Taxonomic Status of Four Rare Alien Fish Species of the Kapchagay Reservoir (Balkhash Basin, Central Asia)

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Abstract—Based on the morphological features, four rare alien species in the Kapchagai reservoir were identified: *Coregonus peled*, *Parasalmo mykiss*, *Megalobrama mantschuricus*, and *Oreochromis niloticus*. The latter two species were recorded for the ichthyofauna of Kazakhstan for the first time. Self-reproducing *P. mykiss* populations have been known in the Balkhash Basin since the late 1990s, whereas the introduction of *C. peled* into the Ili basin in 1968–1969 and 1971 did not lead to the naturalization of the species. The reasons for the great diversity of invasive fish species in the Kapchagai reservoir are overviewed.

Keywords: *Coregonus peled*, *Parasalmo mykiss*, *Megalobrama mantschuricus*, *Oreochromis niloticus*, alien species, Kapchagai reservoir

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INTRODUCTION

Currently, the problem of biological invasions of alien species has become one of the key issues in studies of various ecosystems. Biological invasions are recognized as one of the main threats to native species and natural ecosystems; therefore, ichthyologists pay great attention to issues related to the distribution of fish outside of their natural ranges (Strayer, 2010; Ricciardi and MacIsaac, 2011; Larranaga et al., 2019). The study of species in the new environment also broadens the understanding of their adaptive capabilities (Goryunova and Serov, 1954; Karpevich, 1975).

The Balkhash Basin is a large isolated water system in Asia, where the composition of ichthyofauna have radically changed in the second half of the 20th century as a result of the planned and unintentional introductions of a large number of alien species (Mitrofanov and Dukravets, 1992b; Tereshchenko and Strel'nikov, 1995). The occurrence of new invasive species has also been noted there in the following years (Dukravets, 2007; Ismukhanov and Skakun, 2008; Isbekov and Zharkenov, 2014; Vasil'eva et al., 2015). The Ili River is the largest river in the basin. It rises in the People's Republic of China (PRC) and flows into the western part of Lake Balkhash in the Republic of Kazakhstan, contributing 73–80% of the total inflow (including groundwater) of the lake. The Kapchagai (local name Kapshagai) reservoir was created in the middle course of the Ili River in 1970. The reservoir dam is located 75 km north of the city of Almaty. The

reservoir is approximately 140 km long and 22 km wide; depths over 10 m compose approximately 48% of the reservoir area and are located mainly along the left bank (Mitrofanov, 1975). Studies over the past 15 years have recorded the findings of freshwater whitefish (Coregonidae), rainbow trout *Parasalmo mykiss*, black bream (identified as *Megalobrama* sp. or *M. terminalis*), and tilapia *Oreochromis* sp. in the reservoir (Karpov, 2005; Dukravets, 2007, 2013; Ismukhanov and Skakun, 2008; Isbekov and Zharkenov, 2014; Abilov et al., 2016; Dukravets et al., 2016); however, these works contain no information that would confirm the identification of the species new to the basin.

The goal of the present study is to verify the taxonomic status of four rare alien species of the Kapchagai reservoir based on morphological analysis and to discuss their adaptive capabilities in the new distribution range.

MATERIALS AND METHODS

The material was collected in March and June–September 2019 in the course of studies on the composition of catches by amateur fishermen and six fishing teams engaged in legal fishing in different parts of the Kapchagai reservoir (Fig. 1).

The studies were conducted on chilled fishes stored on ice for no longer than 3 days. For the morphological analysis of the fishes, we applied the systems of characters used to identify species in the correspond-

Fig. 1. Schematic map of studied area with locations of catches of studied species: (◆), peled *Coregonus peled*; (◇), rainbow trout *Parasalmo mykiss*; (■), black bream *Megalobrama mantschuricus*; (▲), Nile tilapia *Oreochromis niloticus*; fisheries: (○), cold-water; (●), warm-water; (●), produce fish of cold- and warm-water species; (→), direction of stream. Scale 50 km.

ing orders and families (Berg, 1948; Reshetnikov, 1980; Vasil'eva, 2004; Kottelat and Freyhof, 2007). The following designations of the characters are used in the work: *SL*, standard body length; *FL*, fork length (to the middle caudal fin rays); *W*, total body weight; *w*, body weight without viscera; *ll*, number of perforated scales in the lateral line; *D*, *A*, *P*, *V*, and *C*, number of rays in dorsal, anal, pectoral, pelvic, and caudal fins, respectively; *sp.br.*, number of gill rakers on the 1st gill arch; *r.br.*, number of branchiostegal rays; *pc*, number of pyloric caeca; *vert.*, total number of vertebrae. For the number of branched rays of the dorsal and anal fins, the last two rays attached to one pterygophore were counted as $1\frac{1}{2}$ (Kottelat and Freyhof, 2007). The age of the fishes was determined based on the scales and the last vertebrae of the thoracic region.

