Zoodiversity, **54**(5): 363–374, 2020
DOI 10.15407/zoo2020.05.363

Ecology

UDC 597.2/.5:627.8(282.255.2)

IMPACT OF DESIGNED QUAIROKKUM HYDROPOWER PLANT RECONSTRUCTION ON THE SYR DARYA RIVER ICHTHYOFAUNA

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Impact of Designed Quairokkum Hydropower Plant Reconstruction on the Syr Darya River Ichthyofauna. Afanasyev, S. A., Roman A. M., Dolinskii, V. L., Karimov, H. N., Erhashboev, I. K. — The article presents data on actual state of the fish fauna in the middle section of the Syr Darya River (including Quairokkum Reservoir and not-regulated river section downstream the dam), with regard to their migration behavior and protection status. Based on this list report also considers the actual state of the fish survival at Quairokkum HPP and analyzes of the main species affected and main factors increasing their chance to survive. Three methods to increase fish survival are proposed: by replacement of the turbines by more fish-friendly ones, by construction of the fish pass and by activation of fish deterrent devices in case of large fish accumulations.
Key words: Syr Darya River, Quairokkum Reservoir, fish fauna, Quairokkum Hydropower Plant reconstruction.

Introduction

The Syr Darya River is one of the longest in the Central Asia; it is formed by the confluence of the Kara Darya and Naryn Rivers merging in FerganaValley in the territory of Uzbekistan. It is 3019 km long (including the Naryn River). The first fundamental works on the Syr Darya River fish fauna were carried out by K. Kessler (1872, 1877), L. Berg (1905, 1948, 1949 a, b) and G. Nikolskiy (1940). Further, owing to irrigation agriculture and hydropower energetic development the most part of ichthyological researches was aimed at regional problems in view of economic activity. Many scientific researches were carried in the Farkhad and Quairokkum Reservoirs (Ozhehova, 1955; Maksunov, 1961, 1968 and others). Some data on the Syr Darya River within the Uzbekistan territory are presented in studies by G. Kamilov (1965, 1973), Z. Kasymova (1971) and others. Some studies dedicated to individual parts of the river (Baltabaev, 1971 etc.).

On the basis of these data, in the lower and middle section of the river from 15 (Kessler, 1872; 1877) to 23 (Berg, 1905) native fish species were registered (totally 25); in the upper river section — from 8 (Nikolskiy, 1940) to 22 (Berg, 1905). Actually some native fish species (especially migratory) extinct; instead several alien species appeared, which were either purposefully introduced to increase fish productivity, or invaded accidentally, for instance along with fish seedling or from neighbor pools through the irrigation channel system. The recent comprehensive research on the Syr Darya River fish fauna was carried out by M. Vundtsettel (1994), and T. Salekhov's and B. Kamilov's (1995) work on the fish fauna of the middle river section.

Since these works any researches in Syr Darya River basin were not carried out, except M. Vundtsettel's monograph (2012), but this was only published doctoral thesis (Vundtsettel, 1994) without new data.

Over the last years the reconstruction of some hydropower plants in the Syr Darya River was planned. Thus, the actual state of fish fauna of the Syr Darya River middle section is of special interest.

Materials and methods

Our researches based on data collected during long investigation period in Quairockum Reservoir and not regulated river part lower the dam (fig. 1). Used data include Khudzhand University Biological Department fishes collections (collector — I. Erhashboiev) for approximately 30 years. Also was used fishery assessment analysis for industrial fishering (Mokhiparvari Guliston fresh and freeze samples also fishering ichthyological notes). Also were used our personal data on fish allocation in Quairockum Reservoir and in Syr Darya River lower the Quairockum Hydropower Station dam. This data were got during March–May 2016 on the five locations (fig. 1) and include fishing by swimming nets from the boats and by hand nets. Thus, our research based on data collected from Khudzhand (40.2934, 69.6821) to Kanybadam (40.3412, 70.2755). Noted date include only our personal coordinates. Our research was conducted in Department of ichthyology and hydrobioly of Institute of Zoology and Parasitology, Tajikistan Academy of Sciences (Khudzhand). In totally were examined approximately 10,000 fish samples including industrial fishering data and local fishermans samples. It is approximately because both of them operate by mass but not by number of samples.

Bathymetric survey and distribution of fish in the Syr Darya River was conducted from the boat or from hydraulic structures in the reservoir that limit the station intake using a compact sonar with a radio sensor HUMMIBNBIRD SMARTCAST RF 35e.

Depth profile downstream the HPP dam was determined in order to detect accumulation of fishes for the upstream spring spawning migrations.

The registration of fish that died as a result of passing through the turbines of a hydropower plant was carried out from a boat by visual fixation and catching a net, as well as by interviewing fishermen who picked up stunned fish. In addition, it was made a survey of the HPES dam, water intake structures, shandors and water outlets; acquaintance with the documentation on the reconstruction of the hydroelectric power station, consultation with the station staff and with the workers of the fish industry of the Aquaculture Guliston OJSC (Mokhiparvari Guliston), experts of the Committee for Environmental Protection of the Sughd region.

