



Kuzey Afrika'da Balıkçılığın ve Su Ürünleri Yetiştiriciliğinin Sürdürülebilir Gelişimi: Mevcut Durum ve Geleceğe Yönelik Beklentiler

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Öz

Bu makale, beş Kuzey Afrika ülkesinin (Fas, Cezayir, Tunus, Libya ve Mısır) balıkçılık ve su ürünleri yetiştiriciliği sektörlerini incelemekte ve bölgesel hayvansal protein talebinin arttığı bir ortamda ekonomik istikrar ve gıda güvenliğindeki kritik rollerini vurgulamaktadır. Zengin deniz ekosistemlerine, ulusal ekonomilere ve istihdama önemli katkılara rağmen bu bölgelerin çoğu, sınırlı bilgi, zayıf kurumsal çerçeveler ve yetersiz uluslararası iş birliği nedeniyle, balıkçılık yönetiminde çeşitli zorluklarla karşı karşıyadır. Doğal balık stoklarını korumak ve gıda üretim kapasitelerini artırmak için sürdürülebilir su ürünleri yetiştiriciliği uygulamalarına geçişin gerekliliğini vurgulanmıştır. Yasal ve sürdürülebilir avcılık hayati önemini korusa da, bu çalışmanın odak noktası, su ürünleri yetiştiriciliğinin deniz ekosistemleri üzerindeki baskıları artırmadan, artan nüfusun ihtiyaçlarını karşılama potansiyelidir. Balıkçılık yönetiminin mevcut durumu değerlendirilmiş, su ürünleri yetiştiriciliğinin ölçeklendirilmesindeki zorluklar belirlenmiş ve daha sürdürülebilir ve üretken sonuçlara yol açabilecek yenilikçi uygulamalar tartışılmıştır. Çalışma, balıkçılık sektörünün sürdürülebilir gelişimini sağlamak ve sonuçta gıda güvenliğine, ekonomik büyümeye ve denizel biyolojik çeşitliliğinin korunmasına katkıda bulunmak için gelişmiş yönetim stratejileri, gelişmiş araştırma ve eğitim ve su ürünleri yetiştiriciliğine daha fazla yatırım yapılması çağrısında bulunmaktadır.

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Abstract

This paper delves into the fisheries and aquaculture sectors of five North African countries (Morocco, Algeria, Tunisia, Libya, and Egypt) highlighting their critical roles in economic stability and food security amid increasing regional demands for animal protein. Despite the rich marine ecosystems and substantial contributions to national economies and employment, most of these regions face several challenges in fisheries management due to limited knowledge, weak institutional frameworks, and insufficient international cooperation. The paper emphasizes the necessity of transitioning towards sustainable aquaculture practices to preserve natural fish stocks and augment food production capacities. Although legal and sustainable capture fisheries remain vital, the focal point of this review is the potential for aquaculture to meet the growing population's needs without exacerbating the pressures on marine ecosystems. The paper evaluates the current state of fisheries management, identifies challenges in scaling aquaculture, and discusses innovative practices that could lead to more sustainable and productive outcomes. The study calls for improved management strategies, enhanced research and training, and more significant investment in aquaculture to ensure sustainable development of the fisheries sector, ultimately contributing to food security, economic growth, and conservation of marine biodiversity.

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INTRODUCTION

As the world's population continues to grow, so does the demand for nutrition, especially for animal protein (Henchion et al., 2017). In this regard, seafood, an exceptional source of high-quality proteins and omega-3 fatty acids such as EPA and DHA, provides a wide array of health advantages that are genuinely remarkable (FAO, 2016; Singer et al., 2016). These foods have been shown to promote heart health by significantly lowering triglycerides and blood pressure, thereby reducing the risk of coronary artery disease (Bowen et al., 2016; Singer et al., 2016). Seafood is an excellent option for obtaining a substantial amount of top-notch protein that is easily digestible and crucial for muscle repair and growth (Jayasekara et al., 2020; Ford et al., 2022). Seafood stands out due to its rich concentration of vital nutrients like vitamin D, B12, iodine, selenium, and zinc (Oehlenschläger, 2012). These nutrients are crucial for maintaining optimal bone health, supporting the proper nervous system functioning, regulating thyroid function, and stimulating the immune system (Kvícala & Zamrazil, 2003; Holick, 2004; Reynolds, 2006). Omega-3 fatty acids, found in abundance in seafood, are vital in supporting fetal development and promoting optimal brain function (Swanson et al., 2012). Studies suggest that seafood consumption can improve brain health, reduce the risk of Alzheimer's disease, and even help manage mental health conditions like depression (Gómez-Pinilla, 2008). Seafood is a superior choice for promoting human health compared to red and processed meats due to its lower calorie content and abundance of beneficial polyunsaturated fatty acids (PUFA) (Hosomi et al., 2012), and plays a critical role in maintaining eye health in preventing age-related macular degeneration, the leading cause of vision impairment and blindness (Koning-Backus et al., 2019). Furthermore, consuming omega-3 fatty acids from seafood can relieve joint pain and stiffness, offering potential comfort for individuals with rheumatoid arthritis (Carballo-Casla et al., 2022).

With the Earth's extensive water coverage, there is a rich abundance of natural fish stocks (despite a depleting trend due to uncontrolled overfishing and pollution), and the availability of water sources enables the cultivation of diverse aquatic organisms (Sala et al., 2021; Araujo et al., 2022). Seafood, a rich source of protein and quality unsaturated fatty acids, has steadily increased production and consumption. Based on the latest data from 2021, global fisheries production stands at around 219.22 million tons. Out of this, aquaculture production accounts for 126.04 million tons, which makes up approximately 57.5% of the total. The remaining 93.18 million tons, roughly 42.5%, comes from capture production (FAO, 2024a). Since 1950, there has been a consistent upward trend in the global production of aquaculture, which has become an integral part of the world's fisheries industry. There has been a noticeable shift in the fishing industry over the years. The amount of aquatic products caught through fishing has either decreased or remained stable, particularly after 2000. However, the production of aquatic products through aquaculture has been steadily increasing. In fact, after 2010, the amount of aquaculture production surpassed that of capture production, as shown in Figure 1.

