TÜRKİYE CUMHURİYETİ'NİN YÜZÜNCÜ YILI

RAIN

"Raising Awareness in Fisheries"

Editor
İlker AYDIN
Ozan SOYKAN

BIDGE

BIDGE Publications

RAIN "Raising Awareness in Fisheries"

Editor: İlker AYDIN & Ozan SOYKAN

ISBN: 978-625-372-328-6

Page Layout: Gözde YÜCEL

1st Edition:

Publication Date: 09.12.2024

BIDGE Publications,

Certificate No: 71374

www.bidgeyayinlari.com.tr - bidgeyayinlari@gmail.com

Krc Bilişim Ticaret ve Organizasyon Ltd. Şti.

Güzeltepe Mahallesi Abidin Daver Sokak Sefer Apartmanı No: 7/9 Çankaya / Ankara

Content

Prospects for the Lithuanian Fishery Sector in Implementing European Green Deal Goals.......... 4
Anželika DAUTARTĖ.......... 4

Present Status of Aquaculture in Central Asian Countries.......... 21
Özgür ALTAN.......... 21

Unforeseen Problem in Fishing: Jellyfish.......... 50
Nurçin KİLLİ.......... 50

Microplastics and Their Effects in Aquaculture.......... 74
Serhat ENGİN.......... 74

Adaptive Responses of Fish to Fishing Pressure.......... 91
Hasan CERİM.......... 91
Özgen YILMAZ.......... 91

Mentoring awareness for 21ST century skills in fisheries engineering education.......... 112
Huriye GÖNCÜÖĞLU-BODUR.......... 112
Deniz GÜNAY.......... 112

CHAPTER I

Prospects for the Lithuanian Fishery Sector in Implementing European Green Deal Goals

Anželika DAUTARTĖ

Introduction

The implementation of sustainable fishing practices is becoming increasingly crucial in addressing global environmental challenges and aligning with regional initiatives such as the European Green Deal (EGD). The latter aims to make Europe the first climate-neutral continent by 2050 through the adoption of sustainable practices across multiple sectors, including fisheries (Sikora, 2020). Lithuania, renowned for its diverse marine life and substantial fishing industry, confronts distinctive challenges and prospects in aligning its practices with the objectives of the European Green Deal. The Lithuanian fishery sector demonstrates considerable potential for sustainable growth and modernisation, with substantial EU financial support providing a significant boost to this endeavour.

Approximately €6.1 billion has been allocated across the EU's fishery sector through the European Maritime, Fisheries and Aquaculture Fund (EMFAF) for the 2021-2027 period, with a substantial share of this being allocated to Lithuania to enhance its environmental, economic, and social sustainability efforts (European Commission, 2021). The allocation of financial resources serves to reinforce the capacity of the Lithuanian fishery sector to address the priorities of sustainable development, thereby supporting objectives that are aligned with the enhancement of biodiversity, economic growth, decarbonisation and resource efficiency.

The European Union and Lithuania are engaged in the implementation of joint initiatives that support the sustainable development of fisheries, with a particular focus on environmental sustainability, economic innovation, and social welfare. Lithuania is aligning its operations with the European Green Deal's objectives through this support, with an emphasis on biodiversity, sustainable growth, and decarbonisation initiatives. These are backed by €61.2 million from the EMFAF for the 2021-2027 period (European Commission, 2022; Eurofish, 2023). These efforts are of particular significance because the fisheries and aquaculture sectors in Lithuania support in excess of 4,500 full-time equivalent jobs. This highlights the necessity of aligning with the Green Deal's climate neutrality targets and ensuring resilience within the sector.

Sustainable Development and Environmental Management

EU funding has enabled Lithuania to prioritize sustainable fishing practices, which are essential for preserving marine ecosystems and maintaining fish stock health. Under the guidance of the Common Fisheries Policy (CFP) and in alignment with the European Green Deal, Lithuania has made significant progress in marine biodiversity conservation. Lithuania's Marine Protected Areas (MPAs) now cover approximately 29% of its territorial waters, above the EU average of 26% (Nausėda, 2023). These initiatives align with Sustainable Development Goal (SDG) 14 on Life Below Water, ensuring the long-term viability of Lithuania's marine resources. According to recent reports, Lithuania has reduced overfishing rates by 15% over the past decade (European Commission, 2021). The CFP's catch limits, based on Maximum Sustainable Yield (MSY), have been integral to these efforts, with Lithuania adhering strictly to EU quotas. This approach has helped Lithuania keep its fish stocks within safe biological limits, supporting the country's goal to achieve SDG 14 on Life Below Water.

Climate Adaptation and Decarbonization Efforts

In line with SDG 13 on Climate Action, Lithuania's fishery sector has integrated climate action strategies supported by EU funding. An essential part of this is the decarbonization of its fishing fleet, with over 30% of vessels now equipped with energy-efficient engines or hybrid systems (Lithuanian Ministry of Environment, 2022). This shift not only reduces carbon emissions but also aligns with the EU's goal of achieving climate neutrality by 2050. Notable projects, such as the implementation of Recirculating Aquaculture Systems (RAS), funded by the EMFAF, have reduced energy consumption and minimized water pollution in fish production (Lithuanian Ministry of Environment, 2022). Furthermore, adaptive management practices, including flexible fishing quotas and habitat restoration, help enhance resilience to climate change impacts, safeguarding both environmental and economic aspects of the industry. The RAS initiative alone has led to a reduction of energy consumption by 20% within Lithuania's aquaculture sector, which, coupled with the reduction in water usage by 25%, has made the sector more resource-efficient (European Commission, 2020). Flexible fishing quotas and habitat restoration projects further enhance climate resilience, enabling the sector to adapt to changing climate conditions while securing biodiversity.

Lithuania's Integration of Sustainable Development Goals in Fishery Policy

Lithuania's sustainable fishery policy aligns with the United Nations SDG by focusing on environmental sustainability, economic resilience, and social well-being. Through this alignment with the SDGs, Lithuania promotes a sustainable, resilient, and inclusive fishery industry, advancing environmental, economic, and social equity goals. Key aspects are presented in Table 1.

Economic Growth and Employment Opportunities

One of the primary economic benefits of EU funding for Lithuania's fishery sector is job creation and economic resilience. Approximately 4,000 people are directly employed in Lithuania's fishery sector, with an estimated 30% increase in employment in aquaculture due to investments in sustainable practices and modernized technologies (European Commission, 2021). This support is particularly vital for small-scale fishers and coastal communities, as EU funds enable improvements in infrastructure, including port facilities and transportation networks. By bolstering local economies and creating sustainable livelihoods, EU funding contributes to the stability of Lithuania's fishing sector and coastal regions. Investments in digital technology, including digital reporting and monitoring systems, have helped reduce illegal, unreported, and unregulated (IUU) fishing activities by 12%

(Lithuanian Ministry of Environment, 2022). This technological shift not only supports legal and sustainable fishing but also boosts economic output, with sector revenues growing by an estimated 8% annually.

Table 1. Lithuania's Sustainable Fishery Policy: Advancing Environmental, Economic, and Social Goals through SDG Alignment

SDG	Actions
SDG 1. *No Poverty* and SDG 10. *Reduced Inequalities*	Policies promote socio-economic resilience in coastal areas by supporting alternative income streams in blue biotechnology, renewable energy, and eco-tourism. A "just transition" approach assists small-scale fishers with targeted subsidies and reskilling.
SDG 8. *Decent Work and Economic Growth*	EMFAF supports small-scale fishing, providing stability for coastal communities and creating jobs. Investments in technology boost employment and skill development through fleet modernization and digital monitoring.
SDG 11. *Sustainable Cities and Communities*	Investments in regional infrastructure, including ports and processing facilities, enhance sustainable economic activities in remote and coastal areas.
SDG 12. *Responsible Consumption and Production*	EMFAF funding supports sustainable aquaculture with resource-efficient practices, renewable energy, and waste reduction. Eco-certification initiatives promote market incentives for sustainably sourced seafood.
SDG 13. *Climate Action*	The policy includes goals to decarbonize the fishing sector with energy-efficient engines and renewable energy adoption. Climate resilience strategies include adaptive management, habitat restoration, and low-carbon aquaculture practices.
SDG 14. *Life Below Water*	Lithuania prioritizes marine biodiversity by expanding Marine Protected Areas and managing fish stocks sustainably under the EGDand Common Fisheries Policy. Efforts to reduce overfishing are supported by EU quotas and adherence to Maximum Sustainable Yield.

Socio-Economic Resilience and Community Support

The EMFAF has supported socio-economic resilience in Lithuania’s coastal and rural communities, areas traditionally dependent on the fishing sector. Through Local Action Groups (LAGs), Lithuania has diversified economic opportunities within coastal regions, reducing reliance solely on fishing. Projects in blue biotechnology, renewable energy, and eco-tourism funded by the EU have provided alternative income sources, contributing to an estimated 5% income increase in rural communities (European Commission, 2020). This diversification aligns with SDG 1 (No Poverty) and SDG 10 (Reduced Inequalities) and promotes equitable growth within Lithuania’s fishery sector. The “just transition” approach in the sector has allowed small-scale fishers access to subsidies and reskilling opportunities, with 22% of small-scale fishers participating in skill development programs aimed at enhancing income diversification (Nausėda, 2023).

Strategic Role of EMFAF Support in Implementing the EGD in Lithuania’s Fishery Sector

In Lithuania, the EMFAF program for 2021–2027 provides funding exceeding 87 million euros, with 61.183 million euros contributed by the European Union. This funding aims to promote sustainable fisheries, biodiversity protection, and the implementation of EGD objectives (Ministry of Agriculture, 2022).

The largest portion of funding, 28.85 million euros, is allocated to aquaculture, to foster economically viable and sustainable fishery practices. Fisheries control receives 14.86 million euros, while 13.12 million euros is directed toward the development of fisheries regions. These measures help to strengthen the economic and social development of local communities, contributing to the growth of Lithuania's fishery sector (Ministry of Agriculture, 2022).

The program implementation period spans 2021–2027. The Ministry of Agriculture aims to launch the support program and started accepting support applications by the end of 2022 to ensure the efficient use of funds (Ministry of Agriculture, 2022). Measures and Their Funding are as follows:

1. Production Investments in Sustainable Aquaculture and Related Value-Adding Activities to promote sustainable aquaculture practices, enhance the competitiveness of aquaculture products, and ensure environmental sustainability; funding: €8.5 million.

2. Collaboration between Academic Representatives and Aquaculture Enterprises to promote collaboration between science and business to introduce advanced technologies and methods in the aquaculture sector; funding: €2 million.

3. Promoting Ecosystem Services and Sustainable Production Methods in Aquaculture to support ecological aquaculture production and increase its share in the market; funding: €12 million.

These measures will be implemented throughout Lithuania, with a focus on regions with the highest potential for sustainable aquaculture development. Priority will be given to areas where the aquaculture sector can make the most significant contributions to sustainability and economic growth.

Lithuania has allocated €13.12 million from the EMFAF to promote the development of fisheries regions, aiming to ensure sustainable local economic growth and community development. This funding will be utilized for various activities that contribute to sustainable development and the welfare of local communities. Planned use of funds is presented in Table 2.

It is expected that local economies will be strengthened through the creation of new jobs and improved economic opportunities for communities. Sustainability will be enhanced through improved fisheries infrastructure and practices that contribute to the protection of ecological systems, and community engagement will increase the involvement of local people in fisheries management and sustainability initiatives.

Finally, Lithuania has allocated €14.86 million from EMFAF to enhance fisheries control and enforcement measures. This investment aims to ensure sustainable fishing practices, protect marine resources, align with the European Green Deal's objectives, strengthen fisheries control and enforcement, ensure compliance with regulations and promote sustainable fisheries management. The planned measures, their implementation and scope are presented in Table 3.

Table 2. Planned use of funds for promotion of fisheries region development

Use of funds	Objective	Activities
Economic Infrastructure Development	To enhance local community opportunities and create new jobs	Investments in fisheries infrastructure: upgrading ports, processing facilities, and transportation systems. Support for the development of small and medium-sized enterprises (SMEs) in the fisheries sector.
Promoting Collaboration between Science and Business	To encourage innovation and improve the competitiveness of the fisheries sector.	Funding projects that promote collaboration between researchers and fisheries enterprises. Implementation of advanced technologies and methods in the fisheries sector to increase efficiency and sustainability.
Public Awareness and Education Programs	To increase community engagement and transparency in fisheries practices.	Launching informational campaigns and training for local communities on sustainable fishing practices. Implementing educational programs to raise awareness about biodiversity and sustainability among local residents.
Initiatives for the Protection of Marine Protected Areas and Biodiversity	To ensure sustainable management of marine resources and protect ecological systems.	Investments in the establishment and management of marine protected areas to safeguard ecosystems. Projects aimed at the conservation and restoration of biodiversity.
Development of Sustainable Growth Strategies	To promote coordinated and integrated regional development	Creation of regional development strategies focused on sustainable growth and social welfare. Support for local authorities and communities to create long-term development visions

The measures will be implemented in phases, starting with upgrading systems and training, followed by public awareness initiatives. It is expected that enhanced compliance will improve adherence to fisheries regulations, thereby reducing instances of illegal, unreported and unregulated (IUU) fishing; promote sustainable fisheries management through better protection of marine ecosystems and fish stocks, contributing to long-term sustainability; and, finally, increase transparency, as more transparent and efficient reporting processes will foster trust among stakeholders and the public.

Table 3. Planned measures to enhance fisheries control and enforcement

Measures	Implementation	Scope
Modernization of Monitoring Systems	Upgrading existing monitoring, control, and surveillance (MCS) systems to enhance data accuracy and real-time tracking of fishing activities	Nationwide application, covering all Lithuanian fishing vessels operating in national and international waters
Digitalization of Reporting Processes	Developing and integrating electronic reporting systems to streamline data collection and improve transparency in fisheries operations	Applicable to all stakeholders in the fisheries sector, including fishermen, processors, and regulatory bodies
Capacity Building and Training	Conducting training programs for fisheries inspectors and stakeholders to ensure effective enforcement of regulations and adoption of best practices.	Targeted at personnel involved in fisheries management and enforcement across Lithuania.
Public Awareness Campaigns	Launching initiatives to educate the public and industry stakeholders about the importance of sustainable fishing practices and compliance with regulations	Nationwide campaigns utilizing various media platforms to reach diverse audiences

Future Outlook

EU support signals a promising future for Lithuania's fishery sector, with anticipated growth through further investments in technological innovation, eco-certification programs, and sustainable production practices. Eco-certification initiatives have seen a 40% increase in certified products in Lithuanian markets, responding to consumer demand for sustainably sourced seafood (Lithuanian Ministry of Environment, 2022). These prospects underscore the importance of ongoing EU funding in promoting a resilient, sustainable, and inclusive fishery sector in Lithuania.

Policy Framework and Stakeholder Engagement

The Lithuanian Ministry of Agriculture oversees fisheries policies, coordinating closely with stakeholders to align with EGD and CFP standards. EMFAF funding supports the establishment of 10-12 Local Action Groups, focused on blue economy projects such as blue biotechnology, renewable energy, and eco-tourism, which provide income diversification for fisheries-reliant communities. In 2022, Lithuania's fisheries and aquaculture sectors employed 4,458 FTEs, with the processing industry accounting for 5,685 employees, highlighting its role in regional economies (Eurofish, 2023; European Commission, 2022).

Sustainable Fishing Practices and Decarbonization Efforts

Lithuania's fleet includes over 130 vessels operating in the Baltic Sea, where quotas are tightly regulated due to declining stocks, particularly for cod. EMFAF resources support Lithuania's sustainable fishing goals, with measures to reduce fleet capacity by 10% by 2030 to help recover fish populations. Decarbonization is key, with Lithuania investing in energy-efficient engines, low-emission equipment, and renewable energy systems. The country's annual fishing quotas for species like sprat and herring help manage stocks, with 18,865 tonnes landed in 2022 (Eurofish, 2023; Oceana, 2023).

Biodiversity and Ecosystem Restoration

Biodiversity plays a central role in Lithuania's fisheries sector. The Baltic Sea and inland waters are crucial habitats for species like European eel and Atlantic salmon. EMFAF-funded projects promote biodiversity by expanding Marine Protected Areas (MPAs), enhancing habitat restoration, and safeguarding essential spawning and feeding grounds. Lithuania's commitment includes the Eel Recovery Plan, with an average annual stocking of 650,000 juvenile eels to support population recovery. Additionally, pond-based aquaculture, with over 86% sold domestically, contributes to ecosystem services like flood control and biodiversity preservation (Convention on Biological Diversity, 2014; European Commission, 2022).

Aquaculture Growth and Climate Adaptation

Lithuania's aquaculture strategy, part of its EMFAF programme, aims for a 20% production increase by 2030. The sector emphasizes climate adaptation, with RAS being prioritized to improve energy efficiency. In 2022, Lithuania produced 4,393 tonnes of aquaculture products valued at €18.3 million, with species like African catfish, rainbow trout, and eel being economically significant. The goal is for 25% of aquaculture energy to come from renewable sources by 2030, reducing carbon emissions and supporting EGD objectives (Eurofish, 2023; aquaculture.ec.europa.eu, 2023).

Technological Innovation and Low-Carbon Infrastructure

Lithuania's EMFAF funding emphasizes fleet modernization and low-carbon infrastructure to meet EGD sustainability goals. Investments target fuel-efficient engines, improved selectivity, and onboard safety measures. The processing sector, which handled 147,879 tonnes of fish in 2022 with a value of €753.9 million, relies heavily on imports for raw materials, primarily from Sweden and Norway. This well-established sector adds value through various forms like smoked and filleted products, making Lithuania a regional hub for processed fish exports (Eurofish, 2023; European Commission, 2022).

Digital Transition and Market Expansion

Digitalization supports Lithuania's fisheries management, enhancing transparency and traceability across the supply chain. EMFAF funds digital solutions for data collection and monitoring, ensuring compliance with EU standards. In 2022, Lithuania exported 132,700 tonnes of fish products valued at €739 million, with over 80% destined for EU markets like Germany, Latvia, and France. The digital transition facilitates eco-certification and improves Lithuania's market access, aligning with consumer demand for traceable and sustainable seafood (Cámara & Sánchez, 2019; Eurofish, 2023).

Climate Resilience and Green Transition in Fisheries and Aquaculture

Lithuania's fisheries and aquaculture sectors prioritize renewable energy and emissions reduction, with targets for 25% renewable energy use in aquaculture by 2030. Adaptation strategies, such as flexible quotas, habitat conservation, and biosecurity enhancements, prepare the sector for climate impacts. RAS systems, selective breeding for disease resistance, and low-impact feed options contribute to sector resilience, enabling Lithuania to support both food security and environmental sustainability (Oceana, 2023; Eurofish, 2023).

Conclusion

Through alignment with the EGD, Lithuania’s fisheries and aquaculture sectors are transitioning towards sustainable, resilient, and economically competitive operations. EMFAF’s €61.2 million investment facilitates biodiversity conservation, low-carbon infrastructure, digitalization, and market expansion, ensuring Lithuania’s fisheries contribute to EU climate goals and support a sustainable blue economy (Alexandropoulou et al., 2020; European Commission, 2022).

Lithuania's fishery sector is undergoing a transformative phase, aligning with the European Green Deal's objectives through strategic investments and policy reforms. The support from the EMFAF is instrumental in facilitating this transition, focusing on sustainability, biodiversity conservation, technological innovation, and economic resilience. By addressing current challenges and leveraging available opportunities, Lithuania aims to establish a fishery sector that is environmentally sustainable, economically viable, and socially equitable.

References

Alexandropoulou, V., Koundouri, P., Papadaki, L., & Kontaxaki, K. (2020). New challenges and opportunities for sustainable ports: The deep demonstration in maritime hubs project. In Sustainable Development Goals and Human Rights (pp. 173-197). https://doi.org/10.1007/978-3-030-56847-4_11

Cámara, Á., & Sánchez, R. (2019). Economic, social, and environmental impact of a sustainable fisheries model in Spain. Sustainability, 11(22), 6311. https://doi.org/10.3390/su11226311

Convention on Biological Diversity. (2014). Lithuania's Fifth National Report to the Convention on Biological Diversity. https://www.cbd.int/doc/world/lt/lt-nr-05-en.pdf

Eurofish. (2023). Lithuanian Aquaculture – A strategic plan with ambitious targets. Retrieved from https://eurofish.dk

European Commission. (2019). The European Green Deal. Retrieved from https://ec.europa.eu/info/publications/european-green-deal-communication_en

European Commission. (2020). The European Green Deal and Sustainable Fisheries. European Union.

European Commission. (2021). Common Fisheries Policy and Maximum Sustainable Yield. European Union.

European Commission. (2021). European Maritime, Fisheries and Aquaculture Fund Overview. European Union.

European Court of Auditors. (2022). Fisheries control in EU Member States. Retrieved from https://www.eca.europa.eu/Lists/ECADocuments/SR22_20/SR_Illegal_fishing_EN.pdf

European Parliament. (2022). Common Fisheries Policy (CFP). Retrieved from https://www.europarl.europa.eu/factsheets/en/sheet/114/common-fisheries-policy

Lithuanian Ministry of Environment. (2022). Environmental Protection and Sustainable Aquaculture Development in Lithuania. Government of Lithuania.

lrytas.lt. (2024). Funding for production investments in sustainable aquaculture. Retrieved from https://www.lrytas.lt/verslas/rinkos-pulsas/2024/06/03/news/akvakulturos-sektoriaus-atstovams-parama-gamybinems-investicijoms-i-tvaria-akvakulturos-gamyba-32162881

Ministry of Agriculture. (2022). Lithuanian Fisheries Sector 2021–2027 Program Approved: More than 87 Million Euros for Aquaculture and Fisheries. Retrieved from https://zum.lrv.lt/lt/naujienos/patvirtinta-lietuvos-zuvininkystes-sektoriaus-2021-2027-m-programa-daugiau-kaip-87-mln-eur-akvakulturai-ir-zuvininkystei

Nausėda, G. (2023). Marine Biodiversity and Climate Resilience in Lithuania's Fishery Sector. Baltic Fisheries Journal, 8(2), 45-63.