When estimating the death of fish at hydroelectric power plants, such indicators as mortality (the proportion of dead fish from the total number passed through the turbine) are used or its inverse is survival (Pavlov & Skorobohatov, 2014).

Results and discussion

The considered river section is located upstream the Behovat outcrops (it is flooded now), thus it was the board between upper and middle river section (Kessler, 1877; Berg, 1905; Nikolskyi, 1940 and others).

According to our data, the fish fauna of the considered river section comprises 37 species, among of them 28 native and 9 alien (table 1). The native species present five faunistic complexes: Boreal plain (Pike, Zarafshan Dace, Roach, Turkestan Gudgeon, Gibel Carp), Ancient Tertiary (Pike Asp, Carp, Pike-perch, Catfish), Pontic freshwater (Rudd, Turkestan Barbel, Bream, White-eye Bream, Sichel), Southwest Asian (Striped Bystrianka, Tashkent Bleak, Sharpray, Kuschakewitsch Loach).

Native fish species in the middle Syr Darya River basin belong to seven families: Acipenseridae, Cyprinidae, Nemacheilidae, Siluridae, Salmonidae, Esocidae and Percidae.

Family (Acipenseridae)

1. *Acipenser nudiventris* (Lovetsky, 1828) — Ship Sturgeon. Extremely rare migratory anadromous species. Most time of life it inhabits sea or the lower river sections, spawned only in the river. According to L. Berg (1905), this species does not migrate upstream Behovat rapids at Chinaz, only separate specimens reached up to Khujand. G. Nikolskyi

Table 1. Fishes of the middle section of the Syr Darya River and their Conservation status (our data)

No.	Taxon	River part	Reservoir	IUCN Red list Status
		Native		
1	*Acipenser nudiventris*	?	–	CR (C2a(i, ii); D)
2	*Pseudoscaphirhynchus fedtschenkoi*	?	–	CR (C2a(i, ii); D)
3	*Rutilus rutilus*	+	+	LC
4	*Leuciscus lehmanni*	+	–	NE
5	*Leuciscus idus*	+	+	LC
6	*Scardinius erythrophthalmus*	+	+	LC
7	*Aspiolucius esocinus*	+	–	VU (A1acde)
8	*Leuciscus aspius*	+	+	LC
9	*Gobio gobio lepidolaemus*	+	–	???
10	*Capoeta capoeta*	+	–	
11	*Luciobarbus capito*	+	+	VU (A2cd)
12	*Luciobarbus brachycephalus*	+	+	VU (A2cd)
13	*Schizothorax eurystomus*	+	+	NE
14	*Alburnus chalcoides*	+	+	???
15	*Alburnoides taeniatus*	+	+	NE
16	*Abramis brama*	+	+	LC
17	*Ballerus sapa*	+	+	LC
18	*Capoetobrama kuschakewitschi*	+	+	DD
19	*Pelecus cultratus*	+	+	LC
20	*Cyprinus carpio*	+	+	
21	*Triplophysa dorsalis*	+	+	NE
22	*Triplophysa stoliczkai*	+	+	NE
23	*Nemacheilus oxianus*	+	+	NE
24	*Iskan Darya kuschakewitschi*	+	+	NE
25	*Silurus glanis*	+	+	LC
26	*Salmo trutta*	+	+	LC
27	*Esox lucius*	+	+	LC
28	*Sander lucioperca*	+	+	LC
		Introduced		
29	*Acipenser baerii*	+	+	EN (A2bcd + 4bcd)
30	*Ctenopharyngodon idella*	+	+	NE
31	*Hypophthalmichthys molitrix*	+	+	NT
32	*Hypophthalmichthys nobilis*	+	+	DD
33	*Carassius gibelio*	+	+	LC
34	*Hemiculter lucidus*	+	+	LC
35	*Pseudorasbora parva*	+	+	LC
36	*Rhodeus ocellatus*	+	+	DD
37	*Channa argus*	+	+	NE

Note. CR — Critically Endangered; EN — Endangered; VU — Vulnerable; NT — Near Threatened; DD — Data Deficient; NE — Not Evaluated; LC — List Concerns.

(1940) also noted individual specimens upstream the rapids. In the middle Syr Darya River section Ship Sturgeon was not registered for about 50 years. The last confident case of it sampling in Quairokkum Reservoir was in 1958 (Rare…, 2012). According to local fishermen's information, sturgeons (probably Ship) periodically occur in the Syr Darya. The most probably these specimens belong to one of the introduced species like Starry Sturgeon (*Acipenser stellatus* Pallas, 1771) — billions of juveniles and fertilized eggs were released in different periods; or Siberian Sturgeon *Acipenser baerii* Brandt, 1869, which was introduced to Toktohulsk Reservoir and also noted in the middle Syr Darya River section and in the Quairokkum Reservoir. In 2005 the special fund for sturgeon breeding in this

region was organized, but the program was closed because of salinity crisis in the Aral Sea (Mitrofanov, Mamilov, 2015).