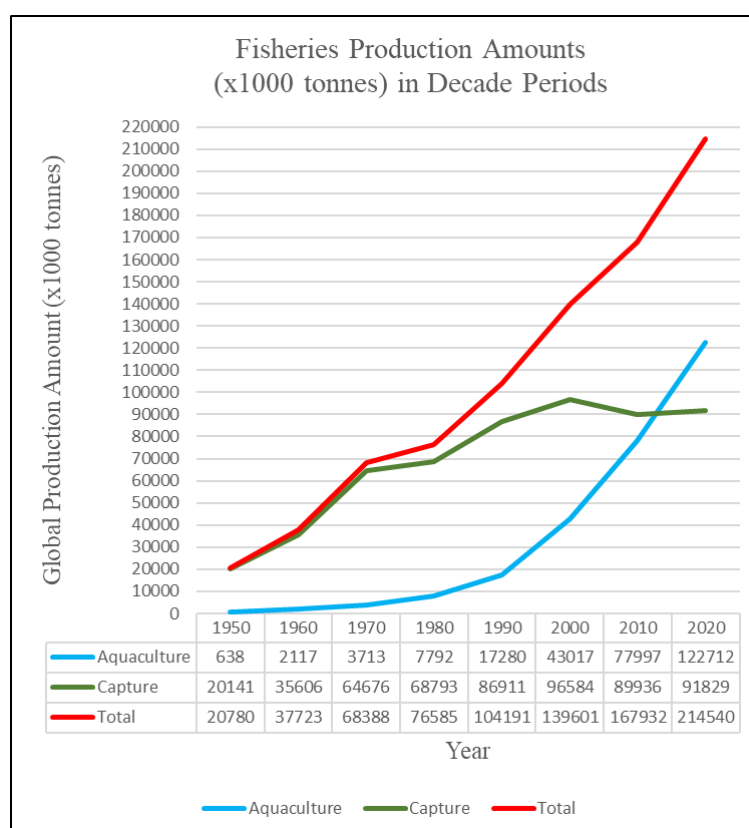


Figure 1. Global Fisheries Production Amounts (x1000 tonnes) in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

Aquaculture provides a viable method for seafood production, alleviating strain on marine resources. Additionally, it has the potential to generate economic advantages for communities, promote employment opportunities, and support the preservation of biodiversity by implementing ethical methods. Moreover, it can aid in generating populations that are diminishing in their natural habitats, enhancing global food security, and fulfilling nutritional requirements worldwide (Naylor et al., 2021a). For this reason, many countries carry out aquaculture activities intensively, especially those bordering marine areas (Gentry et al., 2017).

Surrounded by Europe from the north, Africa from the south, and Asia from the east and connected to the Atlantic Ocean through the Strait of Gibraltar, to the Red Sea through the Suez Canal, and to the Black Sea by the Dardanelles, the Sea of Marmara, and the Bosphorus; the Mediterranean Sea provides a suitable environment for aquaculture due to its climatic conditions (FAO, 2023). The aquaculture production in the nations located in the north of the Mediterranean for the year 2021 is as follows: Spain - 253,825 tonnes, France - 156,117 tonnes, Italy - 76,911 tonnes, Greece - 140,423 tonnes, and Türkiye – 471,686 tonnes (TÜİK, 2022; FAO, 2024a). Conversely, except for Israel, which has a notable production of ornamental fish and employs innovative techniques like integrating fish and plant production with aquaponics systems (Neori et al., 2017), and Egypt, which is a major global aquaculture producer, the countries on the southern side of the Mediterranean have lower levels of aquaculture production. (FAO, 2024a).

Aquaculture has a significant opportunity to promote economic growth in rural regions and alleviate the strain on marine resources in African countries (GSA, 2020). Despite this, the comparatively insufficient development of aquaculture in most North African countries can be attributed to several factors despite their advantageous geographical location regarding marine resources.

This paper aims to assess the fisheries sector and enhance comprehension of the barriers that hinder efficient fisheries management in North African nations. The countries of Morocco, Algeria, Tunisia, Libya, and Egypt were examined for this specific objective (Figure 2). Graphs were generated and analyzed using statistics from FAO, World Bank, and Our World in Data (FAO, 2024a; WB, 2024; OWID, 2024).



Figure 2. Map of North African Countries and the Marine Areas Around Them (display was revised using the map file, MOW, 2024)

Related Countries

Morocco

Situated at the Mediterranean and Atlantic intersection and having a 2945 km long coastline (TWF, 2024), Morocco has diverse marine and inland water ecosystems. The fisheries sector is a vital and fundamental component of the country's economy, supporting people's livelihoods and significantly contributing to the national food supply. This sector plays a significant role in Morocco's economy, donating 3% to the country's Gross Domestic Product (GDP). The industry provides employment opportunities to nearly 400,000 individuals, with 104,000 involved in fisheries. Annually, Morocco's seafood production reaches approximately 1.4 million tonnes. The European pilchard is important for Moroccan fisheries, representing 62% of the total capture production. In 2016, Morocco exported 524,959 tonnes of seafood, making it the 18th largest seafood exporter in the world and the top exporter in Africa (EU, 2021; FAO, 2024b). Morocco provides the majority of this total capture production from the Atlantic (Figure 3).

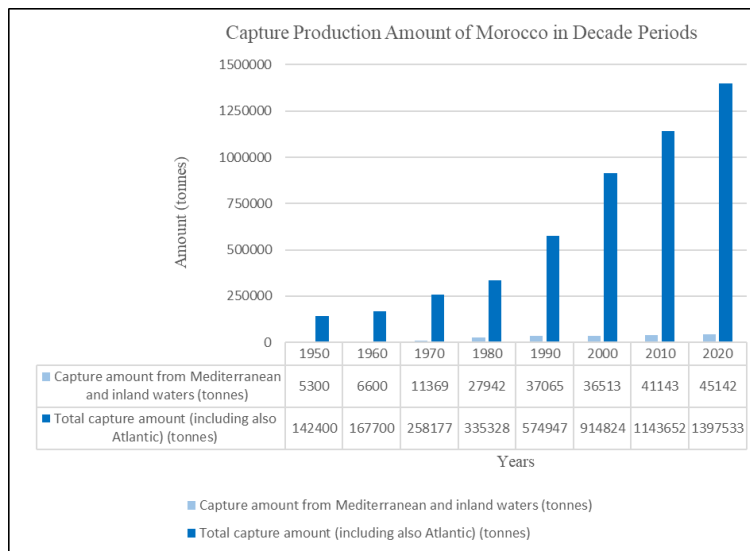


Figure 3. Capture Production Amount of Morocco in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

Despite the significant capture amount and promising prospects, the full potential of aquaculture in Morocco has yet to be fully realized (Figure 4). From 1990 to 2021, there was an increase in aquaculture production, which went from 415 tonnes to 2,006 tonnes. Additionally, the value of this sector experienced a rise, going from \$3.66 million in 1990 to \$14.4 million in 2021. The Moroccan government's Halieutis plan, launched in 2009, aimed at improving performance and sustainability in the fisheries sector, includes development goals for aquaculture. Efforts have been made to increase aquaculture production through this plan (HALIEUTIS, 2024). Aquaculture production includes marine and inland aquaculture, focusing on oysters, seabass, seabream, and trout. Oyster farming is a highly profitable industry, with seabass being a close contender. In 2011, the National Aquaculture Development Agency (ANDA) was established by the authorities to accelerate progress. Aquaculture operations are mainly focused in M'diq, Nador, Oualidia, and Dakhla, where they have been strategically established (Moutchou et al., 2019).

