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The Volga: Management issues in the largest river basin in Europe

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Abstract

The Volga is the longest river in Europe and 16th longest in the world. The riverine landscape of the Volga is of exceptional scientific and economic importance to Russia; the basin contains approximately 40% of the Russian population and relates to 45% of the country's industrial and agricultural produce. The Volga River drains an area of 1.4 million km^2, covering various biomes from taiga to semidesert. Anthropogenic impacts in the 20th century include pollution as well as hydropower production and navigation purposes, incurring a cost for its historically important migratory fish (e.g., sturgeons) and related fisheries. River basin management in Russia, since 2006, is based on the water code that determines federal competencies in water management. Extensive water quality monitoring programmes provide feedback to regional managers. Monitoring of biological parameters is spatially limited and should be extended in order to provide sufficient data for informed management. Some initiatives have been implemented in recent decades in order to restore the ecological health of the river and manage fisheries resources (e.g., restocking programmes and the definition of total allowable catches). As recreational fishing is popular but presently unregulated in Russia, we suggest additional monitoring. Finally, the headwaters and lower river floodplain of the Volga have remained as free-flowing and relatively undisturbed systems. Because reference conditions with low levels of anthropogenic disturbance cannot be found in Central European lowland rivers, both the headwaters and lower Volga floodplains below Volgograd are of great importance on European level.

KEYWORDS

fisheries management, hydromorphology, reference for lowland rivers, river navigation, Russian water code, water quality monitoring

1 | INTRODUCTION

The Russian folk song "Vniz po matushke po Volge" (*Down along the mother Volga*) or more recently hit "Techet reka Volga" (*The Volga River flows*; interpreted by L. G. Zykhina) underline the cultural, social, and economic significance of the Volga River. The Volga basin is the heart land of Russia, approximately 40% of the Russian population reside in the basin and it supports 45% of the country's industry as well as more than 45% of its agriculture. The Volga has been the focus of scientific research for centuries (cf. Behning, 1924; Butorin & Mordukhai-Boltovskoi, 1978; Litvinov et al., 2009; Schletterer & Füreder, 2011). In this manuscript, we focus on management issues along the Volga River and highlight the pan-European importance of this river system.

Early scientific research on the aquatic ecology of the Volga basin focused on fish communities (Baer, 1855; Kessler, 1877; Pallas, 1811). The "Biological Volga Station" (Saratov)' established in 1900 as the first hydrobiological river research station in Europe, fostered much of the early research (Behning, 1924, 1928). After the construction of the Volga-Kama Cascade (VKC) hydrobiological research on the Volga River concentrated mostly on impoundments (Schletterer & Füreder, 2011). Since 1992, international collaborations have increased in the Volga basin, for example, the “Oka-Elbe” project (Eberle & Raynin, 1995) as well as joint Dutch–Russian projects on floodplain ecology and global change (e.g., “Volga–Rhine,” Middelkoop, 2005). The federal programme “Revival of the Volga” (Naidenko, 1998) and the influential research of Naidenko (2003) stipulated UNESCO's “Volga Vision,” which outlined the socio-economic significance of the Volga basin and established “river” targets to be reached by 2030 (UNESCO, 2004). Subsequently, the CABRI-Volga project (cooperation along a big river) was initiated between 2004 and 2007 to assess the status and to develop management plans, in cooperation with political stakeholders, for the long term sustainability of the river (Nikitina, Ostrovskaya, & Fomenko, 2010). Scientific institutions based in the Volga River basin are important for the promotion of a knowledge-based platform underpinning the sustainability in this river system as well as national and international exchanges, for example, the international conference on “Ecological problems in large river basins” (Rozenberg & Saksonov, 2008) and the extension of management principles based on the Volga River (Rozenberg, 2009).

1.1 | Hydrogeographical setting of the Volga River

The Volga—draining into the Caspian Sea—is Europe's longest river and the 16th longest river in the world. It is a complex social–ecological system, with a total river length of 3,531 km, a basin area of 1,431,296 km^2 (Litvinov et al., 2009), and a mean population density of 42 people per km^2 (Revenga, Murray, Abramovitz, & Hammond, 1998). The Volga basin has five major landscape zones—the taiga zone, mixed forest zone, forest-steppe zone, steppe zone, and the semidesert zone. Traditionally, the river is divided into three sections: (a) the upper Volga, down to the mouth of Oka River; (b) the middle Volga, between the confluences of the Oka and Kama Rivers; and (c) the lower Volga (Figure 1). Since the construction of the VKC, Gorky Dam is considered as the border between upper and middle Volga and the Kuibyshev Dam between middle and lower Volga (Litvinov et al., 2009). At Volgograd (catchment = 1,350,000 km^2), the mean annual discharge is 8,364 m^3 s^{-1},