Oceana. (2023). A pathway to decarbonise the EU fisheries sector by 2050. Retrieved from https://europe.oceana.org

paramazuvininkystei.lt. (2024). Collaboration activities between scientific representatives and aquaculture companies in 2024. Retrieved from https://paramazuvininkystei.lt/kvietimai/mokslo-atstovu-ir-akvakulturos-imoniu-bendradarbiavimo-veiklos-2024-m/

Sikora, A. (2020). European Green Deal – Legal and financial challenges of climate change. ERA Forum, 21(4), 681-697. https://doi.org/10.1007/s12027-020-00637-3

zum.lrv.lt. (2024). Focus on sustainable aquaculture. Retrieved from https://zum.lrv.lt/lt/naujienos/demesys-darniai-akvakulturai

CHAPTER II

Present Status of Aquaculture in Central Asian Countries

Özgür ALTAN

Introduction

Inland fisheries and aquaculture production in Central Asian countries (Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) have shown a dramatical decline since the independence of these countries from the former union of the Soviet Socialist Republics in the early 1990s. Although there were a lot of negative impacts such as insufficient management, capital investment, technical know-how and institutional capacity of the countries, many sectors experienced different difficulties. On the other hand, aquaculture, farming aquatic organisms such as fish, shellfish, and aquatic plants, is gaining momentum as a critical industry in Central Asian countries. This sector has grown in importance due to increasing demands for food security, employment opportunities, and economic diversification, particularly in regions facing challenges in traditional agriculture due to climate, geography, or resource constraints (FAO, 2008; FAO, 2011a).

The geographical diversity and abundance of water resources in Central Asia make the region well-suited for aquaculture development. Countries like Kazakhstan, Uzbekistan, and Azerbaijan, with extensive river systems, lakes, and reservoirs, have led the charge in cultivating various fish species for domestic consumption and export. The Caspian Sea, shared by Azerbaijan, has also emerged as a crucial resource for marine aquaculture, supporting the farming of high-value species like sturgeon for caviar. This chapter aims to provide a comprehensive view of the present state of aquaculture across Central Asian countries, focusing on production amounts, species diversity, key statistics, and the challenges and opportunities that face the industry. By examining the current production landscape and ongoing government initiatives, this analysis will highlight the sector's potential for growth and sustainability in the coming years.

1. Overview of Aquaculture in Central Asia

Aquaculture in Central Asia is shaped by the unique geographical and socio-economic conditions of the region. The nations included in this analysis (Kazakhstan, Uzbekistan, Kyrgyzstan, Turkmenistan, Tajikistan, and Azerbaijan) are all landlocked except for Azerbaijan, which borders the Caspian Sea. Despite this limitation, the region boasts significant water resources in rivers, lakes, reservoirs, and artificial ponds, forming the backbone of inland aquaculture.

1.1. Geographical and Water Resources

The aquaculture industry in Central Asia benefits from several large river systems, such as the Syr Darya and Amu Darya, and vast lake systems like Lake Balkhash in Kazakhstan and Lake Issyk-Kul in Kyrgyzstan. The availability of these water bodies provides fertile ground for freshwater aquaculture, particularly in the cultivation of species like carp and trout. However, the region also faces challenges such as water scarcity in arid areas and contamination issues, particularly in downstream river systems (FAO,2011b).

Azerbaijan, on the other hand, has access to both freshwater resources and the Caspian Sea, the world's largest enclosed inland body of water. The Caspian Sea is an essential resource for Azerbaijan's aquaculture industry, particularly for the cultivation of high-value marine species like sturgeon, which supports the country's significant caviar industry (FAO, 2013a).

1.2. Historical Background and Evolution of Aquaculture

Aquaculture in Central Asia has a relatively short history, with formal development occurring only in the mid-to-late 20th century, largely influenced by Soviet-era agricultural and industrial policies. During the Soviet period, fish farming was established to complement inland fisheries and support food production in rural areas. While the collapse of the Soviet Union in 1991 resulted in a significant disruption to aquaculture in the region, many countries have since taken steps to revive and modernize the sector. For example, Kazakhstan has invested heavily in the reconstruction of fish hatcheries and the development of inland aquaculture farms, primarily focusing on carp and trout species. Uzbekistan, similarly, has revived its aquaculture industry by adopting policies aimed at increasing private sector participation and improving productivity through new technologies and training programs (Karimov et al., 2009).

Azerbaijan has a longer fishing history, with its access to the Caspian Sea historically positioning the country as a center for sturgeon fishing and caviar production. However, unsustainable fishing practices and the depletion of sturgeon stocks have necessitated a shift toward aquaculture as a more sustainable alternative. In recent decades, Azerbaijan has invested in sturgeon farming and other marine aquaculture projects to revive its once-thriving caviar industry.

1.3. Economic Significance of Aquaculture

Aquaculture plays an increasingly important role in the economies of Central Asia. As traditional agriculture faces constraints due to climate variability, land degradation, and water scarcity, aquaculture offers an alternative means of food production that can contribute to national food security and reduce dependency on imports. For example, the aquaculture industry in Kazakhstan has expanded significantly in recent years, with government incentives and subsidies encouraging growth. The production of high-value species such as sturgeon and trout has made Kazakhstan one of the leading aquaculture producers in the region. With its warm climate and abundant water resources, Uzbekistan has also seen steady aquaculture growth, driven by private investments and government support. Azerbaijan’s economy has long relied on its oil and gas exports, but the government is actively diversifying its economic base, with aquaculture playing a critical role in this strategy. The revival of the sturgeon farming industry, combined with marine aquaculture in the Caspian Sea, positions Azerbaijan as a key player in the regional and global seafood market, particularly in the luxury segment of caviar production (FAO and World Bank, 2018).

2. Aquaculture Production: An Overview

The aquaculture production in Central Asia varies significantly across countries, depending on their geographical resources, species farmed, and level of government support. This section provides a detailed overview of the production levels in each country.

2.1. Kazakhstan

Kazakhstan is one of the largest countries in Central Asia, and its aquaculture sector has seen considerable growth in recent years. In 2022, Kazakhstan’s aquaculture production reached approximately 8,500 metric tons, with carp and trout being the most farmed species. The government has set ambitious targets to increase fish production to 20,000 metric tons by 2025, supported by subsidies, investment in infrastructure, and modernization of fish farms. Kazakhstan also focuses on high-value species like sturgeon, which are farmed for caviar production. The country has implemented several initiatives to breed sturgeon in hatcheries and release them into reservoirs and lakes to replenish natural stocks and support the caviar industry (IFAD, 2021; FAO, 2024).

2.2. Uzbekistan

Uzbekistan is one of the region’s most agriculturally productive countries, and aquaculture has become an important part of its agricultural sector. In 2022, Uzbekistan produced around 30,000 metric tons of fish, with carp, catfish, and tilapia being the most popular species. The government has undertaken significant efforts to promote aquaculture, including providing financial support to small-scale fish farmers, facilitating access to feed and equipment, and developing research institutions focused on aquaculture technologies. Uzbekistan’s warm climate and extensive irrigation networks provide favorable conditions for aquaculture, and the government aims to increase fish production to 60,000 metric tons by 2025 (UMA, 2022).

2.3. Kyrgyzstan

Kyrgyzstan's aquaculture industry remains relatively small, producing approximately 1,800 metric tons of fish annually, with trout and carp being the dominant species. The country's cold climate and mountainous terrain limit the expansion of aquaculture, though there is potential for growth in cold-water fish farming, particularly trout. Government initiatives have focused on improving hatchery technology and expanding aquaculture in high-altitude lakes like Lake Issyk-Kul, which has favorable conditions for trout farming (KFD, 2023; FAO, 2024).

2.4. Turkmenistan

Turkmenistan's aquaculture sector is still nascent, producing less than 1,000 metric tons of fish per year. Carp is the most commonly farmed species, but the country has the potential to expand into other species such as tilapia and sturgeon, given the availability of water resources. Government efforts have been slow to support the aquaculture industry, but recent plans aim to increase production by improving infrastructure and providing subsidies to private sector initiatives (TMWR, 2023).

2.5. Tajikistan

Tajikistan, like Kyrgyzstan, has a small but growing aquaculture industry. The country produced around 3,500 metric tons of fish in 2022, with carp and tilapia being the dominant species. Tajikistan's reliance on river systems like the Amu Darya and Syr Darya for aquaculture makes it vulnerable to water shortages, but government programs are attempting to increase production by improving water management practices and offering incentives to fish farmers (TAU, 2023).

2.6. Azerbaijan

Azerbaijan is a key player in the regional aquaculture industry, particularly due to its access to the Caspian Sea. In 2022, Azerbaijan produced approximately 6,000 metric tons of fish, with sturgeon, salmon, and carp being the most farmed species. Sturgeon farming, in particular, is a critical part of Azerbaijan's economy, as the country is renowned for its caviar exports (EC, 2021; AZSSC, 2022).

Figure 1. A female sturgeon for caviar production (Photo courtesy by: Ozgur Altan)

In recent years, Azerbaijan has invested heavily in marine aquaculture, to increase production to 10,000 metric tons by 2025. The government has implemented programs to support the growth of marine species farming, particularly in the coastal regions of the Caspian Sea. It has partnered with international organizations to develop sustainable aquaculture practices.

3. Species Farmed in Central Asia

The choice of species in aquaculture across Central Asia is largely determined by the countries' climatic conditions, water availability, and market demands. Freshwater species dominate the aquaculture industry, with some countries focusing on high-value marine species, particularly Azerbaijan, which has access to the Caspian Sea (Asian Development Bank, 2021).

3.1. Carp

Carp is the most commonly farmed species across the region due to its adaptability to various water conditions and its fast growth rates. In countries like Kazakhstan, Uzbekistan, and Tajikistan, carp represents a significant portion of the aquaculture output. Carp farming is prevalent in both pond systems and larger reservoir-based fish farms. The species is well-suited to the climatic conditions of Central Asia, making it an ideal choice for aquaculture, especially for small and medium-sized enterprises. In Kazakhstan, carp accounts for over 60% of the total aquaculture production, with hatcheries dedicated to the breeding and distribution of juvenile carp to farmers across the country. Similarly, Uzbekistan has a large-scale carp farming industry, with government programs promoting its expansion due to the high demand for this species in domestic markets (FAO, 2011).

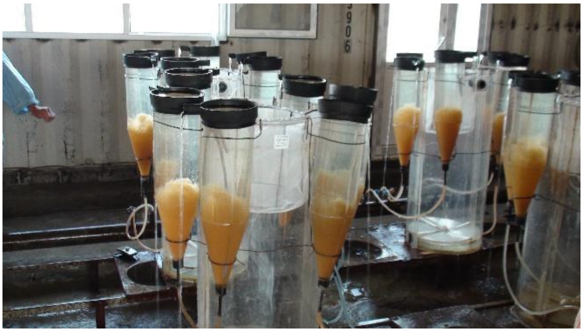

Figure 2. Carp hatchery in Khujand – Tajikistan (Photo courtesy by: Ozgur Altan)

3.2. Trout

Trout, particularly rainbow trout, is another important species in the region, especially in countries with cooler climates and mountainous regions like Kyrgyzstan and Kazakhstan. Trout farming in these countries benefits from the availability of cold-water rivers and high-altitude lakes, which provide optimal conditions for trout cultivation. Kyrgyzstan has a significant trout farming industry centered around Lake Issyk-Kul, which has become a hub for cold-water aquaculture. Trout farming in Kyrgyzstan accounts for a substantial portion of the country's fish production, and the government has prioritized its development to meet growing domestic and international demand.

3.3. Tilapia

Tilapia, a warm-water species, has recently emerged as a popular choice in Uzbekistan and Tajikistan, where the climatic conditions are conducive to farming. Tilapia is valued for its high productivity, ease of farming, and relatively short grow-out period. While tilapia farming is still in its early stages compared to carp and trout, its growth potential is significant, especially in countries with warmer climates and access to irrigation systems.

3.4. Catfish

Catfish farming is gaining popularity, particularly in Uzbekistan. The country has invested in technologies to support the efficient farming of catfish, given its ability to thrive in various environments, including those with lower water quality. Catfish is primarily raised in ponds and is sold both in domestic markets and to neighboring countries.

3.5. Sturgeon

Sturgeon farming is one of the most lucrative sectors in aquaculture, particularly in Kazakhstan and Azerbaijan. The high value of sturgeon is due to its eggs, which are used to produce caviar, a luxury product with high demand in international markets. Both countries have developed sophisticated hatcheries and fish farms dedicated to breeding sturgeon species such as the beluga and sterlet.

Azerbaijan is renowned for its caviar production, which was historically dependent on wild sturgeon from the Caspian Sea. However, due to the depletion of wild stocks and strict international regulations on sturgeon fishing, the country has shifted toward aquaculture-based sturgeon farming. Azerbaijan's government has supported the development of sturgeon farms, which not only help meet the global demand for caviar but also play a role in the conservation of sturgeon populations (FAO, 2013b; EC, 2021; IFAD, 2021).

Figure 3. An indoor facility for sturgeon in Azerbaijan

(Photo courtesy by: Ozgur Altan)

3.6. Marine Species in Azerbaijan

In addition to sturgeon, Azerbaijan has invested in the farming of marine species such as salmon and other high-value fish along the Caspian Sea coast. The Caspian Sea's unique ecosystem offers opportunities for marine aquaculture, and efforts are underway to expand the diversity of species farmed in Azerbaijan's coastal waters.

Figure 4. A net cage culture system for trout from Soviet time (Photo courtesy by: Ozgur Altan)

4. Statistical Analysis: Production Data and Growth Rates

This section provides a statistical overview of aquaculture production in Central Asia, highlighting production volumes, growth rates, and the economic significance of the sector in each country.

4.2. Growth Rate of Aquaculture

The aquaculture industry across Central Asian countries has seen rapid growth in recent years due to increased investment and government support. On average, production in the region has grown by 5-8% annually, with some countries, such as Uzbekistan, experiencing growth rates as high as 10% per year. This growth is driven by rising demand for fish products, both domestically and internationally, as well as efforts to reduce reliance on imports.

4.3. Comparative Data

Compared to global aquaculture producers like China, Southeast Asia, or Norway, Central Asia and Azerbaijan's aquaculture sectors remain relatively small. However, the region's potential for growth is significant, especially given its vast water resources and increasing government support for the industry. Countries like Kazakhstan and Azerbaijan are positioning themselves as regional leaders, particularly in high-value species like sturgeon.

4.4. Exports and Imports

Kazakhstan and Azerbaijan are the only significant exporters in the region, primarily due to their production of sturgeon and caviar. Azerbaijan exports caviar to markets in Europe, the Middle East, and Asia, while Kazakhstan’s sturgeon farms supply caviar both domestically and internationally.

Uzbekistan and Kyrgyzstan are focused more on meeting domestic demand, though Uzbekistan has the potential to become an exporter as it scales up production.

Overall, the region remains a net importer of fish, with imports primarily coming from China, Russia, and other countries. However, with the continued development of the aquaculture sector, several Central Asian countries aim to reduce their dependency on imports in the coming years.

5. Government Policies and Support Mechanisms

Government policies and support mechanisms play a crucial role in the growth and sustainability of the aquaculture industry in Central Asia and Azerbaijan. Many governments have introduced subsidies, infrastructure improvements, and training programs to encourage private investments in fish farming.

5.1. Kazakhstan

The government of Kazakhstan has implemented a series of programs to promote aquaculture, including subsidies for fish farmers, investment in hatchery infrastructure, and the introduction of modern technologies. The Ministry of Agriculture has set ambitious targets for increasing fish production, with a focus on high-value species such as sturgeon and trout. The government also provides financial incentives to private investors and has developed public-private partnerships to improve fish farm productivity (CSEP, 2022).

5.2. Uzbekistan

Uzbekistan's government has made aquaculture a priority in its agricultural development strategy. The country has introduced tax breaks and low-interest loans for fish farmers, as well as providing access to technical expertise and modern equipment. Additionally, research institutions have been established to improve fish farming techniques and enhance productivity. The government's goal is to increase fish production to 60,000 metric tons by 2025, and substantial resources are being allocated to achieve this target (UMA, 2021).

5.3. Kyrgyzstan

Kyrgyzstan has focused its efforts on developing cold-water aquaculture, particularly trout farming. The government has worked to improve hatchery infrastructure and has provided subsidies to fish farmers to help them expand operations. Kyrgyzstan's unique geography, with its numerous high-altitude lakes and rivers, offers significant potential for the growth of cold-water fish farming (KFD, 2023).

5.4. Turkmenistan

Turkmenistan has only recently begun to focus on aquaculture as a means of diversifying its agricultural sector. The government has introduced initiatives to support fish farmers, including grants for infrastructure development and access to specialized training. While the industry remains small, the government's long-term strategy includes the expansion of carp farming and the introduction of new species such as sturgeon (TMWR, 2023).

5.5. Tajikistan

Tajikistan's government has introduced policies aimed at increasing private sector participation in aquaculture. This includes providing incentives to small-scale fish farmers and improving water management practices to address issues related to water scarcity. The government has also partnered with international organizations to promote sustainable aquaculture practices (TAU, 2023).

5.6. Azerbaijan

The Azerbaijani government has played a central role in the development of the country's aquaculture industry, particularly its sturgeon and marine species farming. Government programs include financial support for fish farmers, investment in hatcheries, and collaboration with international partners to promote sustainable practices. Azerbaijan has also focused on improving its regulatory framework to ensure that aquaculture operations meet international standards, particularly regarding the conservation of sturgeon and the sustainability of caviar production (FAO, 2013b; CSEP, 2022).

6. Challenges Facing Aquaculture in Central Asia and Azerbaijan

Despite the promising growth in aquaculture across Central Asia and Azerbaijan, the industry faces several significant challenges. These obstacles range from environmental and technological issues to economic and political constraints that hinder the expansion and sustainability of fish farming in the region (OECD, 2022).

6.1. Climate and Geography

The diverse and often harsh climatic conditions in Central Asia present a considerable challenge for aquaculture development. Countries like Kazakhstan and Kyrgyzstan experience long, cold winters that can inhibit fish farming activities, especially in outdoor pond systems. Low temperatures can reduce species like carp and trout growth rates, which thrive in warmer waters. High-altitude regions, such as those in Tajikistan and Kyrgyzstan, also face difficulties related to seasonal temperature fluctuations and limited access to consistent water supplies.

On the other hand, arid conditions in countries like Turkmenistan and Uzbekistan make water management a critical issue. These countries rely heavily on irrigation systems and reservoirs for fish farming, and frequent droughts or water shortages can limit production. Water scarcity, especially in southern Uzbekistan and Turkmenistan, poses a significant threat to the expansion of aquaculture, as it competes with other agricultural and industrial uses of water.

6.2. Environmental Issues

Environmental degradation, particularly in water bodies such as rivers and lakes, has had a profound impact on aquaculture in the region. Pollution from agricultural runoff, industrial waste, and untreated sewage can lead to water contamination, which affects fish health and productivity. Kazakhstan's Aral Sea disaster is a well-known example of how poor water management and over-extraction can lead to ecological collapse, with devastating consequences for both fisheries and aquaculture.

In Azerbaijan, the Caspian Sea faces environmental challenges from oil and gas extraction, pollution, and overfishing, which have affected marine ecosystems. The depletion of wild sturgeon populations, for instance, has forced the country to invest heavily in sturgeon aquaculture as a means of sustaining its caviar industry.

6.3. Technological Limitations

Most aquaculture operations in Central Asia rely on traditional methods that may not be as efficient or sustainable as modern practices. Many fish farms lack access to advanced technologies such as recirculating aquaculture systems (RAS), which allow for more efficient water use and higher productivity. This limits the sector's ability to increase production while minimizing environmental impact (Karimov et al., 2004).

Figure 5. An old-style trout hatchery in Tajikistan

(Photo courtesy by: Ozgur Altan)

In Uzbekistan, efforts are being made to introduce new farming techniques. Still, the transition to modern, technology-driven aquaculture is slow due to the high infrastructure costs and the lack of technical expertise among local farmers. Access to quality fish feed, disease management, and breeding technologies also remain a challenge for many farmers across the region.

6.4. Infrastructure

Aquaculture in Central Asia is hindered by poor infrastructure, particularly in terms of transportation, storage, and market access. Many fish farms are located in remote or rural areas, far from major markets or processing facilities. This increases the costs of transporting fish to urban centers or exporting products to international markets. Additionally, inadequate cold storage and processing facilities reduce the shelf life of fish products, further complicating efforts to scale up production.

Kyrgyzstan and Tajikistan, with their mountainous terrain, face logistical difficulties in connecting fish farmers to regional and global markets. Poor roads, insufficient transport networks, and a lack of modern storage solutions all contribute to inefficiencies in the supply chain.