RESULTS AND DISCUSSION

Peled *Coregonus peled*. Representatives of the family Coregonidae were found in the catch of a single net,

set for 2 days (June 17–20) near the right bank of the reservoir (Fig. 1): 4 mature individuals (3 females and 1 male) at the age of four years (3+) *SL* 274–300 mm, *W* 321–653 g, *w* 303–585 g. The specimens had the following set of characters. *D* III–IV $9\frac{1}{2}$ –10, *A* III–IV 14–15, *P* I 14–16, *V* II 11, *ll* 80–86, *sp.br.* 54–63, *r.br.* 7, *vert.* 57–58. Body deep, compressed laterally, back risen steeply behind nape; maximum body depth in one specimen approximately $\frac{1}{4}$ of body length, in other specimens slightly more. Mouth small, terminal. Upper jaw approximately equal to or slightly longer than lower jaw; almost reaches the vertical line of the middle of the eye. Nasal openings on each side separated by double skin septum. Snout short. Back and upper head dark blue, sides and belly silvery (Fig. 2a). All of these features correspond to the diagnostic characters of peled (Berg, 1948; Reshetnikov, 1980, 2002; Vasil'eva, 2004; Kottelat and Freyhof, 2007). In contrast to the typical form, the specimens caught in the Kapchagai reservoir had no dark spots on their body

Fig. 2. Peled *Coregonus peled* from Kapchagai reservoir: (a) female SL 300 mm; (b) and (c) dissected females with eggs (B, SL 300 mm; C, SL 281 mm).

and no black dots on their fins; black pigment is found only at the edges of the scale pockets.

The natural range of peled covers the rivers and lakes of the Russian Federation from the Mezen River in the west to the Kolyma River in the east. As a result of acclimatization works, the range has expanded significantly: east to west from Mongolia to Germany and north to south from the Murmansk Oblast to Tajikistan (Reshetnikov, 2002). The previous find of the peled in the Kapchagai reservoir (also in the right-bank area) dates back to September 15, 2009: a male with gonads at the maturity stage IV, SL 33 cm, and weight of 606 g at the age of 4+ (Isbekov and Shar-kenov, 2014). The authors assumed that the peled could have entered the Ili River from the territory of the PRC. However, even before that, freshwater whitefishes had been introduced to the Ili river basin several times: in 1933–1935, Peipsi whitefish *C. maraenoides* and ludoga *C. lutokka*; in 1960–1961, vendus *C. albula*; in 1968–1969 and 1971, peled (Goryunova and Serov, 1954; Dukravets and Mitrofanov, 1992; Goryunova and Danko, 2015). Due to the intensive development of aquaculture in the Ili River basin over the last decade, recent importation of some whitefishes is also possible. The peled differs from all of the

aforementioned species by the greater number of gill rakers.

All the specimens we studied were well-fed and had internal fat. In females, the intestines were filled with plankton mixed with detritus. The intestines of the male were empty, and we found parasitic roundworms in the liver. The growth of fish in the Kapchagai reservoir is approximately the same as of the lake and lake-river forms in the natural distribution area and in other reservoirs they were introduced to (Novoselov and Reshetnikov, 1988; Shustov and Mitrofanov, 1992). By the end of June, all specimens had mature gonads (Figs. 2b and 2c): two females and a male had gonads at the stage of early spawning (fluid). Within its natural range, the peled spawns from September to January in locations with sandy, pebble, or rocky bottom (Berg, 1948; Reshetnikov, 2002; Kottelat and Freyhof, 2007). The specimens studied were caught on such a site in the Kapchagai reservoir, which indicates the possibility of natural reproduction in this water body. However, the spawning period is unusual. Among the whitefishes, spring-summer spawning is known for *C. baunti*, *C. lutokka*, and several species from the lakes of Western Europe (Kottelat and Freyhof, 2007). The shift of the spawning period in the Kapchagai reservoir

Fig. 3. Rainbow trout *Parasalmo mykiss* from Kapchagai reservoir FL 332 mm.

is likely due to a change in temperature and to the great ecological plasticity of the species.

Rainbow trout *Parasalmo mykiss*. One mature male of a salmonid fish (Salmonidae), age 4+ FL 332 mm, W 564 g, w 524 g, was caught July 9 approximately 6 km from the southern bank of the reservoir (Fig. 1). In the studied specimen, *D* IV 10, *A* IV 10½, *P* I 13, *V* I 10, *ll* 139, *sp.br.* 22, *vert.* 59, *r.br.* 10, *pc* 16. Body oblong, head small. Scales relatively large. Mouth large; upper jaw long, reaches behind the posterior edge of the eye. Back dark gray, almost black; sides and belly silvery; light pink stripe along the middle of each side of the body. Upper edges of dorsal and adipose fins dark gray; pectoral and anal fins light pink (Fig. 3). The present description is consistent with the diagnostic characters of the rainbow trout (Berg, 1948; Dorofeev, 2002; Vasil'eva, 2004; Kottelat and Freyhof, 2007). A very low number of pyloric caeca in this specimen is noteworthy. For example, in 25 specimens of rainbow trout FL 21–32 cm introduced into Lake Uryukty (Chilik River basin, Ili river system) (see below), *pc* 30–55 (44.3 ± 1.21), and in 19 specimens FL 28–45 cm from the native Kamchatka population, *pc* 41–56 (48.8 ± 1.23) (Biryukov, 1992); the smallest values of this character within the range of 20–70 are recorded by Dorofeeva (2002).

