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Review

The Changing Dynamics of Kazakhstan's Fisheries Sector: From the Early Soviet Era to the Twenty-First Century

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Abstract: Kazakhstan, a former Soviet republic that is now independent, lies near the center of arid Eurasia. Its sparse hydrographic network includes a small number of large rivers, lakes, and reservoirs, many ponds and smaller streams, as well as littoral zones bordering the Caspian Sea and the Aral Sea. A diverse fisheries sector, initially based on wild fish capture and later including aquaculture, developed in these waters during the Soviet era, when animal agriculture was unable to meet the protein needs of Soviet citizens. The sector, which was originally centered on the Volga–Caspian basin, was tightly managed by Moscow and benefitted from coordinated investments in research, infrastructure, and human resources, as well as policies to increase the consumption of fish products. Independence in 1991 administered a political and economic shock that disrupted these relationships. Kazakhstan's wild fish harvests plummeted by more than two-thirds, and aquaculture collapsed to just 3% of its previous level. Per capita consumption of fish products also declined, as did processing capacity. Favorable recent policies to define fishing rights, incentivize investments, prevent illegal fishing, and make stocking more effective have helped to reverse these trends and stabilize the sector. Continued recovery will require additional steps to manage water resources sustainably, prioritize the use of water for fish habitats, and minimize the effects of climate change. This comprehensive assessment of Kazakhstan's fisheries sector over the past century provides the basis to understand how long-term dynamic interactions of the environment with the political economy influence fisheries in Eurasia's largest country.

Keywords: fisheries; aquaculture; water resources; hydrological regime; Eurasia; Kazakhstan; Soviet Union

Citation: Graham, N.A.; Pueppke, S.G.; Nurtazin, S.; Konysbayev, T.; Gibadulin, F.; Sailauov, M. The Changing Dynamics of Kazakhstan's Fisheries Sector: From the Early Soviet Era to the Twenty-First Century. *Water* **2022**, *14*, 1409. https://doi.org/10.3390/w14091409

Academic Editor: Wayne O'Connor

Received: 1 April 2022
Accepted: 27 April 2022
Published: 28 April 2022

1. Introduction

The collapse of the Soviet Union in late 1991 marked the beginning of a new political and economic reality for Kazakhstan. More than 70 years of centralized control from Moscow was swept away, as the new Republic struggled to shift from a rigidly planned to a free-market economy [1]. Although the state was initially uncertain if independence from the "comfortable" economic relationship with Moscow was a good thing, the transition ushered in new global opportunities. The perceived wonders of a Western-style capitalist market economy took advantage of Kazakhstan's rich mineral resources, generating significant economic activity [2]. Food security was not viewed as a pressing issue, and

so agriculture was neglected and consequently endured a period of crisis during the first decade of independence before entering a long road toward recovery [3–5]. The fate of agriculture in post-Soviet Kazakhstan has received considerable attention [6,7], as have the prospects for future growth of crop and livestock production [8,9].

The fishing industry, which had once flourished but then virtually collapsed after the dissolution of the Soviet Union, has commanded much less attention [10]. In contrast to crop and livestock production, capture fisheries in the Republic's lakes, rivers, and reservoirs have never recovered [11]. Aquaculture (fish farming), which relies on ponds and cages to produce juveniles for stocking natural waters and mature fish for processing, suffered a similar fate [12]. These industries, which we collectively term the fisheries sector, had always made relatively modest contributions to food production in comparison to land-based agriculture. Kazakhstan's fisheries sector was nevertheless a significant source of protein in the Soviet diet [13] and an important means of employment in areas offering few other opportunities [14].

The initial freefall and continuing malaise of the fisheries sector in independent Kazakhstan have been considered from several important perspectives. We and others have analyzed the data documenting the decline [11,15–19]. The damage performed by the sudden relaxation of centralized control during the Soviet era, as well as the new Republic's preoccupation with other issues, has also received attention [14,19]. Nongovernmental agencies, international funding organizations, and others have also made recommendations to revitalize the sector [14,20–23].

Here we update and extend these studies by assessing the changing status of the Kazakh fisheries sector over a period of more than a century, during which the political and economic dynamics abruptly changed. Our working hypothesis is that examination of these long-term dynamics will confirm that many of the current challenges facing the sector trace their origins to the Soviet period. We begin with a synopsis of Kazakhstan's environment and its natural resource base for fisheries. We then turn our attention to the long-term evolution of the fisheries sector before and after the dissolution of the Soviet Union (although Soviet Kazakhstan was officially the Kazakh SSR, we employ the word Kazakhstan pre- and post-independence). Finally, we look to the future by considering a series of emerging factors that are challenging the sector but also providing potential avenues for its resurgence.

2. Kazakhstan's Environment and Hydrographic Network

The regime and flow of Kazakhstan's rivers are governed by the Republic's unique topography and climatic zoning, which ultimately determine the distribution of fish habitat. A vast nation covering 2.7 million km^2 of the earth's surface, Kazakhstan lies at the center of Eurasia (Figure 1). Its climate is distinctly continental, with hot summers, cold winters, and large daily, seasonal, and annual fluctuations in air temperature [24]. About 12% of the country is covered by piedmont areas and high mountains that receive the most precipitation and are located along the south and eastern borders [25]. The remainder consists of low, arid drylands that are classified into five climatic zones from north to south: forest-steppe, steppe, dry steppe, semi-desert, and desert [26]. Average annual precipitation declines from 270 mm in the steppe areas to just 120 mm in the desert zone.