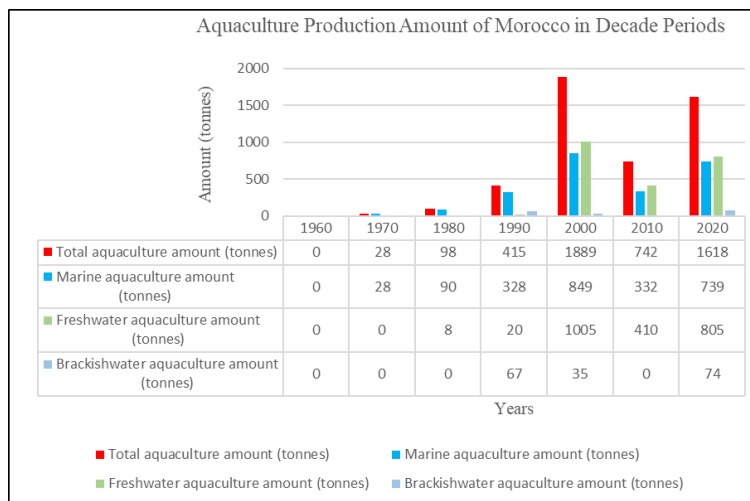


Figure 4. Aquaculture Production Amount of Morocco in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

Algeria

Algeria, with its 998 km coastline along the Mediterranean Sea (TWF, 2024), has a rich marine biodiversity supporting small-scale and industrial fishing activities. The sector primarily focuses on capturing small pelagic fish such as anchovies, sardines, and mackerel, as well as bottom-dwelling species like hake, red and white shrimp, and octopus; and 79,200 tonnes of seafood captured in 2021 (Figure 5). The fisheries sector is an essential source of employment and contributes significantly to the Algerian economy. It also plays a crucial role in ensuring food security for the population (Chakour, 2008). Following Algeria's independence, the fisheries sector has seen difficulties caused by administrative instability. However, it has experienced progress with implementing three significant initiatives since 2000, designed to revive the fishing business. These initiatives encompass the implementation of legislation about fisheries and aquaculture, formulating a comprehensive development plan for the long term, and mapping marine resources to ensure their sustainable utilization. Algeria intends to enhance its fishing operations and capabilities despite a need for pelagic fish production and bottom resources. The total projected potential yield is around 221,100 tonnes per year. Algeria is taking steps to enhance its maritime rights and encourage sustainable practices to prevent overfishing

and the depletion of fish stocks. These efforts involve collaborating with other countries to restore marine biological stocks through reseedling and implementing measures to combat marine pollution and unregulated exploitation (Boutarcha, 2022).

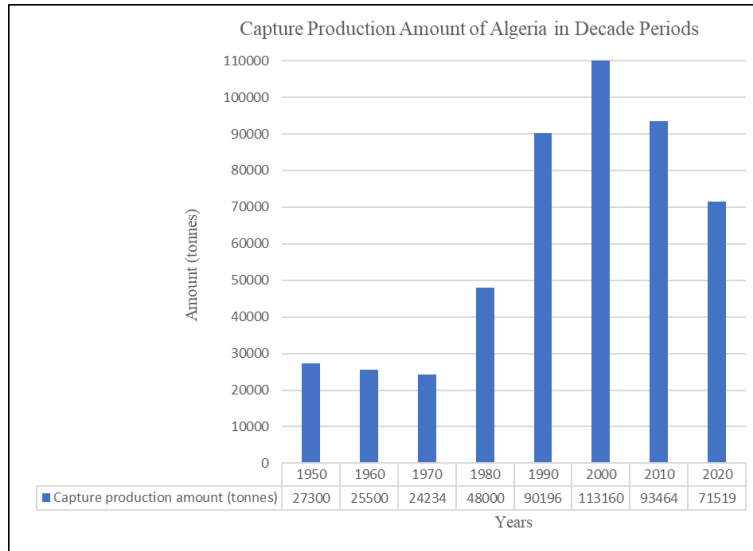


Figure 5. Capture Production Amount of Algeria in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

The aquaculture sector in Algeria is relatively underdeveloped but holds significant potential for growth (Figure 6). Efforts are being made to promote aquaculture to supplement wild fisheries and enhance food security. With a current aquaculture production amount of 4,779 tons in 2021, the 2020-2025 Orientation Plan for the Development of Fisheries and Aquaculture Activities sets ambitious strategic objectives. By 2025, the plan aims to reach a production target of approximately 221,000 tons from marine fisheries and 53,000 tons from various aquaculture projects (Taguemount et al., 2023).

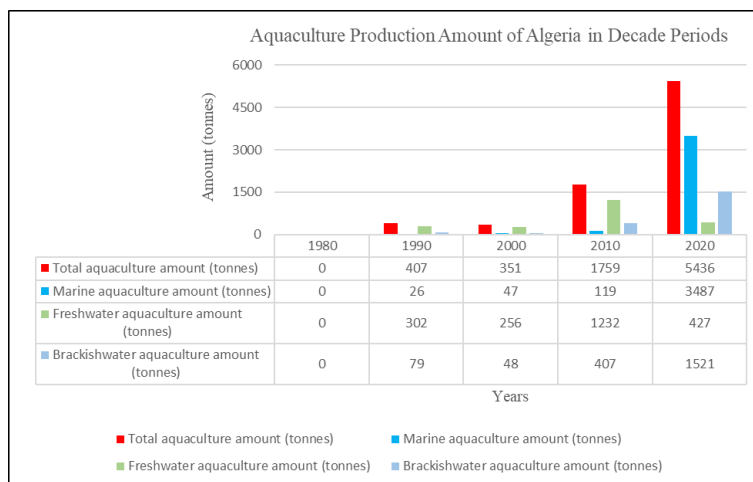


Figure 6. Aquaculture Production Amount of Algeria in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

Tunisia

Tunisia stretches for 1,148 kilometers (TWF, 2024) along the Mediterranean Sea, and many coastal communities have a long fishing history. Over 46,000 individuals were employed in the fishery industry in 2017. Total capture fisheries production has increased in recent years, reaching 124,243 tonnes in 2021, with octopus, cuttlefish, tunas, and shrimp being the most lucrative species captured (FAO, 2024c). Tunisia's fishing industry is marked by small-scale traditional fishing, the dominant force in the sector, and industrial fishing operations. In 2016, 13,144 boats were engaged in fishing, with more than half of them not fueled. In 2017, the fishing industry employed 46,218 people (FAO, 2019a). The nation's predominant fishing gear includes set nets, trawls, and longlines. The industry primarily focuses on species such as sardines, anchovies, seabream, and shrimp. Fishing plays a crucial role in supporting coastal communities, providing employment opportunities, and contributing to Tunisia's food security and export earnings. Tunisia has made significant strides in enhancing fisheries management and sustainability by implementing regulations, establishing marine protected areas, and actively combating illegal, unreported, and unregulated (IUU) fishing. However, bycatch assessments in Tunisia are limited to the Gulf of Gabes, which is recognized as a region with a high level of biodiversity (Louhichi et al., 2023). Overfishing remains a significant threat to marine biodiversity and the long-term

sustainability of fisheries resources. Efforts to enforce fishing quotas and protect critical habitats are ongoing challenges (OECD, 2018).

