Consultant's Report, Caspian Sea Project

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"We are crossing a river by touching a stone"
Chinese saying told by Juning Cai, FAO Expert and Consultant to Azerbaijan

Photo by Hamid Alizadeh Ketek Lahijani, October 2021
from The *Proceedings of the Scientific Conference on the Climate Change in the Caspian Sea* (2021)

Executive Summary

Despite the well-documented environmental and water quantity/quality problems with the Caspian Sea ecosystem, conditions for accelerated aquaculture developments/investments are very good in Kazakhstan and Azerbaijan, especially in water-based sea and reservoir cage aquaculture and coastal, pump-ashore tank aquaculture. Kazakhstan and Azerbaijan have ambitious-but achievable-national aquaculture development plans and plans for agency reorganization. Kazakhstan has a goal to increase aquaculture production to ~270,000 MT by 2030; reservoir cage aquaculture in Azerbaijan is forecasted to increase to ~30,000 MT by 2026; in the Mangystan Region of Kazakhstan ~26 Caspian Sea-based cage aquaculture sites of ~100 ha each with 49-year concessions are planned with investors having a production goal of ~100,000 MT. Previous enterprise modelling by The World Bank and FAO (2022) deemed Caspian Sea cage aquaculture having "considerable potential for this technology to be profitable". Sturgeon farming is growing in both countries. Economic considerations of the most efficient strategies for producing more or less caviar and/or meat are

important to maximize export values and accelerate national food supplies; and technologies are developing allow farmers to slaughter males at a younger age that could change current production strategies. Azerbaijan Fish Farm reported employing ~440 people; many are former sturgeon poachers. Sturgeon farming requires expertise in its farming processes for caviar and meat. To implement aquaculture development plans and protect Caspian Sea ecosystems, attention to institutional capacity-building is required, especially in comprehensive planning for the implementation of modern, nature-based, restorative, conservation and ecosystem-based aquaculture governance systems that prioritize spatial planning and carrying capacity limitations. Azerbaijan and Kazakhstan have active international partnerships and could leverage these to accelerate aquaculture developments that "leapfrog" aquaculture its development to today's state-of-the-art and avoid "recreating the wheel" and repeat past international aquaculture development/policy mistakes. There is a large scope for applied, cooperative and partnership research locally with international institutions that could align aquaculture development more closely with both renewable and hydrocarbon energy industries and agriculture (feeds, water management, etc.) without decreasing water quantities/qualities. Market and trade issues within the region represent significant obstacles to aquaculture development but can be overcome by additional value chain strategic planning and directed, science-based, inter-governmental trade negotiations. Overall, successful integrated, large- and small-scale aquaculture development programmes in both countries can meet production goals if they initiate modern aquaculture governance systems, make new investments in applied R&D, develop applied, cooperative centres of commercial excellence (including bioengineering technology, demonstration of innovations/applications, extension/training), and prioritize regional and international partnerships for technology transfer and investment. Significant opportunities to develop the wealth of indigenous species for aquaculture exist into the future.

National & Environmental Backgrounds – Azerbaijan and Kazakhstan

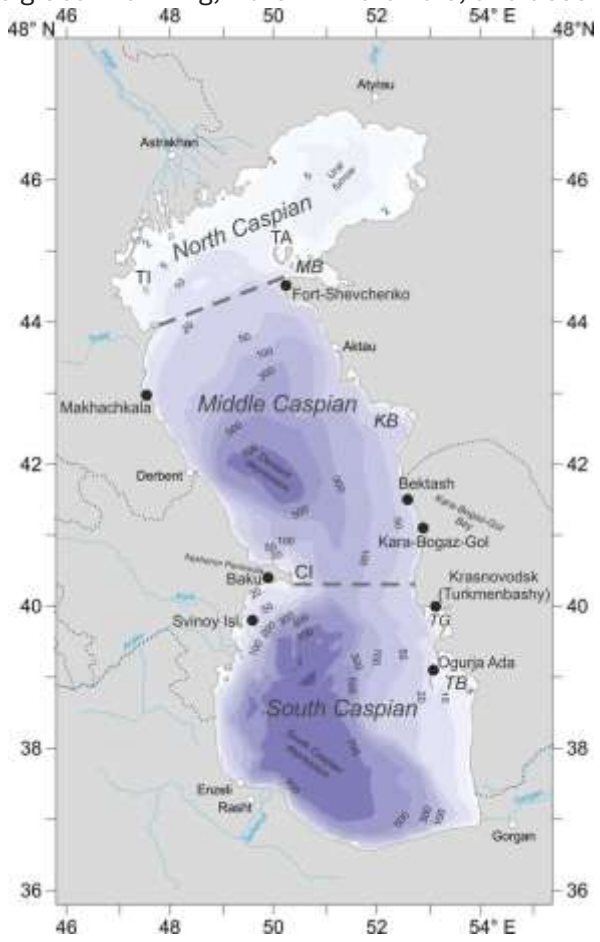
The total area of Azerbaijan is ~86,000 km^2. It has a population of ~10.7 million (2024), and population density of ~120 persons/km^2; ~25% of the country's population live in the metropolitan area of the capital, Baku. The country is a major producer of oil, gas, and minerals. The economy is growing rapidly, driven primarily by the hydrocarbon sector. Three mountain ranges and highlands cover >50% of the country. The rest of the country is lowlands and plains. The climate varies, covering 9 of the 11 climate global climatic zones. The central and eastern parts of Azerbaijan have dry subtropical climate with mild winters and hot summers, averaging 27 °C with maximum temperatures of ~43 °C. The lowlands and foothills of the mountainous regions are steppe and semidesert. Southeastern Azerbaijan has more humid climate. The main rivers are the Kura and its tributary, the Aras. There is a network of irrigation canals between the rivers, and several reservoirs, the largest of which is the Mingäçevir reservoir on the Kura River which has a surface area of ~606 km^2; ~2% of the country's area is covered with water.

The total area of Kazakhstan, the largest landlocked nation in the world, is ~2.7 million km^2; larger that all Western Europe It has a population of ~19 million, and a population density of 8 persons/km^2, making the nation one of the least densely populated countries in the world. Kazakhstan is very diverse geographically having vast steppes (26%), deserts (44%), and mountainous regions**.** The Altai and Tian Shan Mountain ranges dominate the eastern and southeastern regions. Similar to Azerbaijan, Kazakhstan is rich in natural resources**,** oil, gas, coal, and minerals. Kazakhstan's major water resources are the Caspian Sea, Lake Balkhash, the Aral Sea, rivers (Syr Darya, Irtysh, Ili, Ural/Zhaiyk, Tobol), and renewable groundwater resources of ~35.87 km^3/year (some of this estimate overlaps surface waters). However, in many of its regions Kazakhstan faces water shortages due to climate change, inefficient irrigation, and reliance on transboundary rivers originating in neighboring countries. The shared Ural River basin has had significant reductions in water levels over the past 15 years.

Caspian Sea Ecosystem

The Caspian Sea is the world's largest inland water body with a surface area of 371,000 km^2 – the size of Japan - from north to south ~1,200 km and ~200 to 450 km wide. The total length of the coast ~7,000 km. The Caspian seabed in the south is ~1,023 m below sea level, which is the lowest non-oceanic depression on Earth after Lake Baikal, Russia and Lake Tanganyika, East Africa. The Caspian Sea has been called "A Hard Currency Sea," because of the availability of two kinds of "black gold" - oil and caviar (Zonn *et al*. 2010). Oil reserves are ~18 billion metric tons (MT) and 6 billion m^3 of gas.