6.5. Economic and Political Constraints

The development of aquaculture requires significant investments in infrastructure, technology, and human resources. However, many Central Asian countries face economic challenges such as limited access to capital, a lack of financial incentives, and political instability. In Turkmenistan and Tajikistan, where economic development is slower, fish farmers often struggle to access the necessary financing to invest in aquaculture ventures. Political instability in some parts of the region can also disrupt supply chains, hinder investments, and affect government policies related to the agricultural sector. For instance, internal political tensions or policy shifts in countries like Kyrgyzstan and Tajikistan can lead to inconsistent support for the aquaculture industry (World Bank, 2022).

7. Opportunities and Future Prospects

Despite the challenges, the aquaculture industry in Central Asia and Azerbaijan presents numerous opportunities for growth, technological innovation, and market expansion. Governments and private stakeholders are recognizing the sector’s potential to contribute to food security, employment, and economic diversification, and are implementing strategies to capitalize on these opportunities (OECD, 2022; World Bank, 2022).

7.1. Growing Demand for Fish Products

As populations in Central Asia and Azerbaijan grow, so does the demand for fish products. Fish is increasingly seen as a healthy and affordable source of protein, and consumption levels are rising in both rural and urban areas. In countries like Uzbekistan and Kazakhstan, the domestic market for fish products is expanding, driven by increasing health consciousness and efforts to reduce reliance on imported fish.

Moreover, global demand for high-quality, sustainably produced fish is rising. Azerbaijan's sturgeon and caviar products, for instance, are in demand in international markets, providing opportunities for export growth. Similarly, as Kazakhstan and Uzbekistan improve their production processes, they could become significant global seafood players.

7.2. Technological Advancements

Advancements in aquaculture technologies, such as recirculating aquaculture systems (RAS), aquaponics, and integrated multi-trophic aquaculture (IMTA), provide opportunities to overcome some of the region's environmental and infrastructural challenges. By adopting these technologies, countries can improve production efficiency, reduce water usage, and minimize environmental impacts.

In Kazakhstan and Azerbaijan, investments are being made in developing sturgeon hatcheries and introducing modern breeding techniques. This not only helps to boost production but also contributes to the conservation of wild sturgeon populations, which have been under threat from overfishing and habitat degradation.

7.3. International Partnerships

Several Central Asian countries seek to establish partnerships with international organizations and foreign governments to boost aquaculture development. Collaborations with countries like China, Norway, and Russia have brought technical expertise, investment, and market access to the region. For example, China’s Belt and Road Initiative has opened up new opportunities for trade and investment in aquaculture, with Chinese firms investing in fish farms and processing facilities across Central Asia (OECD, 2022).

Furthermore, international organizations such as the FAO (Food and Agriculture Organization) and the World Bank are working with local governments to promote sustainable aquaculture practices and provide technical assistance.

7.4. Sustainability and Environmental Stewardship

As global consumers become more concerned about environmental sustainability, there is growing interest in sustainably farmed fish products. Central Asia and Azerbaijan have the potential to develop environmentally friendly aquaculture systems that minimize the use of chemicals, reduce pollution, and conserve water. By adopting the best aquaculture practices, countries can improve their environmental credentials and tap into lucrative markets for sustainable seafood products.

For instance, Azerbaijan has made progress in promoting sustainable sturgeon farming by working with international conservation groups to manage Caspian Sea resources more effectively. Kazakhstan, too, is exploring ways to balance aquaculture expansion with conservation goals, particularly in areas where water scarcity is a concern.

8. Conclusion

Aquaculture in Central Asian countries has emerged as a vital sector for economic diversification, food security, and employment. Countries such as Kazakhstan, Uzbekistan, Kyrgyzstan, Turkmenistan, Tajikistan, and Azerbaijan each face unique challenges and opportunities. Despite being relatively new in the region compared to other parts of the world, aquaculture has demonstrated significant growth potential, driven by increasing domestic demand for fish products, government support, and international cooperation. Freshwater species such as carp and trout dominate the region’s production, with sturgeon and marine aquaculture playing a significant role in Kazakhstan and Azerbaijan, particularly in the high-value caviar market.

The sector's expansion is supported by government policies that offer subsidies, training, and investments in infrastructure. However, challenges such as water scarcity, climate limitations, outdated farming technologies, and poor infrastructure continue to hamper growth in many countries. Environmental sustainability is another pressing issue, with pollution and overuse of water resources threatening both wild fish populations and farmed fish production.

The future of aquaculture in Central Asian countries looks promising, with most countries setting ambitious production targets and seeking to modernize their fish farming sectors. Kazakhstan and Azerbaijan are poised to be the leaders in aquaculture, with significant investments in sturgeon farming and the production of high-value fish species. Uzbekistan, with its favorable climate and large water resources, is also set to become a major player as it scales up its fish farming infrastructure.

As these countries continue to embrace technological innovations and sustainable practices, they have the potential to not only meet domestic demand but also become significant exporters in the global seafood market. Azerbaijan, with its strong position in the caviar market, is well-placed to increase its footprint in luxury seafood exports, while Kazakhstan can further tap into the global market for freshwater species.

In conclusion, aquaculture represents a significant opportunity for Central Asia and Azerbaijan to diversify their economies, enhance food security, and create new employment opportunities. By addressing the challenges facing the industry and capitalizing on the opportunities available, the region has the potential to emerge as a key player in the global aquaculture market in the coming decades.

9. Recommendations

For Central Asia and Azerbaijan to realize the full potential of their aquaculture industries, the following steps are recommended:

- **Investment in Infrastructure**: Governments should continue to invest in modern aquaculture infrastructure, including hatcheries, feed mills, and cold storage facilities. Improved transportation networks are also necessary to connect rural fish farms to regional and global markets.
- **Adoption of Advanced Technologies**: Countries should encourage the adoption of modern farming technologies such as recirculating aquaculture

systems (RAS), which will help increase productivity, reduce water usage, and mitigate environmental impact. Training programs should be expanded to educate farmers on sustainable practices and modern fish farming techniques.

- **Strengthening Regulatory Frameworks**: Strong regulatory frameworks are essential to ensure that aquaculture practices are sustainable and environmentally responsible. Governments should enforce regulations related to water usage, pollution control, and the conservation of wild fish populations.
- **Fostering International Collaboration**: Partnerships with international organizations and foreign investors can help bring in technical expertise and funding to boost the aquaculture sector. Collaborations with countries experienced in aquaculture, such as Norway and China, should be explored further.
- **Focus on Sustainability**: Central Asia and Azerbaijan should focus on developing environmentally sustainable aquaculture practices. This includes the use of eco-friendly fish feed, reducing pollution, and conserving water resources. Sustainable aquaculture practices will not only benefit the environment but also enhance the competitiveness of these countries' fish products in international markets.

- **Diversification of Species**: While carp and trout dominate the aquaculture landscape, there is potential to diversify the species farmed in the region. Tilapia, catfish, and various marine species (particularly in Azerbaijan) could be further developed to meet both domestic and export market demands.
- **Support for Small-Scale Farmers**: Many fish farmers in Central Asia operate small-scale operations, which could benefit from government support and cooperative models. Expanding access to financing, training, and technology will help small farmers increase their productivity and incomes.

References

Asian Development Bank. (2022). Water Resources and Aquaculture Development in Central Asia: Addressing Climate Challenges. Asian Development Bank - Manila.

Azerbaijan State Statistical Committee (AZSSC). (2022). Statistical Yearbook: Fisheries and Aquaculture in Azerbaijan. Baku: Azerbaijan State Statistical Committee.

Cai, J., Galli, G., Zhou, X. (2020). Aquaculture growth potential in Kazakhstan. FAO Fisheries and Aquaculture Technical Paper. Rome.

Caspian Sea Environmental Program (CSEP). (2022). Sustainability and Aquaculture in the Caspian Sea: Azerbaijan and Kazakhstan Case Studies. Retrieved from http://www.caspianenvironment.org (Access: August 2024).

European Commission (EC). (2021). Caviar Production and Trade: European Market Insights for Caspian Sea Countries. Brussels: European Commission Fisheries Division. Belgium.

FAO. (2024). The State of World Fisheries and Aquaculture 2024 – Blue Transformation in Action. Rome.

Food and Agriculture Organization of the United Nations (FAO). (2018). Report of the regional workshop on inland fisheries and aquaculture in Central Asia: Status and development prospects. FAO Fisheries Report no: 862. Rome.

FAO & World Bank. (2018). *Fishery and Aquaculture Sector Review in Central Asia*. World Bank Report. Retrieved from https://www.worldbank.org/en/where-we-work

Food and Agriculture Organization of the United Nations (FAO). (2011a). Report of the regional workshop to assess the fisheries and aquaculture sector education, training and research needs in Central Asia. FAO Fisheries and Aquaculture Report no: 45. Ankara.

Food and Agriculture Organization of the United Nations (FAO). (2011b). Feasibility of stocking and culture-based fisheries in Central Asia. FAO Fisheries and Aquaculture Technical Paper no: 565. Ankara.

Food and Agriculture Organization of the United Nations (FAO). (2011c). Better management practices for carp production in Central and Eastern Europe, The Caucasus and Central Asia. FAO Fisheries and Technical Paper no: 566. Ankara.

Food and Agriculture Organization of the United Nations (FAO). (2013a). Sturgeon hatchery manual. FAO Fisheries and Aquaculture Technical Paper no: 558. Ankara.

Food and Agriculture Organization of the United Nations (FAO). (2013b). Fisheries And Aquaculture in The Republıc of Azerbaıjan: A Review. FAO Fisheries and Aquaculture Circular No. 1030/4. Ankara.

Food and Agriculture Organization of the United Nations (FAO). (2023). *Aquaculture Overview: Central Asia and Azerbaijan*. Retrieved from http://www.fao.org/fishery (Access: September 2024).

Global Aquaculture Alliance. (2022). Sustainable Aquaculture in Developing Countries: A Case Study of Central Asia.

Retrieved from http://www.aquaculturealliance.org (Access: August 2024).

International Fund for Agricultural Development (IFAD). (2021). Small-Scale Aquaculture Development Projects in Central Asia. Rome: IFAD.

International Sturgeon Research Institute. (2021). Sturgeon Aquaculture and Caviar Production in the Caspian Region. Retrieved from http://www.sturgeon-institute.org (Access: September 2022).

Karimov, B., Joldasova, I., Blanchoud, H., Kurambaeva, M., Chevreuil, M. (2004). Problems of sustainable fishery and aquaculture in the southern Aral Sea region under anthropogenic impact. Conference: The 14th Stockholm Water Symposium, August 16-20. Sweden.

Karimov, B.; Kamilov, B.; Upare, M.; van Anrooy, R.; Bueno, P.; Shokhimardonov, D. (2009). Inland capture fisheries and aquaculture in the Republic of Uzbekistan: current status and planning. FAO Fisheries and Aquaculture Circular. No. 1030/1. Rome.

Kazakhstan Ministry of Agriculture (KMA). (2022). Annual Report on Aquaculture Production in Kazakhstan. Retrieved from http://www.agro.gov.kz (Access: October 2023).

Kyrgyzstan Fisheries Department (KFD). (2023). Cold-Water Fish Farming in Kyrgyzstan: Trends and Data. Bishkek: Kyrgyz Fisheries Department.

OECD. (2022). Fisheries and Aquaculture in Transition Economies: Central Asia and Beyond. Paris: OECD Publishing. France.

World Bank Group. (2022). Aquaculture Development in Central Asia: Challenges and Opportunities. Washington, D.C.: World Bank Publications. The USA.

Tajikistan Agricultural University (TAU). (2023). Aquaculture Practices and Development in Tajikistan. Dushanbe: Tajikistan Agricultural University Press.

Turkmenistan Ministry of Water Resources (TMWR). (2021). Aquaculture Development Strategy 2025. Ashgabat: Ministry of Water Resources. Turkmenistan.

Uzbekistan Ministry of Agriculture (UMA). (2022). Aquaculture Sector Development and Production Data. Retrieved from http://www.agro.uz (Access: April 2023).

CHAPTER III

Unforeseen Problem in Fishing: Jellyfish

Nurçin KİLLİ[1]

1.Introduction

"It is unknown whether the silent inhabitants of the seas were aware that they were being dragged towards the gulf by the current as they slowly floated by taking in and exhaling water from their umbrella parts. Their long and short mouth arms and tentacles began to sway like a bride's veil without them noticing the net approaching them… And then, suddenly, as they were in a crowd, the fish's "ahh!… ugh!" sounds were rising, while the jellyfish's burning cells exploded on whatever they touched inside the net…"

Jellyfish are organisms that have been living in our seas for 550 million years. These organisms, which have two life forms as sessile polyps and motile medusa forms, increase their numbers in certain seasons and form clusters in bays and gulfs under the influence of currents (Raymont, 1983; Mutlu et al., 1994). Factors such as the increase in sea water temperature due to global warming,

[1] Muğla Sıtkı Koçman University, Faculty of Fisheries, Department of Basic Sciences, Muğla, TÜRKİYE, nurcinkilli@mu.edu.tr

eutrophication, overfishing, increase in coastal structures, and aquaculture activities cause excessive increases in jellyfish (Arai, 2001; Purcell, 2005; Purcell et al., 2007; Halpern et al., 2008; Richardson et al., 2009). Jellyfish collected in coastal areas create serious effects for vacationers and local people. Toxic and allergic reactions can be observed in people who come into contact with these species (Burnett, 2001; Fenner, 1998; Mariottini & Pane, 2010).

Sixteen Scyphozoa species are distributed in Türkiye (Mutlu and Biçer, 2021; Cengiz & Killi, 2021; İşinibilir et al., 2022; Çınar et al., 2024) and eighteen of them are alien (Çınar et al. 2024). Among these species, *Pelagia noctiluca* is native to the Mediterranean and causes redness, edema, burning, blistering and severe pain in humans (Scarpa, 1984; Kokelj and Burnett, 1988; Carli et al., 1991; Carli et al., 1995). *Rhopilema nomadica*, one of the Lessepsian migratory species, forms swarms on the Mediterranean coast of our country, clogging fishing nets and causing economic losses. In addition, sea tourism negatively affects holidaymakers and causes hospitalizations due to severe pain and wounds (Öztürk & Isinibilir, 2010; Gülşahin, 2013). *Chrysaora hysoscella* is one of the other dangerous species distributed in the Aegean and Mediterranean coasts of Türkiye. With its long tentacles, this species has a strong burning feature (Gülşahin, 2016). Although *Rhizostoma pulmo* does not cause hospitalization cases, it causes burning, redness, blister formation and rashes (Mariottini & Pane, 2010). Although *Cotylorhiza tuberculata* is one of the harmless skifomedusa (Bernard, 1991), it scares and disturbs holidaymakers when they form swarms with bell diameters up to 40 cm on the South Aegean coasts (Gülşahin, 2017). Scyphozoa species harm fish populations by directly consuming fish eggs and larvae and indirectly consuming zooplankton.

Studies have shown that individuals of *Aurelia aurita* with a bell diameter of 36-50 mm consume 15.9 fish larvae per day. Individuals of the same species with a diameter of 80-260 mm were observed to consume mostly copepods and herring (total 86%). In the stomach analyses of sampled individuals of *Pelagia noctiluca* with a diameter of 10-40 mm, 50 out of 139 jellyfish were found to contain 43% fish eggs (Boero, 2013). It was determined that *Physalia physalis* eats 120 fish eggs and larvae per day, and *Chrysaora quinquecirrha* eats 343 fish eggs and larvae per day (Purcell & Arai, 2001). Considering zooplankton predation, it is known that jellyfish increases affect the development of fish larvae (Purcell & Arai, 2001; Arai, 2005; Purcell, 2005). Jellyfish cause economic losses by clogging fishing nets, damaging fishing and aquaculture activities, and accumulating in the cooling water pipes of power plants (Purcell et al., 2007). In recent years, the increase in jellyfish populations due to global warming has become a nightmare for many fishermen and complaints about this issue have started to increase. This study includes the effects of jellyfish swarms on fishing activities and the economic losses caused by jellyfish swarms in Turkey coasts. In this study, data and observations obtained from my own field studies and also information provided to me by fishermen were used.

2.Bite The Hand That Feeds Us…

Türkiye, which is home to four seas (Black Sea, Marmara, Aegean, Mediterranean) and has rich inland water basins, has great fishing potential. In addition, the seas surrounding our country host fish migration routes. This increases our aquaculture diversity and productivity. At the same time, the different characteristics of the seas in Türkiye in terms of temperature and salinity allow both fishing and aquaculture in these seas. In Türkiye, 335,003 tons of aquaculture was produced by fishing in 2022 and 514,805 tons by aquaculture (TEPGE, 2024). While the total production by fishery in 2023 was 454,059 tons, aquaculture production was realized as 553,862 tons (TUİK, 2023). Türkiye ranks second in Europe in aquaculture (TEPGE, 2024).

According to Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Fisheries and Aquatic Products (2022), the factors that cause the decrease in fishing activities in Turkey are as follows:

1. Decrease in marine resources and diversity,
2. Illegal, unregistered and irregular fishing,
3. Low fish consumption habits in Turkey
4. Inability to evaluate discarded fishery products
5. Socio-economic decrease in small-scale fishing
6. Inadequacy of state support
7. Inadequacy of inspection
8. Increase in invasive species

One of the most damaging factors to aquatic resources is pollution. Due to uncontrolled population growth in coastal settlements, uncontrolled and unconscious environmental planning and waste management, domestic and industrial environmental pollution seriously threatens the marine resources of today and future generations.

Disposal of domestic and industrial waste without complete treatment, excessive use of agricultural fertilizers mixing with sea and fresh water and damaging water quality, uncontrolled waste discharge from hotels in the summer months, anchoring of boats in bays and gulfs much more than their capacity, and difficulties in collecting the waste of these boats are the main pollution elements in aquatic ecosystems.

Another problem is global warming, which is also triggered by anthropological effects. According to IPCC (2018) global climate change has been accepted. Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is expected to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.

Global warming and overfishing are primary triggers of increasing jellyfish populations. Increasing water temperatures triggers the transition and increase in reproductive success of the jellyfish species (Purcell, 2005; Boero et al., 2016). Warming marine waters is causing temperate species to move toward the poles and trophic species distribute through temperate waters (Boero et al., 2016). Moreover, warmer waters bind less oxygen than cold waters. Many jellyfish species could tolerate low oxygen levels (Arai, 1997; Brueggeman, 1998; Condon et al., 2013). Jellyfish species can survive at low resources and extreme parameters (Dawson and Hamner, 2003). For example, *Cotylorhiza erythraea* lives at high temperature and salinity levels. *Cotylorhiza tuberculata*, is affected by global warming, and ephyra production and survival of the polyps of this species increase at high temperatures (Galil et al., 2017).

Excessive and illegal fishing activities are one of the factors that destroy marine ecosystems. Illegal fishing activities can be listed as not complying with the catchable length limit, spearfishing, selling prohibited species, fishing in places where fishing is prohibited, fishing and selling undocumented aquatic products, and fish farming contrary to the regulation. Violating the length limit leads to the fishing before they reach their reproductive size and can reproduce for the next year, and to a decrease in fish populations. This situation makes it difficult to protect the natural habitats in our seas and inland waters and the aquatic resources found there and to benefit from these resources sustainably. The number of illegal fishing activities and administrative fines determined in the inspections carried out in Muğla province in 2021, 2022 and 2023 are given in Table 1.

Table 1. Number of individuals/businesses detected to be engaged in illegal fishing in Muğla province and the fines imposed (Muğla Provincial Directorate of Agriculture and Forestry, 2024).

Year	Person/Business	Punishment of fine (TRL)
2021	83	245.925,00
2022	136	2.345.459,00
2023	62	1.070.881,00

Table 1 shows that illegal fishing activity detected in only one city in Turkey is not at all insignificant. While excessive jellyfish reproduction affects fish stocks by consuming fish eggs-larvae and zooplankton, the degradation of the ecosystem by overfishing increases this effect (Boero, 2013).

Fish actually live longer than jellyfish, and the nektonic food webs they create are sufficient for them. Many fish species do not consume jellyfish. During their mass increase, jellyfish first extract the most energy from the system and then experience massive mortality at the end of the favorable period. Large fish are almost immune to jellyfish predation. In this context, jellyfish success is temporary, and as soon as jellyfish decline, fish retake the scene. However, this situation reverses when fish are subject to human pressures that increasingly use more efficient fishing gear. Global overfishing is removing top predators from the oceans. Fish larvae compete with jellyfish for food on crustacean zooplankton, and if adult populations are large, the number of larvae and juveniles produced can outnumber gelatinous plankton. When fish abundance declines and jellyfish populations increase, the resilience of fish populations already affected by overfishing is further reduced. Especially if we consider that the species that consume jellyfish (some fish, seabirds, sea turtles) are few in number, then the ecosystem gradually ceases to be fish-based and becomes jellyfish-based (Boero, 2013).

Habitat modifications allow settling for the planula larvae and forming polyps which are very resistant to environmental changes by producing scyphistomae. Duarte et al. (2013) observed that polyps settled on wide range of structures such as floating docks and buoys, pier columns, floating pontoons, artificial reefs, oyster shells, plastic bottles, collapsing nets, and shipwrecks. As we increase human-made construction on our coasts, building more beaches, more piers and harbours for holidaymakers, we are not aware that we are actually providing a breeding ground for jellyfish.