The practice of aquaculture was introduced in Tunisia during the 1960s and had significant growth in the 1990s due to the collaborative efforts of the Tunisian-German cooperation project established by the Deutsche Gesellschaft für Technische Zusammenarbeit (German Association of Technical Cooperation) (Losse et al., 1991). As a part of the project, fish species were introduced from Europe in the 1990s to enhance and broaden fish production in Tunisian reservoirs (Mili et al., 2023). Tunisia's relatively modest aquaculture sector has been highlighted as having significant growth potential. It covers freshwater aquaculture with a relatively stable production amount, focusing on species such as carp, freshwater mullet, pike-perch, and tilapia, and a rapidly developing mariculture mainly produces gilthead seabream and European seabass. While farmed marine species (including fattened wild-caught tuna) are marketed internationally, freshwater species are only sold locally (FAO, 2019a). The aquaculture production of Tunisia, which was 56 tonnes in 1980, has increased to 26,077 tonnes in 2021. In the following years, there has been an increase in production through both capture and aquaculture (Figure 7 and Figure 8). The Tunisian government has implemented several initiatives to promote the growth of aquaculture, such as offering technical guidance to farmers, streamlining financial access, and allocating resources to research and development (van Beijnen and Hoevenaars, 2022).

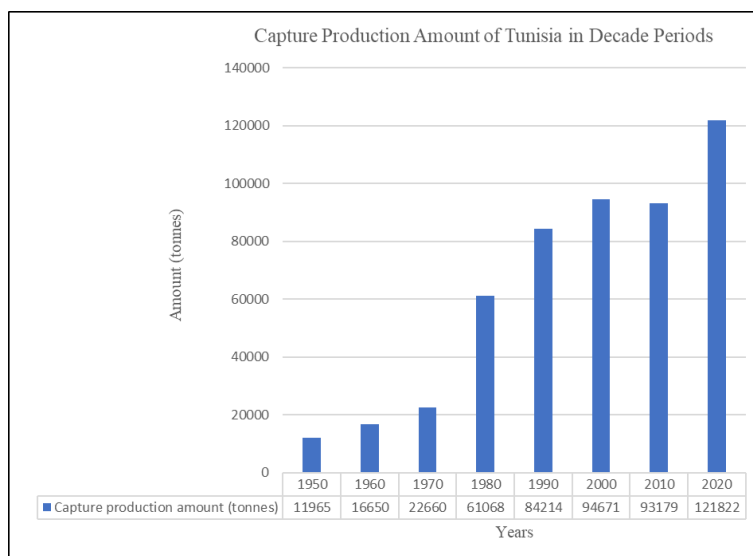


Figure 7. Capture Production Amount of Tunisia in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

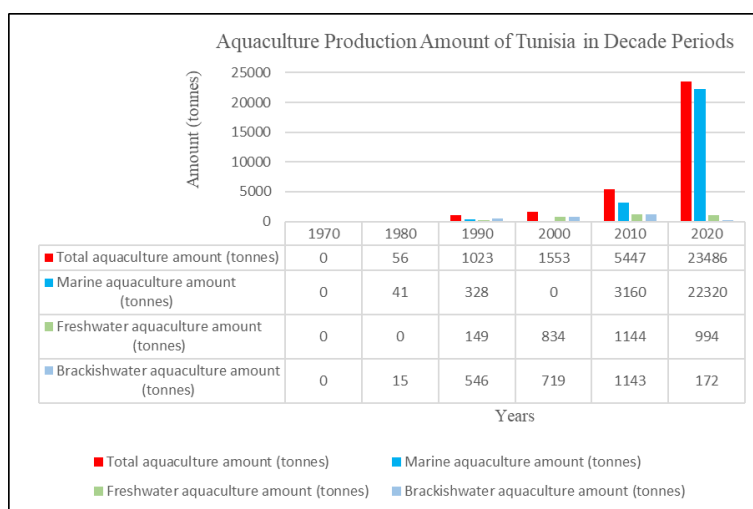


Figure 8. Aquaculture Production Amount of Tunisia in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

Libya

Libya's 1770 km Mediterranean coastline gives the country a strategic advantage for fishing and aquaculture development. Approximately six million country residents live in coastal areas, primarily located in the western part of Tripoli (Milanese et al., 2008). The Libyan economy relies heavily on oil exports, which comprise 75–90% of the country's income (Saleh, 2014). Marine fisheries and fishery-related activities also play an important role in the economy, albeit with a minor national catch compared to other Mediterranean countries (Milanese et al., 2008; Filogh, 2019). Despite the availability of important economic and natural

resources, the production capacity is not proportionate to those resources (Al-Rashed and Sharif, 2000). Although political impotence continues in Libya and affects multiple aspects, Libya has been the primary supplier of Atlantic bluefin tuna for Mediterranean bluefin farms (Harrison, 2011).

Despite having a long history of human residence and one of the Mediterranean's oldest ports (Tripoli), Libyan civilization has not established a strong fishing tradition. On the other hand, fishery output has expanded since the 1970s, before the political turbulence, thanks to significant state expenditures in ports, onshore infrastructure, and services. Efforts were made to improve administrative, technical, and research assistance for the industry (FAO, 2019b). In 1980, the Libyan government initiated the development of the fishery sector by constructing ice facilities along its coastline and boosting demand for fishing products. Six years later, a new port was established in Zuwarah, located in the northwestern region of Libya's coast. Additionally, the Libyan government went into collaborative fishing agreements with Tunisia and Spain to support further growth in the sector. The establishment and funding of the Secretariat of Marine Wealth (SMW) by the Libyan government in 1988 aimed to promote the development of the marine industry by managing 24 marine fishery cooperatives, commonly referred to as "Jamaia" (Khalafallah et al. 2015; Filogh, 2019). Libya has had no official statistics accessible for some years, and data from the mid-2010s are based on FAO's estimates. It is estimated that there were 4,534 fishing vessels in 2017, with the majority being less than 24 meters in length. According to the most recent estimate, aquaculture employs 480 persons, and fishing employs 50,603 (FAO, 2019b). Libya's capture and aquaculture production amounts are given in Figure 9-10.

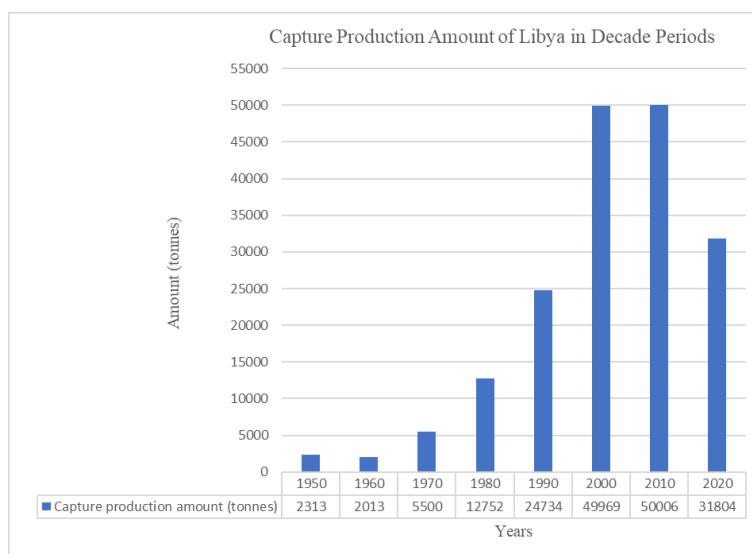


Figure 9. Capture Production Amount of Libya in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