Challenges facing the environment of the Caspian Sea are well known. Participants of the International Scientific Conference "Climate Change in the Caspian Sea Region" (October 2021) by the Coordinating Committee for Hydrometeorology of the Caspian Sea and the Tehran Convention interim Secretariat listed these as: increases in air temperatures, decline in water flow of rivers, increased evaporation from the surface of the sea basin, decreased sea levels, changes in ice regimes. Caspian Sea Environment (2009) and Zonn *et al*. (2010) added: falling water levels due to water withdrawals for agriculture/urbanization, environmental pollution from agricultural and industrial activities, over- and illegal fishing, the release of exotic species, loss of habitats, and accelerated eutrophication. It is predicted that during the 21st century, the depth of the sea will decrease by 9–18 m due to global warming, water withdrawals, and desertification.



The bathymetry of the Caspian Sea is divided into three parts - north, central and south – which order its salinity and biodiversity. These lead to regional differences in water temperatures, salinities, and

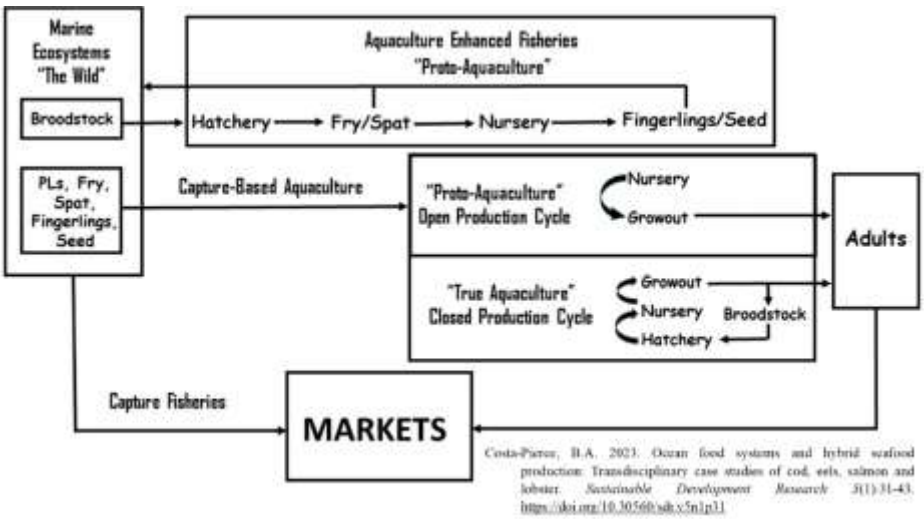
ecologies. Two deep basins occur in its central and southern zones. The northern part (25% of the area but only 0.5% of volume) is shallow (average depths ~5 m) and has a salinity close to freshwater at ~3-5 ppt due to the inflow of large Russian rivers (Volga, etc.). The central part (~34% area and ~34% volume) is deep with the Derbent Depression having depths >500 m. The southern part (~37% area and ~66% volume) has the South Caspian Depression with its deepest point being ~1025 m. Salinity in the central and southern parts is brackish ~12% since these basins have comparatively little inflow. The Garabogazköl lagoon in Turkmenistan, which dried when water from the Caspian was blocked in the 1980s, has been restored but is hypersaline (~340-360 ppt), similar to the salinity of the Dead Sea.

There are considerable indigenous resources of anadromous and semi-anadromous fish in the Sea and surrounding nations. In the Kura River and its tributaries in Azerbaijan, there are ~60 species of fish. Caspian sturgeons comprise 90% of the world's sturgeon biodiversity. They are in a critical condition (IUCN Red List, etc.) due to over- and illegal fishing, habitat destruction, pollution, etc. During the 1980s, Soviet enterprises produced ~2,500 MT/year of black caviar, and Iranians produced ~250 MT/year. In 1990, the permissible catch of sturgeon in the USSR was set at 13,500 MT; by 1996 it was ~1,200 MT. metric tons Total caviar production is now very low or between 500 to 800 MT. Sturgeons reproduce very slowly. In the wild, male sturgeon spawn for the first time at 8 to 13 years old and females at 10 to 16 years (Gesner *et al*. 2010). Hybridization has occurred between Black Sea and Caspian Sea sturgeon due to the Don-Volga Canal. Ecosystem modification leads to the possible loss of sturgeon biodiversity. All riparian Caspian states require better water management, stricter environmental regulations, increased investments in wastewater treatment, the recovery of freshwater ecosystems and fisheries, and conservation programs to protect and recover their native aquatic biodiversity.

Aquaculture Status of Azerbaijan and Kazakhstan

General

There are four typologies of aquatic food systems - capture fisheries, capture based aquaculture, aquaculture enhanced fisheries, and full cycle aquaculture (Costa-Pierce et al. 2022). Conservation aquaculture is also widely practiced. Azerbaijan and Kazakhstan have capture fisheries, aquaculture-enhanced fisheries, and true aquaculture.

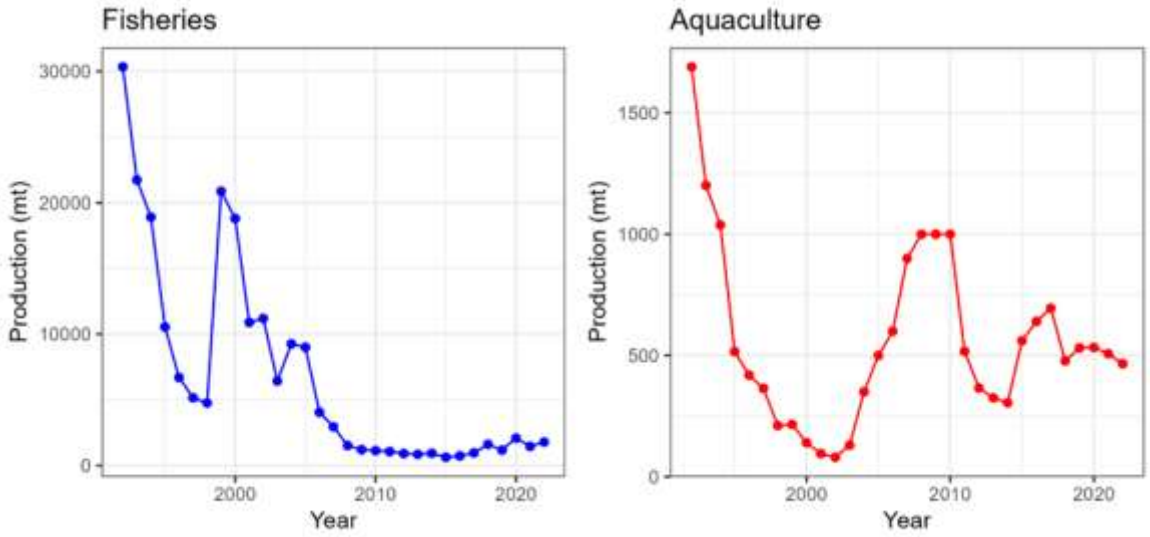


Costa-Pierce, B.A. 2023. Ocean food systems and hybrid seafood production: Transdisciplinary case studies of cod, eels, salmon and lobster. *Sustainable Development Research* 5(1):31-43. https://doi.org/10.30560/sdr.v5n1p31

Conservation aquaculture (TNC 2021) uses aquaculture technologies to produce, restore, and enhance threatened/endangered species rather than just producing food. Traditional aquaculture prioritizes genetic improvement, high survival rates and yields, conservation aquaculture aims to enhance aquatic animal behaviors and genetic traits suited for survival in the wild, encouraging natural selection, and avoiding domestication that could weaken wild populations. It plays a crucial role in aquaculture-assisted fisheries programs, helping stabilize and recover species that are at risk of extinction.

