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Common carp aquaculture *Cyprinus carpio* in Iraq: history, challenges, and opportunities

Akuakultur ikan mas *Cyprinus carpio* di Irak: sejarah, tantangan, dan peluang

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ABSTRACT

Common carp (*Cyprinus carpio*) is a cornerstone of freshwater aquaculture in Iraq, playing a vital role in food security, rural livelihood, and economic development. This article provides a comprehensive overview of the historical introduction and evolution of carp farming in Iraq, highlighting its adaptability to diverse environmental conditions and its integration into various aquaculture systems, such as pond and cage culture. The study examines the economic significance of carp production, particularly in rural areas, where it serves as a primary source of income and animal protein. It also explores the challenges faced by the sector, such as water scarcity, disease outbreaks, and environmental impacts, while emphasizing the importance of sustainable practices and technological advancements. The article underscores the potential for future growth through genetic improvement, integrated farming systems, and government support in line with global sustainability goals. By addressing these challenges and leveraging opportunities, Iraq's carp aquaculture sector can enhance productivity, ensure food security, and contribute to the nation's economic resilience.

Keywords: carp production, food security, polyculture systems

ABSTRAK

Ikan mas (*Cyprinus carpio*) merupakan komponen utama dalam akuakultur air tawar di Irak, memainkan peran penting dalam ketahanan pangan, mata pencaharian pedesaan, dan pembangunan ekonomi. Artikel ini memberikan gambaran komprehensif mengenai pengenalan sejarah dan perkembangan budidaya ikan mas di Irak, menyoroti adaptabilitasnya terhadap berbagai kondisi lingkungan, serta integrasinya ke dalam berbagai sistem akuakultur seperti budidaya di kolam dan keramba. Penelitian ini juga mengkaji signifikansi ekonomi produksi ikan mas, khususnya di daerah pedesaan, di mana ikan mas berfungsi sebagai sumber utama pendapatan dan protein hewani. Selain itu, artikel ini mengeksplorasi tantangan yang dihadapi sektor ini, seperti kekurangan air, wabah penyakit, dan dampak lingkungan, sembari menekankan pentingnya praktik berkelanjutan dan kemajuan teknologi. Artikel ini juga menyoroti potensi pertumbuhan di masa depan melalui perbaikan genetik, sistem pertanian terintegrasi, dan dukungan pemerintah sesuai dengan tujuan keberlanjutan global. Dengan mengatasi tantangan ini dan memanfaatkan peluang yang ada, sektor akuakultur ikan mas di Irak dapat meningkatkan produktivitas, memastikan ketahanan pangan, dan berkontribusi pada ketahanan ekonomi negara.

Kata Kunci: ketahanan pangan, produksi ikan mas, sistem polikultur

INTRODUCTION

Common carp (*Cyprinus carpio*) is one of the most important freshwater fish species in the world, with a domestication history spanning over 2,000 years. Its native range is Eastern Europe and Asia, but it has been introduced to various regions worldwide due to its adaptability and nutritional value (Chen *et al.,* 2022; Fazli *et al.,* 2023). Common carp holds a prominent position among aquaculture species in terms of production volume. According to the FAO (2020), carp species represent a significant portion of global freshwater aquaculture production, especially in Asia. Common carp is known for its ability to withstand harsh environmental conditions such as temperature fluctuations and low oxygen levels.

This adaptability has made it suitable for diverse aquaculture systems and geographic locations (Chen *et al.,* 2022). These characteristics have significantly contributed to the economic importance of common carp, providing employment opportunities for millions of people, particularly in rural areas of developing countries (Yadav *et al.,* 2024). Moreover, common carp is a valuable source of high-quality animal protein, rich in essential fatty acids, vitamins, and minerals, thus playing a vital role in food security in many regions (Ahmed, 2022). Another notable feature of common carp is its compatibility with various aquaculture systems, including monoculture and polyculture systems. It is often farmed alongside other species to optimize resource utilization and enhance overall productivity.

In Iraq, meat and other sources of animal protein are often scarce or expensive making common carp a readily available and affordable source of high-quality protein. The adaptability to diverse environmental conditions and rapid growth rate has made the common carp an ideal choice for enhancing protein supplies for Iraqi citizens. The fish also contributes to dietary diversity as it provides essential omega-3 fatty acids, vitamins, and minerals necessary for health, particularly in rural areas where malnutrition is more prevalent (Mahmud, 2021; FAO, 2017). Furthermore, common carp plays a vital role in Iraq's rural economy. Small family-run farms are often a stable source of income for rural communities, stimulating local economy by providing employment opportunities in hatchery management, fish farming, and marketing.

With increasing demand for fresh fish, carp farming has become more attractive to investors, leading to the development of large-scale aquaculture, projects benefiting Iraq's economy and improving livelihoods in rural areas where job opportunities are limited (FAO, 2020). Historically, Iraq has heavily relied on importing fish to meet local demand. This dependency has led to price fluctuations and supply chain disruptions that are often caused by regional instability. Developing a domestic carp aquaculture industry can help Iraq reduce its reliance on imports, particularly benefiting low-income groups unable to afford high import costs. Increased local production could enable locally produced fish to compete with imports, providing a more stable supply to meet growing demand (Jawad, 2021a).

