Трансформация экосистем
Ecosystem Transformation

ISSN 2619-0931 Online
www.ecosysttrans.com

DOI 10.23859/estr-230420
EDN KJLBLT
UDC 597.2/.5

Article

Features of the distribution of fish species composition of the mountain Akhuryan River (Armenia) under the influence of small hydroelectric power plants

T.V. Vardanyan[1], N.E. Barseghyan[1*], R.E. Barseghyan[2], B.K. Gabrielyan[1]

[1] *Institute of Hydroecology and Ichthyology of Scientific Center of Zoology and Hydroecology of National Academy of Sciences of Republic of Armenia, Sevak St. 7, Yerevan, 0014 Armenia*

[2] *Institute of Zoology of Scientific Center of Zoology and Hydroecology of National Academy of Sciences of Republic of Armenia, Sevak St. 7, Yerevan, 0014 Armenia*

**nelli.barseghyan@yahoo.com*

Abstract. Fish species composition in the Akhuryan River upper and below a small hydroelectric power plant (SHPP) “Amasia” was investigated (2018-2019). Twelth fish species have been identified. For the first time, electrofishing was used for determining fish composition. The highest fish diversity (seven species) was recorded in the spring 2019 in the lower reach of the river near the village of Marmashen, while the lowest (three species) in the autumn 2018 near the SHPP “Amasia” below the water intake point and in the tributary of the Akhuryan. At all fish sampling sites, Kura chub – *Alburnoides eichwaldii* De Filippi 1863 and Kura barbell – *Barbus cyri* De Filippi 1985 were met. In autumn, Kura chub were a super-dominating species in all the sites. In the spring 2019, they were dominating in the lower reach of the river. The absence of Kura khramicarp *Capoeta capoeta* Guldenstadt 1772 below the SHPP’s water intake point and near the dam on the river between the villages Caps and Jradzor was likely the result of SHPP operation. The only listed fish species (status “endangered” in The Red Book of Armenia) found during the study period was the asp *Leuciscus aspius* Linnaeus 1758.

Keywords: ichthyofauna; diversity of fish species, relative frequency; dominance metric; endangered species

ORCID:
T.V. Vardanyan, https://orcid.org/0000-0002-3348-3673
N.E. Barseghyan, https://orcid.org/0000-0002-2819-093X
R.E. Barseghyan, https://orcid.org/0009-0000-4762-0475
B.K. Gabrielyan, https://orcid.org/0000-0003-3670-6470

To cite this article: Vardanyan, T.V. et al., 2025. Features of the distribution of fish species composition of the mountain Akhuryan River (Armenia) under the influence of small hydroelectric power plants. *Ecosystem Transformation* **8** (1), 213–227. https://doi.org/10.23859/estr-230420

Received: 20.04.2023
Accepted: 16.08.2023
Published online: 07.03.2025

DOI 10.23859/estr-230420
EDN KJLBLT
УДК 597.2/.5

Научная статья

Особенности распределения видового состава рыб горной реки Ахурян (Армения) под воздействием малых ГЭС

Т.В. Варданян[1], Н.Э. Барсегян[1*], Р.Э. Барсегян[2], Б.К. Габриелян[1]

[1] *Институт Гидроэкологии и ихтиологии Научного центра зоологии и гидроэкологии Национальной академии наук Республики Армения, 0014, Республика Армения, г. Ереван, ул. П. Севака, д. 7*
[2] *Институт Зоологии Научного центра зоологии и гидроэкологии Национальной академии наук Республики Армения, 0014, Республика Армения, г. Ереван, ул. П. Севака, д. 7*

**nelli.barseghyan@yahoo.com*

Аннотация. Приведены результаты исследования видового состава ихтиофауны р. Ахурян до и после малой гидроэлектростанции (МГЭС) «Амасия», проведенного в 2018–2019 гг. Отмечено 12 видов рыб. Впервые изучение видового состава рыб р. Ахурян было проведено с помощью электролова. Наибольшее число видов (7) было зафиксировано весной 2019 г. в нижнем течении реки у пос. Мармашен, наименьшее (3 вида) – осенью 2018 года на участках отбора проб вблизи МГЭС «Амасия» после водозабора и на притоке реки Ахурян. На всех станциях вылова рыб были отмечены восточная быстрянка *Alburnoides eichwaldii* De Filippi, 1863 и куринский усач *Barbus cyri* De Filippi, 1985. В осенний период восточная быстрянка была супердоминантом на всех исследованных участках. Весной 2019 г. в нижнем течении реки быстрянка стала доминируюшим видом. Отсутствие куринской храмули *Capoeta capoeta* Guldenstadt, 1772 в местах отбора проб вблизи МГЭС после точки водозабора и вблизи плотины на реке между поселками Капс и Джрадзор, вероятно, является результатом влияния МГЭС. За период исследований на обследуемой территории из рыб, занесенных в Красную книгу Армении как находящихся под угрозой исчезновения, был обнаружен только жерех *Leuciscus aspius* Linnaeus, 1758.