2. *Pseudoscaphirhynchus fedtschenkoi* (Kessler, 1872) — Syr Darya Sturgeon. Extremely rare species, which occur the main part of the life cycle in the river stream and migrates only within the river. Its species migration ways were disrupted after the HPP dam constructions, which was the reason of its practically total extinction. The last confident data about Syr Darya sturgeon catching dated back to 1970s (Serov, 1973 (Cited after Vundtsettel, 1994)) in the Keles River of the Syr Darya basin. According to our data (see table 1) there are some local fishermen's notes about recent *Ps. fedtschenkoi* findings in the not-regulated river section, but these data need to be checked.

Family Cyprinidae

3. *Rutilus rutilus* (Linnaeus, 1758) — Roach. Wide spread commercial species. According to L. Berg (1905) and G. Nikolskyi (1940) this species reached upstream to the Kara Darya River, but it was abundant only in the river bays and floodplain lakes. It is a potamodromous migratory species, which formed local populations in the reservoirs. According to our data (see table 1) Roach is widely spread in the not-regulated river section and in the Quairokkum Reservoir.

4. *Leuciscus lehmanni* (Brandt, 1852) — Zeravshan Dace. According to L. Berg (1905; 1949a) this species occurs in Syr Darya River downstream the Chardara. According to the actual data, including personal communications of Tajik ichthyologists and hydrobiologists, Zeravshan Dace occurs only in the not-regulated Syr Darya River section. Its actual occurrence needs confirmation. The taxonomic status of this species also needs revision. Probably, *Squalius squaliusculus* Kessler, 1872, which was found by L. Berg (1949 a) nearby Leninabad and Yanykurhan and *Leuciscus lehmanni* are the same species.

5. *Leuciscus idus* (Linnaeus, 1758) — Ide (Turkestan Ide). Some researches (Kessler, 1877; Berg, 1905, 1949 a; Nikolskyi, 1940) distinguished the subspecies *Leuciscus idus oxianus* (Kessler, 1877). Its recent taxonomic status needs to be revised. Berg (1905) noted this species on migration from the Aral Sea to the lower and middle Syr Darya sections (especially in the flood plain lakes). Based on G. Nikolskiy (1940) data it reached up to Yanykurhan. We noted single specimens in the not-regulated river section and in the Quairokkum Reservoir.

6. *Scardinius erythrophthalmus* (Linnaeus, 1758) — Rudd. Similar to Roach, Rudd was in the past (L. Berg (1905) and G. Nikolskyi (1940) and still is (table 1) quite widely distributed up to the Kara Darya River mouth. *Sc. erythrophthalmus* occurs in the not-regulated river section and in Quairokkum Reservoir.

7. *Aspiolucius esocinus* (Kessler, 1874) — Pike Asp is the Aral Sea basin endemic potamodromous species. According to L. Berg's data (1905, 1949 a) this species occurred in the middle and upper river section. According to our data, Pike Asp is too rare species and occurs only in the not-regulated river section. In Quairokkum Reservoir it is absent.

8. *Leuciscus aspius* (Linnaeus, 1758) — Asp (local name — Red-lips Asp). This taxon was considered by K. Kessler (1872, 1877), L. Berg (1905; 1949 a) and G. Nikolskyi (1940) as Asp subspecies — *Aspius* (*Leuciscus*) *aspius iblioides* Kessler, 1872, which was distinguished by higher dorsal and anal fin rays number. Asp was quite abundant is past (Berg, 1905; Nikolskyi, 1940) as nowadays (see table 1). It is a potamodromous species which reached upstream to the Kara Darya River (Berg, 1905) or to Chinaz (Nikolskyi, 1940). This species forms settled populations in closed reservoirs, like in Quairokkum Reservoir. Asp is widely distributed in the not-regulated river sections and in the reservoir.

9. *Gobio gobio* (Linnaeus, 1758) — Gudgeon. According to K. Kessler's (1872) it was known as subspecies — *Gobio gobio lepidolaemus* Kessler, 1872) — Turkestan Gudgeon. Actual taxonomic status needs to be revised. Based on L. Berg's data (1905) it occurred in the upper Syr Darya River section to Yanykurhan. Later L. Berg (1949 a) changed it area from the Syr Darya River mouth to Kara Darya River (lower and middle river sections).

10. *Capoeta capoeta* (Güldenstädt, 1773) — Sevan Khramulya. Berg (1905, 1949a) registered this species in the upper Syr Darya River basin section (Chyrchyk River). Actual taxonomic status needs to be revised. According to our data, this species occurs only in the not-regulated river section downstream the dam. Khramulya is a potamodromous migratory species, whose migration ways were disrupted after HPP dam constructions.

11. *Luciobarbus capito* (Güldenstädt, 1773) — Turkestan Barbel. This species was noted by L. Berg (1905) only in the upper Syr Darya River section; G. Nikolskyi (1940) registered it in the middle and lower sections — from the Syr Darya mouth to Kara Darya mouth. Turkestan Barbel went extinct in the sea in early 1980s, affected by Aral Sea salinity crisis. It was known only from the Syr Darya River section within the territory of Uzbekistan (Salekhov, Kamilov, 1995). At present Turkestan Barbel is not commercially caught (Mamilov et al., 2007), its stock significantly reduced because of disruption of its migration ways by dams. According to our data *L. capito* rearly occurs in the not-regulated river section downstream the dam and in the Quairokkum Reservoir. Actually the barbel's spawning areas are located in the artificial gravel embankments near the bridges, including sites within Khujand. Actual Turkestan Barbel distribution in the Syr Darya River basin needs additional investigation.