Carp aquaculture in Iraq aligns with several United Nations Sustainable Development Goals (SDGs), including Goal 2 (Zero Hunger) and Goal 12 (Responsible Consumption and Production). It enhances food security, provides sustainable employment opportunities, and promotes environmentally responsible practices. Carp farming contributes to Iraq's sustainable development agenda through government and international organization initiatives aimed at building capacity and infrastructure in the aquaculture sector (Corner *et al.,* 2020). The Iraqi government and international bodies, such as the food and agriculture organization (FAO) have become increasingly involved in promoting aquaculture. Several programs have been established to improve farm management practices, combat fish diseases, and ensure sustainable production. These efforts include training workshops, support for fish hatcheries, and improving access to high-quality feed and fish seeds. These programs aim to enhance Iraq's capacity for achieving self-sufficiency in fish production while reducing environmental impacts by promoting better aquaculture practices (Salman & Saleh, 2021).

Historical perspective

The introduction of common carp in Iraq

Early Stage of Fish Introduction: Impact and Initial Efforts Before the 1950s

Before the official introduction of common carp (*Cyprinus carpio*) in the 1950s, fishing practices in Iraq relied primarily on traditional methods in

rivers, especially the Tigris and Euphrates. The introduction of carp as a cultivated species in fish farms marked Iraq's first significant step toward organized aquaculture, representing a stark contrast to these traditional practices.

Initial government interventions

Inspired by the success of carp farming in neighboring countries, the Iraqi Ministry of Agriculture began conducting preliminary experiments with common carp in the early 1950s. These efforts were part of state-supported agricultural modernization plans aimed at enhancing self-sufficiency and reducing import dependency. With the assistance of international agricultural consultants, Iraq adopted carp aquaculture as the best candidate for this development. The first hatcheries were established in Baghdad in 1981 (AL-Hilali *et al.,* 2025). Despite these efforts, early carp farms faced numerous challenges, including limited aquaculture knowledge among local farmers, inadequate infrastructure, and suboptimal farming techniques, resulting in low survival rates. To address these issues, the government organized training courses and demonstrations to encourage the adoption of essential farming practices and management skills among local farmers (Salman & Saleh, 2021).

Expansion during the 1970s and 1980s

During the 1980s, increased oil revenues from the 1970s provided Iraq with greater resources for agricultural investment including aquaculture. This economic prosperity allowed the government to support the construction of hatcheries and fish ponds in central and southern Iraq utilizing water from the Tigris and Euphrates rivers for aquaculture. This period also witnessed the participation of the private sector. Initially, state-managed farms led the development of aquaculture, but the 1970s saw a push toward private sector involvement.

The government incentivized private fish farming through low-interest loans and financial grants. By the late 1970s, many private farms were operational, particularly in fertile areas such as Babylon, Wasit, and Basra. The growth of the private sector was significant as it reduced reliance on government-supplied fish and accelerated the dissemination of aquaculture knowledge. This marked a turning point in Iraq's aquaculture history, laying the foundation for a more resilient and diversified industry (USAID, 2006).

Further developments in carp hatcheries and polyculture systems

In the subsequent stages of aquaculture development, Iraq advanced its use of hatcheries and polyculture systems to support expansion. The country established large hatcheries capable of producing millions of fingerlings annually. Farmers were encouraged to adopt polyculture systems, raising common carp alongside other cyprinids and local fish species such as bunni (*Mesopotamichthys sharpeyi*). This approach improved productivity and ecological balance in ponds, enabling nutrient recycling within the pond ecosystem and increasing fish yield per hectare (Jawad, 2012).

Challenges of the 1980s and 1990s

Iran-Iraq War (1980–1988)

The prolonged conflict with Iran significantly affected Iraq's economy and infrastructure including the aquaculture sector. Many carp farms suffered from neglect, and labor shortages resulted in decreased productivity. Despite these challenges, the government attempted to support aquaculture by establishing additional hatcheries and providing assistance. However, production remained low due to resource scarcity and limited technological advancements during the war. (Harlioglu *et al.,* 2024).

Economic sanctions of the 1990s

The gulf war and subsequent United Nations sanctions had devastating effects on Iraq's economy. These sanctions severely restricted imports including essential aquaculture inputs such as high-quality feed, medicines, and pond management equipment. As a result, many carp farms closed or reverted to low-cost practices, relying solely on natural resources. This led to reduced production and lower fish quality. Despite these hardships, carp farming persisted in rural communities as a necessity for survival. Farmers innovated by utilizing locally available resources, such as agricultural by-products like rice bran as fish feed. This period also encouraged the sharing of traditional knowledge as experienced farmers mentored beginners in managing low-cost, small-scale ponds (Mahmud, 2021).

Revival post-2003

After the fall of the previous regime in 2003, Iraq's agricultural sector as well as aquaculture encountered new opportunities for recovery through international aid and investments.

Non-governmental organizations (NGOs) and international bodies including the FAO, began assisting Iraq in rebuilding its aquaculture sector. Technical training on modern practices was provided, and rehabilitated and newly established hatcheries distributed high-quality fingerlings, gradually increasing carp production. Research institutions, supported by international partners, launched projects that aimed at developing carp strains suited to Iraq's climatic and water conditions. These efforts focused on improving disease resistance and growth rates. Additionally, studies on locally produced feed using ingredients like soybean and corn helped reduce feed costs and increased self-sufficiency.