Aquaculture in Azerbaijan

Aquaculture has existed in Azerbaijan from the Soviet era to now, practiced primarily in earthen ponds in the lowland river plains. During the time of the USSR, aquaculture production in Azerbaijan was significant, with annual fish production >20,000 MT in the early 20th century; however, after independence production had declined to just 1,570 MT.



Species Groups	Production (MT) (2022)	Production MT (2025)*
Carps (common, grass, silver, Crucian)	2557	
Pike-perch	2078	
African catfish	1316	
Mullets	1250	
Misc. Coregonids	1212	
Minor spp. (European perch, roach, Northern Pike)	203	
Sturgeons	190	20000?
Trout		600-700?
TOTAL	8806	20600-20700?

Fish production in Azerbaijan. Note the different scale of the two figures. FAO FishStat. *Reported by farm owners during field visits in April 2025.

The last available information on fisheries production (2022) from capture fisheries was ~1,790 MT and ~466 MT from aquaculture. However, aquaculture development is increasing due to government policies and incentives (tax policies, subsides, etc.). Salmanov et al. (2010) estimated aquaculture production at ~900 MT. FAO data collected in 2022 report lowland areas around the river Kura are the main farming areas. I estimate additional production here from farm visits made in April 2025.

Aquaculture-enhanced fisheries

The ten largest reservoirs of Azerbaijan, by volume

Reservoir	Area	Storage Capacity
	(km^2)	(km^3)
Mingachevir	605	16.07
Shamkir	116	2.68
Yenikend	23.2	1.58
Araz	145	1.35
Sarsang	14.2	0.565
Jeyranbatan	13.9	0.186
Aqstafachay	6.3	0.12
Varvara	22.5	0.06
Khanbulanchay	24.6	0.052
Khachinchay	1.76	0.02

Table from Salmonov *et al*. (2013)

Azerbaijan has significant reservoir areas of both irrigation and drinking waters (Salmonov *et al*. 2013). Hatcheries produce different species for stocking freshwaters. Salmonov *et al*. (2013) reported 13 hatcheries produce juvenile trout, Caspian salmon, common, grass and silver carps that are released to reservoirs. Inland commercial fisheries in Azerbaijan are concentrated in four waterbodies, the Kura River, Lake Sarysu, Mingəçevir and Shamkir reservoirs. Total inland fisheries production ~222 MT (2010) and total aquaculture-enhanced fisheries production ~110 MT (2010) is low (Salmonov *et al*. 2013).

Azerbaijan has made significant progress in aquaculture development since 2018. Large scale sturgeon facilities have been built in the Neftçala, Ismayıllı, and Mingəçevir districts. There is a growing export market for caviar. A large scale, land-based commercial rainbow trout farm having also a reservoir cage aquaculture operation growing rainbow trout has opened.

The World Bank team visited three large sturgeon farms in April 2025 (**Varvara Fish Farm, Azerbaijan Fish Farm, Astara Fish**), and one small/medium size sturgeon farm (**Beluga Astara Fish Farm**). Varvara in the central Mingəçevir district is the largest and most important sturgeon farm in the country. **Varvara** - opened officially in 2017 - is a sprawling ~40 ha complex of sturgeon hatchery, nursery, tank and 17 pond grow-out areas with ~180 employees. Ponds were flow-through with water piped in directly from the Kura River. The Director of Vavara reported a total of ~20,000 MT of sturgeon meat and caviar production in 2024.

Azerbaijan Fish Farm (AFF) is located 3 hours south of Baku. AFF is a very modern farm that was privatized from a state-owned enterprise privatized in 2018. AFF has implemented a modern recirculating aquaculture system (RAS) with Hesy Aquaculture technology (Netherlands), and also has a coastal, pump-ashore, flow-through tank facility beside the Caspian Sea. The company farms multiple endemic sturgeon species, Beluga *(Huso huso*), *Acipenser stellatus*, *Acipenser persicus*,

sterlet (*Acipenser ruthenus*), and *Acipenser gueldenstaedtii*. Sterlet the fastest-growing species produces caviar within 12 to 18 months, while Beluga takes at least 12 years to mature. AFF is investigating methods to allow harvest of Beluga caviar in 8 years. Sturgeon broodstock were obtained originally from the Caspian Sea but fishing for live capture was very costly (5-6000 manat/trip, ~US$ 2900-3500) and was unproductive (only 2 brood fish were caught). Currently juvenile sturgeon are purchased from the large hatchery/nursery operation in Varvara. It takes ~10 years for a wild fish to produce adequate caviar whereas an aquaculture fish can start producing in ~5-7 years. Methods to obtain eggs for caviar from female sturgeon are killing, squeezing, and surgery. Caviar from killed females was said to produce higher quality caviar (~1500 Euro/100g) vs. "squeezing" methods (600 Euro/100g). The caviar brand produced at AFF is "Baku Caviar" and sell to US (largest market) Germany, UAE, Singapore.

Beluga Astara Fish Farm in the rural Neftçala district is coastal, ~1 ha land-based tank, pump ashore facility with ~15 employees. It pumps Caspian Sea water from an intake pipe at ~ 3 m depth ~250-300 m from shore. The decrease in sea level has made this intake shallower over time (from 3.5-4 m at first deployment to ~3 m now). Water quality is unpolluted from any industrial sources, although on this visit heavy rains had made all waters in the tanks very cloudy/milky, and the farmer had to deploy extra aeration to avoid any oxygen depletions. Tank waters are exchanged 4-5X/day. Juveniles are purchased for Varvara and after ~4 years males are separated from females and used as meat. Only meat is sold now (8-10 MT/year). Females are on-grown until ~30-50 kg. On this day the farmer reported ~50 MT of fish on site. Beluga Astara Fish Farm uses imported fee from Germany (48% protein) and also has fishing botas which capture *kilka* (Black and Caspian Sea sprat [*Clupeonella cultriventris caspia*]) fished from the Sea as feed to sturgeon at a density of ~20 kg/m^3 in tanks. Highest operating cost was electricity (~30%), followed by feed and labour. **Astara Fish** is located in the "neutral zone" on the Azerbaijan/Iran border. It is a land-based tank facility that uses artesian (borehole) water and surface Aras river water (the border river). The artesian well water is used regularly I the summer to cool tank waters as water temperature rise to 27° in summer. A fungal disease is present which was said to be caused by water discharges from an upstream trout farm in Iran. Astara was holding many varieties of sturgeon (sterlet (*Acipenser ruthenus*), Siberian sturgeon (*Acipenser baerii*), Russian sturgeon (*Acipenser gueldenstaedtii*), stellate sturgeon (*Acipenser stellatus*), beluga sturgeon (*Huso huso*) and an unknown hybrid beluga). The farm had not yet produced caviar but was selling meat from 3-4 kg fish that the farm veterinarian stated only took 3-4 years to reach that size.