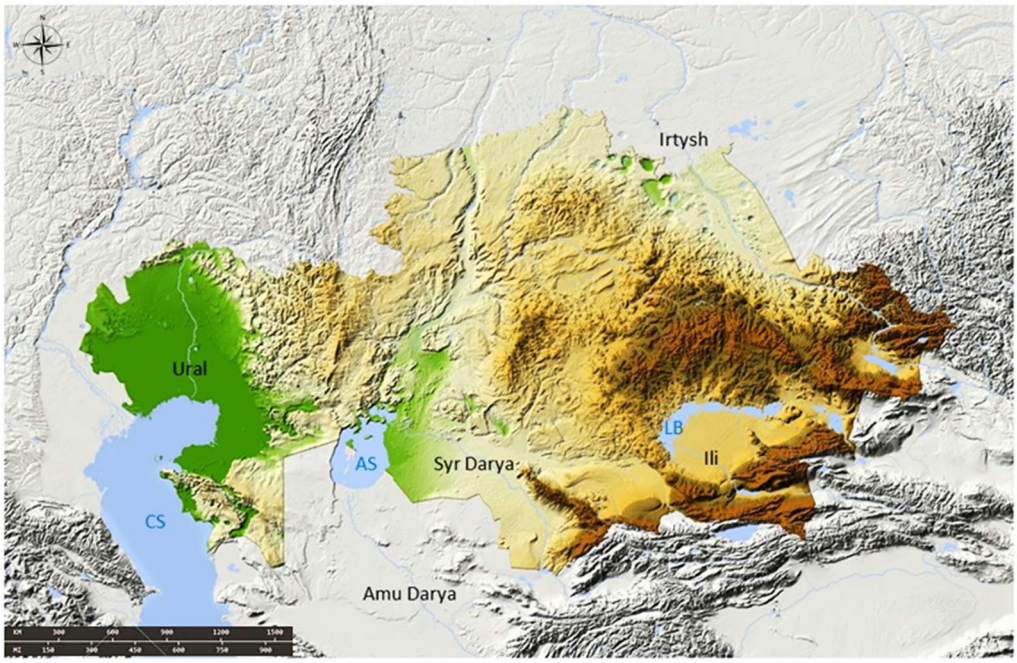

Figure 1. Relief map of Kazakhstan. Higher elevations are shown in brown and lower elevations in green. The Ural, Irtysh, Ili, Syr Darya, and Amu Darya rivers are identified, as are three large lakes: the Caspian Sea (CS), Aral Sea (AS) in its mid-twentieth century form, and Lake Balkhash (LB). Credit: 123RF.com, accessed on 16 March 2022 and used with permission.

Most of Kazakhstan's rivers originate in mountainous areas and are charged by seasonal snowmelt [25,27]. Spring floods are common, and drought periods routinely cause smaller streams to dry up as they flow across the arid lowlands [28,29]. The continental climate of Kazakhstan conditions sporadic drought in the summer and autumn [27,30], and this results in low water availability in some years and adequate or even excess water in others [31,32]. Although the Republic has more than 8000 rivers with lengths greater than 10 km, only 155 are more than 100 km in length and only seven flow for more than 1000 km. Just 53—less than 1% of the total—have an average annual water discharge of more than 5 m^3/s. The Republic's rivers tend to be shallow, and although their total length is 10,500 km [33], they form a very sparse network.

There are four significant rivers from the standpoint of capture fisheries: the Irtysh, Syr Darya, Ili, and Ural (Figure 1) [14]. About 180 reservoirs have been constructed, mainly for irrigation and hydroelectric energy, but some of them also provide important fish habitats. The largest, all of which have important fisheries value [34], are the Bukhtarma and Shulba Reservoirs on the Irtysh River, Kapchagay Reservoir on the Ili River, and Shardara Reservoir on the Syr Darya River [35]. The average annual water discharge rates of Kazakhstan's four large rivers, all of which are transboundary, range from 350 m^3/s for the Ural to 800 m^3/s for the Irtysh. Although the rivers in Kazakhstan produce total water resources that average 100.5 km^3/year, almost half of this volume enters from neighboring countries that are increasingly diverting water for agriculture and industry [35,36].

Kazakhstan's borders also enclose about 3000 lakes with surface areas greater than 1 km^2 and 22 with areas of more than 100 km^2; the total area covered by all lakes in Kazakhstan was nearly 2.9 million ha as of 1978 [33]. Most are in the forest-steppe and steppe zones, but there are also lakes in the deserts of southern Kazakhstan. The total area of these waterbodies is about 45,000 km^2, two-thirds of which is of value for fisheries [30]. Most of the lakes, including Lake Balkhash, the Republic's largest water body, are nevertheless shallow, lack outlets, and because of the climate, subject to abrupt changes in water volumes and surface areas. Lake Balkhash, for example, has a current average depth of just 5.8 m. Fluctuations in inflows over the past few decades have caused its surface area

to vary between 15,000 and 19,500 km^2 [37]. This means that more than 4000 km^2 of the lake's littoral waters, which are important sites for spawning and feeding fish, are subject to periodic desiccation [38]. These unpredictable dynamics, which are not limited to Lake Balkhash, have potentially widespread detrimental impacts on the natural reproduction of fish stocks.

In addition to its inland lakes, Kazakhstan borders two large, shared bodies of saline water of longstanding importance for fisheries: the Caspian Sea and the Aral Sea [13]. With a surface area of 378,000 km^2, the Caspian Sea is the world's largest water body lacking an outlet to the ocean. The Volga and the Ural Rivers flow into the sea from the north and help maintain the degree of salinity at about one-third that of sea water, creating a unique environment for fish. Caspian sturgeon (*Acipenser* spp.), which have been caught commercially since the seventeenth century [39], are the source of the world's most sought-after caviar and consequently of immense economic value [40]. The Caspian Sea is subject to both anthropogenic threats due to pollution, especially from Azerbaijan [41], and periodic natural fluctuations in its surface area [42], which disrupt fish spawning in the shallow littoral zone along Kazakhstan's extensive, 2300-km coastline.

The Aral Sea is much smaller than the Caspian Sea, and although historically valuable for fisheries, its importance never matched that of its larger sister [13]. Fed by the Syr Darya and Amu Darya Rivers, the Aral Sea is well known as an object of human-caused environmental degradation due to ill-advised water withdrawals for irrigation [43,44]. It was reduced from a single waterbody with a surface area of 66,500 km^2 in the mid-twentieth century to a cluster of smaller waterbodies with a total surface area of just 10,000 km^2 as of 2017 [45,46]. Beginning in the early 1990s, the local community took steps to preserve one of these residual water bodies, Kazakhstan's Small Aral Sea [47]. In contrast to the other remaining areas, which appear destined for complete desiccation, its level and hydrological condition have now been stabilized [45,48], and thus from the perspective of Kazakhstan, the Aral Sea is now inland and not a shared resource. Commercially valuable fish have returned, as has a growing fisheries industry [49–51].

3. The Soviet Fishing Sector and Its Implications for Kazakhstan

3.1. Early Development

It was not until the latter half of the nineteenth century that fishing became a significant activity in czarist Russia. Transportation systems were expanding, methods to preserve food were improving, and governance policies were being revised to meet the growing demand for fish products [13]. In 1913, the eve of World War I and the 1917 revolution that would soon lead to the establishment of the Soviet Union, 83% of Russia's fish capture was from inland waters, and three-quarters of this amount was from the Volga–Caspian basin [52]. Domestic demand could nevertheless not be met, a situation that deteriorated during the war as resources were mobilized for fighting. The provisional government issued decrees during the winter of 1917–1918 to abolish private ownership of water resources; fisheries were nationalized, and numerous fishing firms were closed [53]. *Glavryba*, the Directorate for Fish and the Fishing Industry in Russia, was established in October of 1918 and assigned comprehensive responsibilities for the administration, regulation, and production of fish. Five regional directorates termed *Oblastryba* were also created and began to organize fishers into collectives [53–55].