Ключевые слова: ихтиофауна, разнообразие видов рыб, относительная встречаемость, показатель доминирования, исчезающие виды

ORCID:
Т.В. Варданян, https://orcid.org/0000-0002-3348-3673
Н.Э. Барсегян, https://orcid.org/0000-0002-2819-093X
Р.Э. Барсегян, https://orcid.org/0009-0000-4762-0475
Б.К. Габриелян, https://orcid.org/0000-0003-3670-6470

Для цитирования: Варданян, Т.В. и др., 2025. Особенности распределения видового состава рыб горной реки Ахурян (Армения) под воздействием малых ГЭС. *Трансформация экосистем* **8** (1), 213–227. https://doi.org/10.23859/estr-230420

Поступила в редакцию: 20.04.2023
Принята к печати: 16.08.2023
Опубликована онлайн: 07.03.2025

Introduction

The Akhuryan River (transboundary river, left tributary to the Araks River) originates from Lake Arpilich in the Ashotcq highland (Armenia). By water content, it is the third river in the country The Akhuryan's watershed area is 9670 km^2, average discharge is 26.9 m^3/sec (annually, 900 mln m^3). The length of the river is 186 km.

The Akhuryan River is one of the rivers in Armenia with the greatest diversity of fish species (Dadikyan, 1986). In the 1960s–1970s, 14 fish species were found (Table 1) (Dadikyan, 1986). Later works described 24 fish species in the river, 11 of which were recorded in the area of the village of Ashotsk, on the outskirts of the National Park "Arpilich" (Gabrielyan, 2001; Pipoyan and Malkhasyan, 2014) (Table1). The most abundant fish species were the chub, Kura nase, Kura chub, and the Prussian carp; the least numerous were the asp, which have been very rarely encountered. In a study conducted in the lower reach of the river, before the inflow into the Akhuryan Reservoir, 24 species of fish were noted (Pipoyan, 2007). However, the ecology and distribution of fish in the Akhuryan River have not been sufficiently studied. The previous authors did not mention the type of fishing gear used. Pipoyan and Malkhasyan (2014) presented results of a 27-year research, but did not specify which species and when were discovered in the Akhuryan River or Lake Arpilich. Of all the fish species recorded in the Akhuryan River, 3 species (asp, Kura gudgeon and golden spined loach) have been included in the Red Book of the Republic of Armenia as endangered ones (Krasnaya Kniga..., 2010).

According to the data of the Public Services Regulatory Commission of the Republic of Armenia, four small hydroelectric power plants (SHPP) are currently operated on the Akhuryan River: "Jradzor" (since 2013), "Marmashen" (2011), ''Paros" (2012), and "Amasia" (2014). Studies on the fish composition in the Akhuryan were carried out until 2012 and were stopped after construction and operation of these SHPPs.

Streams and rivers in the mountainous regions have great social and economic importance (Winston et al., 2015). However, rivers are complex aquatic-terrestrial networks in which small-scale local changes may result in far-reaching longer impacts (Khosrovyan, 2024). Considering the construction rate of new SHPPs on different rivers of Armenia, the ecological monitoring and assessment of their bioresources become imperative.

Although hydroelectric power plants are considered to be the ecologically-friendly energy source, their operation is associated with the ecosystem degradation caused by water abstraction, hydropeaking, impoundments and fragmentation (Huckstorf et al., 2008; Nilsson et al., 2005; Opperman et al., 2015; Seliger et al., 2016). As shown by numerous studies worldwide, the primary impact of these multiple stressors falls on biodiversity (Vörösmarty et al., 2010). SHPPs imped spawning migrations of anadromous and semi-anadromous fish thereby disrupting their natural reproduction. Sedentary fish populations become isolated from each that leads to the impoverishment of gene pools. The absence and/or inefficiency of fish protection measures brings to the ingress of eggs, larvae, fry and adult fish (especially at lower temperature and suppressed activity) into the turbines and the water taken for technical use, leading to their death (Rubenyan and Gabrielyan, 2011). Moreover, water abstraction from river channels often exceeds the limit for the "ecological flow", which is also detrimental to the inhabiting fish population.

Among other factors of SHPP impacts on the fish communities are changes in the temperature regime, flow rate, water chemistry and gas regime, concentration of biogen elements in the rivers, as well as solid runoff and water level fluctuations (Gabrielyan et al., 2022; Krylov et al., 2013; Rubenyan and Gabrielyan, 2011).

Taking into account the incompleteness of the previous studies and the potential changes occurred in the Akhuryan River ecosystem and its watershed as a result of intensified human activities, there is a need for detailed ichthyologic investigations. The aim of this study was to investigate the ichthyofauna of the Akhuryan River under conditions of increased anthropogenic pressure, and in particular, the operation of small hydroelectric power plants.

Material and methods

Study area

During September-November 2018 and May 2019, ichthyological surveys were conducted along the Akhuryan River at 8 sampling sites (Fig. 1): site N1 in the upper reach; site N2 near the SHPP "Amasia" below the water intake point; site N3 near the village of Jradzor; site N4 on the left tributary of the Akhuryan River; site N5 near the dam on the river between the Caps and Jradzor villages; site N6 near the village of Marmashen; site N7 near the village of Arapi; site N8 near the village of Yerazgaors.

Sampling and identification

Fish were caught using a castnet and electrofishing. The latter was applied only once as a control catch (Guidelines for electrofishing..., 2000). Fish species were identified using freshwater species atlas (Atlas presnovodnykh ryb..., 2003; Dadikyan, 1986).

Species relative richness in the catch was assessed by their occurrence: < 0.1% – rarely met species, 0.1–1.0 % – low abundance, 1.1–5.0% – common, 5.1–10.0% – sub-dominant, > 10% – dominant, > 50% – super-dominant (Tsereshenko and Nadirov, 1996).

Diversity metric was measured by the Shannon index (Shanon, 1948):

$$\mathbf{H} = -\sum_{j=1}^{N} \mathbf{pi} \times \mathbf{log_2}\, \boldsymbol{pi} \ ,$$

where pi is the proportion of the i-th species by number and N is the total number of species in the catch.