A cage aquaculture farm in the Caspian Sea was visited (**Aquaculture LLC**, Farid Mammadaliyev, owner). Farid has the only 2 km^2 Caspian Sea cage lease in Azerbaijan. The site was privatized in 2022-2023 from a former 1972 USSR site. Aquaculture LLC has 17 cages of 320, 600, and 1000 m^3 sizes, 6 m deep nets, with the two smaller cages used for sturgeon and the large one for trout. Sturgeons are kept year-round in sea cages. Trout are cultured in the cool season from November to May. Cages were fabricated locally and nets imported from China, Turkey. Sturgeon were fed *kilka* fished from the Sea by Farid's fishing boats. *Kilka* were frozen and stored to feed the sturgeon. The farmer fed Caspian prawns to get reddish meat and increased vitamins before and after the cool season (cost was reported at 10-15 manat/kg). This feed supplement was not observed during the visit but is suspected to be the exotic *Palaemon elegans* and *P. adspersus* native to the Atlantic–Mediterranean and introduced into the Caspian Sea 1930–1934 by Soviet authorities (Grigorovich et al., 2003). Sturgeon in cages grown on natural feed were reported to continue growing in the cool season, as opposed to land-based pond operations. From 1 March stocked 7.3 kg average weight sturgeon grew to 20.5 kg by 7 December. 12.5% of sturgeon body weight was caviar. Trout juveniles

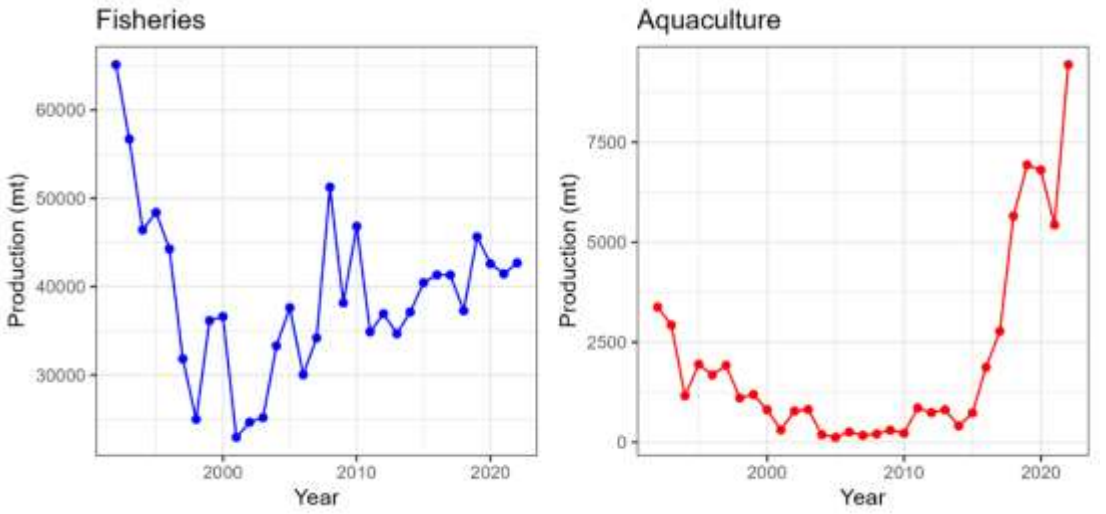
at ~100g trout were purchased and grown to ~1 kg. *Kilka* cost 0.5 manat/kg. Food conversion ratios for *kilka* were high 6.0 kg wet fish/1.0 kg sturgeon vs. 3.5 kg dry feed/kg wet fish meat for formulated feeds. Juvenile sturgeon of 1-2 kg was purchased from the large hatchery in Varvara. 50 MT of meat and 5 MT of caviar were produced in 2024. All caviar was reported to be certified by the Food Safety Authorities and was exported under contracts to the US, Germany, France. There is an expansion plan to reach 100 cages.

Higher elevations have lower temperatures ideal for pond culture of salmonids (imported, highly selected rainbow trout). The World Bank mission visited **AZFOREL** a large commercial trout farm (Adil Adilzade, manager). The farm produced triploid rainbow trout in a large flow through raceways and plastic lined ponds with clean, clear, optimal water temperature (15-18°C) water from a large mountain reservoir. Triploid eyed eggs were purchased from South Africa and hatched in ~40 hatching units purchased from Turkey. Juveniles were grown in flow through raceways to small, ~300g portion sized fish then frozen on site for sales to local and Baku markets. Large fish (2-5 kg) were grown in large, flow-through, plastic lined ponds. All feeds were imported from Denmark, Germany and Israel. AZFOREL also operates an intensive, Norwegian-style "polar circle"-type cage aquaculture farm for rainbow trout in the Shamkir reservoir, a reservoir NW of the Mingəçevir reservoirs on the Kura River. AZFOREL stated that cage culture operations in the reservoir produced ~600 MT in 2024, with plans to increase production in 2025-2026 to ~30,000 MT. The farm is 80% financed by an investor from the UAE. There is a high demand for large, whole trout in the round but less for the portion-sized trout sold as packets as frozen fish. The farm markets ~60 MT in the summer tourist markets in Russia.

Pictures of raceway, pond, facilities, ~300g portion trout in freezer, packages of frozen trout marketed locally for 6.5 – 7.0 manat/package (US$ 3.5-4.1) at AZFOREL (2025)

Kazakhstan

The historical development, status and potential of fisheries and aquaculture in Kazakhstan have been well documented (The World Bank and FAO 2022). Aquaculture began in the Soviet era in the 1970s. By the early 1990's it was a reported there were ~47 fish farms covering >5,000 ha. Kazakhstan's total seafood production (aquaculture and capture fisheries) declined rapidly in just 10 years from ~85,000 MT to ~26,106 MT from 1988 to 1998. Aquaculture production was relatively stagnant from 2001 to 2014; however, from 2014 to 2022 aquaculture production grew at a rate of 46%/year. The number of fish farms has been reported to double from 2021 to 2023, reaching >500, with aquaculture production increasing to ~9,000 MT.



Fish production in Kazakhstan (2022) Source: FAO FishStat

Species Groups	2022 Production* (MT)	2025 World Bank Mission Comments
Carps (common, silver, grass, crucian)	2557	Production from aquaculture uncertain as these are dominant not only in small farms but also widely caught in irrigation canals, lakes, ponds. Important local, low-cost food.
Pike-perch	2078	
African catfish	1316	Said to be introduced illegally. Enjoyed as smoked fish.
Mullets	1250	Widely available in Aktau markets; uncertain how much is cultured, or mostly fished.
Northern Whitefish ("peled" *Coregonus peled)*	1212	A reservoir aquaculture-enhanced fishery? As it was reported to be from hatcheries in Russia and released to lakes.
Minor spp. (European perch, roach, Northern pike, etc.)	203	Widely caught in irrigation canals, lakes, ponds and present as a minor species in carp ponds. Local, low-cost food enjoyed smoked & "jerky".
Sturgeons	190	Production has likely increased 100X

Limited field time during this mission was spent on investigating the full breadth and depth of Kazakhstan aquaculture – this is one of the world's largest countries – therefore, no direct observations/interviews were conducted and a limited assessment of the extent and development of aquaculture in 2025 and especially in the more water-rich areas of eastern Kazakhstan, where trout is also known to be farmed. However, study of the in-depth assessment conducted by the World Bank and FAO (2022) did give important insights that were discussed among experts during the mission.