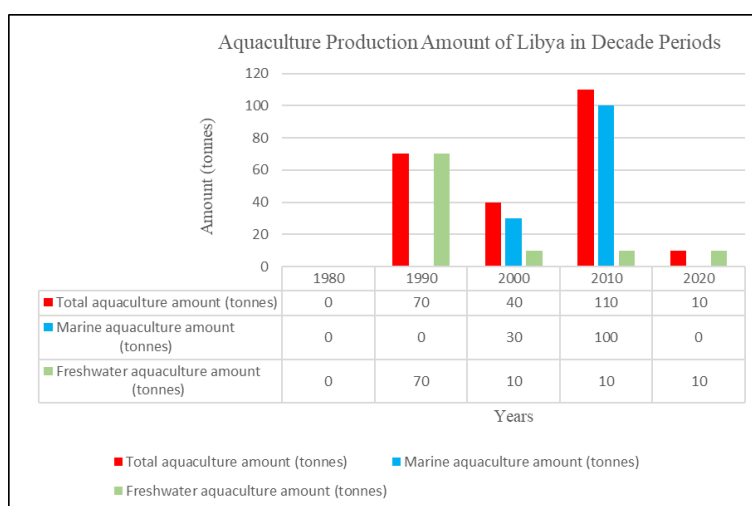


Figure 10. Aquaculture Production Amount of Libya in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

Egypt

Egypt's strategic location between the Mediterranean and Red Seas and ample freshwater resources make it unsurprising that the fishing industry plays a critical role in the country's socio-economic landscape (Samy-Kamal, 2020). In a developing nation with over 100 million people, fisheries in Egypt provide an essential source of animal protein for most low-income people. Many

Egyptians rely heavily on seafood for protein, constituting nearly 20% of their animal protein consumption (Samy-Kamal, 2015; Lucchetti et al., 2016). In Egypt, fish production through aquaculture and capture is vital for ensuring food security, creating employment opportunities, alleviating poverty, and improving the livelihoods of individuals, particularly those residing in rural communities. Approximately 1.9 million tons of seafood are produced annually in the country, with 1.6 million tons derived from aquaculture and 300,000 tons harvested from natural water bodies. There has been a decline in Egypt's natural fish resources, both in marine and inland environments, over the past few decades. This decline highlights the need to adopt sustainable and responsible practices in fisheries and aquaculture and protect marine ecosystems (Mehanna, 2022).

In Egypt, a country with a longstanding tradition in capture fisheries, the last two decades have seen a remarkable shift towards aquaculture, with its production surpassing capture fishery in volume by 2003 (Figure 11). The marine sector yields diverse species, notably sardine, shrimp, and anchovy, with the Mediterranean Sea and the Red Sea being the primary areas for these activities. The fishing fleet comprises over 8,000 vessels, engaging nearly 90,000 fishermen, and employs various fishing gears and practices across both seas. Management efforts by the General Authority for Fish Resources Development (GAFRD) focus on sustainable fishing practices, including effort control, gear and area restrictions, and promoting modern fishing techniques. Fishermen's cooperation is facilitated through union membership, providing a support system during closed seasons and representing their interests at the administrative level. Inland fisheries, benefiting from Egypt's extensive lake systems and the Nile River, contribute significantly to the country's fish production, with tilapia, catfish, grass carp, and mullets being the principal species. Management strategies include restocking programs, closed seasons, and habitat conservation to support both inland and marine fisheries (FAO, 2024d).

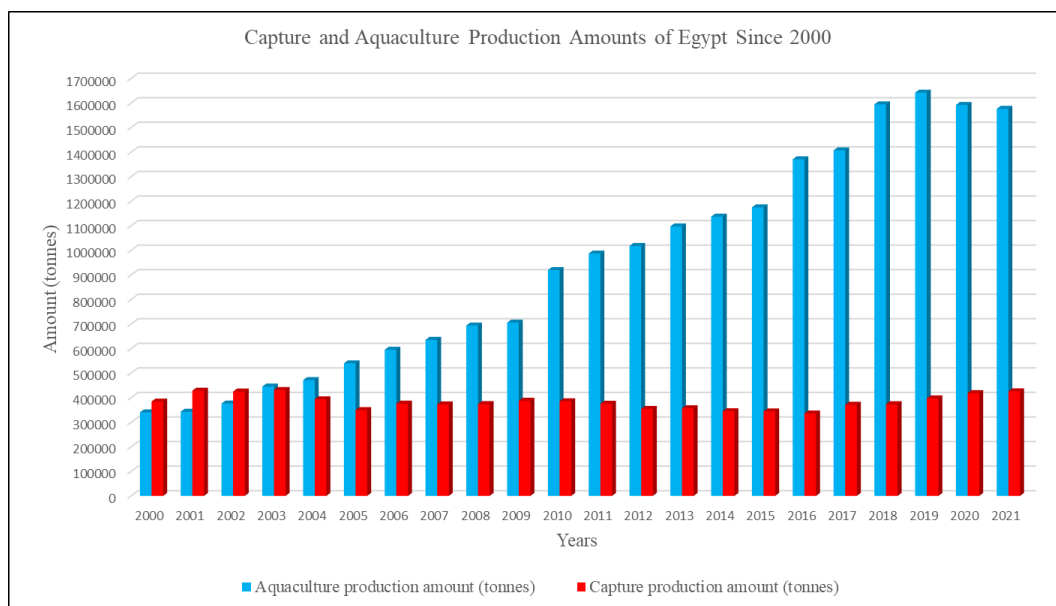


Figure 11. Capture and Aquaculture Production Amount of Egypt Since 2000 (prepared using FAO FishStat data, FAO, 2024a)

The Egyptian government initiated aquaculture in 1978 to promote private investment in the sector. With around 600 hatcheries and approximately 600,000 acres of land allocated for aquaculture development, the sector has grown significantly, accounting for 65% of Egypt's fish production in 2009, primarily through semi-intensive culture in brackish water. Tilapia dominates the production, followed by mullets, contributing to the majority of aquaculture output. Despite declining marine aquaculture species like European seabass and gilthead seabream, the introduction of meagre culture marked a significant development. Egypt has emerged as a leading aquaculture producer, particularly noted for its production of cultured tilapias and mullets. The growth rate of aquaculture production has been substantial, with a more than tenfold increase from 1990 to 2010 (Figure 12). The sector not only fulfills a significant portion of domestic fish demand but also contributes to food security, employment, and rural development, supporting communities along Egypt's extensive coastlines and inland water bodies (FAO, 2024d; Menezes et al., 2024).

In Egypt, the artisanal nature of fisheries, characterized by using gillnets, trammel nets, and longlines by small boats, juxtaposes with larger vessels employing bottom trawls and purse seines. Annual capture production is approximately 400,000 tons, mainly supplied from the Mediterranean (FAO, 2024a) (Figure 13).