The dominance metric was estimated using the Ferster's index (Antomonov, 1977):

$$\mathbf{R} = \mathbf{1} - \left[-\sum_{j=1}^{N} \boldsymbol{pi} \times \boldsymbol{log_2\, pi}\right] / \boldsymbol{log_2\, N} \ ,$$

where pi is the proportion of the i-th species by number and N is the total number of species in the catch.

Results and discussion

As it can be seen from Table 1, different authors have reported about 25 fish species and subspecies in the Akhuryan River over the past 60 years. In the present study, 12 fish species were detected. No specimen of brown trout *Salmo trutta* Linnaeus 1758 was found, however, they were met in the tributary of the river near the village of Egnadjur. Brown trout is more typical for the upper reaches of the Akhuryan. However, few in number and isolated populations may inhabit some small tributaries, which serve for the species reproduction.

The relatively small number of species registered during this study may be due to several reasons:

We considered all caught khramicarp fish as *Capoeta capoeta* Guldenstadt, 1772 since our studies did not reveal any significant differences that would allow us to determine subspecies. This requires a more detailed study using modern molecular methods.

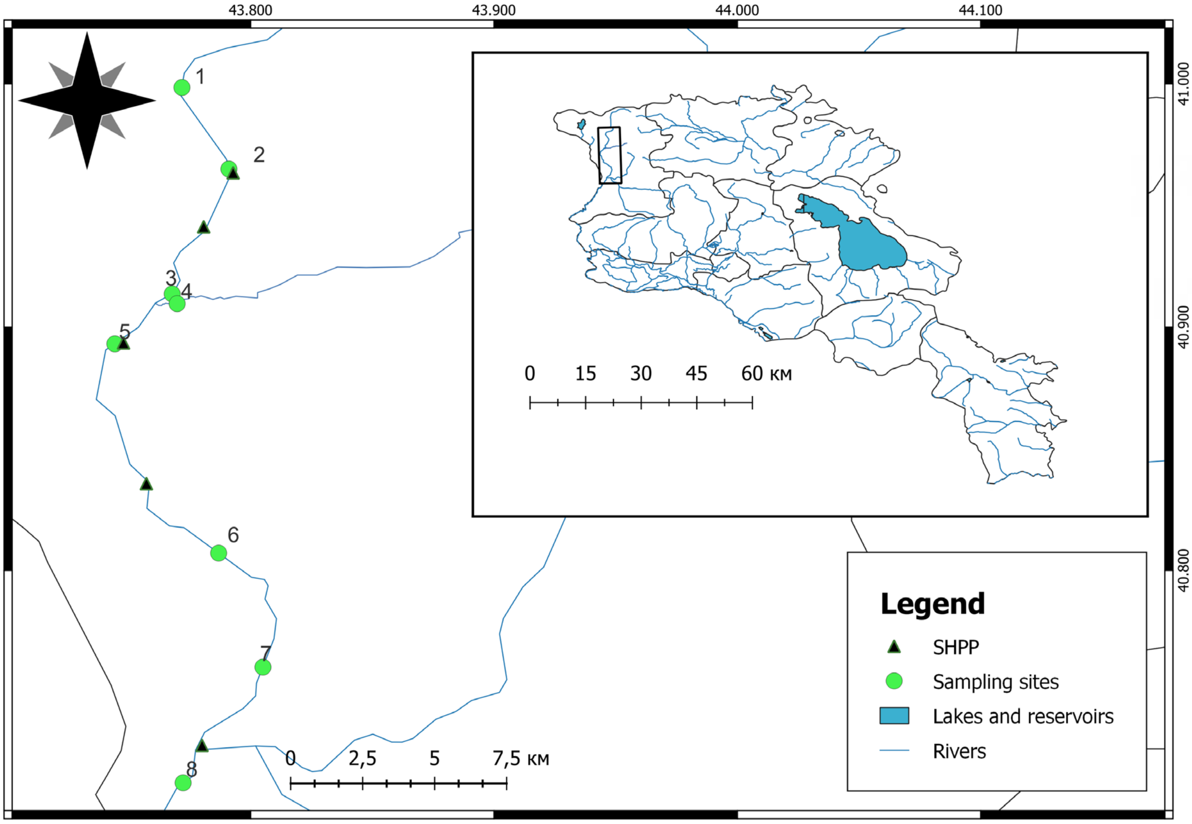

Fig. 1. Location of the sampling sites on the Akhuryan River basin.

Previous studies describing the ichthyofauna of the Akhuryan did not provide a detailed description and exact location of the sampling sites where these 25 species and subspecies of fish were caught.

Our sampling sites were spread from the upper to the lower reaches of the river, which could be affected by SHPP.

Presumably, such species as the mursa, blachbrow bleak, grass carp, bighead carp, golden spined loach, wels catfish, etc. (described in the previous studies) may inhabit Lake Arpilich, the Akhuryan reservoir and the lower reaches of the river.

The diversity assessment analysis showed that the highest diversity (H = 2.5) was observed in the spring 2019 in the lower reach at site N6. The lowest diversity (H = 0.5) was recorded in the autumn 2018 at sites N2 (below the water intake) and N4 (left tributary) (Table 2). Three species that do not undertake long annual migrations were encountered here. Higher diversity was noted in the spring compared to the autumn that was likely related to the dominance of carp species undertaking feeding and spawning migrations in spring.