The Kazakhstan national expert stated that trout *(Oncorhynchus mykiss)* are farmed in the mountainous areas of the Turgen and Issyk Rivers (Mamilov et al. 2024). A wild trout from Kamchatka, Russia and a cultured fish from European fish farms have been introduced waters in Kazakhstan's Balkhash basin. Populations of rainbow trout in the Balkhash basin were reported to be under intensive recreational fishing pressure. The population in Kolsay Lakes is also under pressure by illegal fishing (Mamilov et al. 2024). It was stated that only triploid rainbow trout from Denmark, Poland, and Turkey are now cultivated in Kazakhstan.

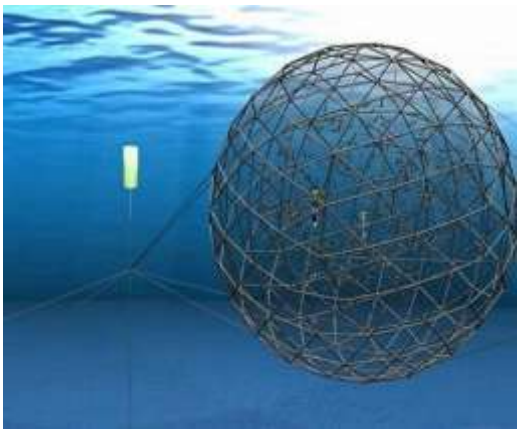
Two field visits were made to the **Fisheries Inspection Office** in the Mangystan Region and **Kazakhstan Sturgeon Farm**, an integrated sturgeon farm, and an interview with the head of the **Caspian Salmon Reproduction Project** was conducted.

The meeting at the **Fisheries Inspection Office** in the Mangystan Region was held attended by many inspection/enforcement officers and the Mayor. The Mayor reported that ~26 Caspian Sea sites of 100 ha each have been designated for cage aquaculture development with concessions having a 49-year duration. The eventual production goal was stated to be ~100,000 MT, mainly of sturgeon and Caspian salmon. A company from Norway ("Organic Fish") was reported on planning to invest ~13 billion tenge (~US$ 25 million) and produce ~5,000 MT. Another company from Switzerland ("Red Pearl") planned to invest and produce ~100 MT of sturgeon meat and ~10 MT of caviar. The permitting and regulatory framework, fee structures, spatial planning (map) developed and processes moving forward were unclear, but it was said that company business plans and investments were in control of the process.

The **Kazakhstan Sturgeon Farm** is a land-based, freshwater tank farm founded in 2014, but in 2024-25 has undergone a complete change in management and direction. The hybrid Sterlet x Russian hybrid sturgeon was being developed as it was said to produce caviar in a shorter time. During the visit the farm appeared new as new tanks and many juvenile sturgeon were present, and very few adults. Future development plans discussed were very interesting as the farm was being developed as integrated farm producing sturgeon caviar and meat production, but also planned developments of aquaponics, greenhouse agriculture, and Caspian Sea cages. The manager discussed the many partnerships developed with close marketing connections to retail establishments locally and the greater Aktau region. Another interesting aspect is that the seized, poached fish from illegal harvests were brought here and held live until the judicial system decided on violations and enforcement actions.

The new manager of Kazakhstan Sturgeon Farm discussing wide ranging development plans for an integrated, land-based aquaculture facility that included sturgeon tank aquaculture for meat and caviar, aquaponics, greenhouses, and Caspian Sea cage aquaculture.

The **Caspian Salmon Reproduction Project** is developing its own engineering "copy" of the submersible cages called "Aquapods", investing ~90 million tenge (~US $175,000) for a demonstration cage in stage 1 and ~96 million tenge (US$ 186,000) planned for expansion.



A submersible fish cage called an "Aquapod" that the Caspian Salmon Reproduction Project is proposing to develop in the Caspian Sea for Caspian salmon aquaculture.

Observations & Recommendations

Conditions for accelerated aquaculture development are good in both countries, especially outside of the urban areas which have suboptimal water qualities of both groundwaters and Caspian waters due to pollution and extractive competition from other sources. Overall, an integrated programme of accelerated development of large- and small-scale aquaculture with good governance (marine and coastal spatial planning, additional applied R&D investments, development of applied centers

of excellence, technology transfer and regional and international partnership development will help facilitate ambitious national aquaculture development plans.

Aquaculture Governance

It was reported that there are ~600-700 aquaculture operations in Azerbaijan but that only ~7% were registered/permitted/licensed. Thus, it was difficult to determine the total number of operational farms in 2025. There is clear commitment by the government to build aquaculture development in the country. In 2023, Azerbaijan announced a "State Programme for the Development of Aquaculture in Azerbaijan for 2023-2027" by decree signed by President Ilham Aliyev, titled "On Additional Measures for the Development of Fisheries and Aquaculture in Azerbaijan." The programme aims to advance fisheries and aquaculture in the country, including enhancing productivity, improving management and control systems, developing fish resources with consideration for their environmental impacts, and organizing, regulating, and modernizing fisheries and aquaculture operations. The decree establishes a Fishing and Aquaculture Centre under the Ministry of Agriculture. The Centre will be responsible for the organization and management of fisheries and aquaculture, including enhancement, conservation, and control of fish and other aquatic biological resources. The Ministry of Ecology and the Ministry of Agriculture will monitor and assess the environmental impact of existing aquaculture operations that are not registered with the state in order to establish a proper registry of fish farming facilities in the country.

A wide variety of government tax incentives and subsidies (reimbursements, loans, credit) were reported for both capital and operating (fingerlings, feeds, medicines) which could expire in 2030 at the end of government-announced initiatives or with future, changing national priorities. Early planning for the economic determination of the value of these incentives is important for meeting national goals for accelerating aquaculture production.

Capacity Building

Throughout the World Bank mission to both nations, farm owners and managers mentioned that a lack of trained aquaculture workers and local aquaculture extension advisors limit their rapid development. It is recommended that a complete assessment of national and local educational and training institutions, certificate programs, and services be done including associations such as the Azerbaijan Fisheries Association which could lead to an investment a plan for aquaculture capacity building in both countries. The World Bank and FAO (2022) suggested a genetic resource centre be created in Kazakhstan; this could be an important part of a larger, cooperative, applied R&D, training, and aquaculture extension service as a partnership between industry, universities and government services. In Azerbaijan, singular aquaculture activities were mentioned at ADA University, Baku State University, Azerbaijan State Agricultural University, Azerbaijan Technological University and Azerbaijan State Pedagogical University, but no findings of a dedicated faculty unit, school or speciality in aquaculture. Not enough time to assess aquaculture activities at universities and training centres was available during the short stay in Kazakhstan; however, Almaty Technological University was mentioned for their work on use of native agricultural products in fish feeds (sunflower oil, etc.).