Iraq also introduced biosecurity protocols to prevent the spread of diseases that had previously plagued carp farms (FAO, 2025). As illustrated in Figure 1, Iraq's aquaculture sector has undergone three major phases: decline during the Iran-Iraq War, further deterioration under the 1990s sanctions, and gradual recovery after 2003 through international collaboration and modernization efforts.

Integrated aquaculture practices

Integrated aquaculture practices gained increasing acceptance, particularly in water-scarce regions such as Basra and Diyala. Farmers adopted systems combining fish farming with rice cultivation which improved water quality and increased productivity. Fish waste served as a natural fertilizer for crops while rice fields provided a suitable environment for carp. These integrated systems created a symbiotic ecosystem, enhancing both fish and crop yields (Rasheed, 2023).

Capacity building and modernization

To support modernization in fish farming, International Organizations and the Iraqi government invested in training programs for farmers. These programs covered topics such as water quality management, disease prevention, and feeding practices. Field workshops facilitated knowledge transfer, enabling Iraqi farmers to adopt advanced techniques in an increasingly modern aquaculture sector (Jawad, 2021b; Salman, 2011; Jawad & Abdulsamad, 2021). This holistic approach has helped Iraq rebuild and advance its aquaculture industry, ensuring sustainable practices while supporting food security and economic growth.

Future prospects

With the increasing impacts of climate change, escalating droughts, and water scarcity, common carp farmers in Iraq face significant challenges. The

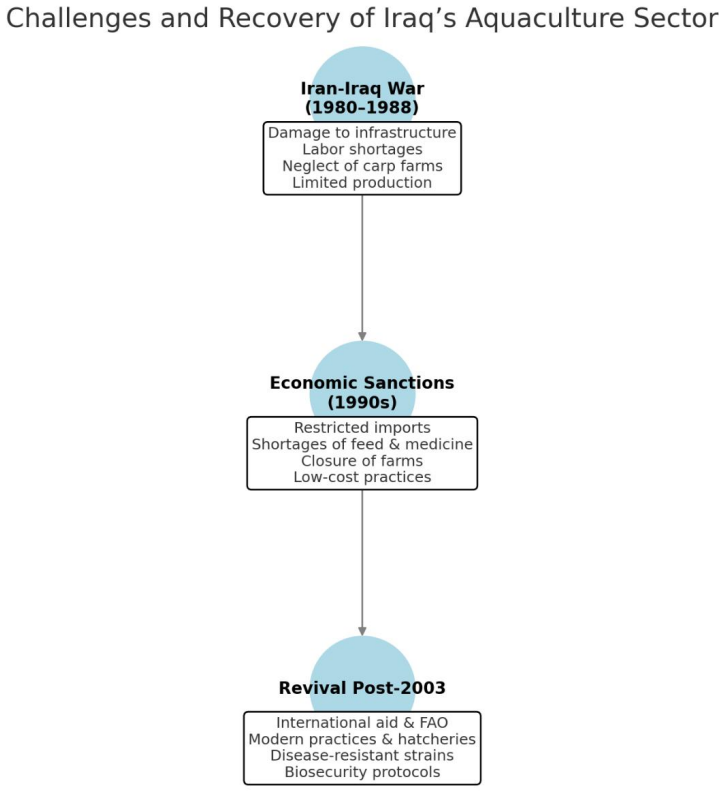

Figure 1. Historical struggles and revival of Iraq's aquaculture industry.

Iraqi government, in collaboration with research institutions, is exploring closed aquaculture systems and water-saving technologies to address these issues. Such systems enable more efficient water use which is crucial given Iraq's reliance on the Tigris and Euphrates rivers, whose water resources are managed by neighboring countries (Dyck, 2017).

Rising demand and commercial expansion

In recent years, Iraq has experienced a steady rise in local demand for common carp, driven by the growth of the middle class and increased awareness of the nutritional benefits of fish. This growing demand has attracted investments, particularly in southern Iraq, where large commercial farms have been developed to meet market needs. Innovations in pond construction and water management have also enabled the expansion of carp farming into new areas previously unsuitable for aquaculture (FAO, 2017).

Potential for export

While Iraq's primary focus remains on meeting domestic needs, the government has expressed interest in developing the aquaculture sector to eventually support fish exports. Neighboring countries with high demand for fish represent a promising market. Achieving export capability would not only improve food security but also contribute to economic diversification, reducing Iraq's heavy reliance on oil exports (Kitto & Tabish, 2004). By addressing water challenges, leveraging technological innovations, and fostering private and international investments, Iraq's carp aquaculture industry has the potential to become a cornerstone of sustainable food security and economic development in the future. As summarized in Figure 2, Iraq's carp aquaculture modernization has progressed through integrated systems, capacity building, and technological innovations, leading toward commercial expansion and export potential.