12. *Luciobarbus brachycephalus* (Kessler, 1872) — Aral Barbel. According to L. Berg (1905) and G. Nikolskyi (1940) data this species was distributed mainly in the Aral Sea and migrated to rivers for spawning. In the Syr Darya River main channel it ascended up to Chinaz and even to Chyrchyk and Arys Rivers. After the dam construction its population declined. The Aral Sea salinity crisis also was one of the key factors (Mitrofanov, Mamilov, 2015). According to our data this species is extremely rare in the not-regulated river section and Quairokkum Reservoir (see table 1). Aral Barbel is a commercial species. In the 1960ies some projects were realized on the Aral Barbel reproduction (Bezdieniezhnykh, 1956; Halaktionova, 1963; 1966) and its actual occurrence needs detailed investigations.

13. *Schizothorax eurystomus* Kessler, 1872 — Common Marinka. It is a potamodromous migratory species, occurring in the not-regulated river section and Quairokkum Reservoir (see table 1). This species taxonomic status needs revision. L. Berg (1905, 1949a) registered it in the upper Syr Darya River section (upstream the Chyrchyk River mouth) as *Schizothorax intermedius* McClelland, 1842. We also assume the presence of *Schizothorax curvifrons* (Heckel, 1838) — Sattar Snowtrout in the Syr Darya River basin.

14. *Alburnus chalcoides* (Güldenstädt, 1772) — Danube Bleak (local — Aral Bleak). L. Berg (1905) and G. Nikolskyi (1940) registered the species in the Aral Sea. Every year it migrated to river, but did not precede upstream the Kamyshlybash (Berg, 1905; Nikolskyi, 1940). After the active dam construction it was not numerous in the Syr Darya River basin, but over the years 1993–1994 only one specimen was collected nearby the Biekabad (Saliekhov, Kamilov, 1995). Collectors supposed that Bleak penetrated through ameliorative channels system from the Zarafshan River. We also registered this species in the middle river section and even in Quairokkum Reservoir (see table 1). Probably, it also forms local residential populations in the separate river sections and reservoirs.

15. *Alburnoides taeniatus* (Kessler, 1874) — Striped Bystranka. This species is endemic for the Aral Sea basin. Initially it was described by Kessler (1874) in Tashkent. *A. taeniatus* was widely distributed in the Syr Darya River main channel from Naryn (Uch-Kurhan) and Kara Darya (Uzgen) to Kzyl Orda (Berg, 1949 a). It is a low migratory species, which does not carry out significant migration within the river channel. It was found in the river channel and the Quairokkum Reservoir. Striped Bystranka is quite rare species.

16. *Abramis brama* (Linnaeus, 1758) — Freshwater Bream. Based on L. Berg's data (1905) Bream occurred in the lower and middle river sections up to Chinaz; G. Nikolskii (1940), based on G. Bulgakov's data about Bream's finding in Fergana Valley, considered it as widely spread species up to piedmont (uppermost) river section. At present it is widely distributed in the main river channel and Quairokkum Reservoir (see table 1). Bream is

a commercial fishery object, however over the last decade it is taken only as by-catch. At present it does not migrate, and in the reservoir occurs its local population.

17. *Ballerus sapa* (Pallas, 1814) — White-eye Bream, is a potamodromous species, but without long distance migration. According to Berg (1905) and Nikolskyi (1940) it occurred in the lower and middle river section up to Kara Darya mouth. After the migration way disruption it formed local populations. Based on our data (see table 1) it is distributed in the not-regulated river section and Quairokkum Reservoir.

18. *Capoetobrama kuschakewitschi* (Kessler, 1872) — Sharpray is the Aral Sea endemic, which was described by K. Kessler (1872) nearby Khujand. According to Berg (1905) and Nikolskyi (1940) it occurred in the lower and middle sections up to Kara Darya mouth. However, its numbers sharply declined along with increase water transparency and flow velocity decrease. This species is known only in the Syr Darya River main channel (see table 1), and was not noted in the Quairokkum Reservoir.

19. *Pelecus cultratus* (Linnaeus, 1758) — Sichel is a migratory potamodromous species. According to L. Berg (1905) and G. Nikolskyi (1940), Sichel was distributed in the lower and middle river sections up to Kara Darya mouth. At present it occurs in the not-regulated section and in Quairokkum Reservoir. It is quite abundant fish of commercial value.

20. *Cyprinus carpio* Linnaeus, 1758 — Common Carp was noted by Berg (1905) in the lower and middle river sections up to Chinaz; and Nikolskyi (1940) noted it somewhat upstream — to Uzgen. Widely spread commercial species, occurring in the floodland lakes and sometimes in the main river channel. Common Carp was also introduced into the Chakwak and Quairokkum Reservoirs in early 1980s to increase fish production. Actually it is widely distributed in the not-regulated river section and in the Quairokkum Reservoir.