Most importantly, FAO Azerbaijan on request of the government will assess aquaculture in that nation 2025 with lead FAO experts Dr. Juning Cai and Dr. Thomas Shipton. Dr. Shipton will be on a longer-term assignment as an aquaculture expert in Azerbaijan. Active participation by the two countries in

FAO COFI Sub-Committee on Aquaculture Central Asian and Caucasus Regional Fisheries and Aquaculture Commission (CACFish) and the Network of Aquaculture Centres in Asia-Pacific (NACA) would allow rapid transfer of international developments in aquaculture, so that the countries will allow both to "leapfrog" to the latest advances rather than wasting time and money on "recreating the wheel" which is done far too much in aquaculture development. Azerbaijan and Kazakhstan were reported to be cooperating more actively in knowledge sharing and especially in feeds but few detailed of these partnerships were obtained.

Sturgeon aquaculture development

Sturgeon are considered excellent aquaculture species due to their high commercial value (caviar production and meat). Sturgeon aquaculture has good potential in both Azerbaijan and Kazakhstan, but sturgeon farming is capital and knowledge intensive; water quality and use is a vitally important issue. Sturgeon farming requires expertise in its farming processes for caviar and meat. The sturgeon meat market requires much more in-depth analysis.

Onofri *et al*. (2024) give a good case study analysis in Italy of the economic considerations of meat and caviar production in sturgeon farming. Businesses that plan for the most economically efficient strategy for producing more or less caviar and/or meat are the most successful. New genetic research for early sex-determination may allow farmers to slaughter males at a younger age than is currently possible changing current production strategies (Onofri *et al*. 2024).

There is good potential for building a circular economy of 100% use of all parts of the sturgeon harvested (leather, etc., an example is Switzerland's Oona Caviar). A European Market Observatory for Fisheries and Aquaculture Products (EUMOFA) report, according to which, for 1 MT of caviar, on average, approximately 20 MT of sturgeon meat and other by-products and waste, such as tails, heads, and entrails, are produced (EUMOFA 2023).

The global market for caviar is strong, reported to have increased from ~500 MT to ~800 MT in 2025. China has become the largest sturgeon aquaculture country in the world, and hybrid sturgeons are widely bred in captivity. Conflicting issues between the drastic reduction in natural populations and the large profits in the business of sturgeon farming are the main driving force promoting the development of sturgeon aquaculture in China, which has become the largest sturgeon aquaculture country in the world.

It was reported by managers at Baku Caviar in Azerbaijan that ~35-40% of the market was Chinese caviar called "Caluga", and that "a generation of people are now used to the lower salt taste and price of Chinese caviar" (~70% of the US caviar market is Chinese caviar, before the "Trump Tariffs"). In Azerbaijan, the total caviar market was estimated at ~15 MT/year, and ~6 MT/year is imported from China. Azerbaijan is positioning itself at the high end of the caviar market (900 manat/kg [US$ 528/kg]) vs. 300 manat/kg (US$ 176/kg) for Chinese imported caviar. Baku Caviar, the marketing arm of Azerbaijan Fish Farm, has obtained GAP Certification (the first in the world for black caviar), Friends of the Sea, and Halal certification (exporting to KSA and the GCC countries and Singapore).

Azerbaijan Fish Farm “Baku Caviar” storefront and product in Old Town of Baku

Fish markets in Kazakhstan displayed a wide range of imported salmon and other caviars from seaweeds, etc. – said to come from Kamchatka, Russia - demonstrating local consumer acceptance of a wide diversity of caviar in the country.

Nature-Based Solutions, Restorative & Conservation Aquaculture*:*

Salmonov et al. (2013) reported that “The Khilly Sturgeon Hatchery was constructed in 2003 with a concession loan of US$6 million (including 3 years of operating costs) from the World Bank as part of the Urgent Environmental Investment Project”. Conservation aquaculture (TNC 2021) for sturgeon species recovery was widely reported during the World Bank mission in 2025, with Azerbaijan Fish Farm and Varvara both reporting ~100-150,000 juvenile sturgeon released each year into the Caspian Sea from aquaculture farms.

Banners at the Azerbaijan Fish Farm (2025)

Conservation aquaculture (TNC 2021) uses aquaculture technologies (the "aquaculture toolbox") to produce, restore, and enhance threatened/endangered species rather than just producing food. It plays a crucial role in aquaculture-assisted fisheries programs, helping stabilize and recover species that are at risk of extinction. Restorative aquaculture is defined as "…occurring when commercial or subsistence aquaculture provides direct ecological benefits to the environment, with the potential to generate net positive environmental outcomes." (Alleway *et al*. 2023), and examples of restorative aquaculture are available and the number growing internationally (Costa-Pierce 2024).

Traditional aquaculture prioritizes genetic improvement, high survival rates and yields. Modern sturgeon aquaculture widely breed hybrid sturgeons which dominate sturgeon farming globally. A recent survey recorded more than 17 sturgeon strains (including both purebreds and hybrids) cultured in China, with two "pure" species (*Acipenser baerii*, *A. schrenckii)* and three hybrids: (1) *A. baerii* × *A. schrenckii*, (2) *A. schrenckii* × *Huso dauricus*, (3) *A. baerii* × *A. gueldenstaedti*) (Zhang *et al*. 2013). Without extensive genetic testing it is difficult to identify hybrid strains of sturgeon, especially at the early stages of growth (fry, juveniles). In addition, surprising hybridization between sturgeon and paddlefish has occurred ("Sturddlefish", https://www.cnn.com/2020/07/21/world/sturddlefish-paddlefish-sturgeon-hybrid-scn-trnd/index.html). All possible measures should be taken to prevent the entry/importation of this hybrid to nations of the Caspian Sea.

Conservation aquaculture does not emphasize enhancement of genetic improvement and traits, rather encourages natural selection, and avoids domestication that could weaken wild populations. Sturgeon are one of the most ancient fish in the world with 27 species in 2 families (*Acipenseridae*, sturgeon, 25 species and *Polydontidae*, paddlefish, 2 species). Most sturgeon species are near extinction and since 1997 are listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), Moscow Protocol (part 4) of the Tehran Convention tehranconvention.org, World Sturgeon Conservation Society).

Sterlet (*Acipenser ruthenus*), Siberian sturgeon (*Acipenser baerii*), Russian sturgeon (*Acipenser gueldenshtaedtii*), and Stellate sturgeon (*Acipenser stellatus*) were the most common Caspian Sea species mentioned during the Mission. However, crossbreeding among different sturgeon species is known to be frequent and sturgeon F_2 hybrids are fertile. The Azerbaijan Fish Farm is collaborating with universities to map the DNA of Caspian sturgeon and find the genetic status of local species, as there has been decades of cross-breeding in Iran, Russia, and China, and reports are available stating that some distributors have previously introduced unknown sturgeon species.

Large-scale sturgeon farming can have negative impacts on wild populations if releases and escapes of hybrid and exotic sturgeons occur, threatening native sturgeon species by exotic varieties establishing or hybridizing with native species. Thus, with the potential for genetic pollution of the remaining wild Caspian Sea populations from accelerated aquaculture, it is recommended that investigations of results from the sturgeon releases be conducted (see Chebanov *et al*. 2011).