The freshwater form of rainbow trout, widely used in aquaculture, is considered by some authors as a separate subspecies *P. mykiss irideus* (Sideleva and Telpukhovskiy, 2004); in 1964–1970, it was repeatedly and in large quantities introduced from the fisheries of former Czechoslovakia into different inflows of the Ili River in Kazakhstan, and in 1971 and 1974, directly into the Kapchagai reservoir (Dukravets and Mitrofanov, 1992; Sidorova, 1992). The fertilized eggs of the Kamchatka rainbow trout, collected in 1975–1976 from the natural populations, were incubated in the Turgen trout fishery, and then the juveniles were dispersed in small batches into the mountainous and foothill lakes of the southeastern Kazakhstan. One of these lakes, the aforementioned Lake Uryukty, in 1988

was displaced by a mudflow, as a result of which the rainbow trout was brought into the Chilik River (Biryukov, 1992); since then, it occurs in the catches of amateur fishermen (Klimov and Mamilov, 2012). After that, by entering the Ili River, rainbow trout was able to spread upstream into the PRC territory (Ren et al., 1998). In Chinese studies, this species is included in the genus *Oncorhynchus*.

In 1971 and 1974, more than 1.3 million larvae of another salmon species, Sevan trout *Salmo ischchan*, were released into the Kapchagai reservoir. Some of the fish were able to grow to a commercial size, and over the next several years, Sevan trouts were recorded in the catches (Dukravets and Mitrofanov, 1992). Sevan trout differs from the rainbow trout by many characters, including a small mouth, fewer branched rays in the dorsal and anal fins, larger scales (up to 114 transverse rows), and a greater number of pyloric caeca (50–70) (Berg, 1948). Previously, it was reported that Sevan trouts did not naturalize in the Kapchagai reservoir (Dukravets and Mitrofanov, 1992).

In the captured rainbow trout male, the intestines were filled for approximately 3/4 with zooplankton, and there was a small supply of visceral fat. Therefore, rainbow trout in the Kapchagai reservoir continues to actively feed in summer, despite the high water temperature for this species ($\sim 22^{\circ}\text{C}$ at a depth of 1.5 m). It was previously shown that the rainbow trout can successfully exist in flowing and sufficiently deep water reservoirs of the arid and hot zone of the United States, where, due to temperature stratification, these fish spend most of the time below the thermocline (Tate et al., 2007). Obviously, the finding of rainbow trout in the Kapchagai reservoir is not accidental. It was previously recorded that in the 1960s, the rainbow trout was acclimatized and formed self-reproducing populations in the water bodies of the Chilik river basin (Dukravets et al., 2016).

Black Amur bream *Megalobrama mantschuricus*. One specimen of an alien representative of the family

Fig. 4. Black bream *Megalobrama mantschuricus* from Kapchagai reservoir *SL* 324 mm.

Cyprinidae was caught on July 26–27 near the reservoir dam (Fig. 1). This mature male, age 4+ *SL* 324 mm, *W* 564 g, *w* 524 g, has the following characters: *D* II 7½, *A* III 29½, *P* I 16, *V* I 7½, *ll* 49, *sp.br.* 11, *vert.* 42. Scales large, tightly attached. Gill rakers sparse and sharp. Three rows of pharyngeal teeth 5 : 3 : 2. Body deep, strongly laterally compressed; greatest body depth 47.5% *SL*. Belly narrows into scaleless keel from pelvic to anal fins. Dorsal fin with robust bony ray, groove along its posterior edge; anal fin long. Mouth small (jaws do not reach the posterior edge of the eye), semi-inferior. Back black, color gradually lightens towards belly to light gray on the belly (Fig. 4). All aforementioned features of morphology and color are consistent with the diagnostic characters of the black Amur bream (Vasil'eva and Makeeva, 2003; Vasil'eva, 2004), which is widespread in the Amur basin and in a number of Chinese river systems to the south up to the Yangtze River and rivers of the South China Sea basin (excluding the Zhujiang and Xi rivers) (Bogutskaya et al., 2008). Notably, *M. mantschuricus* is for the first time recorded for the fish fauna of Kazakhstan in the present study (Froese and Pauly, 2019).