At site N1, the following fish species were recorded: Kura barbel, Kura nase, chub, khramicarp and Kura chub. In the autumn 2018, adult specimens of khramicarp were not met, only fry were found. The latter may point to a possible spawning of khramicarp in this section of the river. In the spring of 2019, mature khramicarp specimens (stage V of gonadal maturity) were caught. In the autumn of 2018, the Kura chub was the superdominant (73.8%), the Kura nase was a dominant one (13.1%), the chub was subdominating (6.6%), and the Kura barbel and khramicarp were common (3.3%). In the spring of 2019, the Kura chub was still superdominant (57.1%), the Kura barbel and khramicarp became dominant (11.9% and 14.3%, respectively), and the chub and Kura nase were subdominant (9.5% and 7.1%) (Figs. 2, 3). The high proportion of the Kura barbel and khramicarp in the spring could be related to the occurrence of their spawning migration.

Table 1. Fish species revealed in Akhuryan River basin in different periods

N	Fish species	Years of study			
		1960–1970 (Dadikyan, 1986)	1988–1970 (Pipoyan, 2007)	1985–2012 (Pipoyan and Malkhasyan, 2014)	2018–2019 (our data)
	Family Salmonidae				
1	*Salmo trutta* Linnaeus, 1758 Brown trout	+	+		+
2	*Oncorhynchus mykiss* Walbaum, 1792 Rainbow trout		+		
	Family Cyprinidae				
3	*Squalius cephalus* Linnaeus, 1758 Chub	+	+	+	+
4	*Leuciscus aspius* Linnaeus, 1758 Asp	+	+	+	+
5	*Chondrostoma cyri* Kessler, 1877 Kura nase	+	+	+	+
6	*Luciobarbus capito* Güldenstädt, 1773 Bulatmai barbell	+	+		
7	*Barbus cyri* De Filippi, 1985 Kura barbel	+	+	+	+
8	*Luciobarbus mursa* Güldenstädt, 1773 Mursa	+	+		
9	*Capoeta capoeta* Guldenstadt, 1772 Khramicarp	+	+	+	+
10	*Capoeta capoeta heratensis* Keyserling, 1861 Herat scarper		+		
11	*Capoeta capoeta sevangi* Filippi, 1865 Sevan khramicarp		+		
12	*Alburnus filippi* Kessler, 1877 Kura bleak	+	+	+	+
13	*Acanthobrama microlepis* De Filippi, 1863 Blackbrow bleak		+		

N	Fish species	Years of study			
		1960–1970 (Dadikyan, 1986)	1988–1970 (Pipoyan, 2007)	1985–2012 (Pipoyan and Malkhasyan, 2014)	2018–2019 (our data)
14	*Alburnoides eichwaldii* De Filippi, 1863 Kura chub	+	+	+	+
15	*Pseudorasbora parva* Temminck and Schlegel, 1846 Stone moroko		+	+	+
16	*Cyprinus carpio* Linnaeus, 1758 Common carp	+	+	+	+
17	*Carassius gibelio* Bloch, 1782 Gibel (Prussian) carp		+	+	+
18	*Ctenopharyngodon idella* Valenciennes, 1844 Grass carp		+		
19	*Hypophthalmichthys nobilis* Richardson, 1845 Silver carp		+		
20	*Hypophthalmichthys molitrix* Valenciennes, 1844 Bighead carp		+		
	Family Nemachelidae				
21	*Oxynoemachelius angorae* Steindachner, 1897 Angora loach	+	+	+	+
22	*Oxynoemacheilus brandtii* Kessler, 1877 Kura loach				+
	Family Gobiidae				
23	*Neogobius fluviatilis* Pallas, 1814 Monkey goby		+		
	Family Cobitidae				
24	*Sabanejewia aurata* De Filippi, 1863 Golden spined loach	+	+		
	Family Siluridae				
25	*Silurus glanis* Linnaeus, 1758 Wels catfish	+	+		

Table 2. Indicators of fish species composition in the Akhuryan River.

Station number	Season	Number of species	Shannon index	Ferster index
1	Autumn 2018	5	1.3	0.4
	Spring 2019	5	1.8	0.2
2	Autumn 2018	3	0.5	0.7
	Spring 2019	3	0.8	0.5
3	Autumn 2018	5	1.1	0.5
	Spring 2019	5	1.4	0.4
4	Autumn 2018	3	0.5	0.7
	Spring 2019	3	0.9	0.4
5	Autumn 2018	4	1.4	0.3
	Spring 2019	4	1.2	0.4
6	Autumn 2018	5	1.6	0.3
	Spring 2019	7	2.5	0.1
7	Autumn 2018	5	1.2	0.5
	Spring 2019	7	2.4	0.1
8	Autumn 2018	4	1.7	0.2
	Spring 2019	5	1.6	0.3

At site N2, Kura barbel, Kura chub and Angora loach were met. In the autumn 2018, Kura chub were superdominant (90.9%), Angora loach – subdominant (5.2%), Kura barbell – common (3.9%). In spring 2019, Kura chub again was superdominant (83.9%), while Kura barbell became dominant (10.7%) and Angora loach – subdominant (5.4%). The higher proportion of the Kura barbel was likely related by their spawning migration (Figs. 2, 3).

At site N3, Kura barbel, chub, khramicarp, Kura chub and Angora loach were met. In the spring 2019, the specimens of khramicarp and Kura chub were at stage V of the gonad maturity. In the autumn 2018, the Kura chub was a superdominant species (77.7%), khramicarp was dominant (11.6%), Kura barbel was subdominant (7.8%), Angora loach was common (1.9%), and chub was rare (1.0%). In the spring of 2019, the Kura chub were still superdominant (67.3%), while the Kura barbel and khramicarp became dominant (11.5% and 15.4%, respectively), and the chub and Angora loach were common (1.9% and 3.8%, respectively) (Figs. 2, 3).