The introduction of non-indigenous species (NIS) is an important element of global change in marine ecosystems. The Suez Canal is the main pathway of NIS introduction into the Mediterranean Sea. Invasive species have also caused fish populations to decline and fishing activities to be negatively affected in recent years. Since its opening in 1869, the Suez Canal, used for both trade and military affairs, is one of the most important artificial waterways in the world. With the opening of the Suez Canal, many Indo-Pacific jellyfish species have migrated to the Mediterranean and successfully established themselves thanks to the tropicalizing climate. The Levant Sea is unique in hosting six Erythraean scyphozoan jellyfish: *Cassiopea andromeda*, *Chrysaora pseudoocellata*, *Cotylorhiza erythraea, Marivagia stellata, Phyllorhiza punctata*, and *Rhopilema nomadica* (Galil, 2023).

The lionfish (*Pterois miles*), an opportunistic piscivore, has spread to the eastern Mediterranean in the last 10 years. This species, which feeds on small fish in rocky areas, threatens the native species of the Mediterranean (Galil, 2023). Similarly, the pufferfish (*Logocephalus scleratus*), which migrates from the Red Sea to the Mediterranean via the Suez Canal, has been reported as one of the invasive species with high invasive power (Bedry et al., 2021; Filiz & Er, 2004; Akyol & Aydın, 2016). It is known that puffer fish, one of the most widespread and invasive species seen in our country's waters, have spread as far as the Aegean Sea and the Marmara Sea due to factors such as their rapid adaptation, high reproduction and growth reproductive abilities, not being commercial because they are poisonous, lack of natural predators and overfishing on commercial species (Bilecenoğlu et al., 2006; Beköz et al., 2013; Irmak & Altınağaç, 2015).

The Lessepsian jellyfish *Rhopilema nomadica*, native of the tropical Indian Ocean, Mozambique, and the Red Sea, was noticed in the 1970’s for the first time in the Levantine sector of the Mediterranean Sea (Öztürk & işinibilir 2010; Gülşahin 2013). To date, *R. nomadica* has reportedly spread to Turkish, Greek, Maltese, Italian (Pantelleria Island, Egadi Islands, Sardinia) and Tunisian coasts (Deidun et al. 2011; Daly-Yahia et al. 2013; Balistreri et al. 2017). This species forms huge aggregations almost every summer along the Levantine coasts, resulting in thousands of bathers being stung each year (Gülşahin, 2017). *R. nomadica* has clogged the intake pipes of power, desalination, and industrial plants in the Mediterranean; furthermore, its ability to sting people negatively affects tourism (Boero, 2013). Massive aggregations of *Rhopilema nomadica* cause clogging of fishing nets and difficulties for fishermen pulling their nets full of jellyfish into the boat, with consequent economic losses, as reported for the Mediterranean coasts of Turkey (Gülşahin, 2017). As a warm-water species, global warming conditions could benefit *Rhopilema nomadica* (Killi et al., 2020).

R. nomadica was first seen in Turkey in 1995 in Mersin Bay (Kıdeyş & Gücü, 1995). It was later reported from İskenderun Bay by Avşar et al. (1996). The species' distribution along the Turkish coast has moved westward and has been recorded from Antalya Bay (Öztürk & İşinibilir, 2010) and Marmaris Bay (Gülşahin & Tarkan, 2011). Although the route of entry of the tropical jellyfish *P. punctata* into the Mediterranean has not been fully proven, its first record in the eastern Levant basin suggests that it entered the Red Sea via the Suez Canal (Galil et al., 1990). The species' first record was given in 1965 by (Galil et al., 1990). In 2010, the species was recorded from İskenderun Bay, SE Türkiye (Çevik et al., 2011) and then it was found in Sülüngür Lake is part of the Köyceğiz-Dalyan lagoon system, a protected natural reserve in the province of Muğla (Gülşahin & Tarkan, 2012).

3.Jellyfish Fishing!!!

R. nomadica was encountered in trawl samples conducted in the Northeastern Levantine Sea between January 2009 and April 2011. It was reported that this species started to increase in trawl samples from July 2009 onwards and was seen intensively in the summer of 2009 and the winter of 2010-2011 (Sakınan, 2011).

Turan et al. (2011) reported the proportions of jellyfish in the total catch in fishing with various fishing gears in the Gulf of İskenderun, Antalya and Mersin in March and April 2011. *R. nomadica* constituted 68% of the total catch in the Gulf of İskenderun, 546 in the Gulf of Mersin and 15% in the Gulf of Antalya in trawling operations. The amount of *R. nomadica* caught in purse seine operations was 3% in the Gulf of Antalya, 70% in the Gulf of Mersin and 89% in the Gulf of İskenderun. In fishing with gill nets and trammel nets, *R. nomadica* was found in 61% of the catch in the Gulf of İskenderun, 24% in the Gulf of Antalya and 14% in the Gulf of Mersin.

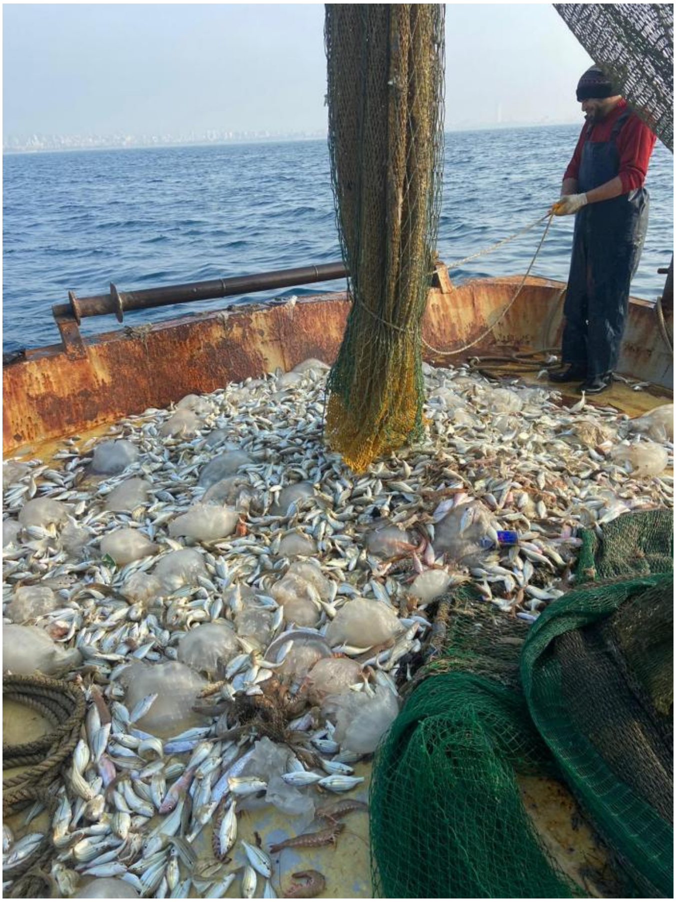

Figure 1. R. nomadica swarm in troll operation from Mersin Bay in 2022.

Gökova Bay is facing *Aurelia aurita* invasion… *A. aurita* is a cosmopolitan species and is seen on all coasts of Turkey. Although it is not an alien species, it occasionally invades the region by forming masses in bays and gulfs. This species gathers heavily in İzmir Bay every year in April, May and June, and in the Bosphorus and the Black Sea coast in spring, summer and autumn. *A. aurita*, which has invaded the region in Gökova Bay for the last five to six years, has become a nightmare for small-scale fishermen. It was determined that Mehmet Doğan, one of the gillnet fishermen, suffered a loss of 51973.85 dollars between 2018 and 2022 (Tarkan et al., 2024). Again, in February 2023, an excessive increase in *A. aurita* was observed in Gökova Bay and economic damage occurred (personal information). Other fishermen in Gökova Bay, like Mehmet Doğan, caught mostly *A. aurita* between 2018 and 2022.

Figure 2. R. nomadica in Mersin Bay and A. aurita in Gökova Bay from the trammel nets, respectively.

This time, *R. nomadica* was on the scene again. In March 2022, when many trawlers and purse seines fishing in the Gulf of Mersin pulled their nets, they encountered a lot of jellyfish with huge umbrella parts (Figure 2, 3, 4). Some fishermen even declared that they left their nets because they did not want to waste time and effort cleaning these gelatinous species and because the fish caught with the jellyfish would be spoiled by the jellyfish poison (Personal communication). Unfortunately, the economic loss of just one purse seine boat between 2017 and 2022 due to *R. nomadica* aggregation was calculated as 3.125.000 TL (Tarkan et al. 2024) (Figure 1). In February 2024, *R. nomadica* swarms were seen in the Gulf of Mersin again. Complaints from fishermen show the extent of *R. nomadica* swarm (Figure 2). During Summer and Autumn 2023, Izmir Bay was invaded by the species *Rhizostoma pulmo*. Especially on the coasts of Foça and Karaburun, the *R. pulmo* masses lasted for weeks and caused great losses to both the fishing and tourism sectors (https://www.aa.com.tr/tr/gundem/izmir-korfezinde-deniz-anasi-yogunlugu-yasaniyor/2966917).

Figure 3. R. nomadica swarm in Mersin Bay in 2024.

Figure 4. R. nomadica from the trammel net.

4.Conclusion

In recent years, it has been observed that the number of studies conducted with jellyfish has increased due to the negative effects caused by these species. In particular, these studies have focused on the paralytic, neurotoxic, cytotoxic, dermotoxic and hemolytic effects of jellyfish biomass and venoms as well as their pharmacological potential, anti-inflammatory, antihypertensive, antimicrobial, analgesic, anticoagulant, antioxidant, anticancer and antitumor activities (Mariottini & Pane, 2010). Jellyfish, which are processed and produced as food in Southeast Asian countries, are not consumed in other parts of the world. Thanks to the evaluation of the mass increase of these species, which do not have many predators, in different biotechnological fields, they are evaluated as resources in different sectors and added to the economy. In addition, the production of products such as plastic, wound dressing and leather materials from jellyfish biomass has been successful (Steinberger at al. 2019; Nudelman et al. 2019; Pavani et al. 2024). In particular, the evaluation of invasive jellyfish species and their addition to the economy is also important in terms of protecting natural species. For example; It has been observed that the venom of the *R. nomadica* species, which disrupts fishing activities in Turkey and causes economic and operational losses, has a strong cytotoxic effect on colon cancer cells (unpublished data).

It is our responsibility to future generations to protect and enrich our natural resources in the face of a growing population. Therefore, it is our primary duty to protect our aquatic ecosystems and resources. Due to the decreasing agricultural lands and the increase in diseases seen in animal husbandry, our seas are considered the only source that will save humanity from the anticipated famine problem. Humanity should act with this awareness and protect marine and freshwater ecosystems. Accepting and implementing this as our duty is our responsibility to nature.

5.Acknowledgements

I would like to thank Mr. Sedat EREZ and Mr. Mehmet DOĞAN for their valuable helps in knowledge-sharing and operational assistance.

References

1. Raymont, J. E. G. (1983). Vertical migration of zooplankton. Plankton and productivity in the oceans, 2, 489-524.

2. Mutlu, E., Bingel, F., Gücü, A. C., Melnikov, V. V., Niermann, U., Ostr, N. A., & Zaika, V. E. (1994). Distribution of the new invader Mnemiopsis sp. and the resident Aurelia aurita and Pleurobrachia pileus populations in the Black Sea in the years 1991–1993. ICES Journal of Marine Science, 51(4), 407-421.

3. Arai, M. N. (2001). Pelagia coelenterates and esutrophication: a review. Hydrobiologia, 451(1-3),69-87.

4. Purcell, J. E., (2005). Climate effects on formation of jellyfish and ctenophore blooms: a review. Journal of the Marine Biological Association of the United Kingdom, 85(3), 461-476.

5. Purcell, J. E., Uye, S. I., & Lo, W. T., (2007). Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. Marine Ecology Progress Series, 350, 153-174.

6. Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., d'Agrosa, C., ... & Watson, R. (2008). A global map of human impact on marine ecosystems. science, 319(5865), 948-952.

7. Richardson, A. J., Bakun, A., Hays, G. C., & Gibbons, M. J., (2009). The jellyfish joyride: causes, consequences and management responses to a more gelatinous future. Trends in ecology & evolution, 24(6), 312-322.

8. Burnett, J. W. (2001). Medical aspects of jellyfish envenomation: pathogenesis, case reporting and therapy. Hydrobiologia, 451, 1-9.

9. Fenner, P. J. (1998). Dangers in the ocean: the traveler and marine envenomation. I. Jellyfish. Journal of Travel Medicine, 5(3), 135.

10. Mariottini, G. L., & Pane, L. (2010). Mediterranean jellyfish venoms: A review on scyphomedusae. Marine drugs, 8(4), 1122-1152.

11. Mutlu, E., & Biçer, E. (2021). Second occurrence of Chrysaora pseudoocellata in Antalya Gulf, the eastern Mediterranean Sea. International Journal of Natural and Engineering Sciences, 15(3), 79-82.

12. Cengiz, S., & Killi, N. (2021). Nematocysts types and morphological features of some scyphozoa species in the Southwest Turkey. Fresenius Environmental Bulletin 30 (1): 32-40.

13. İşinibilir M, Yüksel E, Turkeri E, Doğan O, Karakulak FS et al. (2022). New additions to the jellyfish fauna of the Sea of Marmara. Aquatic Sciences and Engineering 37 (1): 53-57. https://doi.org/10.26650/ASE2021981468

14. Çınar, M. E., Açık, Ş., & Aker, H. V. (2024). Diversity of Cnidaria and Ctenophora from the coasts of Türkiye. Turkish Journal of Zoology, 48(6), 356-378.

15. Scarpa, C. (1984). On skin injuries provoked by Coelenterata and Echinodermata. UNEP: Workshop on Jellyfish Blooms in the Mediterranean, Athens, Greece, 31 October–4 November 1983; UNEP: Athens, Greece, 1984; pp. 95–97.

16. Kokelj, F. & Burnett, J.W. (1988). Reazioni inusuali indotte dal contatto con la medusa Pelagia noctiluca. Giornale Italiano di Dermatologia e Venereologia, 123, 501-503.

17. Carli, A., Cotta, S., Mariottini, G.L. & Pane, L. (1991). Considerazioni sulla proliferazione di Cnidari planctonici nel Mar Ligure. Meditravel 1991, 0, 112-120.

18. Carli, A., Mariottini, G.L. & Pane, L. (1995). Ecological and medical aspects of jellyfish poisoning. In Epidemiological studies related to the environmental quality criteria for bathing waters, shellfish-growing waters and edible marine organisms MAP Tech. Rep. Ser. 1995, No 93; UNEP: Athens, Greece, 1995; pp. 1-21.

19. Öztürk, B. & İşinibilir, M. (2010). An alien jellyfish Rhopilema nomadica and its impacts to the Eastern Mediterranean part of Turkey. Journal of Black Sea/Mediterranean Environment, 16(2), 149-156.

20. Gülşahin, N., (2013). Muğla neritik bölgesi Scyphozoa (Cnidaria) ve Ctenophora türlerinin bolluk, dağılım ve biyomas özellikleri. PhD, Muğla Sıtkı Koçman University, Muğla, Turkey (in Turkish).

21. Gülşahin, N. (2016). Nematocyst types of Chrysaora hysoscella (Linnaeus, 1766) from Turkey. 5th International Jellyfish Bloom Symposium, May 30- June 3, 2016, Barcelona, Spain, p.166.

22. Bernard, P. (1991). Recapitulation des résultats de la surveillance des proliférations de méduses sur les côtes méditerranéennes françaises durant l'été 1987. UNEP: Jellyfish blooms in the Mediterranean Proceedings of the II Workshop on

Jellyfish in the Mediterranean Sea MAP Tech. Rep. Ser., No 47; UNEP: Athens, Greece, 1991; pp. 51-57.

23. Gülşahin, N. (2017). Jellyfish Blooms and Injuries in Turkey. In Gian Luigi Mariottini, Ed. Jellyfish: Ecology, Distribution Patterns and Human Interactions (p.149-162). Nova Science Publishers, ISBN 978-163-485-68-81.

24. Boero, F. (2013). Review of jellyfish blooms in the Mediterranean and Black Sea. General Fisheries Commission for the Mediterranean. Studies and Reviews, (92), I,III,IV,1-53.

25. Purcell, J. E., & Arai, M. N. (2001). Interactions of pelagic cnidarians and ctenophores with fish: a review. Hydrobiologia, 451, 27-44.

26. Arai, M. N. (2005). Predation on pelagic coelenterates: a review. Journal of the Marine Biological Association of the United Kingdom, 85(3), 523-536.

27. TEBGE (2024). Report of Agricultural Products Market. https://arastirma.tarimorman.gov.tr/tepge/Menu/27/Tarim-Urunleri-Piyasalari.

28. TUİK (2023). Su Ürünleri Üretimi 2023 yılı verileri. https://data.tuik.gov.tr/Bulten/Index?p=Su-Urunleri-2023-53702.

29. IPCC (2018). Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. (https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/).

30. Boero, F., Brotz, L., Gibbons, M. J., Piraino, S., & Zampardi, S. (2016). 3.10 Impacts and effects of ocean warming on jellyfish. Explaining ocean warming: Causes, scale, effects and consequences, 213-237.

31. Arai, M. N. (1997). A functional biology of Scyphozoa. Chapman & Hall, London.

32. Brueggeman, P. (1998). Cnidaria–Scyphozoa: jellyfish. Scripps Institution of Oceanography Library.

33. Condon, R. H., Duarte, C. M., Pitt, K. A., Robinson, K. L., Lucas, C. H., Sutherland, K. R., ... & Graham, W. M. (2013). Recurrent jellyfish blooms are a consequence of global oscillations. Proceedings of the National Academy of Sciences, 110(3), 1000-1005.

34. Dawson, M., & Hamner, W. M. (2003). Geographic variation and behavioral evolution in marine plankton: the case of Mastigias (Scyphozoa, Rhizostomeae). Marine Biology, 143, 1161-1174.

35. Galil, B. S., Gershwin, L. A., Zorea, M., Rahav, A., Rothman, S. B., Fine, M., ... & Rinkevich, B. (2017). Cotylorhiza erythraea Stiasny, 1920 (Scyphozoa: Rhizostomeae: Cepheidae), yet another erythraean jellyfish from the Mediterranean coast of Israel. Marine Biodiversity, 47, 229-235.

36. Duarte, C. M., Pitt, K. A., Lucas, C. H., Purcell, J. E., Uye, S. I., Robinson, K., ... & Condon, R. H. (2013). Is global ocean sprawl a cause of jellyfish blooms? Frontiers in Ecology and the Environment, 11(2), 91-97.

37. Galil, B. (2023). A Sea, a Canal, a Disaster: The Suez Canal and the Transformation of the Mediterranean Biota. C. Lutmar and Z. Rubinovitz (eds.), The Suez Canal: Past Lessons and Future Challenges, Palgrave Studies in Maritime Politics and Security, https://doi.org/10.1007/978-3-031-15670-0_10.

38. Bédry, R., De Haro, L., Bentur, Y., Senechal, N., & Galil, B. S. (2021). Toxicological risks on the human health of populations living around the Mediterranean Sea linked to the invasion of non-indigenous marine species from the Red Sea: A review. Toxicon, 191, 69-82.

39. Filiz, H., & Er, M. (2004). Akdenizin yeni misafiri (New guests in the Mediterranean Sea). Deniz Magazin (Istanbul), 68, 52-54.

40. Akyol, O. & Aydın, İ. (2016). A new record of Lagocephalus guentheri (Tetraodontiformes: Tetraodontidae) from the north-eastern Aegean Sea. Zoology in the Middle East, 62(3), 271-273.

41. Bilecenoglu, M., Kaya, M., & Akalin, S. (2006). "Range expansion of silverstripe blaasop, Lagocephalus sceleratus (Gmelin, 1789), to the northern Aegean Sea". Aquatic Invasions, 1(4):289-291.

42. Beköz, A. B., Beköz, S., Yilmaz, E., Tüzün, S., & Beköz, Ü. (2013). Consequences of the increasing prevalence of the poisonous Lagocephalus sceleratus in southern Turkey. Emergency medicine journal, 30(11), 954-955.

43. Irmak, E. & Altınağaç U. (2015). "First record of an invasive lessepsian migrant, Lagocephalus sceleratus

(Actinopterygii: Tetraodontiformes: Tetraodontidae), in the sea of Marmara”. Acta Ichthyologica et Piscatoria, 45 (4): 433-435.

44. Deidun, A., Arrigo, S., & Piraino, S. (2011). The westernmost record of Rhopilema nomadica (Galil, 1990) in the Mediterranean-off the Maltese Islands.

45. Daly-Yahia, M. N., Daly-Yahia, O. K., Gueroun, S. K. M., Aissi, M., Deidun, A., Fuentes, V., & Piraino, S. (2013). The invasive tropical scyphozoan Rhopilema nomadica Galil, 1990 reaches the Tunisian coast of the Mediterranean Sea.

46. Balistreri, P., Spiga, A., Deidun, A., Gueroun, S. K. M., & Daly-Yahia, M. N. (2017). Further spread of the venomous jellyfish Rhopilema nomadica Galil, Spannier & Ferguson, 1990 (Rhizostomeae, Rhizostomatidae) in the western Mediterranean. BioInvasions Records (2017) Volume 6.

47. Killi, N., Tarkan, A. S., Kozic, S., Copp, G. H., Davison, P. I., & Vilizzi, L. (2020). Risk screening of the potential invasiveness of non-native jellyfishes in the Mediterranean Sea. Marine Pollution Bulletin, 150, 110728.