Black bream has not been introduced to Ili river basin purposefully. There is information about transfers of this fish into the Tarim Basin (Mitrofanov and Turkia, 1994; Turkia, 1997). The authors identified these introduced fishes as the Chinese black bream *M. terminalis*. Previously, black breams from the Amur Basin were also incorrectly identified as this species (Berg, 1949; Nikolsky, 1956; Sokolov, 2002), as well as the black breams discovered earlier in the Kapchagai reservoir (Dukravets et al., 2016). This finding consists of one specimen, age 7+, *TL* 515 mm, *SL* 445 mm, identified as *Megalobrama* sp., dated 1999 (Ismukha-

nov and Skakun, 2008). Unfortunately, the study does not provide any information that would allow for species identification. Supposedly, the bream could have entered the reservoir from China (Zharkenov and Isbekov, 2014; Dukravets et al., 2016). In recent years, another species of the genus, *M. amblycephala*, is distributed from southern China by different fisheries (Novomodny et al., 2004). However, both aforementioned species differ significantly from *M. mantschuricus* by the shorter anal fin, the number of branched rays in which is no more than 28 (Vasil'eva and Makeeva, 2003; Guan et al., 2017; Hagiwara, 2017).

Thus, the occurrence of black bream in the Kapchagai reservoir cannot be associated with the distribution of endemic Chinese species *M. amblycephala* and *M. terminalis*. The Amur black bream, most likely, could have entered the reservoir as a result of the earlier planned dispersal of herbivorous fish in the water bodies of Kazakhstan. The stocking of water bodies was conducted with fish eggs, larvae, fingerlings, and individuals of different ages (Zharkenov and Isbekov, 2014), which could have possibly included the juvenile specimens of unplanned alien species.

The studied specimen of the black Amur bream was well-fed: visceral fat covered all internal organs. The intestines were filled with algae.

Nile tilapia *Oreochromis niloticus*. Three specimens belonging to the Cichlidae family were caught by amateur fishermen on March 29 in the Ili River (Fig. 1). The fishermen used two specimens as bait for catching northern snakehead *Channa argus*, and one specimen was given to us for morphological analysis. It was a male, age 1+, *SL* 136 mm, *W* 95.17 g, *w* 89.12 g. Its characters are *D* XVII 14, *A* III 9, *P* II 15, *V* I 5, *C* 17, *sp.br.* 29, *r.br.* 4, *vert.* 31. Two incomplete lateral lines

Fig. 5. Nile tilapia *Oreochromis niloticus* from Ili River upstream of Kapchagai reservoir SL 136 mm.

on each side of the body, 26 scale rows along the middle of the body and three more rows overlapping the caudal fin. Body deep, laterally compressed. Head large. Caudal peduncle short. Mouth terminal, small: upper jaw almost reaches the vertical line of the anterior edge of the eye. Most teeth with a forked apex, arranged in several rows, outer row is even. Dorsal fin long; pectoral and pelvic fins also long, almost reaching anal fin. General coloration tone grayish blue, back almost black, along color brightens towards belly. Dorsal and caudal fins with black and white stripes (Fig. 5). The listed features are consistent with the diagnostic characters of *O. niloticus* (Eccles, 1992; Kottelat and Freyhof, 2007; Genner et al., 2018); to date, this species has not been recorded in the composition of the fish fauna of Kazakhstan (Froese and Pauly, 2019).

The natural range of the Nile tilapia is limited to the water bodies of western and eastern Africa (the Nile basin) and Israel (Kottelat and Freyhof, 2007). Due to its rapid growth and sexual maturity, relatively modest food and water quality requirements, this species has become widespread throughout the world as an object of aquaculture. By the beginning of the 21st century, the species was already introduced in 85 countries: in 58% of the cases, the introduction led to naturalization, and a negative effect on the environment was already identified in 14% of water bodies (Vicente and Fonseca-Alves, 2013). In the Kapchagai reservoir, tilapia was found for the first time in 2009 (Isbekov and Zharkenov, 2014). In Kazakhstan and the Xinjiang Uygur Autonomous Region of the PRC, three tilapia species are cultivated: Nile tilapia, Mozambique tilapia *O. mossambicus*, and blue tilapia *O. aureus*, as well as their hybrids. The Nile tilapia differs well from the latter two species by the presence of

gray or black vertical stripes on the caudal fin (Kottelat and Freyhof, 2007). There were examples of successful cultivation of Nile tilapia in thermal springs and in ponds in the summer period in the area of the Kapchagai reservoir (Asylbekova et al., 2019). Obviously, tilapia from these farms constantly escapes to the Ili River and in the Kapchagai reservoir.

The studied male had gonads at maturity stage V: thick white cords of the paired testes occupied ~1/3 of the body cavity. The fish was well-fed: visceral fat covered the intestines, which were filled with algae and several caddisfly larvae. Despite the low water temperature for this species (~15°C), the tilapia continued to feed actively: the fishermen caught it using bread crumb as bait.

Factors contributing to the naturalization of invasive species. The four alien species studied and identified in the present work are added to the list of ichthyofauna of the Ili River in the area of the Kapchagai Reservoir, currently consisting entirely of invasive species, the diversity of which is constantly increasing (Karpov, 2005; Dukravets, 2007; Ismukhanov and Skakun, 2008; Isbekov and Zharkenov, 2014; Vasil'eva et al., 2015). In addition to the species of the temperate zone from the basins of the Caspian and Aral seas and the Amur River, there are now typically cold-water representatives of the order of salmoniforms and such a thermophilic species as tilapia. There are several causes of the great diversity of invasive fish species in the Kapchagai reservoir.