The cultural importance of common carp in Iraq

Carp farming in Iraq: A comprehensive historical perspective

Common carp (*Cyprinus carpio*) farming in Iraq has become an inseparable part of the social, cultural, and culinary fabric, especially in regions where river fish are a staple food. Although carp farming is relatively recent compared to

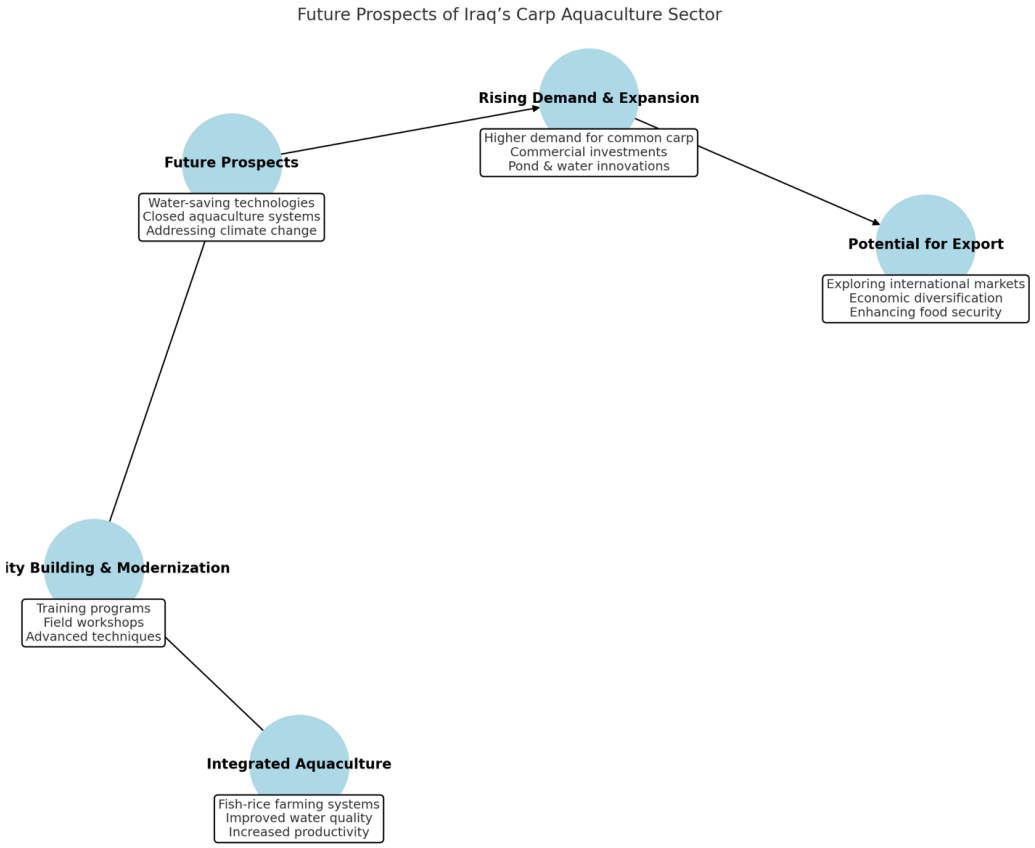

Figure 2. Modernizing Iraq's carp aquaculture: challenges and opportunities.

traditional fishing practices, many cultural and traditional aspects related to carp have emerged over the years, enhancing its importance in Iraqi society.

Culinary tradition: The Iconic Dish "Masgouf"

One of the most prominent cultural aspects associated with carp in Iraq is the traditional dish known as masgouf. This iconic Iraqi dish is prepared by splitting the fish, seasoning it, and grilling it over an open flame, often using wood. Masgouf is considered the national dish of Iraq and holds a central place in social gatherings and family events. While this dish was traditionally prepared using wild-caught carp from rivers such as the Tigris and Euphrates, farmed carp has become the preferred choice with the expansion of the fish farming sector (Shabout, 2021).

Cultural significance of Masgouf

Masgouf is more than just a culinary dish, it represents Iraqi heritage and brings families and friends together around the grill, often in open spaces or along riverbanks. The preparation of masgouf is inherently social, with family members participating in the cooking process, using the time to share local news and tell stories. This cultural aspect has significantly contributed to the growing popularity of carp farming, as the demand for carp has increased, particularly in urban restaurants and households in Iraq figure 3 (Lonergan *et al.,* 2024).

A symbol of hospitality and generosity

In Iraqi culture, serving fish, particularly carp, is a symbol of hospitality. Due to its relative availability and affordability, carp has become a staple meal for welcoming guests, especially during holidays and special occasions. Carp dishes are often served alongside traditional rice and bread, creating a shared dining experience that reflects the generous spirit of Iraqi hospitality. This tradition has bolstered carp farming, as farmers strive to meet the cultural demand for readily available and high-quality fish to support family gatherings and celebrations figure 4 (Fast, 2004).

Figure 3. Masgouf by the Tigris: A symbol of Iraq's culinary identity (Harver, 2020).

Figure 4. Bringing people together: the role of Masgouf in Iraqi culture (Bourhrous & O'Driscoll, 2023).

Religious and ethical considerations

Fish, including carp, are widely consumed in Iraq due to their compliance with religious dietary rules. Islam permits the consumption of fish as halal, and unlike other animals, fish do not require specific slaughtering methods, making them readily accessible and permissible for consumption. Carp farming aligns with cultural and religious practices, providing an acceptable source of protein for Iraq's predominantly Muslim population. Carp is especially popular during the holy month of Ramadan, when many families prepare masgouf and other carp dishes for *iftar* (breaking the fast). The high demand for carp during this period led to increased production and distribution by fish farmers who recognized the cultural significance and economic opportunity associated with this time (Jawad, 2021c).

Social importance and community practices

Fish farming, including carp, has evolved into a communal practice in many rural Iraqi communities. In some regions, it is common for families or community members to jointly own fish ponds. This shared agricultural model allows small-scale farmers to participate in carp production without requiring the full capital investment needed to own an independent fish farm. This cooperative approach strengthens social bonds in rural areas and fosters a shared knowledge base about carp farming techniques and challenges. Carp farms also serve as gathering places in the Iraqi countryside where farmers discuss farming methods, exchange carp for other goods, and build social networks. This collective spirit promotes cooperation and mutual support, enhancing the role of carp farming in strengthening rural communities and providing a stable income source for many households (Agnoletti, 2023).