At site N4, the Kura barbel, khramicarp, and Kura chub were met. In the autumn 2018, the Kura chub was superdominant (91.9%), the Kura barbel subdominant (5.7%), and the khramicarp common (2.3%). In the spring 2019, the Kura chub remained superdominant (79.4%), the Kura barbel became dominant (11.8%), and the khramicarp subdominant (8.8%) (Figs. 2, 3).

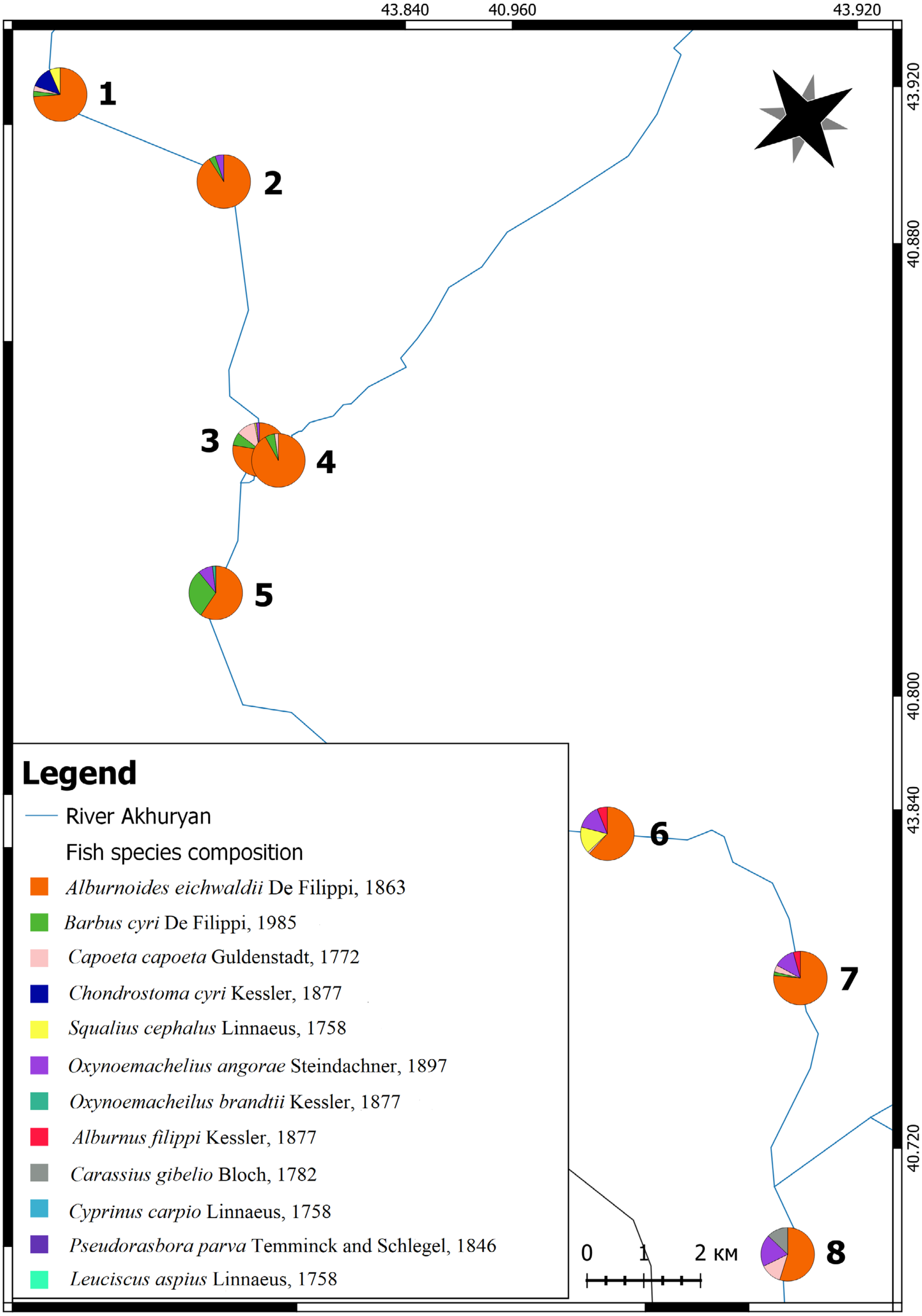

Fig. 2. Relative frequency of Akhuryan River ichthyofauna at sampling sites (species share in catches, %) in fall 2018.