1. The Kapchagai reservoir is located in the foothill zone at the junction of the Tian Shan and Dzhungarian Paleozoic orogens with large reserves of groundwater, the Ili artesian basin and the Dzhungarian hydrogeological massif, respectively. As a result, artesian basins with cold (12–16°C) and hot (25–47°C)

water can occur in the same locations, but at different depths; in some places they can spontaneously discharge (Kamenskiy et al., 1959; Leonov and Zagainov, 1963). Outlets of cold and hot groundwater are located near and at the bottom of the Kapchagai reservoir. They can probably serve as sheltering habitats for species with specific temperature preferences.

2. Fishing has a significant effect on the composition of the ichthyofauna. In 2017, the highest fishing effort values over the last decade were recorded for the reservoir: 92 teams of fishermen from 19 organizations were fishing using 3645 nets, 22 seines, and 244 boats. However, only 816 tons of fish were caught, much less than the highest value of 1129 tons in 2010. Due to the evident overfishing, in 2018 a limit of only 640 tons was set (Abilov et al., 2019). At the same time, state facilities (Kazakh production and acclimatization station and Kapchagai breeding and rearing fishery) working with reproduction of carp, common carp *Cyprinus carpio* and grass carp *Ctenopharyngodon idella*, were privatized and lost their role of the reproduction of these species, and the large-scale removal of the dominant fish species (common bream *Abramis brama*, asp *Aspius aspius*, wels catfish *Silurus glanis*, northern snakehead, pikeperch *Sander lucioperca*, common carp, silver carp *Hypophthalmichthys molitrix*, and grass carp) without the appropriate restocking considerably weakens interspecific competition and provides rare species with the opportunity to increase their population size.

3. Due to reservoirs being artificial ecosystems, the hydrological regime there is unpredictable for aquatic organisms, the physical and chemical parameters of water and the content of biogenic elements are much more variable, and therefore, the feed base is unstable. Therefore, reservoirs provide significant advantages to alien species over native species (Havel et al., 2005; Han et al., 2008).

4. In recent years, additional water wells have been drilled in the vicinity of the reservoir, the water from which is used in the vegetable or fish farming. Water of different temperatures taken from different wells makes it possible for some fisheries to keep trout, tilapia, and other fish species on a small area at the same time (for example, the “Rybolovnaya Baza Chiliksii Karp”, “Tengry Fish”, and “Halyk Balyk” fisheries). Other fisheries specialize only in cold-water (Turgen trout fishery) or warm-water (Kapshagai NVH-1973, “Kaz Organic Product”) fish species (Fig. 1). Therefore, alien species can be restocked by fishes that have escaped from fisheries.

As previously mentioned, the rainbow trout has formed self-reproducing populations in the water bodies of the Chilik River basin (Dukravets et al., 2016); the naturalization of Kamchatka rainbow trout has also been reported in Lake Uryukty (Chilik Basin) (Biryukov, 1992; Mitrofanov and Dukravets, 1992a). At the same time, the introduction of peled into the

basin of Lake Balkhash in 1968–1969 and 1971 was unsuccessful (Mitrofanov and Dukravets, 1992, 1992b). There is no data on the reproduction of black Amur bream and Nile tilapia in the Kapchagai reservoir. According to Zharkenov and Isbekov (2014), black bream, peled, and tilapia (as well as snakehead) appeared here only in recent years and can be considered accidentally introduced through the Ili River from the territory of the PRC. Without a doubt, to assess the impact of alien species on the ecosystem of the Kapchagai reservoir and Ili River, regular monitoring of the ichthyofauna and invasive process is required.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflicts of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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REFERENCES

- Abilov, B.I., Barakbaev, T.T., and Ablaisanova, G.M., Development of commercial ichthyofauna in Kapchagay Reservoir, *Izv. Nats. Akad. Nauk Resp. Kazakh., Ser. Biol. Med.*, 2016, no. 5 (317), pp. 94–98.