The Kura River Delta Azerbaijan wild sturgeon population needs special attention/status as it was stated that the diverse and unique populations of sturgeon and Caspian *Salmo* spp. have been decimated by overfishing, poaching, water withdrawals, climate changes and sea level changes. Brackish Caspian Sea water was reported to have entered and caused a large fish die-off. One informant interviewed during the mission insisted that the sturgeon releases has been so successful that populations had recovered to the point where fishing should be allowed again.

The World Sturgeon Conservation Society (WSCS) https://www.wscs.info/ is a key international player in sturgeon conservation and conservation aquaculture. We are aware there has been some participation in the Society in the past by Azerbaijan and Kazakhstan. Given the large expansion plans for aquaculture and environmental concerns, however, greater engagement is recommended. The 10th international conference of the WSCS is October 2025 in Yichang, China (https://iss10.whu.edu.cn).

Native Salmo spp.

There is considerable scientific uncertainty about the status and hybridization of *Salmo* spp. in the Caspian Sea as there have been imports of non-native species and hybridization between native and exotic species. *Salmo ciscaucasicus*, the Caspian salmon or Terek trout, is endemic to the Caspian Sea and its inflowing rivers. It was described in 1967 as a subspecies of *Salmo trutta*, a brown trout. The fish lives on the western shore of Caspian Sea from northern Azerbaijan to the Ural River with a main breeding of the Terek River. There are said to be anadromous, lacustrine, and resident varieties of this fish. But it is widely reported to have been hybridized; for example, in the northern Ural and Volga, there are hybrids between *S. ciscaucasicus* and *S. trutta*. Ninua *et al*. (2017) suggested using the *Salmo caspius* for brown trout from the rivers flowing into the Caspian Sea from the south and southwest, and *S. ciscaucasicus* for fish found in the Terek River and other rivers flowing into the Caspian from the north and northwest. Kalayci et al. (2018) stated that Caspian trout (*Salmo caspius*) and the Black Sea salmon (*Salmo labrax*) and the Abant trout (*Salmo abanticus*) are not distinct species but are instead morphs of the brown trout (*Salmo trutta*).

There is conservation aquaculture of *Salmo* spp. being conducted by Azerbaijan Fish Farm who reported it reproduces and releases juvenile Caspian salmon (*Salmo ciscaucasicus*). No evaluative reports of the success of these efforts were available.

Low-Cost Aquaculture for Expansion of Domestic Food Supplies

Pond Polyculture of Carps

Until recently (from 2017-18), the majority (numbers of farmers, areas farmed, production) fish farmers in the two countries practiced traditional pond aquaculture of carps (common – an ancient variety called *sazan*, Crucian carp, and imported silver and grass carps). Grass carp was reported to be more preferred by consumer, but common carp (called *sazan*, an indigenous and ancient variety of *Cyprinus carpio carpio*) was said to "be everywhere" in ponds, rivers and lakes as a vital and low-cost protein food. There are abundant areas around the main rivers and tributaries for a further expansion of integrated aquaculture/pond polyculture aquaculture of Chinese and local carps but careful site selection to ensure continuous supplies of surface waters and/or good water quality from rivers/boreholes will be required. Fish markets for carps are local and widely dispersed, especially in riverine locations, but centralized at the large market visited in Aktau, Kazakhstan (2500 tenge/kg, US$ 4.80/kg). It was fascinating (and a delight!) to eat *sazan* it at a high-end white tablecloth restaurant in Aktau, Kazakhstan. A wide variety of aquaculture and inland native species were found at markets as smoked fish and fish "jerky", which were stated by informants to be widely appreciated. The World Bank and FAO (2022) reported dried/salted/smoked imports and exports totaling ~6690 MT.


Common carp (L) and silver carp (R) at the market and served at a white tablecloth restaurant in Aktau, Kazakhstan


A selection of the wide variety of smoked fish and fish "jerky" at markets in Kazakhstan

A small-scale urban tank farm (Som Farm) started in 2020-21 was visited in Aktau, Kazakhstan growing African catfish and tilapia. Water was sourced from urban boreholes and was said to be of poor quality. The farm produced 40 MT year of fish, mainly smoked fish, and marketed directly to urban consumers. Consumer demand was reported to be high, and expansion plans have been developed. Government subsidized feeds were imported from Russia and Denmark. Smoked catfish and tilapia were said to be in high demand.

Development of Indigenous and Other Species for Aquaculture

Applied aquaculture research and development of indigenous species appeared limited. Three species caught attention: (1) Caspian *kutum* or Caspian white fish (*Rutilus frisii*), (2) Northern whitefish *or peled* (*Coregonus peled*), and mullets. The indigenous Caspian *kutum* is highly prized due to its excellent flesh and roe. Wild populations of *kutum* in Caspian Sea have decreased dramatically due to water level changes, river flow reductions, increased agricultural and industrial pollution, all leading to the degradation of its spawning areas, especially in the southern Caspian Sea. However, artificial breeding and restocking programs have been successful, and a substantial portion of Caspian *kutum* stocks in the southern basin are reported to originate from hatcheries (Kashiri *et al*. 2018). An interesting aquaculture enhanced fishery in lakes/reservoirs for the *peled* (*Coregonus peled*) was reported in Khazakstan. A hatchery in Russia provides juveniles which are stocked into lakes/reservoirs, and the fish is delicious smoked.

Mission leader and consultant appreciating the business of smoked *peled* in Kazakhstan.

Mullets are an excellent candidate species for aquaculture. They have wide environmental tolerances and feed low in the aquatic food web (euryhaline [freshwater to 38‰], eurythermal [3 to 35 °C], feed on periphyton, detritus, small invertebrates). Mullet grows quickly in aquaculture, in one year 0.75-1 kg, and in two years, 1.5-1.75 kg. Females grow faster than males of the same age. Jumping mullet (*Chelon saliens*) and golden grey mullet (*C. auratus*) were introduced to Iran from the Black Sea and wild populations have established in Azerbaijan, Kazakhstan and Turkmenistan. About 3 million juvenile Black Sea grey mullet (*Mugil cephalus*, *Liza aurata* and *L. saliens*) were introduced from Black Sea into the Caspian Sea in 1930 and 1934 but only *Liza aurata* and *L. saliens* established in the Caspian Sea. They appeared in catches by the middle of the 1950s reaching ~3000 tons for the USSR and Iran. They provide one of the principal fishing resources, especially in the southern Caspian Sea (Fazli *et al*. 2008).

Mullet in the market in Aktau, Khazahkstan

Feeds

Feeds being used in aquaculture in both countries were almost universally imported from international sources (Poland, Russia, Denmark, Germany were mentioned). Local feeds do exist in both countries but were said to be of poor quality, yielding poor performances. An in-depth study of the availability and existing uses and economics of in-country agricultural, marine and freshwater and rendering wastes (meat and bone and blood meals) resources could inform any plans for improving existing or expanding into new aquaculture feed mills is recommended. In addition, both nations could explore investing in knowledge acquisition and technology transfer options for alternative meal and oil production innovations that now exist internationally (production of insect meals to replace fish meal and algae oil production to replace fish oils, etc.). Incentives for increasing cooperative, applied aquaculture feeds development between universities and companies are recommended. Examples of such types of actions is the Caspian Environmental Consortium Ltd.