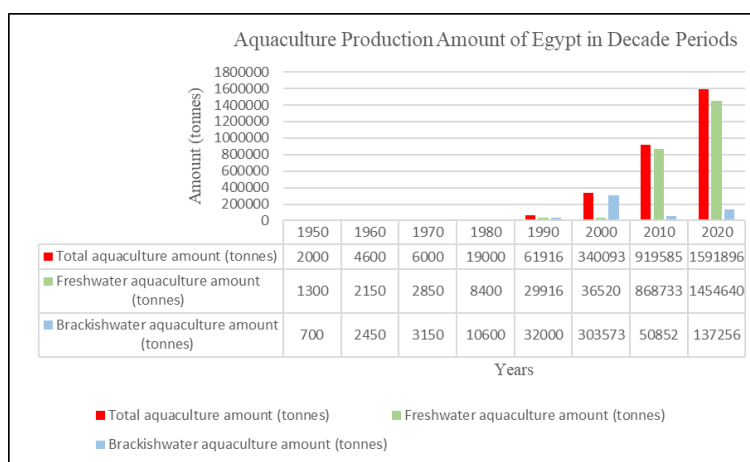


Figure 12. Aquaculture Production Amount of Egypt in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

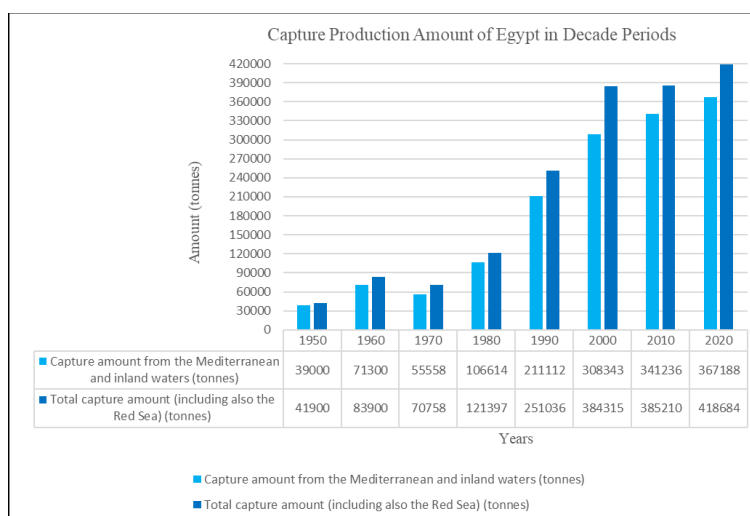


Figure 13. Capture Production Amount of Egypt in Decade Periods (prepared using FAO FishStat data, FAO, 2024a)

DISCUSSION

Aquaculture is widely accepted as the most rapidly growing sector within the food industry. In 2021, the total global fish production reached 219 million tonnes, with 126 million tonnes (57.5%) produced through aquaculture (FAO, 2024a). In comparison, wild capture supply has remained relatively stagnant since the 1980s. As a result, aquaculture is becoming increasingly essential in fulfilling the rising global demand for fish consumption (Abdel-Hady et al., 2024). Countries in North Africa that have a coastline along the Mediterranean Sea (Morocco also has a coastline along the Atlantic Ocean, and Egypt along the Red Sea) possess significant production potential, both through wild capture and aquaculture, owing to their rich marine water (Egypt also has inland waters) resources (FAO, 2023).

Fisheries play a crucial role in the economies of some North African countries, significantly contributing to GDPs, employment, and food security. In Morocco, the fisheries sector is particularly important, supporting the livelihoods of hundreds of thousands of people and being a key component of the country's economy. To maintain the economic benefits generated by fisheries and ensure environmental stewardship, the Moroccan government has implemented strategic initiatives like the Halieutis plan, aimed at enhancing the sustainability and efficiency of the sector (HALIEUTIS, 2024). Even better than that, Egypt is making commendable strides, particularly in its leading aquaculture production among all African countries and its emphasis on the fisheries sector. Thanks to the government's support for aquaculture since 1978, fish production has increased significantly since the 2000s, and Egypt has become an important supplier of animal protein (FAO, 2024d). In addition to Tunisia being a country of considerable importance in terms of marine biodiversity, there have been substantial developments in aquaculture through a partnership with Germany since the 1990s, resulting in a significant increase in production in recent decades. The industry, characterized by traditional small-scale and industrial fishing operations, plays a vital role in supporting coastal communities, enhancing food security, and contributing to national export earnings. Significant strides have been made to improve fisheries management and sustainability, despite ongoing challenges in combating overfishing and protecting marine biodiversity (Losse et al., 1991; Louhichi et al., 2023). Algeria's fisheries sector, which plays a critical role in employment and economic contribution, is vital for the country's food security. Despite facing various challenges after gaining independence, the sector has made

substantial progress through legislative reforms and sustainability initiatives since 2000. These efforts aim to enhance fishing operations and prevent the depletion of resources. Additionally, the comparatively underdeveloped aquaculture sector presents significant growth potential, with ambitious targets set for 2025 to increase marine fisheries and support food security. Most Libyans reside in coastal regions, predominantly around western Tripoli, significantly contributing to local demographics and economic activities. While Libya's economy is heavily dependent on oil exports, accounting for 75–90% of its income, marine fisheries and related activities also play a crucial but modest role compared to other Mediterranean nations (Saleh, 2014). Despite substantial natural and economic resources, the fishing industry's productivity remains disproportionately low. Political instability has hindered development, yet significant governmental investments since the 1970s have spurred modest growth in the sector, with expansions in port facilities and international collaborations enhancing the fishery's infrastructure and operational capacity.

Concurrently with the rapid growth of aquaculture in Tunisia, there has been a notable increase in the annual per capita seafood consumption. Furthermore, it is commendable that scientific studies have been carried out on various significant topics, including the use of statistical modeling to estimate fish demand in the country (Dhehibi et al., 2005), determining the impact of economic and socio-demographic factors on fish consumption (Dhraief et al., 2012), heavy metal accumulation and its effects in bivalves (Bejaoui et al., 2020), fish diseases (Charfi-Cheikhrouha et al., 2000; Chaabane et al., 2017), effects of environmental pollution on fishes (Jebali et al., 2013), identification of the seasonal reproductive cycle in bivalves (Derbali, 2013), and the production of biofuel from fish by-products (Kraiem et al., 2015). This indicates that scientific investigations of aquatic ecosystems and organisms are highly regarded nationwide. Establishing good neighborly practices and enhancing cross-border cooperation in the maritime domain between Tunisia and the southern regions of Italy can serve as an additional foundation for developing sustainable employment opportunities in the southern countries. The government of Tunis intends to address the modernization of fisheries and aquaculture, as well as the rehabilitation of the port of Kelibia, within the framework of a cooperative atmosphere with Italy (SUREFISH, 2021).