A surplus-appropriation system was imposed on the fishing sector during this period. Private fishers were declared to be state fishers, and all harvests were forcibly seized and transferred to the People's Commissariat of Food, which took charge of distribution. The once-flourishing Volga–Caspian fisheries became a testing ground for the new political ideology, which funneled support to poorer, nonproductive peasants while denying it to the wealthier, most productive group of fishers [56]. Lenin's New Economic Policy of 1921 counteracted some of the damage caused by these stringent policies by restoring fishing firms, removing the state monopoly on fishing grounds, and allowing fishers to work privately and sell their own catches [53–57].

The die for centralization had nevertheless been cast [54]. Beginning with the first Five Year Plan for 1928–1932 and continuing until the collapse of the USSR in 1991, the Soviet fishing sector was issued production targets and provided with resources to achieve them. The Ministry of Fish Industry, which had existed in earlier forms until its establishment in 1939 and was reorganized several times thereafter [58,59], exerted vertical control over this process. The Ministry allocated production targets issued by the State Planning Committee of the Council of Ministers of the USSR (*Gosplan*) to these units, one of which, the Caspian Sea Fisheries Directorate (*Kaspryba*), reflected the importance attached to the Volga–Caspian basin.

The Ministry of Fishing Industry also controlled the entire supply chain, which grew to include a fleet of well-equipped fishing trawlers (some are especially designed for use on the Caspian Sea; see [59]), a refrigerated transportation network, port infrastructure, and processing facilities that were assigned to the various *Oblastryba* [60–62]. A world-class research and fish conservation fleet was established, as were specialized research and educational institutions such as KaspNIRO, the Caspian Scientific Research Institute [59], and the Kazakh Research Institute of Fisheries, which was created in 1959 under the auspices of the Kazakh Academy of Sciences. Moscow managed everything from the production of tin cans and fishing gear to quality control of fish products to the operation of supply and sales outlets [13]. *Glavrybvod*, the Ministry's Main Administration for the Preservation and Reproduction of Fish Stocks and the Regulation of Fisheries, had broad authority over Soviet fisheries, but it devolved responsibility for scientific and technical issues to subordinate regional agencies such as the Ministry of Fishing Industry of Kazakhstan and its predecessors, which also had jurisdiction over local fishing and fish processing associations [13,21,59].

3.2. Characteristics of the Soviet Fisheries Sector

Commercial fishing in the Soviet Union was performed by either *solkhozy* (state-owned enterprises) or *kolkhozy* (cooperative enterprises). Fish harvested by *solkhozy* were state property, but those caught by *kolkhozy* belonged to the cooperative, which held all property communally and sold its fish to the government at a set price determined by the State Committee of the Council of Ministers. *Kolkhozy* consequently achieved advantages of scale unobtainable by individual fishers [13]. The All-Union Association of Fishery Kolkhozy and Cooperative Organizations was organized in 1931 to manage the affairs of *kolkhozy* [59], which by 1950 were responsible for more than 80% of catch from the Volga–Caspian basin [52]. As many as 30 *kolkhozy* once operated on the Aral Sea [63], and five were still in operation on Lake Balkhash when the Soviet Union disintegrated [20].

Although more than one million people were eventually employed across the Soviet fisheries sector, investments were modest and recovery slow prior to World War II, which destroyed the Caspian fleet and processing facilities [59]. The post-war Soviet Union again lacked sufficient agricultural resources to provide its population with animal protein, and so beginning with the 1946–1950 Five Year Plan, major investments were made to rebuild capacity in fisheries. Expenditures rose from 1.3 billion rubles between 1952 and 1958 to 1.7 billion rubles between 1966 and 1968, as *Gosplan* increasingly turned its attention to the exploitation of lucrative ocean fishing grounds [13,64]. Beginning in 1965, the Ministry also introduced a bonus system of remuneration, which provided financial incentives to stimulate the production of fish products. Catches from inland waters remained essentially flat between 1930 and 1972, but those from ocean waters increased more than 14-fold during the same interval [61]. Thus, although overall fisheries production increased rapidly (Figure 2), exceeding 10 million tonnes for the first time in the mid-1970s, inland fisheries, including those in Kazakhstan [65,66], were losing their significance.

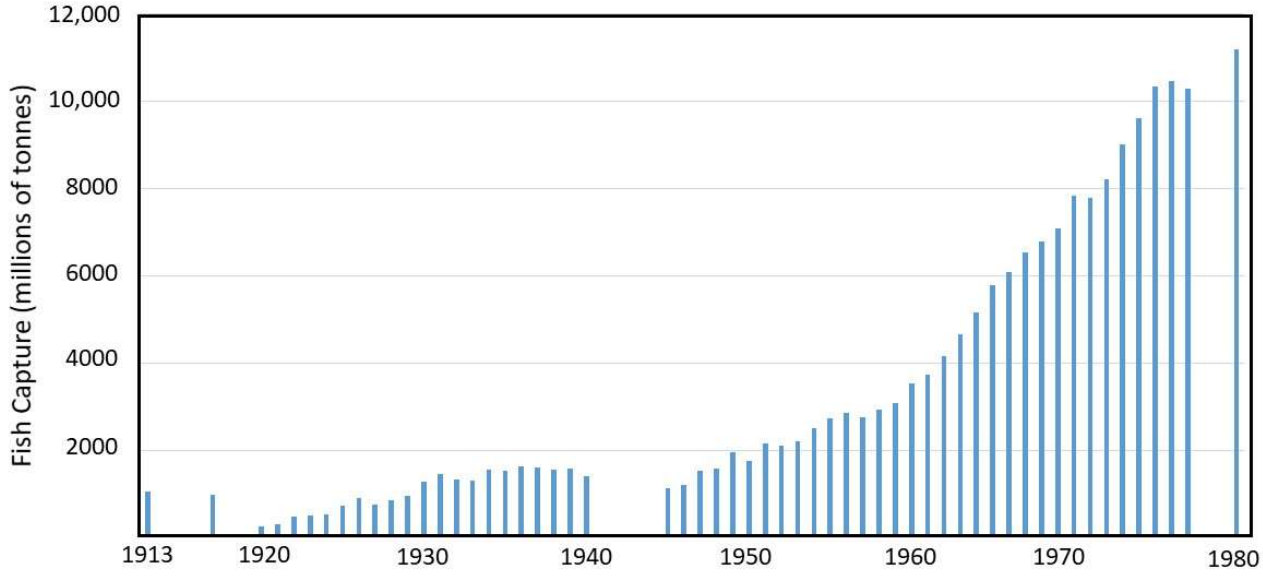

Figure 2. Commercial production of fish and other sea organisms in late czarist Russia (1913), immediately after the revolution (1917–1921), and in the Soviet Union (1922–1980). Data source: [52].