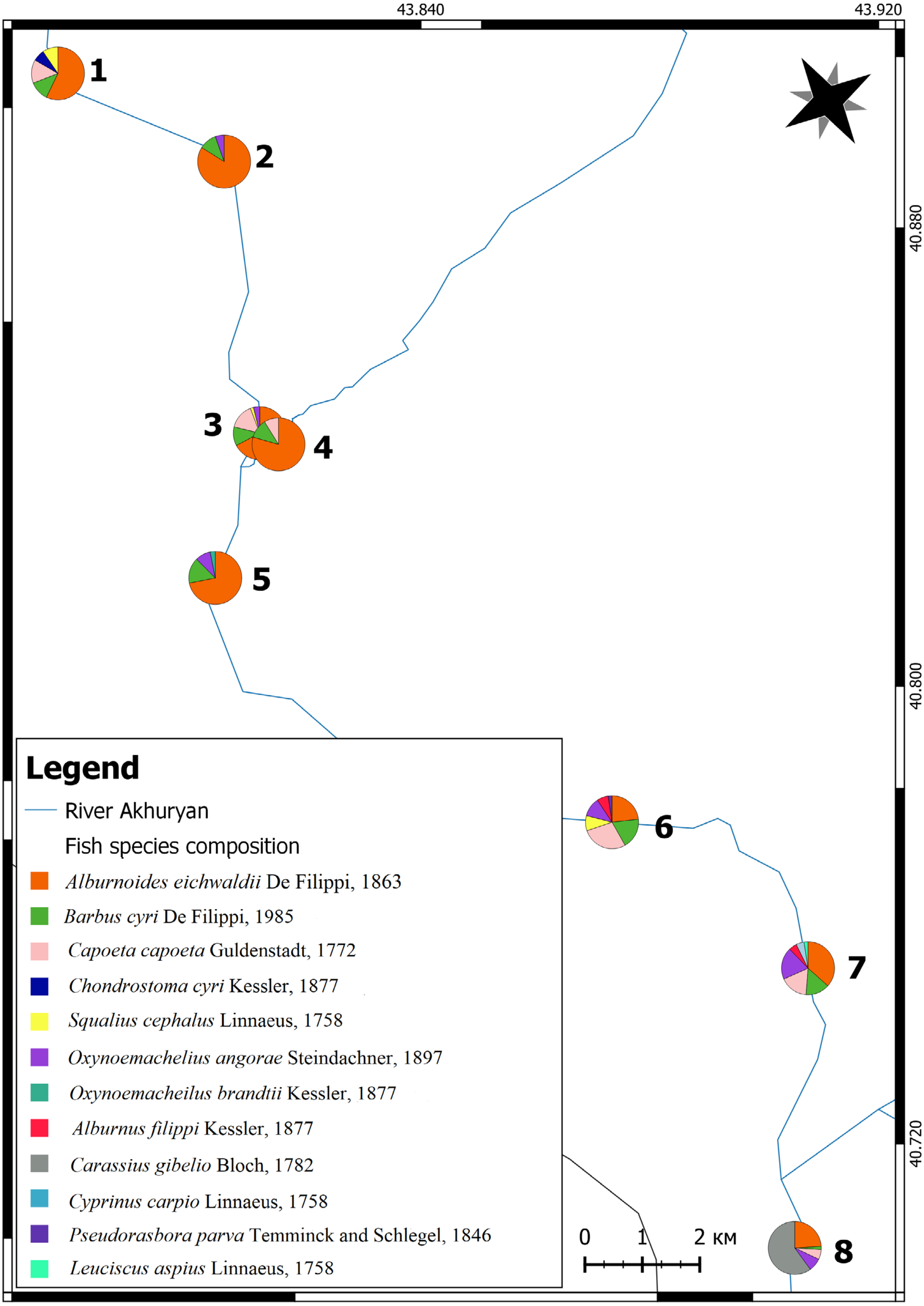

Fig. 3. Relative frequency of Akhuryan River ichthyofauna at sampling sites (species share in catches, %) in spring 2019.

At site N5, the following fish species were met: Kura barbel, Kura chub, Angora loach, and Kura loach. Throughout the study period, the Kura chub was superdominant (59.4% and 71.9%), the Kura barbel dominant (29.7% and 15.6%), the Angora loach subdominant (8.9% and 9.4%), and the Kura loach common (2.0% and 3.1%) (autumn 2018 and spring 2019, respectively) (Figs. 2, 3).

At site N6, the Kura barbel, chub, khramicarp, Kura chub, Angora loach, Kura bleak and stone moroko were found. In the autumn 2018, the Kura chub was superdominant (61.7%), the chub and Angora loach were dominant (16.1% and 14.8%), the Kura bleak was subdominant (6.2%), and the khramicarp was rare (1.2%). In the spring 2019, the dominant species were the Kura chub, Angora loach, khramicarp, and Kura barbel (23.1%, 11.6%, 27.9%, and 18.6%, respectively). Subdominants were the chub and Kura bleak (9.3% and 7.0%), while stone moroko was common (2.3%) (Figs. 2, 3).

It is important to note that SHPP is located between sampling sites N5 and N6. After the SHPP's dam, the river becomes shallow for along 500 m. Fish passes of the SHPP are about 25 m long with a slope of 75%. In spring, they practically dry up. These are the obstacles for fish migration upstream (Fig. 4). After the embankment, where the river practically turns into a lake, Prussian carp can be found, according to fishermen.

At station N7, the following fish species were found: Kura barbel, khramicarp, Kura chub, Angora loach, Kura bleak, common carp and asp. In the autumn 2018, Kura chub were superdominant (76.6%), Angora loach – dominant (12.8%), Kura barbel, khramicarp and Kura bleak – common (2.1%, 4.2% and 4.2%). In the spring 2019, Kura chub, Angora loach, Kura barbel and khramicarp were dominant (36.6%, 19.5%, 14.6% and 17.1%, respectively), while Kura bleak, common carp and asp were common (4.9%, 4.9% and 2.4%) (Fig. 2, 3). In this site, there was a fence, which practically impeded fish migration due to the blockage of its holes by plant remains and branches.

Fig. 4. Site N6 with fish corridors of a hydro-power station and a small lake.

At station N8, the following species were recorded: khramicarp, Kura chub, Angora loach, and Prussian carp. In addition, Kura barbel was recorded in the spring catches. In the autumn 2018, the Kura chub was superdominant (54.8%), while the Angora loach, khramicarp, and Prussian carp were dominant (19.4%, 12.9%, and 12.9%, respectively). In the spring 2019, the Kura chub was dominant (24.0%), the Prussian carp was the superdominant (60.0%), the Angora loach and khramicarp were the subdominants (8.0% and 6.0%), the Kura barbel was common (2.0%) (Figs. 2, 3).