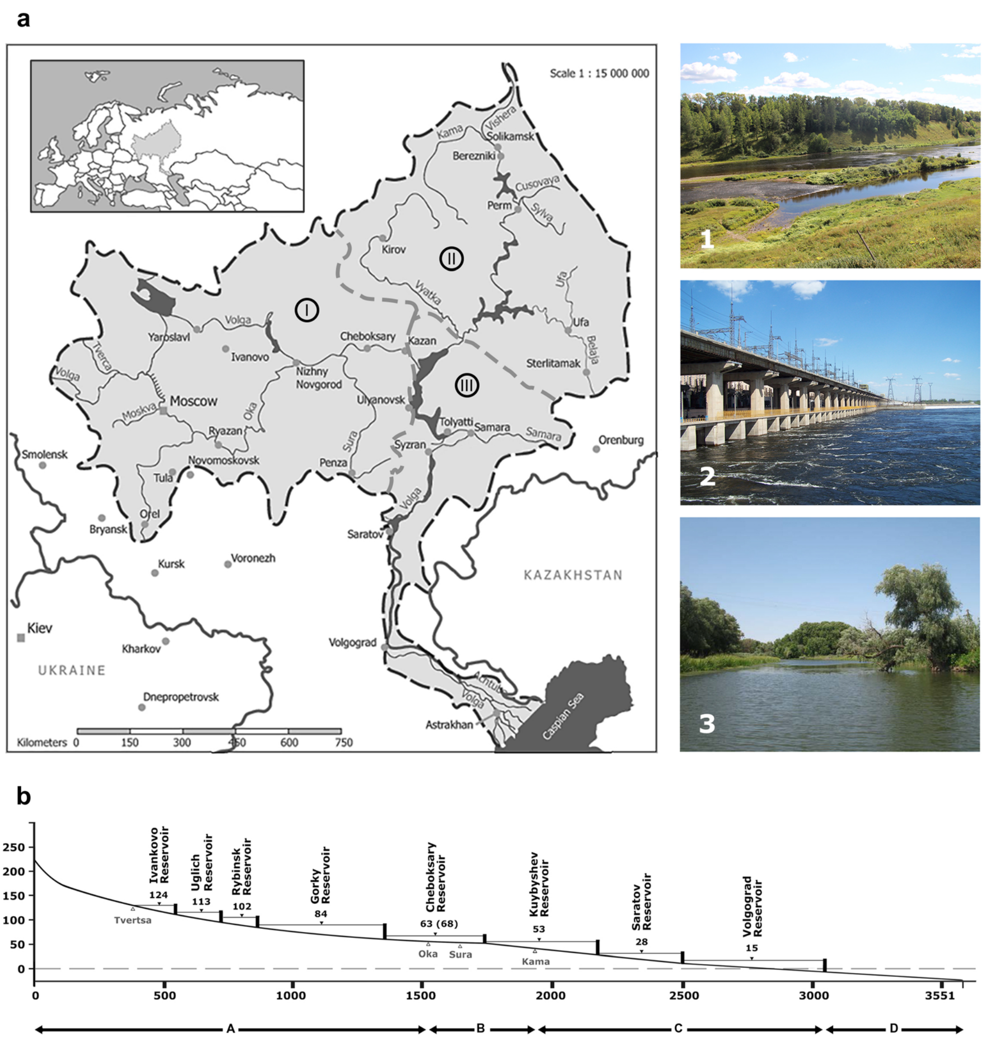

FIGURE 1 (a) Map of the Volga basin (from www.cabri-volga.ru, with permission) including management districts (I, II, III); views from the river: (1) the free-flowing section in the headwaters of the Volga at Rzhev (photo: M. Schletterer), (2) the dam at Volgograd (photo: K. Górski), and (3) a branch in the Volga Delta (photo: M. Schletterer); (b) a longitudinal profile of the Volga, including the reservoirs and dams of the hydropower plants as well as an indication of the longitudinal subsections: (A) upper, (B) middle, (C) lower, and (D) delta (from Schletterer et al., 2017) [Colour figure can be viewed at wileyonlinelibrary.com]

with the lowest and highest mean monthly discharge of 3,085 m^3 s^{-1} occurring in January and 25,805 m^3 s^{-1} in May, respectively (Figure 2). The annual sediment load is low in comparison with other European rivers, presumably because of catchment conditions. The majority of suspended sediment originates from river bank and bed erosion in the main channel (60–80%), from the tributaries of the Volga (20–40%) and a minor part related to biological production (1%). Over the last century, suspended sediment loads in the Volga River have decreased, as a consequence of the reservoir cascade trapping between 60% and 98% of the total load (Ziminova, 1973). In the lower Volga, for example, the annual suspended sediment load decreased from ~19 million tons to ~8 million tons as a result of dam construction (Tarasov & Beschetnova, 1987).

1.2 | Governance

In the Russian Federation, water management is based at the Ministry of Natural Resources and Environment, which also coordinates related executive authorities: the Federal Agency for Water Resources, the Federal Service for Hydrometeorology and Environmental Monitoring, and the basin administrations (river basin councils). Further, the Ministry of Agriculture (Federal Agency for Fishery) as well as with the Ministry of Transport (Federal Agency for Sea and Inland Water Transport) and the Ministry of Energy (hydropower) are involved.