Fisheries in Kazakhstan achieved their greatest development during the Soviet era, but they also faced chronic challenges, none of which escaped the attention of Moscow. The once-dominant Volga–Caspian fisheries were reduced to insignificance by the 1960s (Figure 3) and those on the Aral Sea ceased operation in the late 1970s [67]. Dams were constructed to impound rivers and generate hydroelectric power, even though it was clear that their hydrological effects would damage fish habitats and interfere with fisheries [68–70]. Pollution of waters used for fisheries was tolerated [67,71], and introduced species intended to bolster fisheries [72–74] often disturbed fish populations without delivering the intended benefits [33,45,72,75]. Uncontrolled overfishing greatly exacerbated these problems [76].

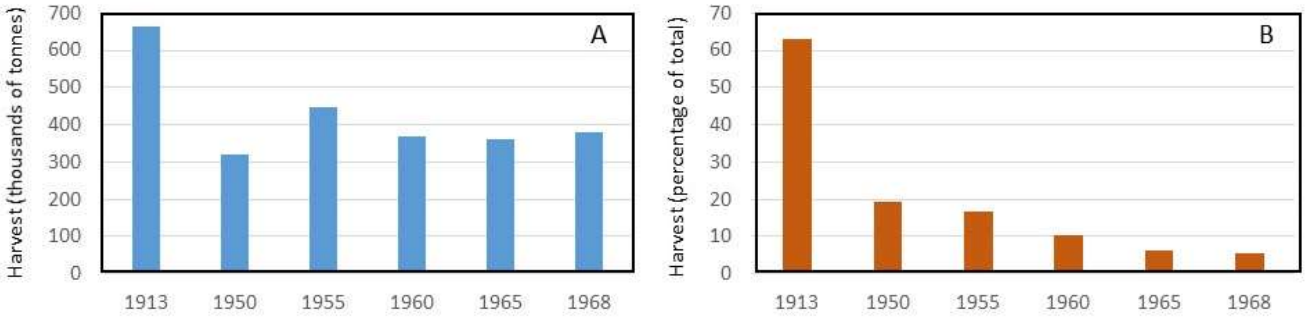

Figure 3. (**A**) Commercial fish harvests from the Caspian Sea and (**B**) fish harvests from the Caspian Sea as a percentage of the total Soviet production. Data sources: [13,52].

The Soviets undertook a number of steps to mitigate these challenges. Artificial reproduction was introduced to restore natural populations. This necessitated the construction of a network of fish hatcheries and breeding farms to produce immense numbers of juveniles to stock water bodies unable to maintain adequate fish populations under natural conditions [33,52,77]. Reservoirs came to be viewed as assets for commercial fish production, and their numbers were increased [64,78]. High-value predatory fish species were also introduced into smaller lakes to eradicate low-value trash species [11], and beginning in the 1930s, a substantial effort was also made to improve the food base for fish production by the introduction of invertebrates that could serve as prey [33,74,79].

The first Soviet fish farms were established in the 1930s [52,59], and seven zones were defined, six in Kazakhstan [80]. These facilities were assigned increasing priority, not

just to propagate juveniles for release but also to elevate inland production of marketable fish. Raising fish in ponds was viewed as efficient use of land unsuitable for agriculture and a means to locate production near natural waterways (in the case of stocking) or population centers (in the case of marketable fish). Although fish production in ponds was plagued by inefficiency [13] and the subject of constant complaints and recommendations for improvement [52,59,64], stocking became an established practice. By 1968, 7.6 billion juveniles were being released annually into Soviet waterways [13].

The yield of market fish from aquaculture increased dramatically in the mid-twentieth century, but it constituted a negligible 0.6% of total Soviet production [13]. With the exception of the Volga–Caspian basin, where *kolkhozy* emphasized the development of pond fisheries [59], aquaculture was of little importance in Kazakhstan, where the first fish farm was established in 1937 [11]. Production of marketable fish from ponds, which was just 692 tonnes in 1970, rose almost 15-fold over the following two decades (Figure 4), but this constituted just 2.2% of the Soviet Union's total aquaculture production [11,77].

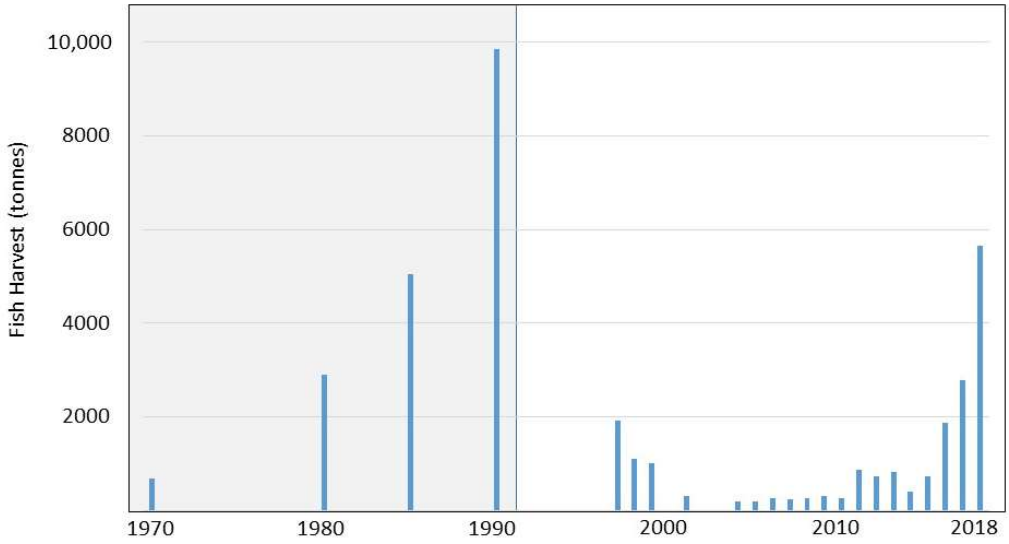

Figure 4. Production of market fish from aquaculture in Kazakhstan. Harvests during the Soviet era are shaded. Data sources: [11,81].