Economic source and rural identity

Carp farming in Iraq has become intertwined with local identity and economic resilience in many rural communities. Given the economic challenges faced by Iraq, particularly in rural areas, fish farming has provided an alternative or supplementary source of income for many families. This economic reliance on carp farming has ingrained it into the cultural fabric of rural Iraq, where current generations view fish farming as an essential part of their livelihoods. In some villages, seasonal events are tied to the carp farming cycle. For example, harvest seasons bring local farmers together for communal harvest events in which carp are prepared, sold, or distributed among families. This cyclical activity reinforces carp farming as a vital component of the social and economic structure of these communities, providing both financial stability and a sense of shared purpose (Fawzi *et al.,* 2016).

Carp farming in Iraq: Production, key areas, and challenges

In 2020, the total fish production in Iraq has reached approximately 241,848 tons, with common carp (*Cyprinus carpio*) accounting for a significant portion of this output. The aquaculture sector has witnessed substantial growth driven by increasing demand for fish protein and efforts to enhance food security Table 1 (Harlıoğlu *et al.,* 2023).

Key areas for carp farming

In the central Euphrates Region, provinces such as Babylon, Najaf, and Karbala are hubs for carp farming due to favorable water resources. However, the area faced a significant challenge in late 2018 when millions of carp died due to an outbreak of Koi Herpes Virus (KHV) (Ababneh *et al.,* 2020). In southern provinces like Basra and Maysan have seen growth in carp farming, benefiting from extensive marshlands and suitable water bodies for aquaculture (Ahmed *et al.,* 2020). Over the past two decades, the northern region Kurdistan has developed several carp farms which are now operational, contributing to economic growth and aquaculture development (Salman & Saleh, 2021; Al-Thamir, 2022).

Extensive carp farming in the Marshlands

Dependence on natural food sources

In Iraq's marshlands, particularly in southern provinces like Maysan and Basra, extensive carp farming relies on natural resources. Fish are stocked at low densities, and feed on naturally available plankton, algae, and plant material found in the marshes and water channels (Hussain *et al.,* 2021).

Seasonal management

Carp farming in the marshes typically occurs during periods of high water levelswhich coincide with seasonal floods. Fish grow in these natural habitats and are harvested before water levels drop. This approach minimizes costs but limits production due to the lower productivity of extensive systems (Verdegem *et al,* 2023).

Minimal environmental impact

Extensive farming is environmentally sustainable. It does not require artificial feed or additional inputs, preserving the natural ecosystem of Iraq's marshlands. This approach aligns with conservation efforts for these ecologically sensitive areas (Abdullah *et al.,* 2024).

Disease control and biosecurity measures

Early detection programs

In response to the 2018 Koi Herpes Virus (KHV) outbreak, the Iraqi government and international partners implemented disease surveillance programs in key carp farming regions. These programs involve regular health checks and water quality testing to detect pathogens early (Bavarsad *et al.,* 2024).

Quarantine and isolation

Large farms implement quarantine protocols for new fish stock, reducing the risk of disease transmission. Quarantine tanks are equipped with filters and ultraviolet sterilizers to eliminate pathogens before introducing carp into main ponds or cages (Can *et al,* 2023).

Vaccination trials

Experimental trials for vaccines targeting viral and bacterial infections in carp are underway. When successful, vaccines could become a cornerstone of biosecurity practices in Iraq, reducing reliance on antibiotics and improving fish survival rates (Razzak *et al.,* 2024).

Innovations in feeding practices and feed quality

Local feed production

To reduce dependence on imported feed, Iraqi farmers increasingly use locally available ingredients such as rice bran, wheat by-products, and soybean residues. These feeds are cost-effective and support the local economy.

Supplemental feeding with high-protein meals

Some farms have begun using protein-rich supplements to boost carp growth rates,

Table 1. Expected carp production by aquaculture system in Iraq.

Governorate	Earthen basins		Cage culture		closed system	
	Number of projects	Expected production /ton / year	Number of projects	Expected production /ton / year	Number of projects	Expected production / ton / year
Baghdad/Rusafa Total	239	1730	9	3334	0	0
Baghdad/Karkh	247	1431.5	78	20520	1	100
Babylon	111	3200	103	41305	3	0
Wasit	200	399	64	29066	2	200
Diwaniyah	79	56	225	40414	20	Under construction
Muthanna	9	23	18	6685	0	--
Maysan	35	40	9	1018	1	250
Karbala	6	10	12	4926	1	-
Kirkuk	29	60	-	-	1	100
Dhi Qar	33	168	70	10894	0	0
Basra	44	40	380	22098	1	300
Najaf	34	935	12	2554	3	500
Salah al-Din	-	-	4	612	-	0
Anbar	18	2004	36	17926	-	0
Nineveh	4	6	2	15	0	0
Diyala	39	144.6	11	6146	1	200
Total	1127	13.408.6	1033	207513	33	1650

Note: Carp production statistics based on reports from the directorate of Animal Resources in Iraq.

especially in intensive systems. This ensures carp achieve optimal market weights to meet consumer demands (Jawad, 2021d).