Currently, the main legal document for water management is the Water Code of 2006 (Federal Law № 74-FZ), which strengthened the position of the federal authorities and determined federal competencies (Art. 24). Certain responsibilities, such as protection of waters, pollution prevention, the conclusion of agreements with water users, flood mitigation, and disaster relief, were transferred from federal level to the regions. The Water Code also enabled the private ownership of waters and the possibility of regulating water relations through civil law. All state-owned water bodies were declared "accessible to public" (Art. 6), and licences were replaced by agreements (Art. 8) to legal entities (water users) for up to 20 years (Art. 13 and 17). Water

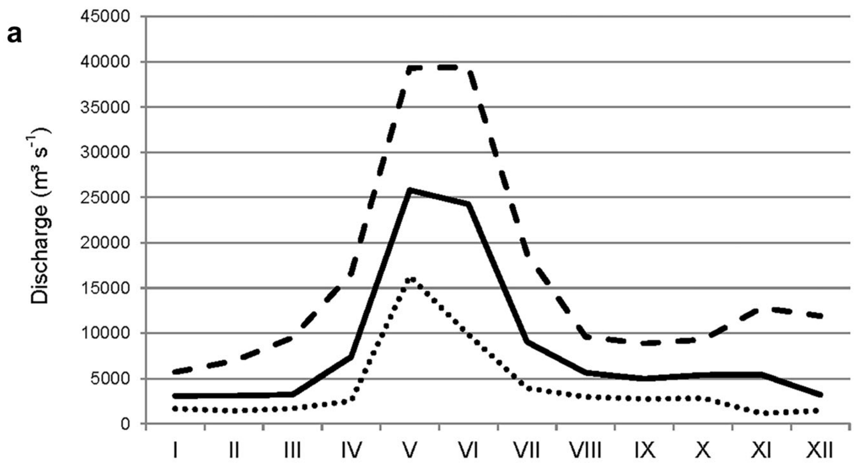

FIGURE 2 (a) Hydrological regime (m^3 s-1; black line = mean monthly discharge; dotted line = lowest monthly discharge; dashed line = highest monthly discharge) at Volgograd (1879–1958 from Shiklomanov, 1999; no data from the years 1936–1952) and (b) the Volga at Volgograd below hydropower plant Volgograd (photo: M. Schletterer) [Colour figure can be viewed at wileyonlinelibrary.com]

use fees (Art. 18 and 20) are an agreement-based payment, rather than a tax. Federal entities claimed, however, that water use fees are a primary financial tool and collected funds serve purposes that are often very distant from water management (Kotov, 2009). The Water Code has also established water protection zones and near-shore protective belts, which are located within water protection zones, with the purpose of managing economic and other activities (Art. 65) and to ensure the protection of riverine landscapes and floodplains. However, in this context, the permit (previously there was a prohibition) of residential development in these zones is critical (Shaporenko, Leonov, Deriy, & Fedorov, 2009). In addition to the Water Code, protected areas on national level (e.g., zakasnik—"nature monument", zapovednik—"national park") and some international agreements that enhance protection of ecosystems within the Volga basin, for example, 13 reserves under the UNESCO Man and Biosphere Programme, are assured. For managing the natural assets of the Volga River, three districts based on the physical character of the river system, that is, the upper Volga, the Kama, and the lower Volga (Figure 1), were defined. However, in 2006, four basin districts were established, with the separation of the Oka basin from the upper Volga basin (http://water-rf.ru/).

2 | ECONOMIC ACTIVITIES, PRESSURES, AND ECOLOGICAL STATE

2.1 | Economic activities in the Volga basin

There is a high degree of agricultural development (46%; Table 1) within the Volga basin. Although there is a marked difference between the north and south regions of the basin. In the northern administrative regions of the Tver and Vologda, approximately 10% of the area is farmland, whereas in the more southern administrative regions (e.g., Kursk, Lipetsk, and Orel), over 80% of the land is cultivated (Georgievsky, 2015). By comparison, the Kama subbasin is mostly forested, with the Kostroma Region and the Komi Republic having the highest forest covers (~75%).

In the mid-2000s, the population of the basin reached about 60 million, of which approximately 47 million are urban based. The Volga basin is the significant economic region of Russia. Forty seven percent of industrial production occurs within the basin (Demin, 2008): The upper Volga region is most developed, as the Moscow metropolitan area is located there, and distinguished by a high concentration of industrial production (almost 56% of the production of the Volga basin). Also, the middle Volga basin is highly industrialized (machine building, and chemical and petrochemical industries), including agricultural production. Finally, the lower Volga region has more than 7,000 km^2 of irrigated agricultural land, and aquaculture is widely developed. Industrial production in this region is mainly machine building and oil production. Over the past decade, water consumption for industrial purposes has decreased by about 48% and is presently around 57 km^3 per year for the entire basin (Demin, 2008). Changes in water consumption and withdrawals from natural water course are not uniform across the basin, decreasing overtime in the upper and middle Volga but increasing in the lower Volga. These changes in water consumption are associated with reductions in industrial and agricultural consumption in the upper and middle regions and an increase in irrigation in the lower regions of the Volga basin.