- Abilov, B.I., Kasymbekov, E.B., and Zharkenov, D.K., Catch dynamics of commercial fish species in Kapchagay Reservoir, *Vestn. Nauki Kazakh. Agrotekh. Univ.*, 2019, no. 1 (100), pp. 12–22.
- Asylbekova, S.Zh., Ismukhanov, Kh.K., and Pazylbekov, M.Zh., The tilapia (*Tilapia*) as the prospective object for commercial fish farming in Kazakhstan, in *Sostoyanie vodnykh biologicheskikh resursov i akvakul'tury Kazakhstana i sopredel'nykh stran* (The State of Aquatic Biological Resources and Aquaculture of Kazakhstan and Adjacent Countries), Almaty: Kazakh. Nats. Univ., 2019, pp. 494–501.
- Berg, L.S., *Ryby presnykh vod SSSR i sopredel'nykh stran* (Freshwater Fishes of the Soviet Union and Adjacent Waters), Moscow: Akad. Nauk SSSR, 1948, part 1.
- Berg, L.S., *Ryby presnykh vod SSSR i sopredel'nykh stran* (Freshwater Fishes of the Soviet Union and Adjacent Waters), Moscow: Akad. Nauk SSSR, 1949, part 2, pp. 469–926.
- Biryukov, Yu.A., The rainbow trout *Salmo mykiss* Walbaum, in *Ryby Kazakhstana. Tom 5. Akklimatizatsiya, promysel* (Fishes of Kazakhstan, Vol. 5: Naturalization and Fishery), Alma-Ata: Gylm, 1992, pp. 119–125.
- Bogutskaya, N.G., Naseka, A.M., Shedko, S.V., et al., The fishes of the Amur River: updated check-list and zoogeography, *Ichthyol. Explor. Freshwater*, 2008, vol. 19, no. 4, pp. 301–366.
- Dorofeeva, E.A., The Kamchatka rainbow trout *Parasalmo mykiss* (Walbaum, 1792), in *Atlas presnovodnykh ryb Rossii* (Atlas of Freshwater Fishes of Russia), Reshetnikov, Yu.S., Ed., Moscow: Nauka, 2002, vol. 1, pp. 92–95.
- Dukravets, G.M., New alien species in ichthyofauna of Balkhash-Ili basin (Republic of Kazakhstan), *Materialy Mezhdunarodnoi nauchno-prakticheskoi konferentsii "Sostoyanie, okhrana, vosproizvodstvo i ustoychivoe ispol'zovanie biologicheskikh resursov vnutrennikh vodoemov"* (Proc. Int. Sci.-Pract. Conf. "State, Protection, Recovery, and Sustainable Use of Biological Resources of Inland Reservoirs"), Volgograd: Volgograd. Otd., Gos. Nauchno-Issled. Inst. Ozer. Rechn. Rybn. Khoz., 2007, pp. 95–96.
- Dukravets, G.M., Alien fish species in the Republic of Kazakhstan, *Izv. Nats. Akad. Nauk Resp. Kazakh., Ser. Biol. Med.*, 2013, no. 5 (299), pp. 32–37.
- Dukravets, G.M. and Mitrofanov, V.P., The history of fish naturalization in Kazakhstan, in *Ryby Kazakhstana. Tom 5. Akklimatizatsiya, promysel* (Fishes of Kazakhstan, Vol. 5: Naturalization and Fishery), Alma-Ata: Gylm, 1992, pp. 6–44.
- Dukravets, G.M., Mamilov, N.Sh., and Mitrofanov, I.V., Fishes of Kazakhstan: annotated list, corrected and completed by December 31, 2016, *Selevinia*, 2016, vol. 24, pp. 47–71.
- Eccles, D.H., *FAO Species Identification Sheets for Fishery Purposes. Field Guide to the Freshwater Fishes of Tanzania*, Rome: UN Food Agric. Org., 1992.
- Froese, R. and Pauly, D., Eds., *FishBase. World Wide Web electronic publication.*, 2019. <http://www.fishbase.org. Version 12/2019>
- Genner, M.J., Turner, G.F., and Ngatunga, B.P., A guide to the tilapia fishes of Tanzania, Version 12/2018, 2018. https://martingenner.weebly.com/uploads/1/6/2/5/1625-0078/tanzania_tilapia_guide_edition1_2018.pdf.