In Egypt, both artisanal and industrial fishing methods are practiced, demonstrating the country's commitment to improving fisheries management and ensuring long-term sustainability. GAFRD is advancing this goal by implementing sustainable practices, establishing international collaboration, and promoting the growth of aquaculture. These efforts are reinforced by detailed research and training programs conducted by both global and local partners, with the aim of enhancing productivity and conservation activities (FAO, 2024d). Egypt's transition from traditional capture fisheries to aquaculture is a critical shift in addressing food security and economic challenges amidst declining natural fish resources. This strategic pivot highlights the country's adaptive measures to environmental and socioeconomic pressures by leveraging its geographic advantages and freshwater resources (Menezes et al., 2024). Aquaculture now plays a dominant role, significantly exceeding capture fisheries in production since 2003, marking a major transformation in Egypt's fisheries sector. The sustained growth in aquaculture, particularly tilapia and mullets, not only supports a substantial portion of domestic fish demand but also fosters rural development and employment. Continued efforts in sustainable practices, alongside international collaborations, are crucial to further advancing this sector, enhancing its resilience, and ensuring it plays a vital role in Egypt's socioeconomic framework (FAO, 2024d). Egypt, with its present condition and, in particular, its notable advancements in aquaculture production strategies, serves as a model for all water-rich African nations. Taking a glance at the aquaculture value over the past ten years (Figure 14), it is apparent that Egypt has made considerable strides in this domain and reaped substantial economic benefits.

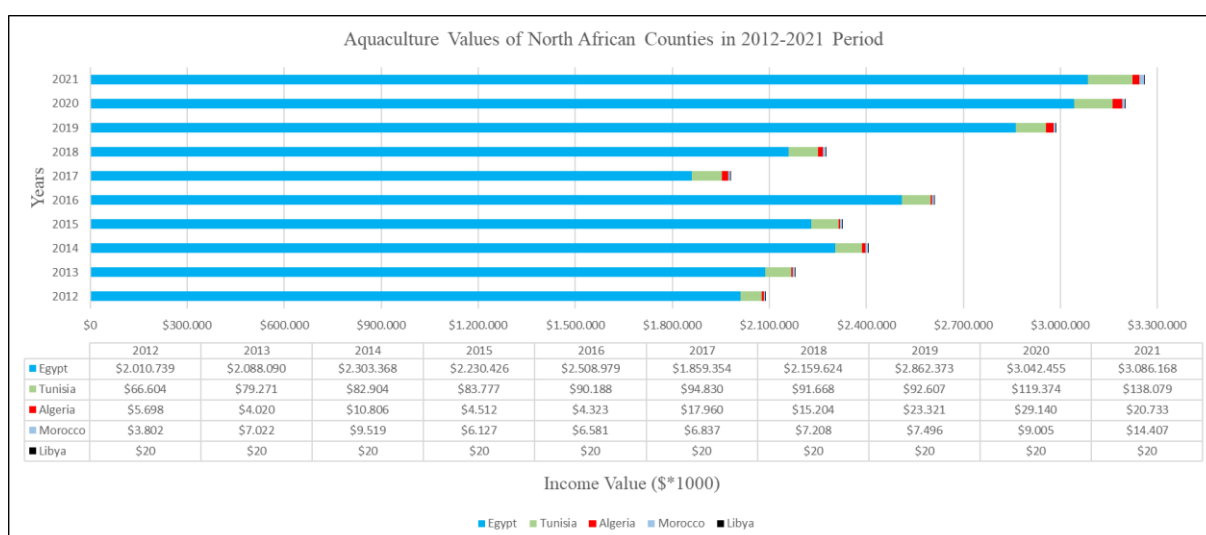


Figure 14. Aquaculture Values of North African Counties in 2012-2021 Period (prepared using FAO FishStat data, FAO, 2024a)

Despite the predominance of capture fisheries, mainly of European pilchard, which dominates the sector in Morocco, aquaculture holds substantial untapped potential. However, the total capacity of aquaculture still needs to be increased vastly. Apart from the

yearly 1.4 million tons of wild capture production, mainly from the Atlantic, the aquaculture production of about 2000 tons is insignificant, even though the government's 2009 Halieutis plan seeks to capitalize on this potential by enhancing the performance and sustainability in the aquaculture sector (HALIEUTIS, 2024). Critical regions like M'diq and Dakhla have been identified for development, focusing on high-value species such as oysters and seabass, highlighting a targeted approach to bolster this nascent sector. This strategic pivot aims to reduce pressure on over-exploited capture fisheries and bolster economic resilience by expanding into profitable aquaculture markets (Moutchou et al., 2019).

Using its almost extensive Mediterranean coastline, Algeria has been progressively revitalizing its fisheries sector, which is central to economic stability and food security (Chakour, 2008). With a focus on sustainable practices, the country is working to prevent overexploitation and enhance marine biodiversity through significant legislative reforms and international cooperation (Boutarcha, 2022). These reforms are part of a broader strategy encapsulated in the 2020-2025 Orientation Plan, which sets ambitious targets for marine fisheries and aquaculture, aiming to significantly increase production by 2025 (Taguemount et al., 2023). However, despite these initiatives, challenges such as the underdevelopment of the aquaculture sector and the need for increased pelagic fish production persist, indicating a crucial area for further development and investment to realize the sector's potential fully. Nevertheless, the progress in aquaculture production in recent decades is noteworthy. However, it is interesting that annual fish consumption per capita in a seaside country is only 3.8 kg (Table 1).

Table 1. Comparative Total Fisheries Production Amounts, Per Capita Seafood Consumption Amounts, Total fisheries production amount / Population, and GDP (nominal) per capita of North African Nations in 2020 (prepared using FAO FishStat data, Our World in Data, and The World Bank Data: FAO, 2024a; OWID, 2024; WB, 2024)

Parameters / Region	World	Morocco	Algeria	Tunisia	Libya	Egypt
Total fisheries (capture and aquaculture) production amount (*1,000 tonnes)	214,540.38	1,399.2	76.96	145.31	31.81	2,010.58
Seafood consumption per capita (kg)	20.3	18.5	3.8	13.7	14.7	25.8
Population (*million)	7,820	36.689	43.452	12.162	6.654	107.465
Total fisheries (capture and aquaculture) production amount (kg) / Population	27.43	38.14	1.77	11.95	4.78	18.71
GDP (nominal) per capita (\$)	10,904.10	3,258	3,354	3,498	7,035	3,572

The demand for a good is determined by many factors, especially the consumer's financial situation, the good's price (Dilek et al., 2019), expectations, and habits. In this context, a positive correlation between countries' per capita seafood consumption and their GPT per capita is generally anticipated. Furthermore, in nations abundant in freshwater or marine water resources, there is an expectation of a high level of seafood consumption (Naylor et al., 2021b). Considering the data from 2020, it is seen that seafood consumption per capita worldwide is 20.3 kg, and it is understood (Table 1) that 7.13 kg of total fishery production per capita is used for fish meal production and various industrial activities. Among the North African countries, only Egypt is above the world average with its seafood consumption of 25.8 kg per capita, and Morocco is close to the world average with its consumption per capita of 18.5 kg. Thanks to Morocco's extensive fishing of natural fish stocks in the Atlantic and its relatively low population, a substantial value of 38.14 kg per capita arises from the country's total fishing production. Thanks to Morocco's extensive fishing of natural fish stocks in the Atlantic and its relatively low population, a substantial value of 38.14 kg per capita arises from the country's total fishing production. As can be seen from the difference of almost 20 kg per capita, Morocco is an important seafood exporter. Although Libya has a comparatively low seafood production of 4.78 kg per capita, its citizens can consume 14.7 kg of seafood per capita through imports. Libya's higher nominal GDP per capita makes this possible. On the other hand, Algeria's fishing production is insufficient to cater to the demands of its substantial populace, resulting in an average of only 1.77 kilograms of seafood per capita. Although per capita seafood consumption is 3.8 kg, including imports, this amount remains far behind the world average. This negative situation could be related to the public's dietary habits or financial resources.