2.2 | Navigation and hydromorphological change

The Volga system is important for waterborne transport and navigation, dating back to before 1500. After the annexation of Kazan (in 1552) and Astrakhan (1556), the main channel of the Volga was under Russian control and attempts were made to develop trade links with Persia and the countries of the Middle East via this waterway. In 1817, the first steamer to be operated on the Volga was built and in the 1850s around 10 shipping companies were operating more than 200 steamships on the Volga (Shubin, 1927). Increased shipping traffic has resulted in negative environmental consequences, as the boilers of the steamships were mostly fuelled with wood, which led to massive riparian deforestation before the 1850s. In the early 1880s, the conversion to oil boilers occurred, resulting in a decline in the use of

TABLE 1 Population density (census 2010; estimated on the basis of the citizens per administrative region, converted according to the share of the region within the Volga basin), area (km^2) as well as land use (in % of their area as of January 10, 2012) in the management districts and in the whole Volga basin as well as a comparison with the Russian Federation (compiled from Rosreester, 2012)

	Upper Volga	Kama	Lower Volga	Volga basin	Russia
Population, thousand persons	36,569	11,988	11,116	59,673	142,900
People per km^2	56	24	40	42	8
Area, thousand km^2	648.0	504.3	278.6	1,430.9	17,098.2
Agricultural land (%)	41.13	33.76	75.05	46.11	12.88
Land in the reclamation stage (%)	0.05	0.00	0.18	0.06	0.03
Forest area (%)	46.71	56.92	9.15	43.97	50.95
Forest area, not in the "forest fund" (%)	1.92	1.32	1.40	1.59	1.54
Water bodies (%)	2.85	1.95	5.71	3.09	4.23
Mires (%)	2.45	1.94	0.79	1. 94	8.94
Build-up lands (developed area) (%)	1.54	0.81	1.29	1.23	0.34
Roads (%)	2.08	1.54	1.66	1.81	0.47
Disturbed land (%)	0.21	0.11	0.05	0.15	0.06
Other land (%)	1.06	1.65	4.74	1.99	20.57

riparian timber for the shipping trade. In the headwaters of the Volga River, the water level of the upper Volga lakes was raised 1843 with the Bejshlot Dam to improve navigation conditions upstream Tver (Behning, 1924). The construction of the VKC, in the mid-20th century, transformed the river to a deep-water transport highway with guaranteed depths of 3.5–4 m, including connection to other basins via man-made channels (Volga–Baltic and Volga–Don).

Currently, about 25% of Russia's hydroelectricity is produced from the hydropower plants (HPPs) of the VKC. This cascade consists of 11 run-off river power plants, eight along the Volga River (Figure 1b) and three along the Kama River. All HPP schemes are characterized by seasonal regulation. The major part of the runoff is formed above the Cheboksary HPP (Volga) and the Nizhnekamsky HPP (Kama) with an average volume of 207 km^3. This represents 80% of the total runoff of the Volga River Volgograd (259 km^3). The useable storage volume—that volume between normal maximum level and dead storage—in the cascade is 78 km^3, of which 56% is located in the three lowermost reservoirs. The current installed capacity of the cascade is 10,192 MW with an average annual output of 37,927 GWh (Aleksandrovsky & Klimenko, 2016).

The VKC also represents an extensive flood control measure due to the dam system (Asarin, 2006) and related embankment, especially in urban areas. Downstream of the lowermost dam at Volgograd, another flood control structure is located—the Astrakhan water divider at Narimanov. This consists of a moveable dam, to reduce or block flows through the western branch of the Volga River—thereby increasing flows down the eastern channel of the Volga Delta. However, due to the raise of the water level of the Caspian Sea, it is no longer in use.

2.3 | Historical and present day fish fauna

Sixty-seven native and 12 introduced fish and lamprey species from 23 families are known from the Volga River (Schletterer et al., 2017). Present day fish fauna differs markedly from historical records in terms of species composition and abundances (Górski et al., 2012). Dam construction and the subsequent regulation of flows has altered migration paths for anadromous fish resulting in severe decreases in abundance (c.f. Khodorevskaya, Ruban, & Pavlov, 2009). Only two of the eight dams along the Volga River (Saratov and Volgograd) are equipped with fish passage (Pavlov & Skorobogatov, 2014). Fluvial habitats have also been altered significantly by the presence of extensive backwater areas behind each impoundment, interrupting fish migration pathways and reducing the area of within-channel spawning grounds. In addition, overfishing during the 19th century, especially of species like beluga (*Huso huso*), Russian sturgeon (*Acipenser gueldenstaedtii*), and starry sturgeon (*Acipenser stellatus*) has resulted in these species being on the verge of extinction. Populations of other rheophilic species such as Volga undermouth (*Chondrostoma variabile*) or chub (*Squalius cephalus*) remain in the tributaries and main channel of the Volga River upstream of Tver (Litvinov et al., 2009). The present day Volga fish community is dominated by eurytopic cyprinids such as roach (*Rutilus rutilus*), common bream (*Abramis brama*), white bream (*Blicca bjoerkna*), blue bream (*Abramis ballerus*), and common carp (*Cyprinus carpio*; Schletterer et al., 2017). The most common piscivorous fish are the European perch (*Perca fluviatilis*), pike (*Esox lucius*), pike-perch (*Sander lucioperca*), and wels (*Silurus glanis*). Twelve non-native fish populations are currently reported in the Volga. Species such as vendace (*Coregonus albula*), Chinese slipper (*Perccottus glenii*), and goldfish (*Carassius auratus*-complex) are common in middle Volga reservoirs (Litvinov et al., 2009). Furthermore, some euryhaline Caspian species such as Caspian Sea sprat (*Clupeonella cultriventris*) and Caspian ninespine stickleback (*Pungitius platygaster*) have spread upstream to the reservoirs in recent decades.