Efforts to stabilize fish populations by protecting habitat and establishing fish farms, and stocking were augmented with policies to achieve what today would be called sustainable fisheries. Regulations were made more stringent, allowable catch sizes were reduced, and certain types of fishing gear were prohibited on some waterbodies [11,13,52]. Outright bans were also put into effect, as in 1962 for sturgeon fishing in the Caspian Sea [76]. These actions were only undertaken after extensive research and data analysis [33,64,72].

3.3. Consumer Demand for Fish in the Soviet Union

Consumer demand played a major role in the development of the Soviet Union's fisheries sector, and similar to other aspects of life in the USSR, Moscow sought to manage it (Figure 5). Early preferences for fish were heavily influenced by products from the Caspian Sea, the major source of fish during the late czarist and early Soviet era [59]. The Academy of Medical Sciences of the USSR emphasized the nutritional aspects of fish consumption but paid little attention to cultural influences. The Commissar for External and Internal Trade designated Thursday as the All Soviet Fish Day of the Week in 1932 [82,83]. Canteens, cafeterias, and restaurants were obligated to serve fish on this day, and a cookbook soon appeared to, among other things, put more fish on the dinner table at home [84]. New processing methods, strict attention to quality, and marketing through specialized shops were all deployed as tools to elevate consumption of the growing Soviet fish harvest [13,52,59,85].

As of the early 1970s, fully one-third of all animal protein consumed by Soviet citizens was supplied by fish [60].

Figure 5. An early advertisement produced by the Soviet Ministry of Fish Industry urges readers to "Save time, buy fish products." Credit: Russia Beyond (www.rbth.com/russian-kitchen/333856-thursday-fish-day-user, accessed on 18 March 2022).

Targets to enhance fish consumption were also set by *Gosplan*, which in 1976 announced the goal of increasing sales of fish by 25%. Even more ambitious targets were in place by the late 1970s, when efforts were underway to propel annual per capita consumption above the 18.2 kg per person then recommended by the USSR Academy of Sciences [52]. Although average annual consumption rose from 6.7 kg in 1913 and 7 kg in 1950 to 16.8 kg in 1975 and 18.5 kg one year later, regional differences were pronounced. As of 1975, per capita annual fish consumption in Eurasia was estimated to be only about one-third that of the country as a whole [86].

4. The Fisheries Sector in the Republic of Kazakhstan

4.1. Adjustments following Independence

Kazakhstan declared its independence on 16 December 1991 and immediately began to grapple with its newfound sovereign status [87,88]. The debate over the superior system of governance seemed to have been settled in favor of democracy, free markets, and the benefits of globalization [89–92]. Now subject to unfamiliar market forces, the new Republic

assigned top priority to the economy, of which the fishing sector was a comparatively small, albeit profitable segment [19,20]. Most post-Soviet states, including Kazakhstan, found the challenges of privatization, deregulation, and reduced public expenditure [93,94] to be daunting and were unable to proceed efficiently [95]. Globalization and restructuring offered substantial promise for growth in wealth [96], but the adjustment would soon lead to much economic pain and disillusionment [97,98]. In some respects, this did not much matter because the lucrative oil and gas sector was doing well enough to outweigh potential disruption and losses in smaller sectors. Food could be readily imported, so rural unemployment and related disruption did not attract much attention [99,100].

The incoherence, competition, and political tension that settled over the Kazakh fisheries sector is a prime example of what went wrong. Old Soviet structures, chief among them the powerful Ministry of Fish Industry and its subordinate agencies, were abolished, and responsibilities for stocking and regulation of fisheries, fisheries research, and processing separated from one another [11,19,21,101]. Staffing was inadequate and financing insufficient. Balkanization of responsibility undermined the enforcement of fishing limits, the inspection of fishing and processing operations, and the establishment of fishing seasons—issues that had previously been handled centrally and guided by expert opinion. Management of fish stocks in Kazakhstan's inland waters was also jeopardized. These shortcomings were partially addressed by the establishment of two agencies within the Ministry of Agriculture [11]. The Kazakhstan Fisheries Scientific Research Institute (KazNIIRKh), which traces its origins to the Soviet-era Kazakh Research Institute of Fisheries and has branch offices across the Republic, was reorganized in 2002 and charged with providing scientific and technical support. One year later, the Fisheries Committee, which had been established in 1992 and then unsuccessfully merged with another committee, was reconstituted and given responsibilities for planning and management of the sector [21].

The new government also privatized the fisheries sector [11,102]. Disposal of fishing vessels, transportation infrastructure, production and storage facilities, and fish processing equipment fragmented the industry and severed supply chains. Soviet-era efforts to increase the amount of fish in the Kazakh diet also ceased, depressing the market for fish products [11,20]. Annual consumption of fish and fish products in Kazakhstan, which had stood at 10.3 kg per capita in 1990, consequently fell to 4.8 kg in 1995 and an estimated 3.5 kg by 1997 before beginning to slowly increase after 2001 [103]. Actual consumption was nevertheless likely higher due to home consumption of unreported harvests [104].

The state's general neglect of the fisheries sector prompted a number of significant challenges that were becoming increasingly apparent by the mid-1990s (Table 1). Prodded by international entities such as the World Bank and the UN Food and Agricultural Organization (FAO), the government slowly began to take these issues seriously [11,19,20]. The reconstituted Fisheries Committee exerted control over the planning and management of capture fisheries and aquaculture. Rights of access to fishing grounds were formalized in 2006, and the Association of Fishery, Fishing Process, Fish Farming, and Fish Trading was founded two years later to give all fishers a united voice [11]. Concurrent steps were also taken to effectively manage the Republic's water resources [22,105].

Table 1. Challenges confronting the fisheries sector in independent Kazakhstan.