Pelleted feed trials

To achieve higher production and more efficient feeding, some farms are adopting pelleted feed. This approach reduces waste and ensures consistent nutrition for carp. Pelleted feed has proven effective in improving feed conversion ratios, making farming practices more efficient (Zhang *et al.,* 2023). These innovations and improvements demonstrate Iraq's commitment to enhancing carp farming sustainability, productivity, and economic viability.

Challenges in carp farming in Iraq

Water availability

Water scarcity

Iraq's reliance on the Tigris and Euphrates rivers is at risk due to reduced upstream water flow resulting from dam construction in Turkey and Syria. This decline in water flow has exacerbated water scarcity, especially in southern regions, impacting agriculture and aquaculture (Shapland, 2023).

Water quality issues

Water quality has deteriorated due to agricultural runoff, industrial pollutants, and soil salinization. This degradation places additional stress on carp populations and increases the likelihood of disease outbreaks (Ewaid *et al.,* 2020).

Competition for water resources

Carp farming competes with agriculture for water resources, particularly in water-intensive areas. This competition imposes constraints in regions where resources are limited, reducing aquaculture productivity (Elaiwi *et al.,* 2020).

Disease management

Koi herpes virus (KHV) outbreaks

The 2018 KHV outbreak in the Euphrates region caused significant carp mortality and economic losses, highlighting Iraq's vulnerability to fish diseases and the need to strengthen biosecurity measures (Toffan *et al.,* 2020; Roohi *et al.,*2021).

Biosecurity challenges

Most small-scale farms lack the resources for essential biosecurity measures, such as quarantine facilities and water treatment systems, which are critical for preventing disease spread (Al-Salih *et al.,* 2020). Various environmental, biological, and human-related factors collectively determine the productivity and sustainability of common carp culture in Iraq. These include water quality, water demand, disease prevalence, and management efficiency, as illustrated in Figure 5.

Environmental impacts

Effects on local ecosystems

Carp farming in natural water bodies can disrupt native species and alter ecosystems. Bottom-feeding carp can increase sedimentation

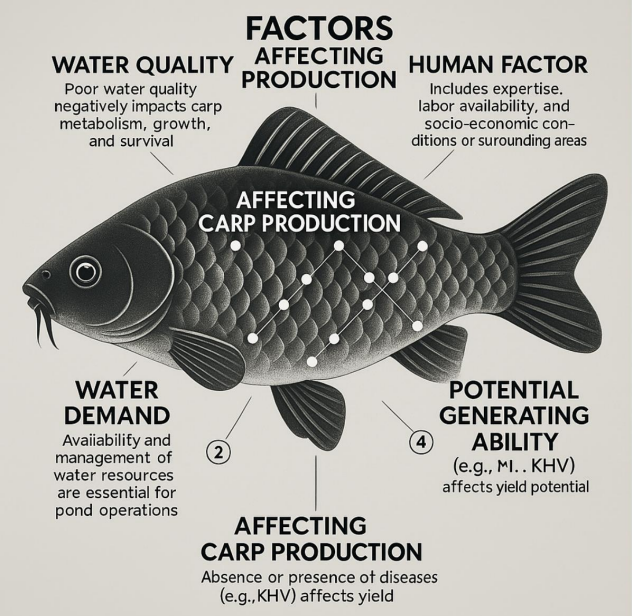

Figure 5. Key factors influencing carp production and sustainability (Adla *et al.,* 2023).

and affect aquatic plants, further impacting biodiversity (Jawad, 2021a).

Nutrient enrichment and eutrophication

Nutrient runoff from feed and fertilizers in intensive carp farms can cause water enrichment, leading to reduced oxygen levels and deteriorated water quality (Wojewódka-Przybył *et al.,* 2024).

Waste management

Waste accumulation in intensive systems, such as floating cages, can degrade water quality and harm both farmed carp and surrounding ecosystems if not properly managed (Yang *et al.,* 2024). These challenges underscore the need for strategic interventions, including improved water management, advanced biosecurity measures, and environmentally sustainable practices to ensure the resilience and growth of Iraq's carp farming sector.

Regulatory challenges

Lack of comprehensive regulations

Iraq currently lacks a clear regulatory framework for aquaculture, leading to inconsistencies in practices related to water usage, disease control, and environmental impacts (FAO, 2017).

Water rights and distribution

Laws governing water usage are unclear, resulting in competition for water resources between agriculture and aquaculture. This ambiguity makes it challenging for farmers to secure reliable water sources (Al-Ansari, 2023).

Limited support for small-scale farmers

Many carp farmers in Iraq operate on a small scale with limited access to financial assistance and training programs. Regulatory barriers often hinder their ability to expand or modernize operations (Salman & Saleh, 2021).

Economic constraints and market access

High input costs

The costs of feed, medicine, and equipment are high, especially since many of these inputs are imported. The lack of local fish feed production further increases production costs, limiting profitability (Mahmud, 2021).

Limited market access

Small-scale farmers face difficulties accessing major markets due to poor infrastructure and supply chain constraints, reducing their ability to sell locally at competitive prices (Abdulhaleem *et al.,* 2018).

Post-harvest losses

A lack of storage and transportation facilities leads to significant post-harvest losses, particularly in rural areas, reducing the profitability of carp farming (Yahia, 2005).