3 | RIVER MANAGEMENT

3.1 | Water quality monitoring and management

An extensive water quality monitoring network, operated by the Federal Service for Hydrometeorology and Environmental Monitoring (Rosgidromet), exists in the Volga River basin. This assessment network is based on quantitative indicators, including physico-chemical parameters (Rosgidromet, 2017a) as well as biological monitoring (in a limited number of areas), which includes periphyton, phytoplankton, zoobenthos, and zooplankton (Rosgidromet, 2017b).

The chemical composition of surface waters in the Volga River basin is not spatially uniform as is related to natural catchment drivers as well as anthropogenic influences, namely, discharges of communal/industrial sewage and land use (e.g., agricultural production). Catchment settings along the upper Volga River are characterized by a high degree of peat bogs, mires, and marshes, which is reflected by low mineralization and increased acidity as well as increased concentrations of organic matter (humic substances), iron, and ammonium. The higher absorption capacity of the grey forest soils and chernozem soils in the middle and lower reaches of the Volga River is associated with an increase of mineralization. The runoff in Kama and Oka Rivers are enriched in iron and manganese because of the geological character (ore deposits) of their respective catchments.

Water quality in the headwaters of the Volga River (upstream of Tver) is classified between Class 2—quite pure water to Class 3a—slightly polluted, according to the integrated indicators of water quality (RD 52.24.643–2002). In the Ivankovo Reservoir, water quality changes to Class 3b (moderately polluted water) and this decreases to Class 3a to 4a (polluted water) in the middle Volga. This variation in water quality in the Volga River basin is associated with variations in the intensity of human impacts and natural processes of self-purification. Some of the tributaries are assigned to Class 4b—very polluted (e.g., Upa river near Tula and Chapaevka river near Chapaevsk) or even Class 5—extremely polluted (e.g., Padovaya river near Samara). By comparison, in the Lower Volga River and the Volga Delta around Astrakhan, water quality is stable at 4a. However, this classification does not always correspond to the real ecological status, as the index is based on indicators (including chemical oxygen demand, copper, iron, manganese, and zinc), which exceed the maximum permissible concentration in almost all rivers of the forest zone for natural reasons (e.g., due to peatlands).

Most sewage water discharges are associated with urban and industrial agglomerations. Nowadays, there are about 9,000 urban waste water treatment plants across Russia: But more than 70% where build 30–50 years ago and require a complete modernization

(Minprirody, 2017). The effects of point sources can extend several kilometres downstream. In the epicentres of these zones, the concentrations of chemical substances (petroleum products, ammonium and nitrite, manganese, iron, copper, zinc, chromium, and nickel) periodically exceed the threshold limit and reach very high values; this is reflected by intensive accumulation of pollutants in sediments of the middle Volga (Rozenberg, 2009). Key indicators of contaminants along the Volga are chemical oxygen demand, copper, and sometimes iron (Figure 3). In the middle Volga reservoirs, main pollutants are aluminium, zinc, copper, manganese, and iron, whereas in the Delta (Astrakhan), sulphates are abundant. Since the 1970s, water quality management was stipulated by monitoring data, that is, renewal or construction of new sewage plants and already in the 1980s, improvements of water quality became evident. Political changes in Russia and subsequent drop of industrial production in the 1990s caused reduction of water withdrawal and further improvement of water quality in the Volga basin. Around 2005, the best water qualities were observed in the basin; however, since that time, due to accelerating economic development, water quality deteriorated again.