Family Nemacheilidae

21. *Triplophysa dorsalis* (Kessler, 1879) — Gray Loach was noted by L. Berg (1905) only for rivers nearby Yany Kurhan. At the first was described by K. Kessler based on samples collected by A. Kushakewitch.

22. *Triplophysa stoliczkai* (Steindachner, 1866) — Tibetian Stone Loach was also described by K. Kessler (1872) as new species *Cobitis uranoscopus* based on samples collected by Fedchenko at Hodzhuk (Lhujand). Also Tibetian Stone Loach was noted by L. Berg (1905) in the Chyrchyk River (upper Syr Darya River basin).

23. *Nemacheilus oxianus* (Kessler, 1877) — Amu Darya Stone Loach according to L. Berg (1905) occurred only in the upper Syr Darya River basin.

24. *Iskandarya kuschakewitschi* (Herzenstein, 1890) — Kuschakewitsch Loach is an endemic species of the Syr Darya River. According to L. Berg (1905) it occurred in the Kara Darya River (upper Syr Darya River basin). According to Mitrofanov and Mamilov (2015) this species also occurs in Arys and Badam Rivers.

We have registered all these four species in the not-regulated river section and in the Quairokkum Reservoir. They are non-migratory and are not commercially caught.

Family Siluridae

25. *Silurus glanis* (Linnaeus, 1758) — Wels Catfish is well known in the Syr Darya River from the last century (Kessler, 1872, 1877; Berg, 1905), where it occurred in the lower and middle river sections up to Kara Darya (Berg, 1905; Nikolskyi, 1940). Now it is one of the most popular commercial fishes in the not-regulated river section and in the Quairokkum Reservoir (see table 1). Over the last years its stock in the reservoir increased.

Family Salmonidae

26. *Salmo trutta* (Linnaeus, 1758) — Sea Trout or *Salmo aralensis* (Berg, 1948), taxonomic status of this species is discussed and needs revision. This is a marine species,

which migrates to the Syr Darya River only for spawning. In recent years, this species has not been caught even once. According to the official data, the last specimen was caught in 2004 in the Syr Darya River mouth (Mamilov et al., 2007). At present (see table 1) in the Quairokkum Reservoir *Salmo* specimens are sometimes caught, but we consider it as one of the introduced species. The most probably data on findings of *Salmo trutta oxianus* (Vundtsettel, 1994) in the Syr Darya River are incorrect — L. Berg (1905) noted this species exclusively in the Amu Darya River basin. It occurs in both not-regulated section and in the Quairokkum Reservoir.

Family Esocidae

27. *Esox lucius* (Linnaeus, 1758) — Pike was widely distributed in the Syr Darya River basin (Berg, 1905; Nikolskyi, 1940). At the present it still occurs in the not-regulated section, in the Quairokkum Reservoir and floodplain lakes (see table 1). Pike is a commercial species, but over the last decade its stock decreased.

Family Percidae

28. *Sander lucioperca* (Linnaeus, 1758) — Zander or Pike-perch was known (Berg, 1905) from the lower and middle river sections to Chinaz, upstream Kzyl-Orda (Nikolskyi, 1940) only individual specimens occurred. Zander was introduced into the Quairokkum Reservoir in 1963 from the Ural River (Maksunov, 1968; Kamilov, 1973). At present it is one of the main commercial species.

Among the native species there are also Turkestan Sculpin, *Cottus spinulosus* Kessler, 1872 and Spined Loach, *Sabanejewia aurata* Kessler, 1877. They occur in the small streams flowing into the Syr Darya River. However these biotopes were not covered by our studies and thus these species were not registered.

Introduced species (9) in the Syr Darya River belong to four families: Acipenseridae, Salmonidae, Cyprinidae and Esocidae.

Family Acipenseridae

29. *Acipenser baerii* (Brandt, 1869) was introduced in 1982 to the Toktohul Reservoir. According to (Vundtsettel, 1994) there are no data on this species distribution in the river. At present single specimens are caught in the middle Syr Darya River section and in the Quairokkum Reservoir.

Family Cyprinidae

These are mainly phytophagous fishes from the Amur River basin, such as 30. Grass Carp, *Ctenopharyngodon idella* (Valenciennes, 1844), 31. Silver Carp, *Hypophthalmichthys molitrix* (Valenciennes, 1844) and 32. Bighead Carp (*Hypophthalmichthys nobilis* (Richardson, 1845)). All of them were delivered in 1961 to the Akkurhan fish farm, where their artificial reproduction was organized (Verihin, Makeieva, 1981). These three species were cultivated by all fish farms in the region with periodical introduction into the natural water bodies. Their number was mainly maintained by the release of juveniles and adult fish from hatcheries, but according to our data (G. Karimov), natural spawning of Silver and Bighead Carps was noted in the Quairokkum Reservoir.

33. *Carassius gibelio* (Bloch, 1782) — Gibel Carp. Probably, introduction into the Syr Darya River basin started at the beginning of the last century, because it was registered by G. Nykolskiy (1940). In early 1950s (Vundtsettel, 1994) it was introduced into the pond farms of the Tashkent Province and into the Quairokkum Reservoir in 1959. Now it is quite abundant object of commercial fishery.