Climate Change and extreme weather events

Impact of rising temperatures

Iraq's high summer temperatures increase evaporation rates, exacerbating water scarcity. Elevated temperatures also stress carp, reducing growth rates and increasing vulnerability to diseases (Cordaid .,2022;Al-Dabbas, 2024).

Drought and water scarcity

Climate change is expected to increase the frequency and severity of droughts, further limiting water availability for aquaculture and intensifying the challenges of carp production in water-scarce areas (Adamo, 2022).

Floods and infrastructure damage

Extreme weather events, including floods, pose risks to fish farms by causing infrastructure damage and introducing contaminants into aquaculture systems (Basra, 2018). These challenges highlight the urgent need for regulatory reforms, climate adaptation strategies, and investments in infrastructure to ensure the sustainability and growth of Iraq's carp farming industry.

High costs and limited processing capacity

The high costs associated with carp farming, coupled with limited processing capacity, hinder the sector's growth. Export opportunities could provide a significant boost, but the current infrastructure and economic constraints limit this potential (Abdulateef *et al.,* 2024).

Environmental and ecological impacts of carp farming in Iraq

Carp farming (*Cyprinus carpio)* is a vital activity for food security in Iraq but has notable environmental and ecological consequences. These impacts affect local ecosystems, particularly native fish species and water quality. The extent of these effects varies based on farming intensity, the systems used, and the proximity of farms to natural water bodies.

Impact on native fish species

Competition and displacement

Carp is a highly adaptable species that can outcompete native fish for resources such as food and space, especially when introduced into natural water bodies like Iraq's marshlands. Carp's bottom-feeding behavior disrupts habitats by stirring up sediments and uprooting plants, altering environments in ways that disadvantage native species (Wang *et al.,* 2024).

Hybridization risks

In some areas, introducing carp has raised concerns about hybridization with closely related species, threatening the genetic diversity of native fish. While this has not been widely documented in Iraq, similar cases in other regions highlight potential environmental risks (Lu *et al.,* 2020).

Predation on eggs and fry

Carp's omnivorous diet allows it to feed on the eggs and fry of other fish species, reducing the natural regeneration rates of native fish. This behavior poses a significant threat to sensitive ecosystems such as the Tigris and Euphrates River systems, where some native species are already endangered due to habitat degradation and overfishing (Mohammed *et al.,* 2024).

Water quality and nutrient enrichment

Nutrient accumulation

Carp farms, particularly intensive systems, contribute to nutrient buildup in water bodies through waste production and feed residues. This enrichment can lead to algal blooms and cyanobacteria growth, reducing oxygen levels and creating hypoxic conditions harmful to both farmed and native species (Hlaváč *et al.,* 2014).

Sediment disturbance

Carp's bottom-feeding behavior stirs up sediments, increasing turbidity in ponds and adjacent water bodies. High turbidity reduces light penetration, affecting aquatic plant photosynthesis and altering primary food chains. Sediment disturbance can also bury fish eggs, degrading habitat quality for species reliant on clear waters (Huser *et al.,* 2022).

Chemical and antibiotic leakage

In some cases, farmers use chemicals, antibiotics, and fertilizers to boost production or prevent disease outbreaks. These substances can leach into surrounding aquatic systems, harming aquatic organisms and degrading water quality, particularly in sensitive ecosystems like Iraq's marshlands and rivers (Manyi-Loh *et al.,* 2018). These environmental and ecological challenges highlight the need for sustainable practices and regulatory measures to balance carp farming's economic benefits with its potential environmental impacts.

Changes in aquatic plants and habitat structure

Destruction of aquatic plants

Carp's bottom-feeding behavior stirs up sediments and uproots aquatic plants, which serve as vital habitats for many organisms. These plants provide food, shelter, and breeding grounds for fish and invertebrates, and their loss can significantly impact ecosystem structure and biodiversity (Mohammed *et al.,* 2024).

Modification of habitat complexity

In natural water bodies like Iraq's rivers and marshlands, carp feeding simplifies habitat structures by removing plants and disturbing sediments. This simplification reduces the habitat complexity needed to support diverse aquatic communities and maintain fish health (Jawad, 2021a).

Impact on marshland ecosystems

Threat to Iraq's Marshlands

The southern Iraqi marshlands are biodiversity hotspots in the region and are particularly sensitive to the introduction of carp. Carp farming in or near these areas disrupts ecological balance by introducing non-native species and altering water quality. The marshlands support numerous native species of fish, birds, and plants, all of which are sensitive to environmental changes caused by carp farming (Salim, 2022).

Impact on endemic species

Some species in Iraq's marshlands are endemic, found only in specific areas, and are threatened by the introduction of carp through competition and habitat modification. This impact has become a significant concern for conservationists aiming to protect the unique biodiversity of Iraq's marshland ecosystems (Vilizzi *et al.,* 2015). These ecological consequences underline the importance of implementing sustainable carp farming practices to mitigate negative impacts on Iraq's ecosystems, particularly its sensitive and biodiverse marshlands.

Solutions and sustainable practices

Environmental impact assessments

Conducting environmental impact assessments for farms, particularly those near sensitive ecosystems, can help mitigate negative effects. By identifying potential environmental risks in advance, stakeholders can implement measures to minimize damage, such as guidelines for stocking densities, feed usage, and waste management (Telfer *et al.,* 2009).