Special Comments on the Development of Cage Aquaculture in the Caspian Sea

There were reports of Norwegian, Swiss and Singapore investors actively seeking cage aquaculture site in southern Kazakhstan. It is very important that the latest available guidance, planning, tools and governance systems be known by authorities and decision-makers to proceed with accelerated cage aquaculture permitting developments that "leapfrog" aquaculture development to today, not to "recreate the wheel" and repeat development/policy mistakes of the past. Spatial planning, ecosystem-based aquaculture approaches, and carrying capacity tools to develop sustainable, ecological cage aquaculture can be used to develop economically-viable and socially beneficial cage aquaculture while preventing any further damage to Caspian Sea ecosystems and its biodiversity. Much expertise, guidance, experiences, and technology-transfer opportunities are available in these areas to both countries (Aguilar-Manjarrez *et al*. 2010, Stigebrandt 2011, Soto *et al*. 2012, Ross *et al*. 2013, Aguilar-Manjarrez *et al*. 2017; Le Gouvello *et al*. 2017 and IUCN Aquaculture and Marine Protected Areas, FAO 2021, IOC-UNESCO/European Commission 2022, FAO 2024).

Aquaspace (Ecosystem Approach to making Space for Aquaculture, 2015-2018) was a project aiming to understand spatial and socio-economic constraints to the expansion of aquaculture, and to test tools to help overcome these constraints (https://aquaspace-h2020.eu/).

There is a growing alignment of the hydrocarbon industry and large scale, exposed, or "energetic" aquaculture in the ocean, led by Norway and China. Both industries have strategic synergies. For example, commercial diving is routinely conducted on oil/gas platforms and is common in offshore aquaculture. It is recommended to engage a central Norwegian authority (Norsk Institutt For Bioøkonomi (Norwegian Institute of Bioeconomy Research) (NIBIO) for contacts and further connections (Dr. Johan Johansen<johan.johansen@nibio.no).

Market Issues

In both nations, fish is a minor source of protein. Both are meat-eating nations. Only 0.1% of the daily caloric intake and 0.6% of protein intake come from fish. Terrestrial animal proteins constitute ~40% of the protein consumption; fish is only ~2%. Azerbaijan has one of the lowest per capita

consumption of fish and seafood products in the world; in 2022 it was estimated at 2.3 kg/capita/yr, much lower than the world average of 20 kg/capita/year.

However, Azerbaijan's total domestic fish and seafood supply was 20,050 MT, with about 95% imported, causing a large trade deficit. One of the reasons mentioned for low fish consumption is that the low supply may have driven up prices. Increasing fish consumption in Azerbaijan, could be challenging even if the supply increased and prices reduced. It may be necessary to launch campaigns to advertise the benefits of eating fish and seafood and an encourage people to increase their consumption.

Not all fish are heart-healthy alternatives with high levels of long chained fatty acids (salmon, sardines top the list). Azerbaijan and Kazakhstan are fortunate to have tradition fish – sturgeon – that is joins this important group of foods valuable for human health and wellness (Chen *et al*. 2022). Accelerated development of sturgeon farming for meat could be a major development in aquatic food systems for the region and needs further in-depth study.

There is serious market competition from Iran and Russia for sturgeon meat and caviar. Iran subsidies were reported. Sturgeon meat from Iran coming into Azerbaijan was 28 manat/kg ($16.8/kg) while Azerbaijan meat was 34 manat/kg ($19.9/kg), and Russian carp was 4-5 manat/kg ($2.3-$2.9t/kg) and Azerbaijan was 7-8 manat/kg ($4.1-$4.7/kg). Iran "flood" fish markets in Azerbaijan especially during important fish consuming holidays (New Year's) in fish consuming districts like Neftçala that borders Iran. Aquaculture LLC the cage farm in Azerbaijan reported that trout from Iran sold at 8 manat/kg ($4.7/kg) while Azerbaijan trout was 9.5 manat/kg ($5.6/kg), and sturgeon from Iran was 18 manat/kg ($10.8/kg) and Azerbaijan 25 manat/kg. ($14.7/kg).

As with many fisheries places across the world, fish and caviar fraud and tracing remain important concerns. Illegal catching of sturgeons was reported throughout the Mission. Fast speed boats from Russia can strike many Caspian Sea areas of other countries very quickly. Fish fraud – replacing higher cost sturgeon meat with lower cost African catfish meat – was widely reported and occurs regularly at festivals, holidays (especially New Year's), bazaars, weddings.

Conclusion: Preliminary Key Learnings and Strategic Gaps

The following insights and gaps are based on observations from the World Bank Mission. While not exhaustive, they offer a possible foundation for shaping future priorities, partnerships, and targeted interventions in the region's aquaculture sector.

Key Learnings

1. **Public-Private Cooperation is Essential:** A thriving aquaculture sector depends on strong collaboration between government, private actors, and applied research institutions. Sustained public support, combined with efforts to attract both local and international investment, is vital for long-term growth.
2. **Reducing Import Dependency**: The heavy reliance on imported aquaculture feeds is a major constraint to sector development. Absence of domestic feed mills and applied aquatic feed research capacities limits productivity, increases costs, and creates supply chain vulnerabilities.

3. **Strengthening Regulation and Governance**: Environmental regulations, spatial planning frameworks, modern, ecosystem-based aquaculture governance mechanisms, and biosecurity protocols are either underdeveloped or poorly enforced. Addressing these weaknesses is crucial for sustainable sector expansion.
4. **Urgent Need for Capacity Building and Technology Transfer**: There is a critical shortage of trained personnel and tailored, applied aquaculture education and training programs. Strengthening extension services and investing in human capital is a priority to meet the sector's evolving technical and operational demands. International consultations and additional partnership developments could allow these nations to rapidly accelerate aquaculture developments that "leapfrog" to today's state-of-the-art and avoid "recreating the wheel" and repeating past international aquaculture development/policy mistakes.
5. **Unlocking Market Potential**: Caviar producers require strategic branding and repositioning to succeed in global markets. Moreover, the potential for sturgeon fish meat production is currently underutilized and lacks structured, coordinated development planning.

Together, these learnings point to clear opportunities for modernizing aquaculture value chains, improving competitiveness, and unlocking export potential across the region.

Key Strategic Gaps

1. **Lack of Operational Roadmaps**: While Kazakhstan has set ambitious aquaculture targets, they are not supported by concrete implementation plans. In Azerbaijan, strategic planning remains at a nascent stage and requires further development and coordination.
2. **Weak Innovation and R&D Ecosystem**: Applied research and development are fragmented and largely confined within private enterprises. A broader, collaborative innovation ecosystem—spanning academia, government, and industry—is lacking.
3. **Financial Access Constraints**: Small-scale operators face significant hurdles in accessing affordable finance, including credit and insurance. Addressing these barriers is essential for inclusive sector growth.
4. **Environmental Vulnerability**: Unchecked expansion of in-water cage aquaculture without robust governance and environmental safeguards poses risks to critical ecosystems, including lakes, reservoirs, and the Caspian Sea. Stronger environmental monitoring and controls are urgently needed.
5. **Fragmented Governance and Coordination**: Ineffective institutional coordination continues to slow progress in aquaculture development. Strengthening interagency collaboration and development of international partnerships are key to scaling up efforts and sharing best practices.

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High quality farmed caviar from Azerbaijan enjoyed during the Mission 😉