Crucian Carp, *Carassius carassius* (Linnaeus, 1758), is very rare species — it was known only from lakes nearby the Syr Darya River mouth (Berg, 1905). But Nikolskyi (1940) in the same locations (lakes at Kazalinsk) registered only Gibel Carp without any other *Carassius* species.

34. *Hemiculter lucidus* (Dybowski, 1872) — Ussuri Sharpbelly. It was shown (Makeeva, 1976) that just this species invaded the Syr Darya basin, but not the Common Sharpbelly, *Hemiculter leucisculus* Basilewsky, 1855 as it was accepted earlier. Actually it is numerous in the river section downstream the dam and especially in the Quairokkum Reservoir.

35. *Pseudorasbora parva* 1846 — Stone Moroko was accidentally introduced along with the Far-East phytophagous fishes. It is completely naturalized in Quairokkum Reservoir.

36. *Rhodeus ocellatus* (Kner, 1866) — Rosy Bitterling. It was also shown (Makeeva, 1976) that just this species invaded the Syr Darya basin not the Amur Bitterling, *Rhodeus sericeus* (Pallas, 1776), as it was accepted earlier. Rosy Bitterling inhabits both the not-regulated section downstream the dam and Quairokkum Reservoir, where it is much more numerous.

Family Channidae

37. *Channa argus* Cantor, 1842 — Snakehead. This species was introduced into the pond farms of the Tashkent Region (Kamilov, 1973). Later through the discharge channels invaded the Syr Darya basin. At present, Snakehead occurs in the Syr Darya River up to the piedmont sections (Salekhov, Kamilov, 1995). It is known in the Quairokkum Reservoir since 1966. This species gradually increased its population, and now is commercially caught

Among the introduced one more species is worth noting — the Mosquitofish, *Gambusia affinis* (Braid & Girard, 1853). It is repeatedly introduced into many reservoirs of the Syr Darya River basin since 1934 (in the Tashkent Region) to control the blood-sucking insects. This fish is rarely found in the large water bodies, it commonly inhabits the additional system and small streams, where sometimes is quite numerous. It is probable in the reclamation canals of the Quairokkum Reservoir.

Among the thirty one species specified for the reservoir, fourteen (45 %) are migratory, which belong to two families — Cyprinidae (Roach, Asp, Turkestan and Aral Barbels, Danube Bleak, Bream, White-eye Bream and Sichel) and Percidae (Pike-perch). Additionally there are a number of introduced fishes: Siberian Sturgeon, Trout, Silver and Bighead Carps and Grass Carp. These species formed the residential populations in the reservoir. However, their breeding sites, as a rule, are located in the upper section of the reservoir. After spawning, the breeders descend to the lower part over the feeding migrations. The larvae and juveniles also descend downstream, making a rolling migration. In such a situation, both adult and juvenile fishes are at risk of getting into the HPP water intake facilities.

Downstream the dam and the Syr Darya River section characteristic

The echo-sound survey showed that opposite to the HPP water discharge, at the distance of 150–300 m from the dam the bottom is even, with insignificant slope from the HPP with the depth of 2.3–3.0 m. Fishes were not found. At the distance more than 600 m from the dam the depth profile is of natural character, at the left bank depth increased to 11 m. Along about 1 km downstream quite significant cross-section depressions were noted with the depth of 10–18 m. The main accumulations of fishes were registered just in these the deepest sites. However, judging from echo grams, these are rather fish shoals wintering than accumulations of spawn-migratory specimens.

Upstream the dam Syr Darya River part characteristic

Depth distribution varies in cross-sections and from the reservoir to the dam. At the left side at the distance 45–50 m from the water edge to the first HPP facility, the depth gradually increases to 15–22 m. At the right side, the depth sharply increased from the supporting wall of the flow-control hydrotechnical facility. At both left and right sides, maximal depth (22 m) was registered at the distance of about 100 m from the water intake (at larger distance bathymetrical measurements were not carried out). At the distance of

about 50–60 m quite sharp shallowing till the depth of 17 m was noted, and episodically — to 12 m, probably, owing to accumulation of the wooden debris and bottom sediments. This assumption was confirmed by the Director of HPP, who reported that the diving examination, executed some years ago showed accumulation of wooden debris.

Closer to the HPP the depth one more time increased to 19–21 m. So, above the water intake at the bottom a kind of "barrier" is formed of the height 5–9 m and width of about 20 m. Fish distribution was characterized by their almost total absence along the left bank and behind the bottom barrier closer to the HPP. Maximal fish accumulations were registered at the bottom elevation at the reservoir side and along the right bank nearby the in-take of the flow-control hydrotechnical facility.