3.2 | The lower Volga: An example of a dynamic managed river system

The atlas of the lower Volga (Korotaev, Babich, & Chalov, 2009) details the morphological structure of Volga River and its potential response to natural and anthropogenic influences. Flow regulation and other channel activities have had a marked influence on the riverine landscape of the Volga River. However, the main river channel is still active in terms of the occurrence and rates of bank erosion, scroll bar accretion, the formation of chutes, and meander cut-offs (Middelkoop, Alabyan, Babich, & Ivanov, 2015). In addition, natural rates of succession of riparian vegetation and dynamic biomorphological interactions are considered to reflect typical riverine vegetation processes and habitat patterns (Middelkoop et al., 2005), although changing rates of overbank

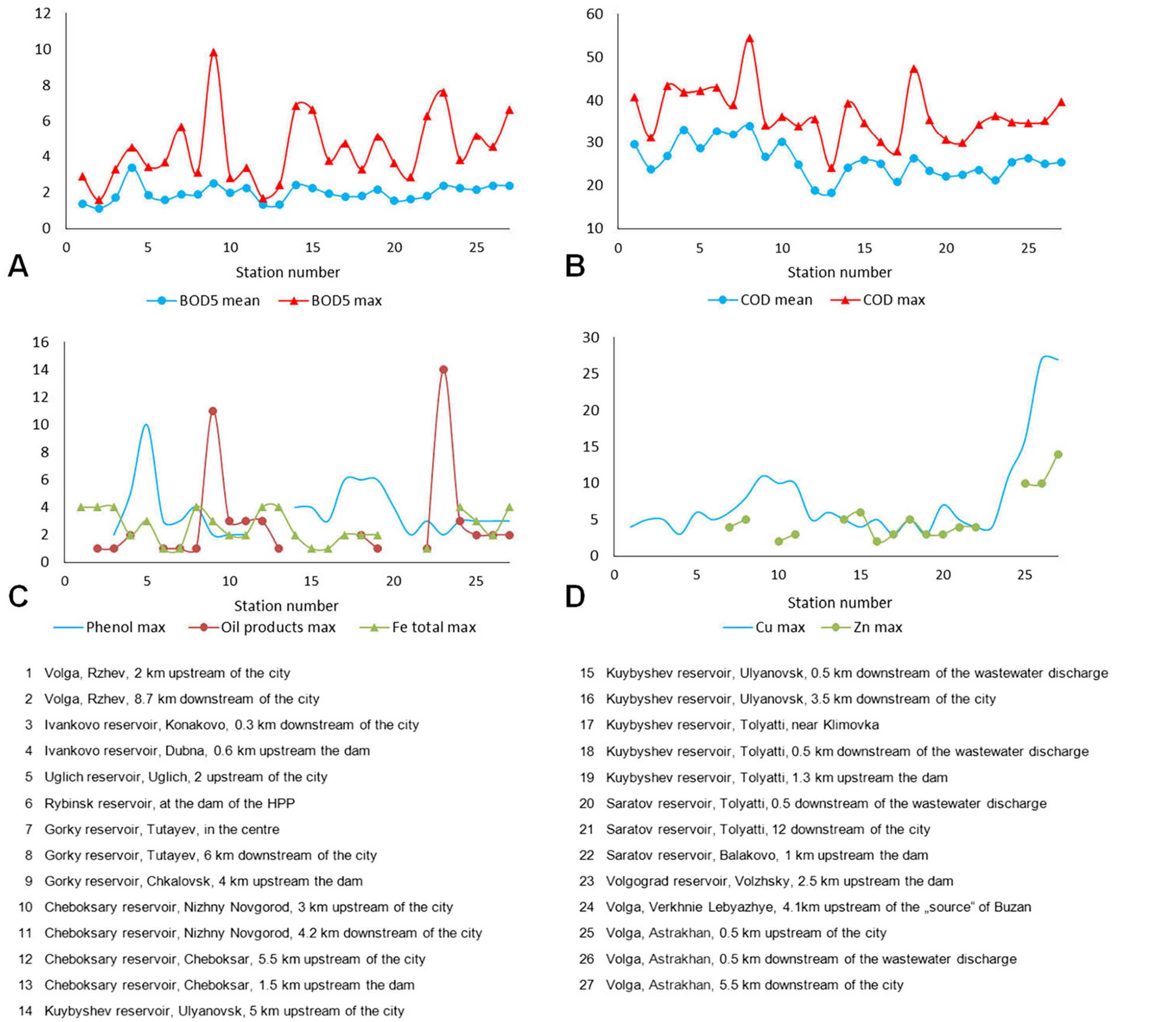

FIGURE 3 Selected parameters along the course of the Volga River in the year 2014 (compiled from Water cadastre of the Russian Federation, 2015): (a) biological oxygen demand (BOD5, mg O/L), (b) chemical oxygen demand (COD, mg O/L), (c) maximal values of phenol, oil products, and total Fe (MPC) and (d) maximum values of Cu and Zn (MPC; 1 MPC phenol = 0.001 mg/L; 1 MPC oil products = 0.05 mg/L; 1 MPC total Fe = 0.1 mg/L; 1 MPC Cu = 0.001 mg/L; 1 MPC Zn = 0.01 mg/L) [Colour figure can be viewed at wileyonlinelibrary.com]

deposition are projected to influence vegetation succession from typical riparian floodplain vegetation with poplar and willow to ash and oak communities. The effects of lower peak flows and reduced sediment load because of dam construction are now noticeable. The absence of extreme flows is considered to be responsible for elevated siltation in a number of secondary channels (Middelkoop et al., 2005).