Integrated and polyculture systems

Integrating carp into polyculture systems with species occupying different ecological niches can reduce environmental impacts by creating balanced ecosystems within ponds. Practices like rice-fish farming, already implemented in some areas of Iraq, improve resource efficiency and minimize environmental disturbances (Milstein, 2005).

Waste management and biosecurity

Implementing biosecurity protocols and waste management systems, such as sedimentation ponds and filtration systems, can reduce nutrient runoff and prevent disease spread. These practices decrease the environmental footprint of intensive carp farming systems, making them more sustainable over time (Weber & Brown, 2009).

Improving the sustainability and productivity of carp farming in Iraq

Enhancing the sustainability and productivity of carp farming in Iraq requires addressing several key areas, including adopting sustainable practices, strengthening genetic selection programs, and developing technologies. These efforts can help make carp farming more efficient, resilient, and environmentally friendly.

Sustainable aquaculture practices

Integrated farming systems

Combining carp farming with other agricultural practices, such as rice-fish farming, optimizes land and water use. Carp raised in rice fields benefit from natural pest control and organic fertilization from fish waste, which enhances rice productivity and reduces pesticide use. This system also conserves water, which is crucial in water-scarce regions of Iraq (Debnath *et al.,* 2013).

Polyculture systems

Adopting polyculture systems by integrating carp with other fish species such as tilapia or catfish improves resource efficiency. Each species utilizes different parts of the pond environment, reducing waste accumulation and maintaining water quality. Polyculture also diversifies production, potentially increasing farmer incomes (Benkeblia & Radeva, 2018).

Best management practices (BMPs)

Implementing BMPs, such as improving feeding practices, regularly monitoring water quality, and applying biosecurity protocols, enhances productivity and sustainability. These practices reduce nutrient runoff and minimize the risk of disease outbreaks, which is essential for protecting both farmed and wild fish populations (Saeedi *et al.,* 2024).

Genetic selection and breeding programs

Selective breeding for rapid growth

Developing genetically improved carp strains with rapid growth traits reduces the time needed to reach market size, improving productivity and profitability. Programs focusing on growth efficiency and feed conversion ratios can greatly benefit small-scale farmers seeking quick returns (Kashyap *et al.,* 2024).

Disease Resistance

Genetic selection for disease-resistant strains is crucial for minimizing carp susceptibility to diseases such as Koi Herpes Virus (KHV). Disease-resistant strains significantly reduce antibiotic use, enhance survival rates, and boost farm profitability while lowering environmental impacts (Das & Sahoo, 2014).

Development of local strains

Developing carp strains specifically adapted to Iraq's climatic and water quality conditions can increase the resilience of farmed carp. Research into locally adapted or regionally optimized strains may yield fish better suited to Iraq's environmental conditions, providing farmers with stocks less sensitive to temperature fluctuations and water quality issues (Dyck, 2017). These solutions represent practical and innovative approaches to overcoming the challenges of carp farming in Iraq, ensuring its long-term viability

and contribution to food security and economic growth.

Technological advances in aquaculture

Recirculating aquaculture systems (RAS)

RAS is a highly efficient system that recycles water within the farming unit, purifying it and removing waste. This technology enables year-round production, supports higher stocking densities, and significantly reduces water use, making it ideal for water-scarce regions. Although initial setup costs are high, RAS reduces long-term operational expenses and minimizes environmental impact (Xiao *et al.,* 2019).

Automated feeding systems

Automated feeding systems ensure consistent and precise feeding for carp, reducing feed waste and improving feed conversion ratios. Precision feeding can significantly lower costs, as feed typically represents the largest expense in aquaculture. In Iraq, these systems could be particularly beneficial for large-scale farms seeking to optimize production (Harlıoğlu *et al.,* 2023).

Water quality monitoring tools

Portable water quality testing kits and sensor-based monitoring systems provide real-time data on parameters such as pH, dissolved oxygen levels, and ammonia concentrations. These tools allow farmers to detect changes early and make immediate adjustments, preventing water quality deterioration and reducing disease risks (Silva *et al.,* 2022).

Use of probiotics and biofilters

Probiotics are increasingly used in aquaculture to enhance water quality by balancing microbial communities and reducing harmful pathogens. Biofilters in pond systems further purify water, improving fish health and reducing the environmental impact of water discharge (Romano, 2021). These technological advancements represent valuable opportunities for Iraq's aquaculture sector to improve sustainability, productivity, and environmental performance.

An overview of Iraq's carp production parameters and economic performance provides valuable insight into the country's aquaculture potential and challenges. Key production indicators, including growth rate, survival, feed efficiency, and profitability, are summarized in Table 2.

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Table 2. Carp production parameters and economic overview.

Parameter	Details
Annual Carp production	150-200000
Main Production System	Pond culture, cage culture, intensive and semi-intensive farming
Average Stocking Density (fish \m3)	2-5 pond 50-100 cages
Growth Tate (g\day)	2-5 g\day (depending on condition)
Feed conversion ratio (FCR)	1.5-2.2(deranging on feed quality)
Average Harvest Size (g)	800-1500 g
Production Cycle (months)	6-12 months
Survival Rate (%)	70-90%
Cost of production (USD\kg)	3-4 USD\kg
Profit Margin	20-40%
Key challenges	Water quality, feed costs, diseases, climate condition
Opportunities 150-2000	Expansion of cage culture improved feed resources government support

Note: Carp Production Statistics Based on Reports from the Directorate of Animal Resources in Iraq.

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