48. Kıdeyş, A.E. & Gücü A.C. (1995). Rhopilema nomadica: a Lessepsian Scyphomedusan new to the Mediterranean coast of Turkey. Israel Journal of zoology, 41: 615-617, 1995.

49. Avşar, D., Çevik, C., Türeli, C. (1996). İskenderun Körfezi için yeni bir tür olan (Rhopilema nomadica)’nın biyometrisi ve Yumurtalık Koyundaki bulunurluğu. XIII. Ulusal Biyoloji Kongresi, 17–20 Eylül 1996 İstanbul. Düzenleyen Kuruluş: İ.Ü. Fen Fakültesi, Biyoloji Bölümü, 1996 (in Turkish).

50. Gülşahin, N. & Tarkan, A.N. (2011). The first confirmed record of the alien jellyfish Rhopilema nomadica Galil, 1990 from the southern Aegean coast of Turkey. Aquatic Invasions, Volume 6, Supplement 1: S95–S97.

51. Galil, B. S., Spanier, E., & Ferguson, W. W. (1990). The Scyphomedusae of the Mediterranean coast of Israel, including two Lessepsian migrants new to the Mediterranean. Zoologische mededelingen, 64(7), 95-105.

52. Çevik, C., Derici, O. B., & Cevik, F. (2011). First record of Phyllorhiza punctata von Lendenfeld, 1884 (Scyphozoa: Rhizostomeae: Mastigiidae) from Turkey.

53. Gülşahin, N., & Tarkan, A. N. (2012). The first record of Phyllorhiza punctata von Lendenfeld, 1884 from the southern Aegean Coast of Turkey. BioInvasions Records, 1(1), 41-44.

54. Sakınan, S. (2011). Recent occurrence of Indo-Pacific jellyfish Rhopilema nomadica in North–Eastern Levantine Sea. In Workshop on Jellyfish and Other Gelatinous Species in Turkish Marine Waters 20-21 May 2011 (p. 58).

55. Turan, C., Gürlek, M., Özbalcılar B., Yağlıoğlu, D., Ergüden, D., Öztürk, B. & Güngör, M. (2011). Jellyfish Bycatch Data by Purse Seine, Trawl and Net Fisheries during March-April 2011 in the Mediterranean Coast of Turkey. First International Workshop on Jellyfish and Other Gelatinous Species in Turkish Marine Waters, 20-21 May 2011, Bodrum, Muğla, Turkey, p. 1-7.

56. Tarkan, A. S., Bayçelebi, E., Giannetto, D., Özden, E. D., Yazlık, A., Emiroğlu, Ö., ... & Haubrock, P. J. (2024). Economic

costs of non-native species in Türkiye: A first national synthesis. Journal of Environmental Management, 358, 120779.

57. Steinberger, L. R., Gulakhmedova, T., Barkay, Z., Gozin, M., & Richter, S. (2019). Jellyfish-Based Plastic. Advanced Sustainable Systems, 3(7), 1900016.

58. Nudelman, R., Alhmoud, H., Delalat, B., Fleicher, S., Fine, E., Guliakhmedova, T., ... & Richter, S. (2019). Jellyfish-based smart wound dressing devices containing in situ synthesized antibacterial nanoparticles. Advanced Functional Materials, 29(38), 1902783.

59. Pavani, C., Rao, P. A., Vishnu, P., Raja, H., Sriram, & Sirisha, N. (2024). Vegan Leather from Agricultural Waste: Exploring Sustainable and Cruelty-Free Alternatives. In From Waste to Wealth (pp. 951-964). Singapore: Springer Nature Singapore.

CHAPTER IV

Microplastics and Their Effects in Aquaculture

Serhat ENGİN

1.INTRODUCTION

Plastic products have brought great convenience to modern life due to their advantageous features and low prices. Since the 1950s, global annual plastic production has increased continuously, and approximately 400 million tons of plastic were produced in 2022 (Plastics Europe, 2023). Both recreational and commercial fishing and aquaculture facilities introduce plastics directly into the marine environment. Cost implications ensure that equipment loss is kept to a minimum through maintenance and equipment recovery where possible, and most manufacturers are committed to properly disposing of materials that have reached the end of their usable life. (Jensen & Zajicek, 2008). In many cases, best practices and operating standards have been produced by government agencies, industry organizations and researchers, but unfortunately, environmental weathering, biodegradation and wear and tear of plastics in use still result in the loss of large plastics and the formation of microplastics. However, it is worth reiterating that it is difficult to estimate the percentage of marine litter originating from marine sources and only a fraction of this will originate from the fishing and aquaculture industry (Jambeck et al., 2015).

2.WHAT IS PLASTİC?

The word plastic is derived from the Greek word ‘Plastikos’ (suitable for molding). This feature allows the material to be cast or shaped into various shapes for various uses. (FAO, 2017). Plastics, which have been developed since the 1800s, are cheap, lightweight, strong and durable materials with high heat properties and are widely used in areas such as production, packaging, construction, transportation, medicine and health, electronics, design and agriculture. The first synthetic plastic was produced in the early 20th century. It was called "Bakelite" (Phenol Formaldehyde Thermoset) and was widely used in everything from household items to radio parts. (Andrady, & Neal, 2009).

3.PLASTIC GROUPS AND CLASSIFICATION

Plastics are a large family of synthetic and semi-synthetic polymers derived from fossil resources and organic products including cellulose, salt and renewable compounds (FAO, 2017). Plastics are divided into 3 classes according to their chemical composition, size and origin (Table 1). Plastic particles released into nature reach microplastic levels over time due to biological degradation (microorganisms), chemical decomposition (with the help of UV rays) or physical factors (with the help of wave action, wind, abrasive sand or sediment). (Barnes et al., 2009; Hidalgo-Ruz et al., 2012; Browne, 2015a). It is easier for plastic products, especially those originating from plastic bags found on the sea surface or on beaches, to decompose and break down under direct sunlight. Microplastics can be accidentally ingested as food by many living creatures such as zooplankton, invertebrates and small fish, especially due to their colors (Veerasingam et al., 2020) and that's how they enter the food chain (GESAMP, 2015).

Detection examinations vary according to plastic size. As their size decreases, their detection and identification due to their physico-chemical properties become more complicated. As microplastic sizes decrease, it becomes increasingly difficult to separate plastic from non-plastic particles. In order to eliminate interference in microscopic and spectroscopic examination, co-extracted organic particles can be extracted using salt solutions (Rochman et al., 2015; Lusher et al., 2016; Tanaka & Tadaka, 2016; Lusher et al., 2017; Iheanacho et al., 2023).

Table 1. Classification of plastics (Hartmann et al., 2019).

	Thermoplastic	Thermosets	Elastomers
Distinguishing Feature	Composed of linear and long-chain, straight or slightly branched molecules, they can be re-softened and re-melted with heat and pressure.	Covalent cross-linking occurs during heating. Therefore, they show permanent solidification when heated.	They have an amorphous structure. They exhibit elastic spring properties.
Examples	Polyethylene Polypropylene Polystyrene Poly Vinyl Chloride (PVC)	Polyimide Polyurethane Polybutadiene Vulcanized Rubber	Chloropene Nitrile EPDM Silicon

Plastik	Plastik Boyutu
Macroplastic (macro-)	>1cm
Mezoplastic (meso-)	1-<10mm
Microplastic (MPs)	1-<1000µm

Nanoplastic (NPs)	1-<1000nm
Plastik Orijini	
Primary	Intentionally produced in a certain size
Secondary	Formed as a result of decomposition in the environment or during use

4.AQUACULTURE AND MICROPLASTICS

Land-based plastic waste is the main source of microplastics in the aquatic environment (Lebreton et al., 2017; Schmidt et al., 2017). Although most plastics are land-based, a large amount of plastic waste and soil-based microplastics eventually enter the aquatic environment (Thompson, 2015; Auta et al., 2017). Aquaculture activities, especially in inland waters, are the areas most affected by this situation. Land-based sources are transported to inland waters as a result of plastics following a certain waterway. However, it is estimated that approximately eight tons of plastic waste enters the oceans each year, and 80% of this comes from land-based sources (Figure 1.) (Jambeck et al., 2015). In addition, industrial, agricultural and domestic wastewater contain microplastics, which are also an important source of microplastics in the aquatic environment (Piehl et al., 2018; Liu et al., 2019; Lv et al., 2019).

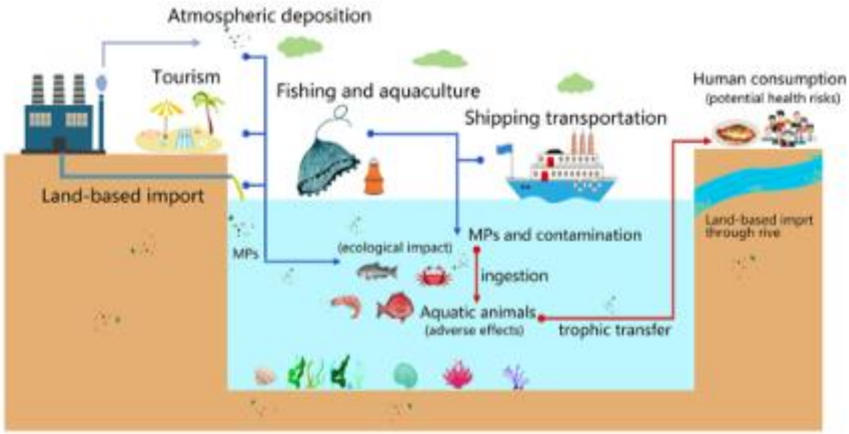

Figure 1. Sources of microplastics in aquaculture systems

Plastic products are an integral part of fishing and aquaculture activities. Most fishing gear, such as fishing nets, fishing rods, buckets and other devices, are made of plastic or contain plastic components. For example, the amount of lost and discarded fishing gear in Norway's commercial fishing grounds has exceeded 4000 tonnes (Deshpande et al., 2020). Plastic fishing gear is the dominant and most important source of microplastics in aquaculture environments. Plastic products such as fishing nets, fishing lines and floating balls are used in offshore cages and raft culture. Corrosion and damage over time lead to the entry of large numbers of plastic fragments into the aquatic environment (FAO, 2020). In addition, baits and medical products contribute to the formation of microplastics in aquaculture environments (Lv et al., 2019, 2020). Artificial baits contain large amounts of microplastics because MPs can be incorporated into the bait during production, transportation, storage and feeding (Zhou et al., 2020). Meanwhile, a large amount of zooplankton, invertebrates, small fish and aquatic plants in natural environments contain microplastics and are used in artificial feed production or directly as natural food in aquaculture (FAO, 2020). Fish meal, used as a protein source, is a frequently used raw material in diets. In a study conducted with fish meal, microplastics with dimensions of 452 ± 161 mm were detected. (Hanachi et al., 2019). Another study showed that microplastic concentrations in water increased significantly from the larval stage to portion size (Lv et al., 2020). In addition, fish medicines, antibiotics and other chemicals used to treat and prevent diseases and improve the quality of water and products bind to microplastics and are therefore another source of microplastic pollution in aquaculture environments (Fao, 2020; Zhou et al., 2020). Another view on the presence of microplastics in the aquatic environment suggests that these substances may be derived from atmospheric fallout, and studies have shown that microplastics in the atmosphere are a significant source of MPs in aquatic ecosystems (Dris et al., 2015). Increasing cumulative production and accumulation pose a serious threat to aquaculture systems and human health through aquatic and food chains.

Microplastics have been found in many species, including commercial species such as fish, mussels, shrimp, and crabs (Rezania et al., 2018). However, such studies detecting microplastics in commercial fish mostly focus on fish in natural habitats, thus information on microplastics in aquaculture remains limited

Microplastics have undoubtedly been found in all investigated aquaculture products in various aquaculture environments, including bays, artificial reefs, coastal areas, rivers, lakes, ponds, fishing farms, net cages, and field fish culture systems, especially rice fields where carp production is carried out (Figure 2).

For example, in a study that quantified microplastics in oysters cultured in 17 coastal areas of China, the average microplastic abundance in oysters was 0.62 items/g (wet weight) or 2.93 items/individual (Teng et al., 2019). In Jakarta Bay, researchers found microplastics in milkfish (*Chanos chanos*) (Priscilla & Patria., 2019). Another study found that gray mullet from fish farms in Hong Kong ingested an average of 0.2 pieces of microplastic per gray mullet, with the most common plastic pieces being smaller than 2 mm (Cheung et al., 2018). In particular, eel (*Anguilla anguilla*) and crayfish (*Astacus leptodactylus*) farmed in rice and sorghum fields had an average microplastic abundance of 1.7 ± 0.5 per individual (Lv et al., 2019). Mathalonand & Hill, in a 2014 study, took the perspective of MPs in a different direction and compared cultured mussels (*Mytilus edulis*) with wild individuals. The results are quite interesting because the MP content was higher in cultured mussels.

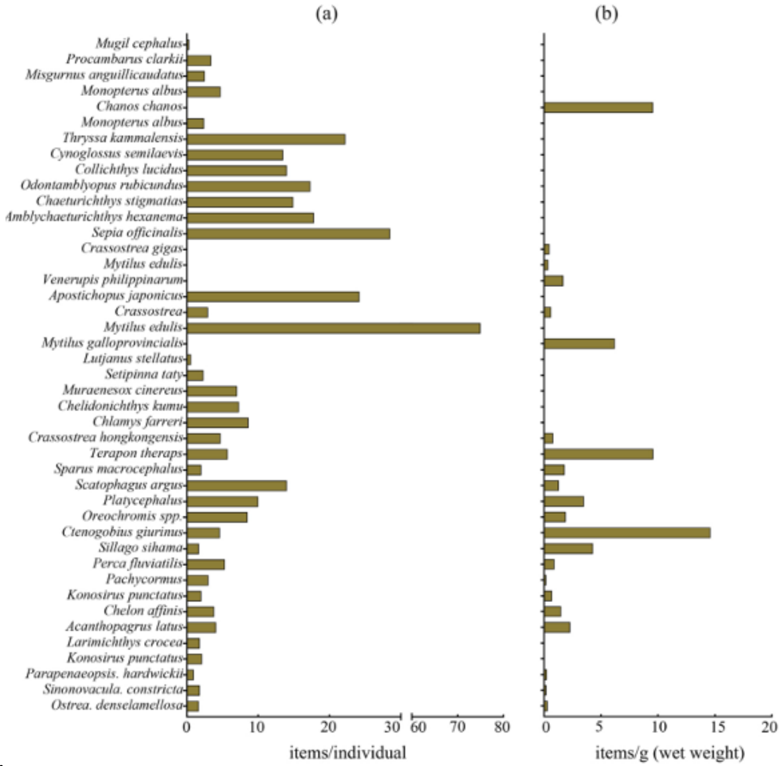

Figure 2. MP levels detected in cultivated species (Chen et al., 2021).

5.CONCLUSION AND RECOMMENDATIONS

Microplastics have been found in a variety of environments and species, including aquaculture systems and products, and are closely related to food supply and security (Zhou et al., 2020). Until recently, there was little information on the presence of microplastics in inland waters, but some studies have shown that microplastics have been studied in inland waters. In lake environments, microplastics tend to be more abundant near urban and industrial centers, but in some river systems this relationship is not the case and may be a result of river flow dynamics and flooding (Klein, Worch & Knepper, 2015). Inadequate waste management and wind-blown microplastics can contribute to the contamination of relatively isolated freshwater environments (Free & al., 2014). In contrast, the presence of MPs in the marine environment has been documented in every habitat in the open ocean and enclosed seas, including beaches, surface waters, water column and deep seabed (Lusher, 2015). In the oceans, the small size and low density of microplastics contribute to their widespread transport over large distances via ocean currents (Cole et al., 2011). This situation negatively affects marine species, especially in aquaculture. In order to prevent this pollution caused by MPs, it is important to detect and analyze the MPs that currently contaminate them. When detecting MPs in aquaculture environments, it is necessary to clarify the sources and fates of microplastics in them. For example, in aquaculture environments such as ponds, the use of filtered water and recycling of discarded plastic fishing gear and garbage can significantly reduce microplastic concentrations (Birnstiel et al., 2019). Furthermore, when ingested, microplastics can inhibit the growth, development, feeding and behavior of aquatic organisms and cause reproductive toxicity, immunotoxicity and genetic damage (Harmon, 2018). Since studies on these pollutants are limited in natural habitats, the extent and how the cultivated species are affected remains a mystery. Therefore, it is essential to conduct some studies to ensure that species contaminated with MP in cultivation do not adversely affect human health. Existing studies are few and limited to in vitro studies. Studies have shown that microplastics can harm human health by inducing oxidative stress, cytotoxicity and inflammation (Yong et al., 2020). Histological studies and even genetic studies will be useful to detect possible damage in the tissues of cultivated species.

REFERANCE

Abelouah, M.R., Ben-Haddad, M., Hajji, S., De-la-Torre, G.E., Aziz, T., Oualid, J.A., Banni, M. and Alla, A.A. (2022). Floating microplastics pollution in the Central Atlantic Ocean of Morocco: insights into the occurrence, characterization, and fate. Mar. Pollut. Bull. 182, 113969 https://doi.org/10.1016/j.marpolbul.2022.113969.

Anderson, P.J., Warrack, S., Langen, V., Challis, J.K., Hanson, M.L. and Rennie, M.D. (2017). Microplastic contamination in Lake Winnipeg, Canada. Environ. Pollut. 225, 223–231. https://doi.org/10.1016/j.envpol.2017.02.072.

Andrady, A. L. and Neal, M. A. (2009). Applications and societal benefits of plastics. Phil. Trans. R. Soc. B 364. (doi:10.1098/rstb.2008.0304)

Auta HS, Emenike, C. and Fauziah, S. (2017). Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. Environ Int 102:165–176.

Barnes, D.K.A., et al., (2009). Accumulation and fragmentation of plastic debris in global environments. Philos. Trans. R. Soc. B 364 (1526), 1985–1998.

Birnstiel, S., Soares-Gomes, A. and Da Gama, B.a.P. (2019). Depuration reduces microplastic content in wild and farmed mussels. Mar. Pollut. Bull. 140, 241e247.

Browne, M.A., Chapman, M.G., Thompson, R.C., Amaral-Zettler, L.A., Jambeck, J. and Mallos, N.J. (2015a). Spatial and temporal patterns of stranded intertidal marine debris: is there a picture of global change? Environ. Sci. Technol., 49(12): 7082-7094.

Cai, L., Wang, J., Peng, J., Tan, Z., Zhan, Z. and Tan, X. (2017). Characteristic of microplastics in the atmospheric fallout from Dongguan city, China: preliminary research and first evidence. Environ. Sci. Pollut. Res. Int. 24 (32), 24928e24935.

Chen, G., Li, Y. and Wang, J. (2021). Occurrence and ecological impact of microplastics in aquaculture ecosystems. Chemosphere 274, 129989. https://doi.org/10.1016/j. chemosphere.2021.129989.

Cheung, L.T.O., Lui, C.Y. and Fok, L. (2018). Microplastic contamination of wild and captive flathead grey mullet (Mugil cephalus). Int. J. Environ. Res. Publ. Health 15 (4).

Cole, M., Lindeque, P., Halsband, C. and Galloway, T.S. (2011). Microplastics as contaminants in the marine environment: a review. Mar. Pollut. Bull. 62 (12), 2588e2597.

Deshpande, P.C., Philis, G., Brattebø, H. and Fet, A.M. (2020). Using Material Flow Analysis (MFA) to generate the evidence on plastic waste management from commercial f ishing gears in Norway. Resour. Conserv. Recycl. X. 5, 100024.

Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N. and Tassin, B. (2015). Microplastic contamination in an urban area: a case of study in Greater Paris. Environ. Chem. 12 (5), 592–599. https://doi.org/10.1071/EN14167.

Egea-Corbacho A, Martin-Garcia A.P., Franco A.A., Albendin G., Arellano J. M., Rodriguez-Barroso R., Goello M.D, Quiroga J.M., Cabello J.F., Prado I.I. and Malta, E. (2023).

Microplastic in industrial aquaculture: Occurrence in the aquatic environment, feed and organisms (*Dicentrarchus labrax*) Science of the Total Environment 904 (2023) 166774

FAO, (2017). Microplastics in fisheries and aquaculture.

FAO, (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in action, Rome.

Free, C.M., Jensen, O.P., Mason, S.A., Eriksen, M., Williamson, N.J. and Boldgiv, B. (2014). High-levels of microplastic pollution in a large, remote, mountain lake. Mar. Pollut. Bull., 85(1): 156-163.

Hanachi, P., Karbalaei, S., Walker, T.R., Cole, M. and Hosseini, S.V. (2019). Abundance and properties of microplastics found in commercial fish meal and cultured common carp (Cyprinus carpio). Environ. Sci. Pollut. Control Ser. 26 (23), 23777e23787.

Harmon, S.M. (2018). Chapter 8- the effects of microplastic pollution on aquatic organisms. In: Zeng, E.Y. (Ed.), Microplastic Contamination in Aquatic Environments. Elsevier, pp. 249e270.

Hartmann, N.B., Huffer, T., Thompson, R.C., Hassellov, M., Verschoor, A., Daugaard, A.E., Rist, S., Karlsson, T., Brennholt, N., Cole, M., Herrling, M.T., Hess, M.C., Ivleva, N.P., Lusher, A.L. and Wagner, M. (2019). Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. Environ. Sci. Technol. 53, 4678–4679.

Hidalgo-Ruz, V., Gutow, L., Thompson, R.C. and Thiel, M. (2012). Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ. Sci. Technol., 46(6): 3060-3075.