Today, the floodplain inundation in spring is controlled by the VKC authorities. Recent studies have reported detailed relationships between the discharge regime and inundation patterns: Typically during overbank flows, flood water is fed from the upper Akhtuba River, a distributary of the main channel just below the lowermost hydropower dam and then onto the floodplain through a network of channels and streams. Large quantities of water are retained on the central and eastern parts of the floodplain, this implicates the hydrological connection of more than 2,000 floodplain lakes (Van de Wolfshaar, Middelkoop, Addink, Winter, & Nagelkerke, 2011). During the dry summer season, only approximately 80 lakes are connected to Volga or Akhtuba and these represent key refugia during this surface water deficit period. There is a distinct pattern of progressive floodplain lake connection during the flood season, resembling an expanding mosaic of available floodplain lakes or aquatic refugia (cf. Thoms & Parsons, 2003).

Flow regulation has reduced the frequency and duration of floodplain lake connection to the main channel of the Volga River (Górski et al., 2013). Changes in hydrological connectivity are more prominent for those floodplain lakes located in the distal regions of the Volga River floodplain. Hydrological distance from the main river channel has been shown by Górski et al. (2013) to be an excellent predictor for changes in connection duration and ecological effects within the different floodplain lakes. However, variations in floodplain topography and thus inundation pathways are important components that may alleviate anthropogenic changes in river-floodplain functioning (Ligon, Dietrich, & Trush, 1995; Van de Wolfshaar et al., 2011; Vaughan et al., 2009). Thus floodplain channels serve as important water bodies connecting the floodplain lakes in addition to the Volga and Akhtuba Rivers and form essential refugia for summer droughts or winter freezing for floodplain fish (Górski, 2010).

3.3 | Management of fisheries in the Volga River basin

Historically, the most valuable commercial fisheries were in the lower Volga and the Volga Delta, with average annual catches of ~200,000 tons at the beginning of the 20th century. In the 20th century, catches decreased and never exceeded 100,000 tons (Górski et al., 2012). Today, the Volga River still contains significant commercial inland fisheries that contribute about 27 percent of the annual inland fish catch of Russia (Brazhnik et al., 2013). Over the past decade, both forecast estimates and declared catches have increased. Following the adoption of the Federal Law № 166-FZ "on fisheries and the conservation of aquatic biological resources" in 2004, annual inland fish catches of Russia increased from 72,000 tons in 2005 to 111,000 tons in 2015 (www.fish.gov.ru). The directive "to carry out functions related to fisheries and the conservation of aquatic biological resources" (Order № 124 + № 166 of the Ministry of Agriculture implementing Ministerial Decree № 317) requires regular monitoring of freshwaters regarding (a) distribution, number, quality, and reproduction status of aquatic biological resources and (b) fisheries and conservation activities related to these resources. Monitoring of the Volga reservoirs is carried out by the State Research Institute on Lake and River Fisheries (GosNIORH). On the basis of this monitoring, the total allowable catches (TACs) as well as licensing of commercial fisheries and restocking programmes are implemented. Presently, TACs are being developed on yearly basis for the following species: sterlet (*Acipenser ruthenus*), pikeperch, common bream, wels, common carp, pike, and crayfish (*Astacus leptodactylus*). Furthermore, for these species predicted yields are subject to state environmental expertise before final approval. The fisheries development programme adapted by Russian authorities supports the development of fisheries in the Volga basin until 2020. The programme specifies that it is more rational to stock juveniles of valuable fish species (including recommendations on the quantities) into reservoirs than to maintain the "fish lifts" to allow migration of the depleted spawning stock. Sturgeon fingerlings are presently restocked from seven sturgeon hatcheries (Alexandrov, Bertulsk, Kizan, Lebyazhinsk, Sergiev, Zhitnensk, and Volgograd; Figure 4).

4 | A REFERENCE SYSTEM FOR EUROPEAN LOWLAND RIVERS

The headwaters of the Volga River contain an intact and specific fauna and flora characteristic of pristine European lowland rivers. This has been the initiative for the development of the joint Russian–Austrian monitoring programme REFCOND_VOLGA (Schletterer, Füreder, Kuzovlev, Zhenikov, & Zhenikov, 2016). Between the source of the Volga River at Volgoverkhovje and the city of Tver, three hydromorphological reaches have been defined: (a) the source region (rkm = 3,531–3,520), (b) the seminatural upper Volga lakes (rkm = 3,520–3,426), and (c) the free-flowing section upstream Tver (rkm = 3,426–3,085). The free-flowing section of the headwaters of the Volga River has provided a reference lowland river status on the basis of minor changes in river morphology, a high degree of natural catchment conditions (high amount of natural forest), and a low population density (Schletterer, Füreder, Kuzovlev, Zhenikov, & Grigorieva, 2014). It also has a high degree of connectivity between the main river channel and its tributaries and as result supports diverse, type specific biological communities. For example, mayflies are an important component of the benthic fauna in this reference section of the Volga River (Schletterer & Füreder, 2010). The taxa lists include many rare and threatened species, for example, the mayfly *Prosopistoma pennigerum*. This indicator of ecological integrity and flagship species of the European potamal was common in lowland rivers but disappeared in the 20th century almost completely (Schletterer, Bauernfeind, & Lechthaler, 2016). Long-term data for this section of the Volga River has enabled the analyses of annual and interannual variation in community indices and metrics (Schletterer et al., 2014). As the headwaters of the Volga River are recognized as one of the last refugia for the potamal fauna of large European rivers, this stretch contributes to the understanding of the variation at reference or least disturbed conditions, which is an important prerequisite for the interpretation of data from impacted sites.