Category	Issue	Consequences for Fisheries Sector
Institutional framework	State responsibilities dispersed and poorly defined [22,104]	Slow capacity to respond to opportunities and challenges
	Property rights unclear [67]	Illegal fishing
	No national fisheries law [102,106]	Overexploitation of fish stocks
	Lax regulatory enforcement [51,76]	Unreported catches, black markets
Financing	Lack of sector-specific funding [14,102]	Fish stocks decline, loss of institutional memory
	Extension and outreach efforts cease [11,20]	Erosion of staff expertise, outmoded technology
	High costs and lack of credit [23,51]	Disincentivized private sector investment
	Decaying infrastructure [14,104,107]	Reduced production and processing capacity
Overriding factors	Neglect and marginalization of the sector by the state [19,20]	The public views fisheries as unattractive
	Lack of research and data collection [21,22]	Policies become disconnected from science
	Policy flux and lack of transparency [11,67,101]	Policies not respected

4.2. Fish Production

Transition to a market economy triggered an immediate contraction of Kazakhstan's fisheries sector, which was highly profitable at the time of independence [11]. By 1998, fish harvests had declined by almost two-thirds, and although they partially recovered in later years, progress was slow and disappointing. Landings from the Caspian Sea, which had been declining for more than a decade, remained on this trajectory after independence [20]. By the late 1990s, the new Republic's harvest of sturgeon and beluga (*Huso huso*) was approaching zero [76]. The government's plan to increase fish capture to 51,700 tonnes by 2006 [108] has not yet been achieved [109]; indeed, fish capture during the second decade of the current century was often below 32,000 tonnes per year and rarely exceeded half of that achieved in 1990 [81,110].

The situation was even more dire for fish farming, which suffered from low production efficiency during the Soviet period and had survived due to state subsidies [13]. Aquaculture literally collapsed following independence. Most fish farms ceased production by the mid-1990s [11], and the 1990 production, 9800 tonnes, consequently plunged by more than 98% to just a few hundred tonnes (Figure 4). Harvest of marketable fish from ponds recovered slowly and only partially; it first exceeded 1000 tonnes per year in 2016, a quarter-century after independence [81]. Aquaculture remains a minor player in the fisheries sector, as indicated by Table 2, which summarizes the changing relationships between the yield from the Republic's fish farms and that from inland water bodies and the Caspian Sea. The latter contributed half of all production at the time of independence, but long-term dynamics have favored inland water bodies. Aquaculture's contributions are negligible. The relative importance of fish farming is, in fact, even less likely than indicated because of underestimated wild fish capture due to illegal, unreported, and unregulated (IUU) catches [11,20,106].

Table 2. Sources of Kazakhstan's fish production during selected years [a].

Year	Fish Production (Percentage of Total)		
	Inland Water Bodies	Caspian Sea	Aquaculture
1989/1990	38.9	49.9	11.2
2000/2001	65.7	33.7	0.6
2010	73.0	26.5	0.5

[a] Data sources: [11,15,19,76]. Production estimates in Kazakhstan can vary, even those from governmental agencies [20]. The numbers used here are best estimates based on FAO data whenever possible.

4.3. Fish Processing and Marketing

The troubles experienced by the fisheries and aquaculture industries had unavoidable effects on Kazakhstan's fish processing industry [13]. Deterioration of equipment, reliance on outdated technologies, and the absence of supportive state structures gradually compromised the profitability and quality standards of fish products. Renovation and modernization were required to avoid obsolescence, but harsh economic reality forced most legacy processors to contract or cease operation as the fisheries sector descended into a state of protracted stress. *Balkhashrybprom*, the largest fishing association on Lake Balkhash during the Soviet era, once employed more than 1000 fishers and processed about 10,000 tonnes of fish annually [107]. *Balkhashbalyk*, its privatized successor firm, is still in business, but as of 2017, only 160 fishers remained, and just 15 of its once 1200-tonne storage capacity were being used [111]. Similar dynamics are at play in the Volga–Caspian basin, where the largest Soviet-era association, *Atyraurybprom*, once processed fish from 11 *kolkhozy* [11]. Its privatized successor, *Atyraubalyk*, continues to harvest fish from the Caspian Sea (Figure 6), but the firm suffers from excess storage capacity [102]. The Aral Sea association survived for a few years but was reduced to making in-kind payments to its fishers before it finally collapsed in 1997 [51]. Other Soviet-era processors failed to adjust to market conditions and suffered similar fates [11].

This gloomy situation improved as smaller competitors appeared, including 20 near the Small Aral Sea [112]. The surviving legacy firms have also stabilized [11,14,102,113], but utilization of Kazakhstan's current 87,000-tonne annual fish processing capacity nevertheless stands at just 43% [104]. The Eurasian Economic Union of post-Soviet states has become a key export market for three relatively low-value species currently produced in Kazakhstan: bream (*Abramis brama*), roach (*Rutilus rutilus*), and asp (*Aspius aspius*) (Figure 7). European countries have also emerged as a lucrative market for zander or pike-perch (*Sander lucioperca*), which flourish in Kazakhstan's environment and have long been a prized menu item in European restaurants [67,111,112,114]. The annual value of high-quality fish product exports to the European Union, mostly zander, ranged from 32 to 39 million Euros between 2017 and 2020 [115]. Total exports in 2020 were estimated at 30,000 tonnes [116].

Figure 6. Fishermen who work for *Atyraubalyk* draw their nets at the far northern end of the Caspian Sea. This legacy firm processes more than one-third of the tonnage of fish from the area. Credit: www.almaty.com, accessed on 27 January 2022 and used with permission.

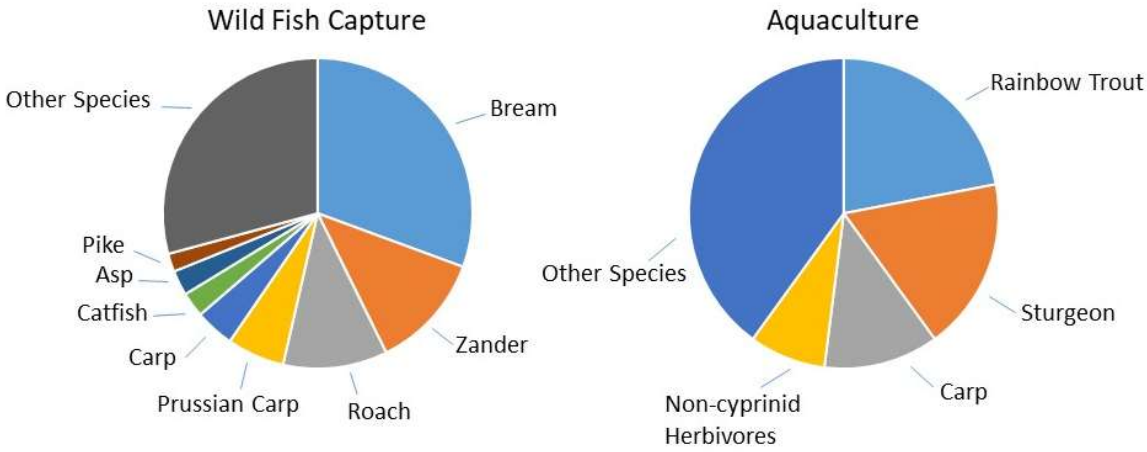

Figure 7. Production by Kazakhstan's fisheries sector in 2017. The Latin names of all species except rainbow trout (*Onchorhyncus mykiss*), pike (*Esox lucius*), and Prussian carp (*Carassius gibelio*) are given in the text. Source: [81].