Based on our data and on the results of local fishermen interviewing, who pick the shocked fish, we assume presence of three "peaks": between noon and 2 pm, and in the morning and evening half-light. Observations over the gulls' activity downstream the dam enabled to state that the maximum intensity takes place between noon and 2 pm In other times, absence of gulls indicated absence of shocked fish. Direct account of died or shocked fishes from the boat and from the dam showed that the majority of fish, passed through the HPP facilities include specimens with the weight below 1 kg. During the survey, the most frequent species to pass through the HPP facilities was the Crucian Carp of the average weight of 450 g (100–1000 g), Pike-perch of the weight up to 400 g, and Common Carp of the weight up to 800 g. In the "peak" time there were 5 boats on the water area with the maximum catches up to 3–5 kg per boat. Thus, for two hours about 50 specimens with total weight of 21 kg were caught. According to Pavlov and Skorobohatov's (2014) data on Kapchahaisk HPP in the Ili River with the similar to Syr Darya River fish fauna, annual average fish number passing daily through Kapchahaisk HPES amounted to 12 specimens/1000 m^3 and maximum 147 specimens/1000 m^3. According to our data, 5 operative hydroaggregates (of total 6) release 160 m^3/s, and thus 1 152 000 m^3 of water over two hours of peak. At this only 50 fish specimens were sampled, that is only one specimen per 23 000 m^3 of water, and this is 276 times lesser than in the Kapchahaisk HPP (Pavlov & Skorobohatov, 2014). The account of fishes number, passed through the turbines, especially portion of died as a result of injury is quite difficult. According to Pavlov and Skorobohatov (2014), underwater observations downstream the dam showed high concentration of dead fishes with such typical traumas as an air bladder rupture and mechanical injuries of the body and the head. Most part of fishes with closed air bladder (Pike-perch, Perch, Ruff, Burbot etc.) after passing through turbines, buoyancy effect became positive and they could not go to the depths. At the Ust-Khantaisk HPS, this effect was observed in some fishes with open air bladder — European Cisco and Pellet. At the Kapchahaisk HPS fishes with closed air bladder in this state were met at a distance of more than 70 km downstream the dam instead of fishes with open air bladder, which recovered already within 3–5 km. Because of the reduced orientation, such specimens became easy prey for predators (fish, birds, mammals, etc.). This, according to our observations, explains the high activity of Gulls, which instantly pick up fish that swim close to the surface, especially small specimens. All these factors make our calculations very approximate and do not allow to the real picture of injury and death of fish as a result of pass through the turbines.

Measures to prevent fish mortality over modernization of Quairokkum HPP

The Quairokkum HPP is equipped by the Kaplan adjustable-blade turbine AB-495-VB-500 with six blades and diameter 4.995 m. At such dimension and at rotation 125 rev/min, lineal velocity at the blade edges exceeds 117 km/h. Such a velocity is a serious threat for fishes, which entered the turbine tract and can cause their injuries and even death. As an example, reported mass death of the grass carp in the Dniester HPP in Ukraine (Khudyi, 2010) since 2007, where, like in the Quairokkum HPP, there is deep water intake and similar turbine with the same velocity.

Frequency of such falls depends on both construction of the water-intake units and availability of the fish-protective facilities, and on biological, ecological and behavioral peculiarities of fishes. Survival (or mortality) of fishes in the turbine tract to the great degree depends on technical features of hydroaggregates.

Based on Quairokkum HPP future reconstruction we proposed three main ways for fish mortality increasing.

The first way is to avoid fish falling into the turbines. In the Quairokkum HPP, the already installed trash grids should be considered as a fish-protective facility. However, these grids are not able to protect juvenile fishes, besides the problem remains of fishes' pressing to the filtering wall. Also, it is considered the bottom elevation prior the water-intake, which was formed by bottom sediments accumulation as a natural fish-protective facility.

The second way is to decrease fish mortality is the establishment of safe condition of turbine passages by improvement of their construction and optimization of their operation regimes. The most essential characteristics affecting fish mortality in the turbine tracts of HPP are the following: turbine type, number of blades, rotational velocity. The most widely used types of turbines are Pelton, Francis and Kaplan. The latter is the most fish-friendly. Among the newest and more fish-friendly are the Alden and reduced gap runner Kaplan turbines are of special interest. There is a principally new type of turbine (Alden) by revolutionary technology, which is able to pass without injuries up to 98 % of specimens of almost 40 fish species. This significantly cuts costs for installation of the fish-protective facilities, and decreases losses in power production over fish releases. High and effective fish passage is reached owing to the following constructive features:

– instead of typical for large HPPs adjustable-blade and radial-axe turbines with 5–18 blades, the proposed turbine has only three blades, spirally located around the cone-shape rotor;

– the front edge of the blades is made with thickening to mitigate injuries of fishes over the passage;

– relatively low rotation velocity — about 120 rev/min;

– turbine design significantly improves hydrodynamic features of the aggregate without decrease of power production and other operation parameter.

Calculations showed, that use of these turbines in HPP with water pressure from 12 to 24 m will provide 95 % survival of specimens of the length up to 200 mm (that is 90 % of all specimens, entered the turbine tracts.

However, actually there is no completed project with the Alden turbine. In 2017 the pilot project of the 8 MW Alden turbine use in the Pebernat HPP (France) was launched. Precise information on this project has not yet been published; however it is obvious that actually there are no Alden turbines of the power output, comparable with power of the Quairokkum HPP turbines.