Iheanacho, S., Miracle, O., Bhuyan, M. S. and Ogunji, J. (2023). Microplastic Pollution: An emerging contaminant in aquaculture, Aquaculture and Fisheries 8 (2023) 603–616.

Jambeck, J. (2015). Plastic waste inputs from land into the ocean. Science 347, 768–771.

Jensen, G.L. and Zajicek, P. W. (2008). Best Management Practice Programs and Initiatives in the United States. In C.S Tucker & J.A. Hargreaves, eds. Environmental Best Management Practices for Aquaculture, Chapter 4, Oxford, UK, Wiley-Blackwell. doi: 10.1002/9780813818672.ch4.

Kedzierski, M., Cirederf-Boulant, D., Palazot, M., Yvin, M. and Bruzaud, S. (2023). Continents of plastic: an estimate of the stock of microplastics in agricultural soils. Sci. Total Environ. 880, 163294 https://doi.org/10.1016/j.scitotenv.2023.163294.

Klein, S., Worch, E. and Knepper, T.P. (2015). Occurrence and spatial distribution of microplastics in river shore sediments of the Rhine-Main area in Germany. Environ. Sci. Technol., 49(10): 6070-6076.

Kunz, A., Schneider, F., Anthony, N. and Lin, H.T. (2023). Microplastics in rivers along an urban-rural gradient in an urban agglomeration: correlation with land use, potential sources and pathways. Environ. Pollut. 321, 121096 https://doi.org/10.1016/j.envpol.2023.121096.

Lebreton, L.C.M. and Borrero, J.C. (2013). Modeling the transport and accumulation floating debris generated by the 11 March 2011 Tohoku tsunami. Mar. Pollut. Bull., 66(1): 53-58.

Lebreton LCM, Van der Zwet J, Damsteeg J.W. (2017). River plastic emissions to the world's oceans. Nat Commun 8:15611.

Li, W.C. and Fok, L. (2016). Plastic waste in the marine environment: a review of sources, occurrence and effects. Sci Total Environ 566:333–349.

Liu, F., Vianello, A. and Vollertsen, J. (2019). Retention of Microplastics inSediments of Urban and Highway Stormwater Retention Ponds.Environ. Pollut., 255, 113335.

Lusher, A. (2015). Microplastics in the marine environment: distribution, interactions and effects. In M. Bergmann, L. Gutow, L. & M. Klages, eds. Marine Anthropogenic Litter, pp. 245-307. Cham, Switzerland, Springer International Publishing.

Lusher, A., Welden, N., Sobral, P. and Cole, M. (2017). Sampling, isolating and identifying microplastics ingested by fish and invertebrates. Anal. Methods, 9: 1346-1360.PlasticsEurope (2023). *An Analysis of European Plastics Production, Demand and Waste Data: Plastics – The Facts*. Available online at: https://www.plasticseurope.org/en/resources/market- data/ (accessed 17 December 17, 2020).

Lv, W., Zhou, W., Lu, S., Huang, W., Yuan, Q., Tian, M., Lv, W.and He, D. (2019). Microplastic pollution in rice-fish co-culture system: a report of three farmland stations in Shanghai, China. Sci. Total Environ. 652, 1209–1218.

Lv, W., Yuan, Q., He, D., Lv, W. and Zhou, W. (2020). Microplastic contamination caused by different rearing modes of

Asian swamp eel (Monopterus albus). Aquacult. Res. 51 (12), 5084e5095.

Mathalon, A. and Hill, P. (2014). Microplastic fibers in the intertidal ecosystem surrounding Halifax harbor, Nova Scotia. Mar. Pollut. Bull. 81 (1), 69e79.

Piehl, S., Leibner, A., Löder, M. G. J., Dris, R., Bogner, C. and Laforsch, C. (2018). Identification and Quantification of Macro-andMicroplastics on an Agricultural Farmland. Sci. Rep., 8, 17950.

Plasticseurope, (2023). Plastics - the Facts 2023 an Analysis of European Plastics Production, Demand and Waste Data.

Production, Demand and Waste Data.Priscilla, V. and Patria, M.P. (2019). Comparison of microplastic abundance in aquaculture ponds of milkfish chanos chanos (forsskål,1775) at Muara kamal and Marunda, jakarta bay. IOP Conf. Ser. Earth Environ. Sci. 404, 012027.

Rezania, S., Park, J., Md Din, M.F., Mat Taib, S., Talaiekhozani, A. and Yadav, K. (2018). Microplastics pollution in different aquatic environments and biota: a review of recent studies. Mar. Pollut. Bull. 133, 191e208.

Rochman, C. M., Tahir, A., Williams, S. L., Baxa, D. V., Lam, R., Miller, J. T., Miller, J. T., Teh, F.-C., Werorilangi, S., and Teh, S. J. (2015). Anthropogenic debris in seafood: Plastic debris and fibers from textiles in fish and bivalves sold for human consumption. *Scientific Reports, 5,* Article 14340.

Schmidt, C., Krauth, T. and Wagner, S. (2017). Export of plastic debris by rivers into the sea. Environ. Sci. Technol. 51, 12246–12253.

Statista, (2018) https://www.statista.com/statistics/282732/global-production-of-plasticssince-1950/. Accessed April 2018.

Tanaka, K. & Takada, H. (2016). Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. Sci. Rep., 6: 34351. doi: 10.1038/ srep34351.

Thompson, R.C. (2015). Microplastics in the marine environment: sources, consequences and solutions. In: Marine Anthropogenic Litter. Springer International Publishing, Cham, pp 185–200.

Veerasingam, S., Ranjani, M., Venkatachalapathy, R., Bagaev, A., Mukhanov, V., Litvinyuk, D., Mugilarasan, M., Gurumoorthi, K., Guganathan, L., Aboobacker, V.M. and Vethamony, P. (2020). Contributions of Fourier transform infrared spectroscopy in microplastic pollution research: A review. Critical Reviews in Environmental Science and Technology, 1-63.

Yong, C.Q.Y., Valiyaveetill, S. and Tang, B.L. (2020). Toxicity of microplastics and nanoplastics in mammalian systems. Int. J. Environ. Res. Publ. Health 17 (5).

Zhou, A., Zhang, Y., Xie, S., Chen, Y., Li, X. and Wang, J. (2020). Microplastics and their potential effects on the aquaculture systems: a critical review. Rev. Aquacult. 13 (1), 719e733.

CHAPTER V

Adaptive Responses of Fish to Fishing Pressure

Hasan CERİM
Özgen YILMAZ

1. INTRODUCTION

In this chapter, information is provided on how fish respond to environmental factors, particularly the responses caused by fishing. A simple introductory section is presented to help understand the subject, with an emphasis on the plasticity caused by fishing. Then, examples from studies on fishery-induced changes are provided. While reading the chapter, it should be noted that some studies were conducted in the wild, while others were indoor experiments. The phenotypic changes reported in empirical studies are approximately four times greater than those observed in modelling studies (Audzijonyte, Kuparinen & Fulton, 2013).

2. PHENOTYPIC PLASTICITY

The phenotype of an organism is the sum of observable traits that reflect its genotype. An organism's genotype (primarily DNA and RNAs) becomes "expressed" through the combination of macromolecules (proteins, etc.) and other structural means, eventually turning into qualitative (pigmentation, hormone production, etc.) and quantitative (number of pigment cells per unit area, amount of a specific hormone in blood during reproduction period, etc.) characteristics of it. The genetic material is mostly durable to the changes (through mutation, recombination, natural selection, gene flow). However, the dynamic nature of phenotype dictates traits to change with the effect of genotype, environmental conditions, and their interactions (Schulze & McMahon, 2004; Winawer, 2006).

The phenotypic evolution is an extension of phenotypic variation, and phenotypic variation arises from the organism's genes and its external environment (Lewontin, 2000; Fusco, 2001). This phenotypic response to environmental conditions might greatly vary showing organism's capability of phenotypic plasticity (Garland & Kelly, 2006). Although there are different approaches to defining the plasticity such as metabolic approach (Kirschner & Gerhardt, 2005), developmental approach, which includes the concept of totipotency, and phenotypic plasticity (Huneman, 2013), the widely accepted definition is genotypic capability of an organism to produce different phenotypes under varying environmental conditions (Skipper, Weiss & Gray, 2010; Kelly, Panhuis & Stoehr, 2012; Sommer, 2020).

Aquatic habitats represent a complex of environmental variables such as dissolved oxygen levels, temperature, light, pH, food, salinity, and these variables affect different organs, structures and behaviour of fishes leading to the observable phenotypic plasticity. The more heterogeneous the habitat, the more prone the fish are to exhibit phenotypic plasticity (Meyer, 1987; Claiborne & Evans, 2006; Whitehead, 2010 in Kelly, Panhuis & Stoehr, 2012).

The epigenetic and ontogenic changes during the development and life-history of organisms has been the scope of many studies since the concept was introduced by Bradshaw (1965). The fish are no expection here to be the subject for the studies about the concept.

In their study, Gamperl & Farrell (2004) investigated the effect of environmental changes on cardiac plasticity of fishes. It was suggested that athletic species have more powerful heart activity compared to sedentary species, thus pointing out that cardiac structures of fish are responsive to external changes like oxygen levels, in short and long terms. According to Crispo & Chapman (2010), gill size varies with low-oxygen treatment in *Pseudocrenilabrus multicolor victoriae*, and a larger gill area under low oxygen conditions prevails in response. As for the brain of fish, a similar result to gill plasticity was observed, suggesting that high-oxygen concentrations yield a heavier brain mass than low-oxygen concentrations.

Environmental factors can affect the neural and sensory structures, and the cognitive capability of fish (Knudson, 2004). The studies on *Gasterosteus aculeatus*' pond and river inhabiting individuals showed that those living in ponds prefer stable landmarks while river dwelling specimens navigate relying on the directions. Because the environmental stability or instability determines the presence of landmarks (Girvan & Braithwaite, 1998; Girvan & Braithwaite, 2000). The degree of environmental stimuli can trigger neural plasticity; for example, small brains are observed to be the result of low-level stimulants (Mayer et al., 2011).

Koganti, Yao & Cleveland (2021) stated that miRNAs and DNA methylation play an important role in muscle plasticy in fish. The variations in these underlying expression mechanisms enhance the epigenetic factors leading to faster muscle growth. Guderley & Johnston (1996), in their study, showed that the properties of mitochondria isolated from sculpin (*Myoxocephalus scorpius*) red muscle were markedly altered by thermal acclimation. According to their results, cold acclimation virtually doubled maximal rates of pyruvate oxidation at all experimental temperatures.

It was stated that species sharing their habitat with predators (*Carassius carassius – Esox lucius*) are more prone to develop deeper bodies, as this type of body shape is more effective in creating burst swimming (Brönmark & Peterson, 1994; Nilsson, Brönmark & Petterson, 1995; Domenici et al., 2008). The areas with high flow speed force fishes to exhibit more frequent tail beats (Bainbridge, 1958). A behavioural perspective at this point suggests that fishes with low swimming speeds would prefer areas with low flow (Binning et al., 2015). Because the interactions between genetic composition and environmental factors, and their effects on plasticity are intertwined it is difficult to assert rules that conclude with fixed and expected results. An example of this is the effect of increasing temperatures on swimming performance, which can be enhancing (Claireaux, Couturier & Groison, 2006; Claireaux et al., 2007) or debilitating (Wilson et al., 2001; Johansen & Jones, 2011) for different species.

3. FISHERIES-INDUCED CHANGES IN FISH STOCKS

Probabilistic Maturation Reaction Norms (PMRNs) are tools used in evolutionary biology and ecology to describe the probability that an individual organism will mature at a given age and size, considering the influence of various environmental and genetic factors (Heino, Dieckmann & Godø, 2002; Barot et al., 2004; Heino and Dieckmann, 2008).

The phenotypic composition of exploited fish stocks is being affected by commercial and recreational fishing, especially for traits associated with life histories and reproduction (Hard et al., 2008; Enberg et al., 2009; Enberg et al., 2012; Heino et al., 2013; Jørgensen et al., 2007 in Hollins et al., 2018).

Genetic changes caused by harvesting in natural populations can impact population productivity, recovery, and persistence (Bowles et al., 2020). Since the late 1970s, the issue of whether genetic variation in fished populations can be caused by sufficiently high fishing mortality (whether selective or not) has been on the agenda and has garnered significant interest (Hutchings & Kuparinen, 2020).

Fisheries-induced evolution can be achieved through selective capture of fish based on specific traits, such as body size, leading to changes in character abundance in the remaining population (Cooke et al., 2017). The potential for evolutionary changes in fish populations is possible due to non-random mortality associated with commercial and recreational fisheries (Hessenauer et al., 2015). The stocks exploited are at risk of high mortalities due to commercial fisheries. Emerged selection pressure leads to evolution in growth rate, age and size at maturation, and reproductive output (Andersen & Brander, 2009; Wheeler et al., 2009). The increase in exploitation, from pristine to fully exploited conditions, result in an increase in somatic growth and adult life spans, and a reduction in age at maturity (Wilson et al., 2019). From 1970s, total egg production of the North Sea plaice decreased by a factor 7-8 in 1999-2000 due to increase in fishing mortality (Rijnsdorp, Van Damme & Godø, 2010). In the first maturation, age and size of *Solea solea* has significantly shifted towards younger age and smaller size (Mollet, Kraak & Rijnsdorp 2007). Similarly, *Pleuronectes platessa* has the same tendency in the North Sea (Grift et al., 2003). Moreover, the mean age at first spawning of Northeast Arctic cod has been decreased about 3 years from 1940s until 2000s (Heino, Dieckmann & Godo, 2000). On the other hand, the population's sensitivity to climate variability can be increased due to changes in the reproductive cycle caused by fishing (e.g. Cubillos, Claramunt & Castro, 2014).

Industrial fishing could be altering fish's tendency to school (Guerra et al., 2020). Trawling has the potential to induce both direct selection and indirect selection on a variety of fish behaviours, potentially leading to evolution over time (Crespel et al., 2021). The evolution caused by fisheries is consistent with the observations of changes in maturation, reproductive investment, and growth (Van Walraven et al., 2010). Different harvest regimes and size selective fishing result in different growth rates, size at maturation and fecundity (Diaz Pauli, 2012). Large-size-fish-harvest regime leads to enhanced reproductive performance early in life for compensation of increased mortality of adult individuals (e.g.; Sbragaglia et al., 2019a). Depending on selectivity, gill nets may lead to the evolution of delayed maturation and baited lines to the evolution of slower growth (Boukal et al., 2008). The genetics of individual growth seems to be significantly influenced by size-selective fishing (Nusslé, Bornand & Wedekind 2009). The evolutionary consequences of intensive fishing have an effect on size- and age-distributions and increase in juvenile growth rate (Pukk et al., 2013). For example, If the harvest rate on biomass is between 5% and 15%, yield is high and harvest-induced evolutionary changes remain small. Intensive harvesting reduces yield and causes evolutionary changes in brook charr (*Salvelinus fontinalis*) (Okamoto et al., 2009).

Targeting large fish could have a negative impact on their growth and life-history traits (maturation schedules and growth rates), leading to strong plastic and evolutionary changes (Wang & Höök, 2009). Consistent body shape selection in exploited populations, genetic changes could be induced relatively quickly (Alós et al., 2014). The loss of genetic diversity is greater when fishing with size-selective gear compared to that of size-independent gear (Therkildsen et al., 2019).

Besides the decrease in population size due to intense fishing and anthropogenic influences, strong declines in matures and recruits may lead to almost irreversible genetic changes in life-history traits (Cuveliers et al., 2011). While fisheries-induced evolution affects biomass lightly, it considerably effects maturation age, spawning stock biomass, and recruitment (Enberg et al., 2009). Somatic growth decreases after maturation and decrease in size at maturation leads to a population that small individuals found in. Moreover, smaller fish has lower fecundity than larger fish, thus low recruitment occurs and this potentially results in reduce in yield (Reithe, 2008). It has been observed that populations with older and larger individuals have a higher reproductive capacity than populations with younger and smaller individuals, and this difference increases with reproductive lifespan (Venturelli, Shuter & Murphy, 2009). Even when harvesting is stopped, it can be challenging to reverse mentioned changes (Dunlop, Eikeset & Stenseth, 2015; Sbragaglia et al., 2019b). However, populations have the inherent capacity to recover from genetic evolution caused by fishing (Conover, Munch & Arnott, 2009). Fishing effort and selectivity determine the nature and extent of the change through fisheries-induced evolution. By implementing a dome-shaped exploitation pattern that protects large fish, adverse evolutionary effects can be minimized or even reversed (Mollet et al., 2016). Populations exposed to fisheries-induced evolution recover themselves rapidly following cessation of overfishing. However, in the mentioned recovery, magnitude of depletion and natural mortality are more important than fisheries-induced evolution (Hutchings & Kuparinen, 2020). On the other hand, the reference points in fishery management used such as the limit (Blim), the precautionary reference points (Bpa) for spawning stock biomass and target reference point for fishing mortality, F0.1, are affected by fishery-induced changes (Heino et al., 2013). When stocks are managed properly, evolutionary changes actually lead to an increase in economic yield due to faster growth and earlier maturation, which boosts the stock's productivity (Eikeset et al., 2013), and if evolution is considered in fishery in management, profits can increase in 29-34% (Faig, 2015).

Also, fishery has different effects on fish behaviours such as predation on all lower trophic levels by regime shift (Savenkoff et al., 2007), increase in biomass in different trophic levels and altering the species composition (Bundy, 2005), migration ability (Jørgensen et al., 2008; Morita, 2019; Wang et al., 2022). Another effect of fishery, interestingly, sperm transfer capacity of male Chilean crabs (*Metacarcinus edwardsii*) which is under high exploitation is affected by fisheries, reversedly (Pardo et al., 2015). On the other hand, in the red king crab (*Paralithodes camtschaticus*), change in size composition of female, males and reduced mean fecundity due to fishing, has negative impact on the potential egg production of the stock (Hjelset, 2014). According to the researchers, hermaphrodite species are also affected (maturations length and sex change length) by size-selective exploitation (Sattar, Jørgensen & Fiksen, 2008; Matthias, St. Mary & Ahrens, 2019).

Based on the literature review, fish populations react to human intervention in addition to environmental conditions. One of the most important biological elements in the management of fish stocks from sustainable sources is undoubtedly reproductive behavior. It is important to increase reproductive outputs and subsequently to increase the recruitment. In this process, after the numerical increase, the amount of yield to be obtained from the stock will also be increased with growth. Therefore, it is important to constantly observe the reactions of stocks to fishing in the management of fisheries and to create management strategies according to the current situation.

REFERENCES

Alós, J., Palmer, M., Linde-Medina, M. & Arlinghaus, R. (2014). Consistent size-independent harvest selection on fish body shape in two recreationally exploited marine species. Ecology and Evolution, 4 (11), 2154-2164.

Andersen, K. H., & Brander, K. (2009). Expected rate of fisheries-induced evolution is slow. Proceedings of the National Academy of Sciences, 106 (28), 11657-11660.

Audzijonyte, A., Kuparinen, A. & Fulton, E. A. (2013). How fast is fisheries-induced evolution? Quantitative analysis of modelling and empirical studies. Evolutionary Applications, 6 (4), 585-595.

Bainbridge, R. (1958). The speed of swimming of fish as related to size and to the frequency and amplitude of the tail beat. Journal of Experimental Biology, 35 (1), 109-133.

Barot, S., Heino, M., O'Brien, L. & Dieckmann, U. (2004). Estimating reaction norms for age and size at maturation when age at first reproduction is unknown. Evolutionary Ecology Research, 6 (6), 659-678.

Binning, S. A., Ros, A. F., Nusbaumer, D. & Roche, D. G. (2015). Physiological plasticity to water flow habitat in the damselfish, Acanthochromis polyacanthus: linking phenotype to performance. PLoS One, 10(3), e0121983.

Boukal, D. S., Dunlop, E. S., Heino, M. & Dieckmann, U. (2008). Fisheries-induced evolution of body size and other life history traits: the impact of gear selectivity. ICES CM 2008/F:07.

Bowles, E., Marin, K., Mogensen, S., MacLeod, P. & Fraser, D. J. (2020). Size reductions and genomic changes within two generations in wild walleye populations: associated with harvest?. Evolutionary Applications, 13 (6), 1128-1144.

Bradshaw, A. D. (1965). Evolutionary significance of phenotypic plasticity in plants. Advances in Genetics, 13, 115-155.

Brönmark, C. & Pettersson, L. B. (1994). Chemical cues from piscivores induce a change in morphology in crucian carp. Oikos, 396-402. https://doi.org/10.2307/3545777

Bundy, A. (2005). Structure and functioning of the eastern Scotian Shelf ecosystem before and after the collapse of groundfish stocks in the early 1990s. Canadian Journal of Fisheries and Aquatic Sciences, 62 (7), 1453-1473.

Claiborne, J. B., & Evans, D. H. (Eds.). (2006). The physiology of fishes. CRC, Taylor & Francis.

Claireaux, G., Couturier, C. & Groison, A. L. (2006). Effect of temperature on maximum swimming speed and cost of transport in juvenile European sea bass (*Dicentrarchus labrax*). Journal of Experimental Biology, 209 (17), 3420-3428.

Claireaux, G., Handelsman, C., Standen, E. & Nelson, J. A. (2007). Thermal and temporal stability of swimming performance in the European sea bass. Physiological and Biochemical Zoology, 80 (2), 186-196.