5. Revitalizing the Fisheries Sector in Kazakhstan: Risks and Challenges

5.1. Water and Other Natural Resources

The withdrawal of the Soviets in 1991 transferred responsibility for dealing with a range of fisheries-critical environmental issues from Moscow to the new Republic [117], and in some ways, the environmental situation improved. Withdrawals of water for irrigation declined and remained well below those during the Soviet era [28,118,119]. This has preserved the quality and quantity of water available for the fisheries sector and mitigated some of the tradeoffs with crop-based agriculture. Kazakhstan has also received much credit for the construction of the Kökaral Dam, which stabilized the Small Aral Sea,

reviving dormant fisheries activities and providing an exemplar for expansion of a sector more commonly characterized by contraction [67,112].

The Republic nevertheless continues to assign priority to the exploitation of natural resources for industrial and agricultural development [120]. Water resources are widely considered to be poorly managed, with undue emphasis placed on quantity rather than quality [22,121]. Industrial pollution has not been curtailed [23,122], and drainage water from irrigation areas continues to carry excess fertilizer, salts, and residues of agricultural chemicals into natural waterbodies [122–126]. Pollution levels consequently remain high in waterbodies that had already become trouble spots for fisheries during the Soviet era—Lake Balkhash [127,128], the Caspian Sea [122], the Aral Sea [129,130], and the rivers that flow into them [128,131,132].

Environmental degradation is an especially acute problem in the Caspian Sea, where levels of heavy metals in harvested fish can exceed thresholds governing the import of fish products into Europe [48,133]. Within just a few years of its introduction in the mid-1990s, *Mnemiopsis leidyi*, an invasive invertebrate, decimated commercially important populations of sprat (*Sprattus* spp.) [134]. Although infrastructure supporting more than 1000 oil wells along Kazakhstan's coast on the sea is aging and beginning to leak [135], aggressive drilling is underway; if constructed, the trans-Caspian pipeline will intensify pressure on the fisheries sector [136]. The sea is also subject to volley discharges of toxicants such as chlorine, which killed 108 tonnes of sturgeon in late 2018 [137]. The lake has also begun to undergo eutrophication, a likely response to heavy nitrogen and phosphorus pollution from onshore agricultural activities [138].

The Republic faces a series of emergent challenges to the fisheries sector that defy internal control. One such issue is climate change, which is depleting the glacial sources of meltwater that charge many of Kazakhstan's rivers. This will lower flow rates over the long term, permanently reducing the quantity of available water [139]. Climate change is also raising air and water temperatures, further stressing fish communities [48,140,141]. Moreover, the water volumes in the Republic's major rivers are declining [142–144]. Efforts to resolve these complex issues are ongoing [145–148], but they are complicated by geopolitical and socioeconomic dynamics. The Caspian Sea, for example, bordered just two countries during most of the twentieth century but now shares a coastline with five sovereign nations, each with its own priorities for the use of this shared water resource [135,149]. China's spectacular economic growth has also dramatically stimulated the economy in the upper Ili River basin; new dams are being built, and withdrawals of water for irrigation and industrial use are reducing flows into Kazakhstan [28,150,151].

5.2. Capture Fisheries

Capture fishing in Kazakhstan's waterways is currently regulated by a system of quotas intended to balance the rights and obligations of the privatized fisheries sector with those of the government [51]. Quotas corresponding to all or part of a given waterbody are determined by KazNIIRKh and put out to tender on a regular basis. Successful bidders must provide evidence that they are financially sound and have access to vessels and refrigeration equipment [11]. They are also required to stock and preserve the habitat of their allotments in a sustainable manner [104,152]. In return, they are granted exclusive, geographically defined rights to harvest fish for a set period of years. Some of the funds raised by this system are re-invested by the government for research and technological upgrades, as well as stocking to maintain fish populations.

The quota system was inaugurated in 2006–2007 and replaced an earlier, more loosely structured system that led to unfilled quotas thought to be due to unreported catches [11,20,153], and indeed, reported harvests went up substantially when the new system was first put in place [19]. Currently, almost 1800 sites are assigned to more than 1000 users [104], but the new system is hardly a panacea for the ills of capture fisheries. The methods used to determine quotas are neither transparent nor based on sound science [20]. Economic

efficiency has proved to be elusive, and since there are no incentives to conserve [23], IUU fishing remains a major—arguably the major—unresolved issue.

The new quota system is top-down, and because it was developed with negligible input from local communities, their needs and expectations were inadequately addressed. The bidding process, for example, has proved to be so expensive and complicated that individual fishers are frozen out, which forces them to either work for successful bidders or fish illegally [23]. Moreover, the resources of some of the smaller successful bidding organizations have proved to be inadequate, forcing them to surrender their plots. Many of these were then consolidated with other plots controlled by larger firms with better access to funds and markets. The result, as described by Wheeler [51,67] for the Small Aral Sea but also relevant to other water bodies [106,111,154], is disrespect for quotas and the boundaries of allotments, use of illegal equipment, and diversion of fish from authorized processing facilities and marketing channels. Some of the IUU catch is simply consumed locally, but smuggling and falsification of labels designed to verify traceability also facilitate illegal exports.

IUU fishing is especially difficult to prevent in developing countries such as Kazakhstan, where the fisheries sector is fragmented and where manpower and resources for effective surveillance and enforcement are lacking [102,155]. Frustration and economic necessity are frequently cited as root causes for poaching by local fishers lacking allotments [67,111], but the shadow economy is also involved, especially on the Caspian Sea, where organized criminals operate well-equipped vessels to harvest sturgeon illegally [156,157]. Most fishers that we (unpublished data) and others [102,111,112] have interviewed freely admit that they significantly exceed their catch quota allocations. Analysis of the changing population structure of bream and sturgeon is consistent with these statements [16,23]. The magnitude of the problem is nevertheless elusive because IUU fishing is by its very nature difficult to quantify [154]. It is estimated to represent from two to ten times that of legal, reported harvests in Kazakhstan [102,106,158,159], making the reported 37,283-tonne catch in 2018 questionable with respect to the allowable 60,000-tonne quota.