There are improved Kaplan turbine designs, using technology of minimum gap runner (MGR). The main principle, put into design of this type, is minimization of gaps between turbine blades and walls of the turbine chamber, which enables to decrease probability of fish entering into this gap and its consequent injuries. In this construction, other possible impacts on fish were minimized, such as pressure pulsation and cavitation. Blades of the runner are of special shape, which enables to remain size of gap independently on the blade position. This also increases ecological safety of the turbine. The features of the modified turbines positively affect their efficiency. Such minimum gap runner turbines were installed in power plants in the USA. According to investigations, survival of the fishes, passed through the turbines, exceeded 86 %.

The third and the most effective way for Syr Darya fish fauna conservation is a fish-ladder construction, especially is considering the high index oh fish migration. Quairokkum Reservoir dam is not single which prevents of fish migration processes, but most of all existing Reservoirs on the Syr Darya River need to be reconstructed. We considered this

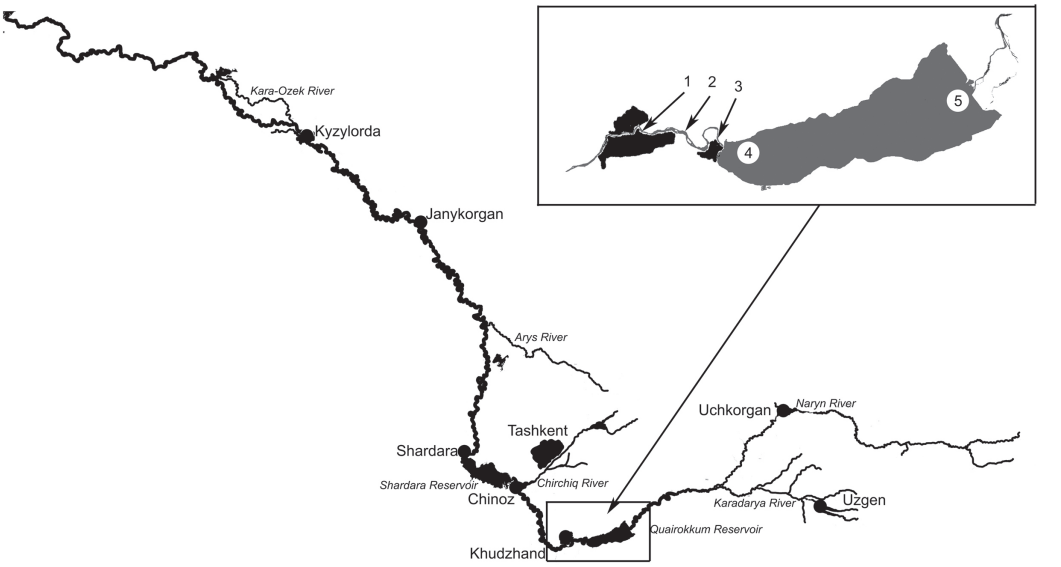

Fig. 1. Syr Darya River basin with main tributaries, reservoirs and towns. Sampling places: 1. 40.2934, 69.6821; 2. 40.2947, 69.7351; 3. 40.2843, 69.8047; 4. 40.2757, 69.8230; 5. 40.3412, 70.2755

way as the most effective for investing despite its high price. The fish-ladder construction will let us to preserve rare, endangered and endemic in the Syr Darya fish species like Syr Darya Sturgeon, Turkestan and Aral Barbels, Pike Asp etc.

The fourth way which can complete three previous is the installation of echo metric sensors before the HPP water intake facility, which will give warning of approach of the mass fish shoals to the HPP and launch deterrent fish-protective device (acoustic or ultrasound). The mode of interaction between echo metric sensors and deterrent fish-protective devices should be elaborated.

Conclusion

Thus, at present fish fauna of the considered river section (Quairokkum Reservoir and not regulated river part) include 37 species. Among them there are 28 native and 9 invasive. Five species (*Acipenser nudiventris*, *Pseudoscaphirhynchus fedtschenkoi*, *Aspiolucius esocinus*, *Luciobarbus capito* and *Luciobarbus brachycephalus*) are included into the IUCN Red List as Critically Endangered and Vulnerable. In the reservoir itself occur 31 fish species, 20 of them are native and 11 — introduced; also 16 species are of commercial value, 14 are migratory. The latter most often die, falling into the water intake hydroelectric station.

Our observations of the fish migration through the Quairokkum HPP are clearly insufficient for comprehensive assessments (at least, a series of daily counts should be carried out in different seasons and under different weather conditions). However, the faunistic index of the Quairokkum Reservoir (the ratio of the number of migratory species to their total number in the reservoir) is ≈ 47 %. The same figure for commercial species is 70 %. These figures indicate the urgency of the problem at the Quairokkum HPP.

Four main ways of Quairokkum HPP reconstruction for fish mortality reducing are proposed. These are: turbine reconstruction and its change on fish friendly designs; ensuring the safe conditions for migration through turbines by improvement of their design; installation of echo metric sensors before the HPP, which will give warning of fish shoals closing to the HPP and launch deterrent fish-protective device (acoustic or ultrasound) and also fish-ladder building.

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Received 20 November 2019
Accepted 26 October 2020