- Goryunova, A.I. and Dan'ko, E.K., *Stepnye ozera Severnogo Kazakhstana* (Steppe Lakes of Northern Kazakhstan), Saarbrücken: LAP Lambert Academic, 2015.
- Goryunova, A.I. and Serov, N.P., Naturalization of fishes in Kazakhstan, *Trudy soveshchaniya po probleme akklimatizatsii ryb i kormovykh bespozvonochnykh* (Proc. Conf. on Naturalization of Fishes and Food Invertebrates), Moscow: Akad. Nauk SSSR, 1954, pp. 109–113.
- Guan, W., Zheng, G., Wu, Ch., et al., Comparative analysis of growth and morphological variations among *Megalobrama amblycephala*, *M. terminalis*, *Parabramis pekinensis* and their hybrids, *J. Fish. Sci. China*, 2017, vol. 24, no. 1, pp. 31–39. <https://doi.org/10.3724/SP.J.1118.2017.16100>
- Hagiwara, T., Records of the non-indigenous Wuchang bream *Megalobrama amblycephala* (Cyprinidae) in Lake Kasumigaura, Ibaraki Prefecture, Japan, *Izunuma-Uchinuma Wetland Res.*, 2017, vol. 11, pp. 75–81. https://doi.org/10.20745/izu.11.0_75
- Han, M., Fukushima, M., and Fukushima, T., Species richness of exotic and endangered fishes in Japan's reservoirs, *Environ. Biol. Fish.*, 2008, vol. 83, pp. 409–416. <https://doi.org/10.1007/s10641-008-9362-6>
- Havel, J.E., Lee, C.E., and Vander Zanden, M.J., Do reservoirs facilitate invasions into landscapes? *BioScience*, 2005, vol. 55, pp. 518–525. [https://doi.org/10.1641/0006-3568\(2005\)055\[0518:DRFI-IL\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2005)055[0518:DRFI-IL]2.0.CO;2)
- Isbekov, K.B. and Zharkenov, D.K., Alien fish species in the Ili River basin and the problem of biological invasions, *Izv. Nats. Akad. Nauk Resp. Kazakh., Ser. Biol. Med.*, 2014, no. 1, pp. 12–19.
- Ismukhanov, Kh.K. and Skakun, V.A., Modern status of biodiversity of cross-boundary Ili River and Kapshagaiskoe reservoir and influence of migrating alien species on their ecosystems, in *Ekologiya i gidrofauna vodoemov trasgranichnykh basseinov Kazakhstana* (Ecology and Hydrofauna of Reservoirs of Cross-Boundary Basins of Kazakhstan), Alma-Ata: Bastau, 2008, pp. 273–280.
- Kamenskii, G.N., Tolstikhina, M.M., and Tolstikhin, N.I., *Gidrogeologiya SSSR* (Hydrological Geology of USSR), Moscow: Gosgeoltekhizdat, 1959.
- Karpevich, A.F., *Teoriya i praktika akklimatizatsii organizmov* (Theory and Practice of Naturalization of Organisms), Moscow: Pishchevaya Prom-st', 1975.
- Karpov, V.E., List of fishes and fish-like species of Kazakhstan, in *Rybokhozyaistvennye issledovaniya v Respublike Kazakhstan: istoriya i sovremennoe sostoyanie* (Fishery Studies in Kazakhstan Republic: History and Modern Status), Alma-Ata: Bastau, 2005, pp. 152–168.
- Klimov, F.V. and Mamilov, N.Sh., Current composition of ichthyofauna of the Shelek River in mountain and foothill zones, *Vestn. Kazakh. Nats. Univ., Ser. Ekol.*, 2012, no. 1 (33), pp. 85–88.
- Kottelat, M. and Freyhof, J., *Handbook of European Freshwater Fishes*, Cornol, Switzerland; Berlin, Germany: Kottelat and Freyhof, 2007.
- Larranaga, N., Wallerius, M.L., Guo, H., et al., Invasive brook trout disrupts the diel activity and aggregation patterns of native brown trout, *Can. J. Fish. Aquat. Sci.*, 2019, vol. 76, pp. 1052–1059. <https://doi.org/10.1139/cjfas-2018-0110>

