farmers. They can also be responsible for producing and distributing aquaculture inputs such as seed and feed, providing technical assistance (including disease,diagnosis, and control),

and giving credit. Upgrading facilities and study programs in these centres may require external help. These centres should focus on production-oriented studies and provide support services for extension work.

3. Seed production and supply: In the initial stages of aquaculture development, the government should manage seed production and supply to support farmers. As aquaculture develops into a significant industry, seed production may transition to the private or cooperative sectors.
4. Focus on culture systems dependent on suitable feeds: Emphasis should be placed on culture systems that rely on the availability of affordable and suitable feeds. Utilising locally available feed sources, such as agricultural and industrial wastes, can be instrumental in achieving this goal. Government assistance may be required to establish feed production as an auxiliary industry. External assistance may also be needed for formulating and preparing feeds for local cultivable species using easily accessible and inexpensive ingredients.

5. Emphasis on practical training: Extensive practical training is crucial to prepare individuals for undertaking production programs. Training centres should have adequate facilities and well-trained staff. While national or group-country training may be necessary for extension personnel, regional cooperation is essential for training aquaculturists responsible for implementing production programs. The knowledge and expertise of trainers fulfil a crucial function in the success of training efforts, and advanced training on a regional or inter-regional basis should be provided to core personnel.

6. Large-scale farms and government initiative: There is a potential for establishing large-scale farms in Algerian freshwater and brackish water areas. The government should consider starting such ventures, including reclaiming suitable wastelands for fish farming and leasing them to individuals, cooperatives, or private companies for operation.

7. Adaptive research and joint ventures: Adaptive research and production tests are necessary to select species and culture systems suitable for local conditions. Joint ventures may be explored, particularly when considering culture species with export potential.

8. Choice of species for culture: The selection of species for culture is of utmost importance. While tilapia and shrimp are commonly used for pond culture and reservoir stocking, respectively, the success of aquaculture largely depends on the species chosen. Priority should be given to species of well-known biology, behaviour, feed requirements, and standardised or well-developed culture technologies.

9. Suitable extension service: Establishing an effective extension service with qualified staff capable of working closely with farmers is essential for aquaculture development in the country.
10. Provision and distribution of inputs: Adequate arrangements for producing and distributing fry, feeds, and other inputs are essential to increase pond yields.

11. Interdisciplinary team and feasibility studies: A multidisciplinary team of experts is required to assist, conduct feasibility studies, and attract investment to the aquaculture field. Collaboration, information exchange, and personnelexchange between countries are necessary for realising the full potential of aquaculture development in Algeria.
12. Periodic revision of targets and programs: As the aquaculture plan is implemented and surveys/studies are conducted, periodic revision of targets and programs is essential to ensure the effectiveness and adaptability of the aquaculture plan.

9. Conclusion

Amidst this challenging landscape, there is an opportunity to reimagine the fish farming industry in Algeria and make it more sustainable. Instead of striving to increase production levels rapidly, it is advisable to adopt a different approach. Redesigning the industry to a smaller scale while promoting sustainability can yield positive outcomes. Although profitability may be reduced, a more equitable distribution of profits among all stakeholders in the value chain, particularly fish farmers, can foster

long-term sustainability and resilience within the shrimp farming sector. To further advance the aquaculture industry in Algeria, it will be essential to address these challenges and continue implementing strategic measures outlined in the Orientation Plan for the Development of Fisheries and Aquaculture Activities. This includes strengthening research institutions like CNRDPA, promoting sustainable practices, fostering collaboration between academia and industry, and providing financial support to facilitate the growth of aquaculture projects. With concerted efforts, Algeria has the potential to develop a thriving and sustainable aquaculture sector, contributing to food security, economic growth, and environmental sustainability.

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