IUU fishing also undermines fishing norms in ways that call stocking efforts into question. Why should the state and allotment holders invest scarce resources into stocking if subversion of fishing regulations prevents stabilization and appropriate legal exploitation of fish populations? Stocking is currently in private hands. Seven fish hatcheries, two spawning farms, and the Kazakh Production Acclimatization Station are all involved in producing juveniles of valuable fish species, including sturgeon, carp, zander, and whitefish (*Coregonus* spp.). Stocks are distributed by state order, which is open to competitive bidding. Almost 130 million immature fish of various sizes were released in 2017 (Table 3) and even greater numbers in earlier years, but there is very little monitoring of the efficiency of stocking.

Table 3. Release of juvenile fish as stocks in Kazakhstan in 2017. Source: [81].

Species	Number (Millions)	Percentage
Sturgeon	7.0	5.5
Non-cyprinid herbivores	11.6	9.1
Whitefish	13.4	26.5
Carp	95.7	74.9
Total	127.7	100.0

It is known that allotment holders typically fulfill their obligations by releasing fingerlings and low-quality species from nearby hatcheries [160] without regard to potential benefits [20]. Indeed, fingerlings with low chances of survival [72] predominate in all releases; between 2000 and 2008, for example, they represented almost 70% of stocks [21]. Economic distortions heighten the inefficiency of stocking because breeding farms receive subsidies from the state on the basis of the number of stocking units rather than their weight. On the one hand, stocking is essential to stabilize populations of threatened species where natural migration routes have been blocked by dams. This requires investment in

new production technologies and the adoption of efficient release strategies to increase the survival of juveniles under Eurasian conditions [161], but these changes are unlikely to be made without evidence that they will provide benefits to the fisheries sector.

5.3. Aquaculture

Aquaculture is more labor-intensive than capture fisheries, requires more inputs that must be purchased on the open market, and increasingly relies on skilled management and technological innovation (Figure 8). Receiving almost no attention in Kazakhstan until after 2005, fish farming fell into obsolescence at a time when it was rapidly advancing elsewhere. Although the state planned for an increase in the harvest of farmed fish, principally sturgeon, trout, and carp, to 10,000 tonnes by 2015 [162], the actual 2015 harvest was less than 1% of this amount, just 730 tonnes (Figure 4). A more recent plan from 2017 set a more realistic production target of 5000 tonnes by 2022 [152], a goal that has been exceeded.

Figure 8. (**Left panel**): Ponds for breeding sturgeon in South Kazakhstan, 2016. Photo credit: Talgarbay Konysbayev. (**Right panel**): Researchers taking measurements as part of a project to increase the production of sturgeon juveniles at the Educational-Scientific Complex for Experimental Industrial Aquaculture Production, Uralsk, Kazakhstan. Photo credit: Turesh Murzashev.

The government's decision to partially reimburse aquaculture producers for capital investments and the cost of feed has been credited for recent favorable trends (Figure 4) [23,104]. KazNIIRKh has also funded applied research to investigate the suitability of water bodies in southern and southeastern parts of the Republic for rearing carp and for cage culture of sturgeon in the east [163–166]. Progress has nevertheless been modest in comparison to neighboring Uzbekistan, where the industry has recovered more rapidly [161,167,168] and in Russia [169]. Both of these countries provide more flexible and substantial support for their commercial fish farming sectors and have reaped the corresponding economic benefits.

6. Conclusions and Future Perspectives

Although unlikely to become a major contributor to Kazakhstan's gross national product, the fisheries sector offers the potential to increase food production and provide jobs in areas of high unemployment [170]. Many of the sector's chronic problems, including polluted water, overfishing, and conflicts with agriculture and hydroelectric power generation, were apparent during the Soviet period—and in some cases, earlier during the czarist era [171,172]. Lenin even found time to write of his concern about illegal fishing [13], and although Moscow exerted firm control over the sector, the powerful Soviet state could not

prevent the kind of conflicts between ministries that continues to this day [173]. It is no wonder that the struggle to optimize fisheries investments and policies persists.

It is widely accepted that fish products will assume a more prominent role in the future human diet. Increases will come not from depleted marine and inland fisheries but from aquaculture, which has expanded at a rapid pace worldwide in recent years [174]. Transportation infrastructure funded by China's ambitious Belt and Road Initiative is reducing the time necessary for goods from Eurasia to reach markets in Europe and Southeast Asia [175], a potentially significant development for Kazakhstan's fisheries sector. Indeed, the Republic recently announced an extremely ambitious program to expand aquaculture by stocking reservoirs, ponds, and cage farms, primarily in the Syr Darya and Irtysh basins. By 2030, Kazakhstan plans to increase fish harvests from the 2019 level of 52,500 tonnes to 270,000 tonnes—a 5-fold increase that is envisioned to subsequently nearly double to 600,000 tonnes over the following decade [176,177].

On the one hand, and based on past experience, it is doubtful that resources will be sufficient to meet these production goals, but on the other, the well-known constraints on the sector would benefit from favorable policies and increased investment at any level. High-quality water must also be made available in sufficient quantities and at the right times [130]. This will require a concerted effort to balance water–energy–food (WEF) interrelationships, avoiding the conflicts that have generated tradeoffs in the past while maximizing synergies in the future [5,178]. Installation of devices to avoid fish kill when water is withdrawn from reservoirs [179] and reduction in the use of agricultural chemicals [180] are straightforward strategies to avoid WEF tradeoffs; allocation of irrigation water to produce forages [181] for use as much needed fish food is a similar strategy to generate WEF synergies. The price paid for juveniles could be indexed to species and body weight per individual to enhance the survival of stocks and improve the profitability of aquaculture. Additional investments could be made in promising new tools to document illicit activities and track fish and fish products through the value chain [182,183].

Kazakhstan is also implementing new policies to make the fisheries sector more attractive to private investors. When matched with funds from the state, private investments in research and development can exploit new technologies [184], providing practical solutions to short-term problems and generating the knowledge base needed to secure the long-term future of the sector [185,186]. In partnership with universities, these investments could easily create a platform to attract desperately needed young talent to the sector [117,187]. In short, and in spite of past failures and persistent challenges, there are reasons to view the future of Kazakhstan's fisheries sector with guarded optimism.

Author Contributions: Conceptualization and preparation of the original draft, S.N., T.K., F.G. and M.S.; data analysis and visualization, S.N. and S.G.P.; editing and English literature review, S.G.P. and N.A.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: S.G.P. and N.A.G. acknowledge the Center for European, Russian, and Eurasian Studies and the Center for Global Change and Earth Observations at Michigan State University for encouragement and support during preparation of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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