Conover, D. O., Munch, S. B. & Arnott, S. A. (2009). Reversal of evolutionary downsizing caused by selective harvest of large fish. Proceedings of the Royal Society B: Biological Sciences, 276 (1664), 2015-2020.

Cooke, E. L., Wilson, A. D., Elvidge, C. K. & Cooke, S. J. (2017). Does capture method or the presence of aquatic protected areas influence the selective harvest of behavioural types in largemouth bass?. Canadian Journal of Fisheries and Aquatic Sciences, 74 (8), 1151-1157.

Crespel, A., Miller, T., Rácz, A., Parsons, K., Lindström, J. & Killen, S. (2021). Density influences the heritability and genetic correlations of fish behaviour under trawling-associated selection. Evolutionary Applications, 14 (10), 2527-2540.

Crispo, E. & Chapman, L. J. (2010). Geographic variation in phenotypic plasticity in response to dissolved oxygen in an African cichlid fish. Journal of Evolutionary Biology, 23 (10), 2091-2103.

Cubillos, L. A., Claramunt, G. & Castro, L. R. (2014). Simulation of fishery-induced changes on the reproductive cycle of common sardine, Strangomera bentincki, off central southern Chile. Fisheries Research, 160, 103-111.

Cuveliers, E. L., Volckaert, F. A. M., Rijnsdorp, A. D., Larmuseau, M. H. D. & Maes, G. E. (2011). Temporal genetic stability and high effective population size despite fisheries-induced life-history trait evolution in the North Sea sole. Molecular Ecology, 20 (17), 3555-3568.

Diaz Pauli, B. (2012). Contemporary evolution caused by fisheries: Contributions from experimental studies. Doctoral thesis, University of Bergen.

Domenici, P., Turesson, H., Brodersen, J. & Brönmark, C. (2008). Predator-induced morphology enhances escape locomotion in crucian carp. Proceedings of the Royal Society B: Biological

Sciences, 275 (1631), 195-201. https://doi.org/10.1098/rspb.2007.1088

Dunlop, E. S., Eikeset, A. M. & Stenseth, N. C. (2015). From genes to populations: How fisheries-induced evolution alters stock productivity. Ecological Applications, 25 (7), 1860-1868.

Eikeset, A. M., Richter, A., Dunlop, E. S., Dieckmann, U. & Stenseth, N. C. (2013). Economic repercussions of fisheries-induced evolution. Proceedings of the National Academy of Sciences, 110 (30), 12259-12264.

Enberg, K., Jørgensen, C., Dunlop, E. S., Heino, M. & Dieckmann, U. (2009). Implications of fisheries-induced evolution for stock rebuilding and recovery. Evolutionary applications, 2 (3), 394-414.

Enberg, K., Jørgensen, C., Dunlop, E. S., Heino, M. & Dieckmann, U. (2009). Implications of fisheries-induced evolution for stock rebuilding and recovery. Evolutionary Applications, 2 (3), 394–414. https://doi.org/10.1111/j.1752-4571.2009.00077.x

Enberg, K., Jørgensen, C., Dunlop, E. S., Varpe, Ø., Boukal, D. S., Baulier, L., Eliassen, S. & Heino, M. (2012). Fishing-induced evolution of growth: Concepts, mechanisms and the empirical evidence. Marine Ecology, 33 (1), 1–25. https://doi.org/10.1111/j.1439-0485.2011.00460.x

Faig, A. (2015). The economic gains to accounting for fisheries-induced evolution.

Fusco, G. (2001). How many processes are responsible for phenotypic evolution?. Evolution & Development, 3 (4), 279-286. Doi:10. 1046/j.1525-142x.2001.003004279.x

Gamperl, A. K. & Farrell, A. P. (2004). Cardiac plasticity in fishes: environmental influences and intraspecific differences. Journal of Experimental Biology, 207 (15), 2539-2550.

Garland Jr, T. & Kelly, S. A. (2006). Phenotypic plasticity and experimental evolution. Journal of Experimental Biology, 209 (12), 2344-2361. Doi: 10.1242/jeb.02244

Girvan, J. R. & Braithwaite, V. A. (1998). Population differences in spatial learning and memory in threespined sticklebacks. Proceedings of the Royal Society B, 265, 913–918.

Girvan, J. R. & Braithwaite, V. A. (2000). Orientation behaviour in sticklebacks: learned or inherited?. Behaviour, 137, 833–843.

Grift, R. E., Rijnsdorp, A. D., Barot, S., Heino, M. & Dieckmann, U. (2003). Fisheries-induced trends in reaction norms for maturation in North Sea plaice. Marine Ecology Progress Series, 257, 247-257.

Guderley, H. & Johnston, I. A. (1996). Plasticity of fish muscle mitochondria with thermal acclimation. Journal of Experimental Biology, 199 (6), 1311-1317.

Guerra, A. S., Kao, A. B., McCauley, D. J. & Berdahl, A. M. (2020). Fisheries-induced selection against schooling behaviour in marine fishes. Proceedings of the Royal Society B, 287 (1935), 20201752.Doi: http://dx.doi.org/10.1098/rspb.2020.1752

Hard, J. J., Gross, M. R., Heino, M., Hilborn, R., Kope, R. G., Law, R. & Reynolds, J. D. (2008). Evolutionary consequences of fishing and their implications for salmon. Evolutionary

Applications, 1 (2), 388–408. Doi: https://doi.org/10.1111/j.1752-4571.2008.00020.x

Heino, M. & Dieckmann, U. (2008). Detecting fisheries-induced life-history evolution: an overview of the reaction norm approach. Bulletin of Marine Science, 83 (1), 69-93.

Heino, M., Baulier, L., Boukal, D. S., Ernande, B., Johnston, F. D., Mollet, F. M., Pardoe, H., Therkildsen, N. O., Uusi-Heikkilä, S., Vainikka, A., Arlinghaus, R., Dankel, D. J., Dunlop, E. S., Eikeset, A. M., Enberg, K., Engelhard G. H., Jørgensen, C., Laugen, A. T., Matsumura, S., Nusslé, S., Urbach, D., Whitlock, R., Rijnsdorp, A. D., and Dieckmann, U. (2013). Can fisheries-induced evolution shift reference points for fisheries management? – ICES Journal of Marine Science, 70, 707–721. Doi: https://doi.org/10.1093/icesjms/fst077

Heino, M., Dieckmann, U. & Godo, O. (2000). Shrinking cod: fisheryinduced change in an oceanic stock. IASA Options Spring, 6-9.

Heino, M., Dieckmann, U. & Godø, O. R. (2002). Estimating reaction norms for age and size at maturation with reconstructed immature size distributions: a new technique illustrated by application to Northeast Arctic cod. – ICES Journal of Marine Science, 59, 562–575.

Hessenauer, J. M., Vokoun, J. C., Suski, C. D., Davis, J., Jacobs, R. & O’Donnell, E. (2015). Differences in the metabolic rates of exploited and unexploited fish populations: a signature of recreational fisheries induced evolution?. PloS one, 10 (6), e0128336.

Hjelset, A. M. (2014). Fishery-induced changes in Norwegian red king crab (Paralithodes camtschaticus) reproductive potential. ICES Journal of Marine Science, 71 (2), 365-373.

Hollins, J., Thambithurai, D., Koeck, B., Crespel, A., Bailey, D. M., Cooke, S. J., Lindström, J., Parsons, K. J. & Killen, S.S. (2018), A physiological perspective on fisheries-induced evolution Evolutionary applications, 11(5), 561-576 Doi: https://doi.org/10.1111/eva.12597

Huneman, P. (2013). Plasticity. in Dubitzky, W., Wolkenhauer, O., Cho, K. H., & Yokota, H. (Eds.). (2013). Encyclopedia of systems biology (Vol. 402). New York, NY, USA: Springer. p. 1717.

Hutchings, J. A. & Kuparinen, A. (2020). Implications of fisheries-induced evolution for population recovery: Refocusing the science and refining its communication. Fish and Fisheries, 21 (2), 453-464.

Johansen, J. L. & Jones, G. P. (2011). Increasing ocean temperature reduces the metabolic performance and swimming ability of coral reef damselfishes. Global Change Biology, 17 (9), 2971-2979.

Jørgensen, C., Dunlop, E. S., Opdal, A. F. & Fiksen, Ø. (2008). The evolution of spawning migrations: state dependence and fishing-induced changes. Ecology, 89 (12), 3436-3448.

Jørgensen, C., Enberg, K., Dunlop, E. S., Arlinghaus, R., Boukal, D. S., Brander, K., Ernande, B., Gardmark, A., Johnston, F., Matsumura, S., Pardoe, H., Raab, K., Silva, A., Vainikka, A., Dieckmann, U., Heino, M., & Rijnsdorp, A. D. (2007). Ecology:

managing evolving fish stocks. Science (New York, N.Y.), 318(5854), 1247–1248. https://doi.org/10.1126/science.1148089

Kelly, S. A., Panhuis, T. M. & Stoehr, A. M. (2012). Phenotypic plasticity: molecular mechanisms and adaptive significance. Comprehensive Physiology, 2 (2), 1417-1439.

Kirschner, M. W. & Gerhart, J. C. (2005). The plausibility of life: Resolving Darwin's dilemma. Yale University Press. 336 pp.

Knudson, E. I. (2004). Sensitive periods in the development of the brain and behavior. Journal of Cognitive Neuroscience 16, 1412–1425.

Koganti, P., Yao, J. & Cleveland, B. M. (2021). Molecular mechanisms regulating muscle plasticity in fish. Animals, 11 (1), 61.

Lewontin, R. (2000). The triple helix: gene, organism and environment. Cambridge, MA: Harvard University Press.

Matthias, B. G., St. Mary, C. M. & Ahrens, R. N. (2019). Evolutionary and demographic impacts of sex change rules and size-selective exploitation on sequential hermaphrodites. ICES Journal of Marine Science, 76 (7), 2140-2149.

Mayer, I., Meager, J., Skjæraasen, J. E., Rodewald, P., Sverdrup, G. & Ferno, A. (2011). Domestication causes rapid changes in heart and brain morphology in Atlantic cod (Gadus morhua). Environmental Biology of Fishes, 92, 181–186.

Meyer A. (1987). Phenotypic plasticity and heterochrony in *Cichlasoma managuense* (Pisces, Chichlidae) and their implications for speciation in Cichlid fishes. Evolution, 41 (6), 1357-1369.

Mollet, F. M., Kraak, S. B. & Rijnsdorp, A. D. (2007). Fisheries-induced evolutionary changes in maturation reaction norms in North Sea sole Solea solea. Marine Ecology Progress Series, 351, 189-199.

Mollet, F. M., Poos, J. J., Dieckmann, U. & Rijnsdorp, A. D. (2016). Evolutionary impact assessment of the North Sea plaice fishery. Canadian Journal of Fisheries and Aquatic Sciences, 73 (7), 1126-1137.

Morita, K. (2019). Earlier migration timing of salmonids: an adaptation to climate change or maladaptation to the fishery?. Canadian Journal of Fisheries and Aquatic Sciences, 76 (3), 475-479.

Nilsson, P. A., Brönmark, C. & Pettersson, L. B. (1995). Benefits of a predtor-induced morphology in crucian carp. Oecologia, 104, 291-296. Doi: https://doi.org/10.1007/bf00328363

Nusslé, S., Bornand, C. N. & Wedekind, C. (2009). Fishery-induced selection on an Alpine whitefish: quantifying genetic and environmental effects on individual growth rate. Evolutionary Applications, 2 (2), 200-208.

Okamoto, K. W., Whitlock, R., Magnan, P. & Dieckmann, U. (2009). Mitigating fisheries-induced evolution in lacustrine brook charr (Salvelinus fontinalis) in southern Quebec, Canada. Evolutionary Applications, 2 (3), 415-437.

Pardo, L. M., Rosas, Y., Fuentes, J. P., Riveros, M. P. & Chaparro, O. R. (2015). Fishery induces sperm depletion and reduction in male reproductive potential for crab species under male-biased harvest strategy. PLoS One, 10 (3), e0115525.

Pukk, L., Kuparinen, A., Järv, L., Gross, R. & Vasemägi, A. (2013). Genetic and life-history changes associated with fisheries-induced population collapse. Evolutionary Applications, 6 (5), 749-760.

Reithe, S. (2008). The cost of fisheries induced evolution. An example using data for North-East Atlantic cod.

Rijnsdorp, A. D., Van Damme, C. J. & Witthames, P. R. (2010). Implications of fisheries-induced changes in stock structure and reproductive potential for stock recovery of a sex-dimorphic species, North Sea plaice. ICES Journal of Marine Science, 67 (9), 1931-1938.

Sattar, S. A., Jørgensen, C. & Fiksen, Ø. (2008). Fisheries-induced evolution of energy and sex allocation. Bulletin of Marine Science, 83 (1), 235-250.

Savenkoff, C., Castonguay, M., Chabot, D., Hammill, M. O., Bourdages, H. & Morissette, L. (2007). Changes in the northern Gulf of St. Lawrence ecosystem estimated by inverse modelling: evidence of a fishery-induced regime shift?. Estuarine, Coastal and Shelf Science, 73 (3-4), 711-724.

Sbragaglia, V., Gliese, C., Bierbach, D., Honsey, A. E., Uusi-Heikkilä, S. & Arlinghaus, R. (2019a). Size-selective harvesting fosters adaptations in mating behaviour and reproductive allocation, affecting sexual selection in fish. Journal of Animal Ecology, 88 (9), 1343-1354.

Sbragaglia, V., López-Olmeda, J. F., Frigato, E., Bertolucci, C. & Arlinghaus, R. (2019b). Fisheries-induced evolution of the circadian system and collective personality traits. bioRxiv, 622043.

Schulze, T. G. & McMahon, F. J. (2004). Defining the phenotype in human genetic studies: Forward genetics and reverse phenotyping. Human Heredity, 58 (3–4), 131–138.

Skipper, M., Weiss, U. & Gray, N. (2010). Plasticity. Nature, 465 (7299), 703. https://doi.org/10.1038/465703a

Sommer, R. J. (2020). Phenotypic plasticity: from theory and genetics to current and future challenges. Genetics, 215 (1), 1-13.

Therkildsen, N. O., Wilder, A. P., Conover, D. O., Munch, S. B., Baumann, H. & Palumbi, S. R. (2019). Contrasting genomic shifts underlie parallel phenotypic evolution in response to fishing. Science, 365 (6452), 487-490.

Van Walraven, L., Mollet, F. M., Van Damme, C. J. G. & Rijnsdorp, A. D. (2010). Fisheries-induced evolution in growth, maturation and reproductive investment of the sexually dimorphic North Sea plaice (*Pleuronectes platessa* L.). Journal of Sea Research, 64 (1-2), 85-93.

Venturelli, P. A., Shuter, B. J. & Murphy, C. A. (2009). Evidence for harvest-induced maternal influences on the reproductive rates of fish populations. Proceedings of the Royal Society B: Biological Sciences, 276 (1658), 919-924.

Wang, H. Y. & Höök, T. O. (2009). Eco-genetic model to explore fishing-induced ecological and evolutionary effects on growth and maturation schedules. Evolutionary Applications, 2 (3), 438-455.

Wang, Y., Zhou, X., Chen, J., Xie, B. & Huang, L. (2022). Climate-induced habitat suitability changes intensify fishing impacts on the life history of large yellow croaker (*Larimichthys crocea*). Ecology and Evolution, 12 (10), e9342.

Wheeler, J. P., Purchase, C. F., Macdonald, P. D. M., Fill, R., Jacks, L., Wang, H. & Ye, C. (2009). Temporal changes in maturation, mean length-at-age, and condition of spring-spawning Atlantic herring (*Clupea harengus*) in Newfoundland waters. ICES Journal of Marine Science, 66 (8), 1800-1807.

Whitehead, A. (2010). The evolutionary radiation of diverse osmotolerant physiologies in killifish (*Fundulus* sp.). Evolution, 64 (7), 2070-2085.

Wilson, K. L., De Gisi, J., Cahill, C. L., Barker, O. E. & Post, J. R. (2019). Life-history variation along environmental and harvest clines of a northern freshwater fish: Plasticity and adaptation. Journal of Animal Ecology, 88 (5), 717-733.

Wilson, R. S., Franklin, C. E., Davison, W. & Kraft, P. (2001). Stenotherms at sub-zero temperatures: thermal dependence of swimming performance in Antarctic fish. Journal of Comparative Physiology B, 171, 263-269.

Winawer, M. R. (2006). Phenotype definition in epilepsy. Epilepsy & Behaviour, 8 (3), 462–476.

CHAPTER VI

Mentoring awareness for 21ST century skills in fisheries engineering education

Huriye GÖNCÜOĞLU-BODUR
Deniz GÜNAY

"For one who embarks on a journey without a guide, a journey of two days becomes a journey of a hundred years."
-Mevlana
"We are currently preparing students for jobs that don't yet exist… using technologies that have not yet been invented in order to solve problems we don't even know are problems yet."
-Richard Riley
"We cannot solve our problems with the same thinking we used when we created them."
-Albert Einstein

As life becomes more international, multicultural and interconnected for many people in the 21st century, new skills are needed to succeed in education and the workplace. Today's technology is rich so that to compete in the global economy, workers and students must be able to solve complex problems, collaborate and communicate well with others, independently acquire new skills and knowledge, and adapt to rapidly changing conditions. These cognitive and affective abilities are called 21st century skills

(Partnership for 21st Century Skills, 2019; Ünüvar, 2023). In the business world after the 4th Industrial Revolution (Figure 1); demands for robotics and autonomous transportation, artificial intelligence and machine learning, advanced materials, biotechnology and genetics are increasing. According to the research findings, 65% of those starting primary school will work in jobs that do not exist, emphasizing the need for the 21st century skills (Uçak & Erdem, 2020; Tonga &Tonga 2022).

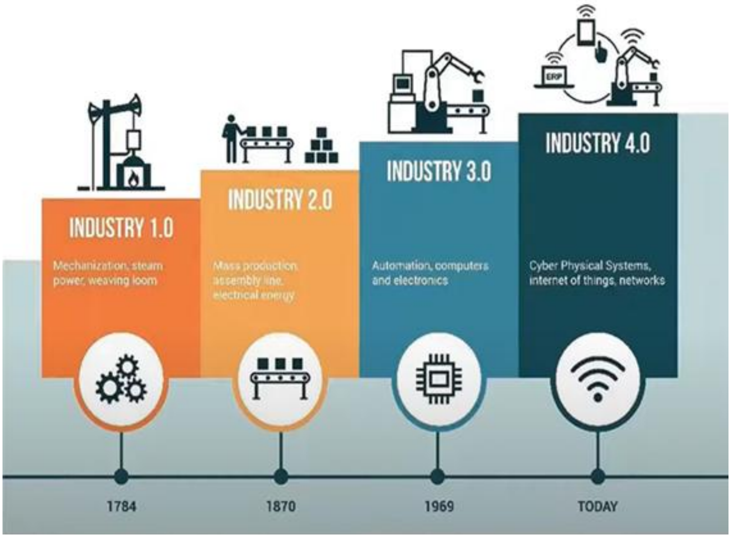

Figure 1. Historical development of industry 4.0 (Kovács et al., 2018).

21st century skills are the abilities and characteristics required to adapt to today's rapid technological and social changes, solve complex problems and be effective at a global level. These skills are important for individuals to be successful in business, education, communication and personal development (Amzaleg & Masry-Herzallah, 2022). Focusing on these skills in education, business and personal development will help individuals evaluate future opportunities more effectively (Diley et al., 2015). Future professions require thinking across disciplines. This requires people to not only approach the events they are involved in flexibly, but also to be ready to use their knowledge in different areas (Özgüzel, 2018)

Education systems today are focusing more on 21st century skills. Many of these skills have attempted to be imparted to students since the establishment of universities, but they are not effective in practice. The traditional 3Rs (reading, writing, arithmetic) skills are still important, but pedagogues and educators are emphasizing the 4Cs skills (Figure 2) such as critical thinking, creativity, communication and collaboration (Saimon et al., 2023). The new understanding of education emphasizes learning and to adapt to changing demands. Additionally, the development of non-cognitive skills such as social and emotional learning is also gaining importance. Although the integration of 21st century skills into the basic education curriculum in Turkey provides significant contributions, it needs to be addressed with a broader perspective (Hamarat, 2019).

Figure 2. P21 Framework for 21st-Century learning. (Partnership for 21st Century Skills, 2019)

Research on 21st century skills (Joynes, et al., 2019; McGunagle & Zizka, 2020; Rios et al., 2020) and reports (Burrus et al., 2013; World Economic Forum, 2021) show that there are 13 skills that the business world prioritizes. These skills are; "critical thinking", "collaboration", "communication", "problem solving", "creativity", "adaptability and flexibility", "leadership", "ethics", "multiculturalism", "self-management", "analytical thinking", "technology literacy" and "lifelong learning" (Table 1). In this context, innovative approaches are needed in educational processes to effectively impart the listed skills. These listed skills have been defined in various ways in the literature and associated with the business world (Sağır et al., 2024).

Table 1. List of 21st century skills sought by employers (Sağır et al., 2024).