The following are some of the identified challenges and modest recommendations: In the Mediterranean Sea, the fisheries typically involve multiple species and various types of fishing gear. Both artisanal and large-scale commercial fishing contribute to the depletion of fish resources in the Mediterranean Sea (Ormerod, 2003; Colloca et al., 2017). Also, incidental bycatch connected with fisheries is considered a significant hazard to vulnerable marine megafauna species, including sharks, cetaceans, and sea turtles, due to the direct mortalities and injuries it causes (Lewison et al., 2004; Louhichi et al.; 2023). To ensure the sustainability of natural fish stocks, protect endangered species, and reduce bycatch, it is necessary to raise the ecosystem

awareness of fishermen, impose strict controls and heavy sanctions by governments to prevent overfishing and illegal capture, carry out studies on the selectivity of fishing gear, and then implement the findings in the sector. Additionally, while several countries strive to enhance their aquaculture production, except Egypt, which serves as a model for others, the amount of aquaculture production remains significantly lower than that of wild capture fisheries, particularly in Morocco (FAO, 2024a). Aquaculture production must take the front stage to ensure the sustainability of natural fish stocks. Furthermore, disadvantageous is the fact that fishmeal is a crucial raw material in the feed used in aquaculture to produce seafood and that natural supplies are depleted to obtain this fishmeal. In order to eliminate this paradox, apart from using plant raw materials as alternatives for fish meal, Nile Tilapia production, which accounts for the majority of aquaculture production in Egypt, should be taken as a model, and herbivorous or omnivorous species should be cultivated in these countries as much as possible. Moreover, while ensuring these developments, it will also be necessary to combat the potential threat of fish diseases consciously. When it is mentioned from general to specific, although fisheries play a significant role in the economy, Morocco's aquaculture industry needs to be developed compared to its marine capture capabilities. To capitalize on this, Morocco could consider expanding its aquaculture species to include high-value, export-oriented offerings such as scallops and premium crustaceans, which could open new markets and increase economic returns. Furthermore, investing in aquaculture technology research and development, particularly in areas such as breeding and disease management, could enhance productivity and sustainability. Algeria faces the challenge of outdated fishing practices and equipment, which limits its fishing efficiency and sustainability. Investing in modern fishing fleets and equipment could significantly boost Algeria's fishing productivity. Additionally, establishing more stringent regulations and surveillance to combat illegal fishing practices will ensure the sustainability of fish stocks. Enhancing cooperative agreements with Mediterranean countries could also aid in sustainable fisheries management. Tunisia struggles with overfishing and the sustainability of its fisheries, which threatens marine biodiversity and the long-term viability of its fishing industry. Tunisia could expand its marine protected areas to cover more critical habitats, particularly spawning and nursery grounds for key species. Implementing more comprehensive bycatch regulations and improving fisheries data collection through technology such as satellite monitoring could support sustainable practices. Political instability and lack of infrastructure investment severely hinder the development of Libya's fisheries sector. Libya could focus on stabilizing the fisheries sector by promoting international partnerships and joint ventures that bring in both capital and expertise. Establishing a stable regulatory framework for fisheries and aquaculture could attract private investment, which is necessary for revitalizing the industry. Investing in aquaculture activities and collaborating with Mediterranean countries can be advantageous. Moreover, it is essential for students getting postgraduate education in fields such as hydrobiology, aquaculture, and fisheries management in various countries to make efforts to enhance their country's fisheries through knowledge and technology transfers upon their return. In Egypt, the artisanal nature of fisheries, characterized by using gillnets, trammel nets, and longlines by small boats, juxtaposes with larger vessels employing bottom trawls and purse seines. Challenges in fisheries management stem from limited knowledge of fishery resources and unreliable data, exacerbated by a weak institutional framework (FAO, 2024d). Enhancing management could be improved by training fishery officers and improving data collection accuracy. Despite leading in aquaculture production, Egypt faces issues with declining marine capture fisheries and the environmental sustainability of aquaculture practices. Egypt could more intensively focus on integrating more sustainable aquaculture practices, such as recirculating aquaculture systems (RAS) and biofloc technology, which reduce environmental impacts. Additionally, promoting the restoration of natural fish habitats in the Nile and along the coast could help replenish natural resources.

CONCLUSION

Undoubtedly, the need for optimal and waste-free utilization of all plant and animal food resources is pressing, as it is the only way to meet the nutrition demands of the rapidly growing human population. The ecological equilibrium is deteriorating at an alarming rate, with numerous species already extinct or on the brink of extinction due to human-caused environmental degradation, the destruction of ecosystems, including sea meadows and forests, and excessive, negligent, and unlawful hunting and fishing. In this context, increasing conservation efforts, reducing strain on natural resources, and promoting more sustainable and advanced farming practices are crucial, and they also hold the promise of a better future for our planet and all its inhabitants. Therefore, in the modern world, where human-effort production based on advanced aquaculture, land-based agriculture, animal husbandry, aquaponics, and hydroponic techniques is expanding day by day, African countries bordering the Mediterranean and oceans must take responsibility and make efforts. In addition to preventing excessive and illegal fishing, which exploits natural stocks, these countries need to increase culture-based production. These countries' climatic and water conditions are suitable for cultivating high amounts of Nile tilapia, carp, seabream, and seabass, as well as shrimp, prawn, and clam farming, which provides high returns. National governments must provide financial and technical support for these endeavors. Additionally, international planning of scientific and sectoral collaborations is vital for maximizing the efficiency of water resources (including aquacultural production), a compulsory requirement for the future.

COMPLIANCE WITH ETHICAL STANDARDS

a) Author Contributions

The paper was conceived by **ŞP**, who also undertook a literature review, performed data analysis, and authored the article. **AJ** contributed suggestions and conducted a literature assessment during the composition's development. **FAHL** undertook a review of the literature.

b) Conflict of Interests

The authors declare that there is no conflict of interest.

c) Statement on the Welfare of Animals

As this study did not involve the use of any animals, there is no need to obtain approval from the ethical committee.

d) Statement of Human Rights

For this type of study, formal consent is not required.

e) Availability of Data and Materials

All data used in the paper were obtained from various statistical sources and presented in the manuscript as prepared by comparative graphing.

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