FIGURE 4 Sturgeon catches and measures: (a) a catch from the 1920s around Kazan (unknown photographer), (b) *Huso huso* from the Volga Delta below Astrakhan in 1993 (photo: J. Thaler), (c) and (d) hatchery at Volgograd and a tank with "mother fish," respectively (photo: K. Górski) [Colour figure can be viewed at wileyonlinelibrary.com]

The seminatural lower Volga riverscape is proposed to form a reference for natural morphodynamics of low-gradient lowland rivers (Middelkoop et al., 2005). The Volga–Akhtuba floodplain inundates each year in April–May during the period of high river flow due to snow melt in the upper basin. This flood pulse causes inundation of large floodplain areas through the numerous floodplain channels, supporting the temporarily connection of floodplain lakes. Depending on the geometry, inundation frequency, and distance to the feeding floodplain channels, these water bodies host different types and abundances of riparian and aquatic vegetation. In the wide unembanked floodplains of the Volga–Akhtuba system, the majority of suspended matter settles within a short distance from the entrance point of river water or a floodplain channel into the floodplain during river flooding (Klaus, Sintermann, Kleinebecker, & Hölzer, 2011). As a result, the overbank flood reaching the remote and distal parts of the floodplain contains very low amounts of suspended material and sediment-associated nutrients. Owing to the large size of the floodplain and the absence of major embankments and levees makes that here, major gradients arise during annual floods in amounts and composition of and nutrient sediment input, resulting in a large scale and wide diversity of aquatic vegetation and fish in water bodies. Along embanked rivers, however, these remote parts of floodplains have been permanently cut off from river flooding by embankments. Consequently, a full gradient in flow velocity and sediment concentrations from turbid fast flowing water near the main channel down to stagnant clear water at longer distances in the floodplains have become scarce along regulated rivers in Europe.

5 | CONCLUDING REMARKS

Despite a multitude of stressors influencing large tracts of the Volga River, the headwaters of this systems still represent seminatural conditions with little disturbance. Today, only very few reference conditions or least disturbed conditions can be found for European lowland rivers; thus, both the headwaters as well as the river below Volgograd are of great importance on European level and may be instrumental to advance our understanding of European riverine ecology as well as guide targets for restoration projects. Restoration of impacted floodplains should therefore aim at re-establishment of the natural transverse gradient between proximal (i.e., frequently flooded, high inflow of sediment and nutrients) and distal (i.e., low hydrodynamics and low sediment inflow) sites to fully enhance the biodiversity of natural floodplains.

Some initiatives have been implemented to restore the ecological health of the Volga River and manage its fisheries resources (e.g., restocking programmes and the definition of TACs). These measures aim to maintain fishing resources. Restocking programmes should also focus on vulnerable and endangered species and consider genetic diversity. Furthermore, actions need to be taken to restore and manage longitudinal connectivity of the system for remaining populations of endangered migratory species and lateral connectivity for fish that use floodplains. Presently, there is no legislation that regulates recreational fishing in the Volga basin, even though this activity can be very popular throughout the basin. Measures should be taken to quantify the scale, monitor, and control recreational fisheries and its potential impact on fish stocks in the basin.

The Russian Water Code provides a framework for extensive monitoring programmes, similar to those established by the Water Framework Directive in Europe. At present, however, monitoring of biological parameters is spatially limited within the Volga basin and management is mostly based on physico-chemical data. Biota integrate environmental conditions at their habitat, although a water sample comprises always a snapshot—especially in running waters. Thus, monitoring of biological parameters should be extended in order to provide sufficient data for informed river management and to preserve ecological and societal functions of the river system. Overall, a central data platform (repository) combining different datasets across the involved agencies could facilitate more complete analyses.

In order to rehabilitate the water quality and ecosystem services in the Volga basin, the federal programme "Improvement of the Volga" (2017–2025) was recently established (Rozenberg et al., 2017). Main targets are a reduction of sewage water discharges (modernization of wastewater treatment facilities), to clear the river channel (e.g., salvage of shipwrecks), to intensify monitoring, and to improve the situation of the lower Volga floodplains (ensure reliable water supply to the Akhtuba River). This programme will contribute to river health and provide the potential to intensify monitoring as well as could also strengthen international collaboration in Europe's largest river basin.

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