Contents Resources	List of 21st Century Qualifications Required by Employers		Methods Used in the Preparation of Qualifications	Top Five Competencies in order of importance
Rios et all., 2000	Cooperation Problem Solving Communication Critical Thinking Ethic Cultural Sensitivity	Compatibility Creativity Continuous Learning Self-Management Leadership Social Intelligence	By scanning 142,000 job postings, the qualifications employers were looking for in the postings were determined and these qualifications were ranked according to their frequency.	Cooperation Problem Solving Communication Critical Thinking Ethic
McGunagle and Zizka, 2020	Self motivation Verbal Communication Cooperation Problem Solving Being proactive Decision making	Compatibility Leadership Written communication Data collection Confidence	250 human resources managers from the sector were interviewed and the following list was obtained as a result of the analysis made as a result of these interviews.	Self motivation Verbal Communication Cooperation Problem Solving Being proactive

Burrus et all, 2013	Problem Solving Fluid intelligence Teamwork Innovation Communication skills	The competencies written on the left were defined as components in the research, and more specific qualifications were defined under these components.	Using the job analysis data prepared by the USA Ministry of Labor, a principal component analysis was conducted and five basic components were determined.	Problem Solving Fluid intelligence Teamwork Innovation Communication skills
World Economic Forum, 2021	Analytical thinking Meta Learning Problem Solving Critical thinking Creativity, originality Leadership	Using technology Technology design Robustness, stress tolerance and flexibility Reasoning, comprehension ability	The list in question was created in order of frequency based on the data obtained through the Linkedin platform.	Analytical thinking Meta Learning Problem Solving Critical thinking Creativity, originality

In line with this need, it is a necessity to develop a mentoring program that is goal-oriented and includes a learning design in Fisheries Engineering education. These mentoring programs provide a dynamic learning environment, allowing for rapid development of skills and the creation of practical solutions.

Mentoring and Related Definitions

Mentoring is when an experienced and knowledgeable person helps a less experienced and knowledgeable person in a one-on-one relationship to achieve their goals (Kram, 1983; Goff & Torrance, 1999). Mentoring is an intensive developmental relationship in which a mentor provides advice and development opportunities, thereby shaping the career experiences of mentees (Eby, 1997). Integrating research and application studies into the experiences of undergraduate students within the framework of a mentoring program has become a part of higher education in many countries (Moore & Felten, 2018). Mentoring practices that contribute to a student's personal and academic development provide benefits such as improving mentee's abilities, providing developmental opportunities, creating confidence to overcome challenging tasks, and gaining guidance and consultancy (Tükeltürk & Balcı, 2014).

A mentor is a person who has experience in the mentoring process and helps the recipient in the role of a consultant, teacher, guide, protector or friend (Hinton, 2006). Mentor; they are often senior and experienced individuals who serve as role models and support younger individuals in career planning, interpersonal relationships and personal development, and increase the mentee's visibility to decision makers by providing feedback (Noe, 1988). In this relationship process, the mentor helps the mentee develop her/his own characteristics and shows her/his how to achieve these characteristics, rather than sharing experiences unilaterally (Kocabaş & Yirci, 2012). One of the definitions related to mentoring is the concept of "mentee". A mentor's friend, with whom he/she shares his/her experiences, mutually shares knowledge, and helps the person to be more successful in her/his field by supporting herself/himself, is called "Protégé or Menteé" in the literature (Gisbert, 2017). Mentees need the guidance of a more professional colleague, teacher or mentor, and want to improve their skills in areas where they are lacking (Yıldırım, 2013). The mentee, whose knowledge and experience is not sufficient and who applies or is handed over to a mentor to compensate for these deficiencies, develops under the patronage, guidance and protection of an important and wise person (Eby & Lockwood, 2005).

Types of mentoring vary from author to author. Klasen & Clutterbuck (2002), divide mentoring into formal, semi-formal and informal mentoring. While mentoring types are examined under two main headings as formal and informal mentoring in some sources, in some sources they are examined in five stages as formal, informal, situational, managerial mentoring and e-mentoring, which has come to the fore with the development of technology (Tunçay, 2014).

Types of mentoring are one-on-one mentoring, peer mentoring, group/team mentoring, reverse mentoring and self-mentoring (Crisp & Cruz, 2009). One-on-one mentoring is considered the classic and most basic mentoring model. One-to-one mentoring is defined as an older person (mentor) sharing her/his knowledge and experience with a younger person (mentee). The preferred type of mentoring in the training of new managers in the business world is one-on-one mentoring. Team or group mentoring is preferred to increase interaction and sharing. In reverse mentoring, the experienced ones are the young ones, especially in recent times the new generation (internet generation) can access information more easily and can be more experienced than the elderly in the use of computers and technology. Self-mentoring is when a person individually carries out the process on his/her own in line with certain goals. Peer mentoring involves peers with similar conditions supporting each other in the learning process. Peer mentoring practice is used more in educational institutions. The most commonly used mentoring models in university education are e-mentoring (Günay & Göncüoğlu-Bodur, 2023) and peer mentoring (Crisp & Cruz, 2009).

Knowledge and experience can be learned and put into practice more quickly from peers. In peer mentoring, the mentor increases the knowledge level and self-confidence of the peer, performs her/his job expertly and increases the confidence of the mentee in this regard. By understanding her/his importance and position, the mentee can shape his/her future more easily (Palankök, 2004). Mentors and mentees whose knowledge level increases, skills develop and self-confidence increases will have the opportunity to take stronger steps in life. In this process based on mutual interaction, the benefits of the mentoring program can be listed as follows (Rawlings, 2007; Hobson et al., 2008):

•Developing more effective problem-solving methods

•Being aware of new practices

•Providing professional development

•Increasing self-esteem

•Seeing different approaches

•Increasing job satisfaction

•Encouraging new learning

All of these benefits are themes in 21st century skills. Therefore, the basis of 21st century skills can be formed with awareness of the concept of mentoring. Thanks to the mentoring programs to be prepared at universities, the foundation of 21st century skills can be formed and a solid educational opportunity can be obtained.

Fisheries Engineering and Education

The aim of the education in the Fisheries Faculties is to equip them with the necessary information and to put them into practice in order to train technical personnel (Fisheries Engineers) who have technological knowledge in the fields of marine and inland water sciences, fisheries, fisheries processing technology and aquaculture. Education in the fishery faculty aims to conduct the necessary research and studies to identify environmental problems in the aquatic environment, problems related to fisher and fishery businesses, and to offer solutions.

There are 16 universities in Türkiye with a fisheries engineering program (Figure 3). Among these universities, the Fisheries Faculties of Ege University and Atatürk University are accredited by ZİDEK (The Association for Evaluation and Accreditation of Agricultural Engineering Educational Programs). The number of students enrolled in the Fisheries Engineering program in 2023 was 1854. The number of students graduating in 2023 was 128. This number was 145 in 2021 and 122 in 2022 (The Council of Higher Education, 2024). Despite having so many registered students, the number of graduating students is quite low and is decreasing from year to year. According to the results of the Türkiye Family Structure Survey 2021, the rate of young people in the 15-24 age group who dropped out of education (including university) despite wanting to continue their education is 7.6%. When the reasons for leaving education of young people are examined, the first reason for leaving education is economic reasons with 48.1%, followed by failure in education with 23.6% and family not giving permission with 10.8%. (TURKSTAT, 2021). Failure in university education usually occurs due to many factors such as not being able to adapt to the university and/or faculty, not being able to establish a social circle, having difficulty in classes, exam anxiety, decreasing interest in the profession, anxiety about the future. For this reason, having a peer as a guide, in other words, a mentor, can completely reverse this situation.

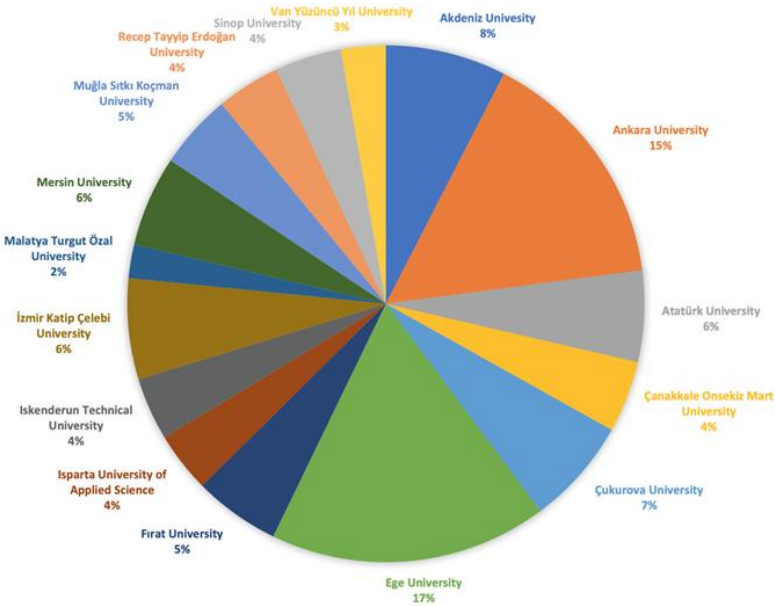

Figure.3. Percentage of students enrolled in Fisheries Engineering programs in Türkiye in 2023.

Application-oriented education such as Medicine, Nursing and Engineering involves a challenging education process. The academic, social and emotional support provided to students in this challenging education strengthens their bond with the school (Zhao & Kuh, 2004). Engineering education provides the ability to convert theoretical knowledge into practical application. In addition, it is a discipline that aims to raise individuals who are proficient in interdisciplinary work skills, in other words, compatible with teamwork, sensitive to the environment and have high awareness. Thus, students who graduate from this discipline can contribute to the positive development of civilization (Akgül et al., 2013).

Fisheries engineering, a branch of engineering, is a broad interdisciplinary field of study that includes the sustainable management of marine and inland ecosystems, the protection of aquatic resources and the development of fisheries technologies. Fisheries engineering requires a research-based approach to understand and manage the dynamic structure of ecosystems (Kimura, 2020). Therefore, it is essential for fisheries engineering candidates to have both theoretical knowledge and practical skills. However, they also need to have 21st century skills. Peer mentoring is an important learning strategy that is implemented to help students gain 21st century skills while transforming theoretical knowledge into practical skills (Topping, 2005). In field and laboratory studies, which are frequently applied in the training of Fisheries Engineer candidates, peer mentoring supports students to learn from each other and enables the development of practical skills (Boyle et al., 2010). Upper-class students providing guidance to lower-class students not only on course subjects, but also on faculty and university life increases the sense of belonging of students who are new to university life, accelerates their learning process, increases self-confidence, encourages cooperation and strengthens social ties (Falchikov, 2001). Peer mentoring programs implemented in Fisheries Faculties will not only provide many benefits to students but also to the sector in the future (Göncüoğlu-Bodur & Günay, 2023). People with strong social ties, self-confidence and high motivation can more easily acquire 21st century skills such as analytical thinking, problem solving, critical thinking and creativity. In addition, mentor students can guide less experienced students on scientific research materials and methods, helping them develop skills such as scientific literature review, data analysis, and report writing. These interactions also increase communication skills and support teamwork, contributing to the acquisition of 21st century skills.

Traditional Fisheries Engineering education cannot fully meet the requirements of Industry 4.0. Although we have passed the first quarter of the 21st century, Fisheries Engineering Education and Training in Türkiye is content-focused, curriculum-focused and unfortunately not focused on developing 21st century skills. The main reason for this is due to the competencies of the academics who design the educational programs at the university who are not up to date. Because academics come from the same traditional education system, they ignore the issue of skill development and self-updating. For example, among the 21st century skills and the skills expected by the business world are critical thinking, creativity, innovation and collaboration. For example, among the 21st century skills and the skills expected by the business world are critical thinking, creativity, innovation and collaboration. However, many higher education systems in Türkiye have an established hierarchical structure and an educational program design that is competitive, based on ranking exams, score-based and focused on in-class education. During undergraduate education, students are dependent on the academician who teaches the course. Unfortunately, 21st century skills cannot develop because the contact between them remains only on the basis of information transfer. Undergraduate students are left alone to develop these skills. If students who have not acquired 21st century skills during their education and who then become undergraduate students at university are not given the opportunity to acquire these skills at university, it is impossible to expect continuity and success in business life. This shows that fishery faculties cannot produce the graduates that the business world (fishery sector) wants and needs. Fisheries Faculties continue to train unemployed graduates or graduates who are unable to fulfil their specialization and have to work in different sectors. For these reasons, there is a need for a new educational model that includes 21st century skills for fisheries engineers. The most effective training model that can meet the need in training models is mentoring training programs.

Since fisheries engineering is a profession that requires interdisciplinary teamwork, developing students' social communication skills through peer mentoring can also be effective in their professional lives. The mentee is not the only one who is positively affected by this interaction. The mentor also reaches the ability to take a more solid and confident step into the business world thanks to the inner peace and confidence that comes with being a guide. In addition, while providing guidance, she/he will also have the opportunity to check the incomplete information he/she has. He/she will also experience the first steps of cooperation and teamwork as a mentor. Within the scope of all these issues; peer mentoring programs, which are an educational method targeting 21st century skills, are an educational program that allows the training of successful and aware fisheries engineers of the future.

REFERENCES

Akgül, A., Uçar, M., Öztürk, M. & Ekşi, Z. (2013). Recommendations for improving engineering education, future engineers, and workforce analysis. Süleyman Demirel University Journal of Institute of Natural and Applied Sciences, 17(1), 14-18.

Amzaleg, M. & Masry-Herzallah, A. (2022). Cultural dimensions and skills in the 21st century: The Israeli education system as a case study. Pedagogy, Culture & Society, 30(5), 765-785.

Burrus, J., Jackson, T., Xi, N., & Steinberg, J. (2013). Identifying the most important 21st century workforce competencies: An analysis of the Occupational Information Network (O* NET). ETS Research Report Series, 2013(2), i-55. Doi:10.1002/j.2333-8504.2013.tb02328.x

Boyle, F., Kwon, J., Ross, C. & Simpson, O. (2010). Student–student mentoring for retention and engagement in distance education. Open Learning: The Journal of Open, Distance and e-Learning, 25(2), 115-130. Doi:10.1080/02680511003787370

Crisp, G. & Cruz, I. (2009). Mentoring college students: A critical review of the literature between 1990 and 2007. Research in Higher Education, 50(6), 525-622.

Dilley, A., Kaufman, J., Kennedy, C. & Plucker, J. (2015). What do we know about critical thinking? Partnership for 21st Century Learning. Retrieved on 10/10/2024 from https://tinyurl.com/y74mkhf5).

Eby, L. T. (1997). Alternative forms of mentoring in changing organizational environments: A conceptual extension of the mentoring literature. Journal of Vocational Behavior, 51(1), 125-144.

Eby, L. T. & Lockwood, A. (2005). Protégés' and mentors' reactions to participating in formal mentoring programs: A qualitative investigation. Journal of Vocational Behavior, 67(3), 441-458.

Falchikov, N. (2001). Learning together: Peer tutoring in higher education. London: Routledge Falmer.

Gisbert, J. P. (2017). Mentor–mentee relationship in medicine. Gastroenterol Hepatol (English Edition), 40(1), 48-57.

Goff, K. & Torrance, E. P. (1999). Discovering Developing & Giftedness through Mentoring. Gifted Child Today, 22(3), 14-53. Doi:10.1177/107621759902200305

Göncüoğlu-Bodur, H. & Günay, D. (2023). Content Analysis of the Impact of Peer Mentoring on Academic Development in University Education. EGE 2nd International Congress on Natural & Medical Sciences. Full Texts Book. ISBN - 978-625-367-172-3. Iksad Publications, 90-96.

Günay, D. & Göncüoğlu-Bodur, H. (2023). Content Analysis of E-Mentoring Applications in Higher Education. EGE 2nd International Congress on Innovation Technologies & Engineering. Full Texts Book. ISBN: 978-625-367-170-9. Iksad Publications, 115-120.

Hamarat, E., (2019). Turkey's Education Policies Focusing on 21st Century Skills. SETA. Ankara. pp.28.

Hinton, K. G. (2006). The true meaning of mentorship. Diverse: Issues in Higher Education, 23(20), 60-61.

Hobson, A. J., Ashby, P., Malderez, A. & Tomlinson, P. D. (2008). Mentoring beginning teachers: What we know and what we don't. Teaching and Teacher Education, 25, 207-216.

Joynes, C., Rossignoli, S., & Amonoo-Kuofi, E. (2019). 21st century skills: Evidence of issues in definition, demand and delivery for development contexts (K4D Helpdesk Report). Brighton, UK: Institute of Development Studies. (Retrieved on 12/10/2024 from https://www.ids.ac.uk/publications)

Kimura, N., Fisheries Engineering. In: Modern Fisheries Engineering (Eds: Bortone S., Otake, S.) CRC Press, 2020. 168 p., ISBN: 978-0-367- 34792-5.

Klasen, N. & Clutterbuck, D. (2002). Implementing Mentoring Schemes. Oxford: Butterworth Heinemann Publishing.

Kram, K. E. (1983). Phases of the mentor relationship. Academy of Management Journal, 26(1), 608-625.

Kocabaş, İ. & Yirci, R. (2012). Mentoring practices around the world. In Ramazan Yirci & İbrahim Kocabaş (Eds.), A mentoring practice in Turkey: The training of prospective teachers (pp. 227-244). Ankara: Pegem.

Kovács, G., Benotsmane, R., & Dudás, L. (2018). The concept of autonomous systems in industry 4.0. Advanced Logistic Systems-Theory and Practice, 12(1), 77-87.

Lopez-Cruz, O. (2022). An Essential Definition of Engineering to Support Engineering

Research in the Twenty-First Century. International Journal of Philosophy, 10(4),130-137. Doi: 10.11648/j.ijp.20221004.12

McGunagle, D. & Zizka, L. (2020). Employability skills for 21st-century STEM students: the employers' perspective. Higher Education, Skills and Work-Based Learning, 10(3), 591-606. Doi:10.1108/HESWBL-10-2019-0148

Moore, J. L. & Felten, P. (2018). Academic development in support of mentored undergraduate research and inquiry. International Journal for Academic Development, 23(1), 1-5.

Noe, R. A. (1988). An investigation of the determinants of successful assigned mentoring relationships. Personnel Psychology, 41(3), 457-479.

Özgüzel, S. (2018). The Academic Concept of Education in the 21st Century and the Role of Universities. Education and Society in the 21st Century, 7(21), 951-964.

Palankök, N.Y. (2004). Mentoring and Coaching as Career Management Tools. Master’s Project, Ankara University, Institute of Social Sciences, Department of Human Resources Management and Career Counseling.

Partnership for 21st Century Skills. (2019). Framework for 21st century learning. Retrieved on 8/10/2024 from http://www.p21.org/about-us/p21-framework)

Rawlings, J.K. (2007). Mentoring Basics. Delta Heritage Books, US.

Rios, J. A., Ling, G., Pugh, R., Becker, D. & Bacall, A. (2020). Identifying critical 21st-century skills for workplace success:

A content analysis of job advertisements. Educational Researcher, 49(2), 80-89. Doi:10.3102/0013189X19890600

Sağır, D., Kirazcı, F. & Büyükgöze-Kavas, A. (2024). Examination of university students' perceptions of competencies required in the business world. Bingöl University Journal of Social Sciences Institute, (27), 101-121.

Saimon, M., Lavicza, Z. & Dana-Picard, T. (2023). Enhancing the 4Cs among college students of a communication skills course in Tanzania through a project-based learning model. Education and Information Technologies, 28(6), 6269-6285.

Skinner, E. A., Kindermann, T. A., & Furrer, C. J. (2009). A motivational perspective on engagement and disaffection. Educational and Psychological Measurement, 69(3), 493-514. Doi:10.1177/0013164408323233

Uçak, S., & Erdem, H.H. (2020). On the skills of the 21st century and philosophy of education in terms of searching for a new perspective in education. Journal of Uşak University Education Research, 6(1), 76-93.

Ünüvar, S. H. (2023). The Importance of Educational Administration in Promoting 21st Century Skills. International Academic Social Resources Journal, 8(47), 2269-2277. Doi: 10.29228/ASRJOURNAL.67977.

The Council of Higher Education (2024). (YÖK) Higher Education Program Atlas. (Retrieved on 18/10/2024 from https://yokatlas.yok.gov.tr/lisans-bolum.php?b=10196).

TURKSTAT, 2021. Youth in Statistics. (Retrieved on 18/10/2024 from https://data.tuik.gov.tr/Bulten/Index?p=Istatistiklerle-Genclik-2021-45634).

Tunçay, S. (2014). A Study on Mentoring Practices in Education. Master's Project, Trakya University, Institute of Social Sciences, Department of Business Administration

Tükeltürk, A. & Balcı, M. (2014). The institutionalization process, importance, and benefits of mentoring in universities; a study on Çanakkale Onsekiz Mart University. Journal of Organization and Management Sciences, 6(1), 137-155.

Tonga, M.Y. & Tonga, M. (2022). Overview of Industry 4.0: The future of the industry. Gaziantep University International E-Journal of Faculty of Economics and Administrative Sciences in Islahiye, 6(6), 40-60.

Topping, K. J. (2005). Trends in peer learning. Educational Psychology, 25(6), 631-645. Doi:10.1080/01443410500345172.

World Economic Forum (2021). Education, skills and learning. World Economic Forum. https://www.weforum.org/agenda/2020/10/top-10-work-skills-of-tomorrow-how-long-it-takes-tolearn-them/

Yıldırım, R. (2013). The role of school administrators as mentors in terms of academic success and certain variables. Master's Thesis, Necmettin Erbakan University, Institute of Educational Sciences, Konya.

Zhao, C. M. & Kuh, G. D. (2004). Adding value: Learning communities and student engagement. Research in Higher Education, 45(2), 115-138. Doi:10.1023/B:RIHE.0000015692.88534.de.


BIDGE