- Leonov, G.M. and Zagainov, V.I., Underground waters and mineral springs, in *Iliiskaya dolina, ee priroda i resursy* (The Ili River Valley: Nature and Resources), Lomonovich, M.I., Ed., Alma-Ata: Akad. Nauk KazakhSSR, 1963, pp. 174–189.
- Mitrofanov, V.P., Physical and geographical description of the middle streams of the Ili River and Kapchagay Reservoir, *Biol. Nauki*, 1975, no. 9, pp. 5–8.
- Mitrofanov, V.P. and Dukravets, G.M., The history of naturalization of fishes in Kazakhstan, in *Ryby Kazakhstana. Tom 5. Akklimatizatsiya, promysel* (Fishes of Kazakhstan, Vol. 5: Naturalization and Fishery), Alma-Ata: Gylym, 1992a, pp. 6–44.
- Mitrofanov, V.P. and Dukravets, G.M., The theoretical and practical aspects of fish naturalization in Kazakhstan, in *Ryby Kazakhstana. Tom 5. Akklimatizatsiya, promysel* (Fishes of Kazakhstan, Vol. 5: Naturalization and Fishery), Alma-Ata: Gylym, 1992b, pp. 329–371.
- Mitrofanov, V.P. and Turkiya, A., Ichthyofauna of the Tarim River basin and its role for ichthyological geography, *Selevinia*, 1994, no. 4, pp. 18–21.
- Nikolsky, G.V., *Ryby basseina Amura. Itogi Amurskoi ikhtiologicheskoi ekspeditsii 1945–1949 gg.* (Fishes of the Amur River Basin: The Results of Amur Ichthyological Expedition 1945–1949), Moscow: Akad. Nauk SSSR, 1956.
- Novomodny, G., Sharov, P., and Zolotukhin, S., *Amur Fish: Wealth and Crisis*, Vladivostok: Apel'sin, 2004.
- Novoselov, A.P. and Reshetnikov, Yu.S., Peled in new habitat conditions, in *Biologiya sigovykh ryb* (Biology of the Whitefishes (Coregonidae)), Moscow: Nauka, 1988, pp. 78–114.
- Ren, M., Guo, Y., Zhang, Q., et al., *Fisheries Resources and Fishery of River Yili*, Harbin: Heilongjiang Sci. Tech. Press, 1998.
- Reshetnikov, Yu.S., *Ekologiya i sistematika sigovykh ryb* (Ecology and Systematics of Whitefishes), Moscow: Nauka, 1980.
- Reshetnikov, Yu.S., The peled *Coregonus* (Gmelin, 1789), in *Atlas presnovodnykh ryb Rossii* (Atlas of Freshwater Fishes of Russia), Reshetnikov, Yu.S., Ed., Moscow: Nauka, Moscow: Nauka, 2002, vol. 1, pp. 149–151.
- Ricciardi, A. and MacIsaac, H.J., Impacts of biological invasions on freshwater ecosystems, in *Fifty Years of Invasion Ecology: The Legacy of Charles Elton*, Richardson, D.M., Ed., Chichester: Wiley, 2011, pp. 211–224. <https://doi.org/10.1002/9781444329988.ch16>
- Shustov, A.I. and Mitrofanov, V.P., The data on morphology and biology of Coregonidae fishes in reservoirs of Kazakhstan, in *Ryby Kazakhstana. Tom 5. Akklimatizatsiya, promysel* (Fishes of Kazakhstan, Vol. 5: Naturalization and Fishery), Alma-Ata: Gylym, 1992, pp. 316–328.
- Sideleva, V.G. and Tel'pukhovskii, A.N., Invasive fish species in the Baikal Lake and Baikal region, in *Biologicheskie invazii v vodnykh i nazemnykh ekosistemakh* (Biological Invasions in Aquatic and Terrestrial Ecosystems), Alimov, A.F. and Bogutskaya, N.G., Eds., Moscow: KMK, 2004, pp. 171–186.
- Sidorova, A.F., The rainbow trout *Salmo gairdneri* Richardson is a residential form of the steelhead salmon *Oncorhynchus mykiss irideus*, in *Ryby Kazakhstana. Tom 5. Akklimatizatsiya, promysel* (Fishes of Kazakhstan, Vol. 5: Naturalization and Fishery), Alma-Ata: Gylym, 1992, pp. 56–119.
- Sokolov, L.I., The black Amur bream *Megalobrama terminalis* (Richardson, 1846), in *Atlas presnovodnykh ryb Rossii* (Atlas of Freshwater Fishes of Russia), Reshetnikov, Yu.S., Ed., Moscow: Nauka, 2002, vol. 1, pp. 281–282.
- Strayer, D., Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future, *Freshwater Biol.*, 2010, vol. 55, suppl. 1, pp. 152–174. <https://doi.org/10.1111/j.1365-2427.2009.02380.x>
- Tate, K.W., Lancaster, D.L., and Lile, D.F., Assessment of thermal stratification within stream pools as a mechanism to provide refugia for native trout in hot, arid rangelands, *Environ. Monit. Assess.*, 2007, vol. 124, pp. 289–300. <https://doi.org/10.1007/s10661-006-9226-5>
- Tereshchenko, V.G. and Strel'nikov, A.S., Analysis of transformations in fish communities in the Balkhash Lake as the result of introduction of new fish species, *Vopr. Ikhtiol.*, 1995, vol. 35, no. 1, pp. 71–77.
- Turkiya, A., Ichthyofauna of reservoirs of Xinjiang region and its change during acclimatization, *Extended Abstract of Cand. Sci. (Biol.) Dissertation*, Alma-Ata: Inst. Zool. Genofonda Zhivotn., Akad. Nauk Resp. Kazakh., 1997.
- Vasil'eva, E.D., *Populyarnyi atlas-opredelitel'. Ryby (Popular Atlas-Guide for Identification of Fishes)*, Moscow: Drofa, 2004.
- Vasil'eva, E.D. and Makeeva, A.P., Taxonomic status of the Black Amur bream and some remarks on problems of taxonomy of the genera *Megalobrama* and *Sinibrama* (Cyprinidae, Cultrinae), *J. Ichthyol.*, 2003, vol. 43, no. 8, pp. 582–597.
- Vasil'eva, E.D., Mamilov, N.S., and Magda, I.N., New species of Cypriniform fishes (Cypriniformes) in the fauna of the Balkhash–Ili basin, Kazakhstan, *J. Ichthyol.*, 2015, vol. 55, no. 4, pp. 447–453. <https://doi.org/10.1134/S0032945215040141>
- Vicente, I.S.T. and Fonseca-Alves, C.E., Impact of introduced Nile tilapia (*Oreochromis niloticus*) on non-native aquatic ecosystems, *Pak. J. Biol. Sci.*, 2013, vol. 16, no. 3, pp. 121–126. <https://doi.org/10.3923/pjbs.2013.121.126>
- Zharkenov, D.K. and Isbekov, K.B., Biological invasions in reservoirs of the Blakhash-Ili basin, *Materialy II Vserossiiskoi konferentsii "Sovremennoe sostoyanie bioresursov vnutrennikh vod"* (Proc. II All-Russ. Conf. "Modern Status of Biological Resources of Inland Waters"), Moscow: Poligrafplyus, 2014, vol. 1, pp. 177–183.

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