During our study from three listed species (asp, golden spined loach, and Kura gudgeon) (Red Book of the Republic of Armenia, 2010), only asp was met (spring 2019, site N7).

Adults of asp inhabit lower reaches of rivers and estuaries. They migrate from lakes to tributaries for spawning in April-June (water temperature 12-14 ^{O}C) (Muus, Dahlström, 1968; Billard, 1997). Spawning occurs in fast-flowing waters on gravel or submerged vegetation. The species is threatened due to river morphology alteration (Kottelat and Freyhof, 2007). Asp is a rare species, which numbers and habitats are constantly reduced (Dadikyan, 1986; Krasnaya Kniga..., 2010). In Armenia, the fish was met in the rivers Akhurian, Arpa, Metsamor and Vorotan and in the reservoir Akhurian and Lake Arpilich (Gabrielyan, 2001). The ecology and biology of the fish is poorly studied in Armenia. Factors, causing a decline of the fish population, include river flow regulation, ambient pollution, disruption of natural reproduction and poaching (Pipoyan, 2007). Asp is of recreational importance, but measures on its protection are not undertaken. According to IUCN criteria it is categorized as Vulnerable (VU Blab(iii)), listed in the Red Book of Armenia (2010), and included into Resolution 6 to Bern Convention.

In addition to the asp, the golden spined loach and Kura gudgeon are listed. The golden spined loach is the endangered and also poorly studied species. Rarely, specimens were found in some rivers of Armenia (Gabrielyan, 2001). The factors affecting the population on the territory of Armenia are not known. The fish is not important for both commercial and recreational fishing. According to IUCN criteria it is categorized as Data Deficient (DD), listed in the Red Book of Armenia (2010), and included into Resolution 6 to Bern Convention.

The Kura gudgeon is endangered species, but practically uninvestigated in Armenia. According to IUCN criteria it is categorized as Data Deficient (DD) (Red Book of the Republic of Armenia, 2010). The absence of the gudgeon in the Akhuryan River is, probably, related to the construction and operation of the SHPP, which has led to changes in the temperature and hydrological regime of the Akhuryan reservoir.

Conclusion

The results revealed 12 fish species in the study area of the Akhuryan River. The greatest fish diversity was recorded in the spring 2019 in the lower reaches of the river near the village of Marmashen, the lowest - in the autumn below the water intake point of the SHPP and in the river tributary.

In all sampling sites, the Kura chub and the Kura barbel were met. In the autumn 2018, the Kura chub was superdominating in the catches at all sites. However, in the spring 2019, in the sites of the lower reach N6-8, its relative richness decreased from superdominant to dominant. The absence of the khramicarp at the sampling stations near the SHPP (after below the water intake and near the dam between the villages of Kaps and Jradzor) is likely due to the influence of the SHPP. Of all the species listed in the Red Book of Armenia, only the asp was encountered.

Thus, the Akhuryan River, remaining one of the rivers with the greatest fish diversity in Armenia, demonstrates a declining tendency in diversity of the ichthyofauna. This may be a result of an increased anthropogenic pressure, in particular, due to the construction of the SHPP, that caused the changes in fish reproduction and feeding conditions. The most vulnerable are fish valuable in terms of biodiversity (often listed in the Red Book).

References

Antomonov, Yu.G., 1977. Modelirovanie biologicheskikh system [Modeling of biological systems]. Naukova Dumka, Kiev, Ukraine, 248 p. (In Russian).

Atlas presnovodnykh ryb Rossii. T. 1 [Atlas of freshwater fishes of Russia. Vol. 1], 2003. Reshetnikov, Yu.S. (ed.). Nauka, Moscow, Russia, 379 p. (In Russian).

Billard, R., 1997. Les poissons d'eau douce des rivières de France. Identification, inventaire et répartition des 83 espèces. Delachaux & Niestlé, Lausanne, Switserland, 192 p. (In French).

Dadikyan, M.G., 1986. Ryby Armenii [Fishes of Armenia]. National Academy of Sciences of the Armenian Soviet Socialist Republic, Yerevan, USSR, 245 p. (In Russian).

Gabrielyan, B.K., 2001. An annotated checklist of freashwater fishes of Armenia. *Naga, ICLARM* **24** (3–4), 23–29

Gabrielyan, B., Khosrovyan, A., Schultze, M., 2022. A review of anthropogenic stressors on Lake Sevan, Armenia”. Journal of Limnology **81** (s1). https://doi.org/10.4081/jlimnol.2022.2061

Guidelines for electrofishing waters containing salmonids listed under the endangered species act, 2000. National Marine Fisheries Service, USA, 5 p.

Khosrovyan, A., 2024. Biodiversity and ecosystem services in rivers. *Water 2024* **16** (15), 2091. https://doi.org/10.3390/w16152091

Huckstorf, V., Lewin, W-C., Wolter, C., 2008. Environmental flow methodologies to protect fisheries resources in human-modified large lowland rivers. *River Research and Applications* **24** (5), 519–527.

Kottelat, M., Freyhof, J., 2007. Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin, 646 p.

Krylov, A.V., Gerasimov, Y.V., Gabrielyan, B.K. et al., 2013. Zooplankton in Lake Sevan during the period of high water level and low fish density. *Inland Water Biology* **6**, 203–210. https://doi.org/10.1134/S1995082913030085

Muus, B.J., Dahlström, P., 1968. Süßwasserfische. BLV Verlagsgesellschaft, München, Germany, 224 p. (In German).

Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005. Fragmentation and flow regulation of the world’s large river systems. *Science* **308**, 405–408.

Opperman, J., Grill, G., Hartmann, J., 2015. The power of rivers – finding balance between energy and conservation in hydropower development. The Nature Conservancy, Washington, DC, USA, 50 p.

Osteichtyes (Bony Fishes), 2010. In: Aghasyan, A.; Kalashyan, M. (eds.), *The Red Book of Animals of the Republic of Armenia.* Zangak, Yerevan, Armenia, 183–194.

Pipoyan, S.Kh., 2007. Ikhtiofauna Armenii i etapy ee formirovaniia [Ichthyofauna of Armenia and the stages of its formation]. *Doctor of Sciences in Biology thesis*. Yerevan, USSR, 429 p. (In Russian).

Pipoyan, S.Kh., Malkhasyan, A.H., 2014. Ichtyofauna of the state Armenia reserves and national parks. *Biological Journal of Armenia* **1** (66), 18–25.

Rubenyan, A.R., Gabrielyan, B.K., 2011. Vliianie gidroenergeticheskoi promyshlennosti na bioraznoobrazie gidroekosistem Armenii [The impact of hydropower industry on the biodiversity of hydroecosystems of Armenia]. *Materialy mezhdunarodnoi konferentsii “Biologicheskoe raznoobrazie i problemy okhrany fauny Kavkaza” [Proceedings of the international conference “Biological diversity and problems of protection of fauna of the Caucasus”].* Yerevan, Armenia, 256–261. (In Russian).

Seliger, C., Scheikl, S., Schmutz, S., Schinegger, R., Fleck, S. et al., 2016. Hy: Con: a strategic tool for balancing hydropower development and conservation needs. *River Research and Applications* **33** (2), 1438–1449.

Shannon, 1948. A mathematical theory of communication. *The Bell System Technical Journal* **27** (3), 379–423.

Tereshchenko, V.G., Nadirov, S.N., 1996. Formirovanie struktury rybnogo naseleniia Predgornogo vodokhranilishcha [Formation of the structure of the fish population of the Predgorny Reservoir]. *Voprosy ikhtiologii [Journal of Ichtyology]* **36** (2), 169–178. (In Russian).

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A. et al., 2010. Global threats to human water security and river biodiversity. *Nature* **467**, 555–561.

Список литературы

Антомонов, Ю.Г., 1977. Моделирование биологических систем. Наукова Думка, Киев, СССР, 248 с.

Атлас пресноводных рыб России. Т. 1, 2003. Решетников, Ю.С. (ред.). Наука, Москва, Россия, 379 с.

Дадикян, М.Г., 1986. Рыбы Армении. НАН АрмССР, Ереван, СССР, 245 с.

Пипоян, С.Х., 2007. Ихтиофауна Армении и этапы ее формирования. *Диссертация на соискание ученой степени доктора биологических наук.* Ереван, СССР, 429 с.

Рубенян, А.Р., Габриелян, Б.К., 2011. Влияние гидроэнергетической промышленности на биоразнообразие гидроэкосистем Армении. *Материалы международной конференции “Биологическое разнообразие и проблемы охраны фауны Кавказа”.* Ереван, Армения, 256–261.

Терещенко, В.Г., Надиров, С.Н., 1996. Формирование структуры рыбного населения Предгорного водохранилища. *Вопросы ихтиологии* **36** (2), 169–178.

Billard, R., 1997. Les poissons d’eau douce des rivières de France. Identification, inventaire et répartition des 83 espèces. Delachaux & Niestlé, Lausanne, Switserland, 192 p. (In French).

Gabrielyan, B.K., 2001. An annotated checklist of freashwater fishes of Armenia. *Naga, ICLARM* **24** (3–4), 23–29

Gabrielyan, B., Khosrovyan, A., Schultze, M., 2022. A review of anthropogenic stressors on Lake Sevan, Armenia”. Journal of Limnology **81** (s1). https://doi.org/10.4081/jlimnol.2022.2061

Guidelines for electrofishing waters containing salmonids listed under the endangered species act, 2000. National Marine Fisheries Service, USA, 5 p.

Khosrovyan, A., 2024. Biodiversity and ecosystem services in rivers. *Water 2024* **16** (15), 2091. https://doi.org/10.3390/w16152091

Huckstorf, V., Lewin, W-C., Wolter, C., 2008. Environmental flow methodologies to protect fisheries resources in human-modified large lowland rivers. *River Research and Applications* **24** (5), 519–527.

Kottelat, M., Freyhof, J., 2007. Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin, 646 p.

Krylov, A.V., Gerasimov, Y.V., Gabrielyan, B.K. et al., 2013. Zooplankton in Lake Sevan during the period of high water level and low fish density. *Inland Water Biology* **6**, 203–210. https://doi.org/10.1134/S1995082913030085

Muus, B.J., Dahlström, P., 1968. Süßwasserfische. BLV Verlagsgesellschaft, München, Germany, 224 p. (In German).

Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005. Fragmentation and flow regulation of the world's large river systems. *Science* **308**, 405–408.

Opperman, J., Grill, G., Hartmann, J., 2015. The power of rivers – finding balance between energy and conservation in hydropower development. The Nature Conservancy, Washington, DC, USA, 50 p.

Osteichtyes (Bony Fishes), 2010. In: Aghasyan, A.; Kalashyan, M. (eds.), *The Red Book of Animals of the Republic of Armenia.* Zangak, Yerevan, Armenia, 183–194.

Pipoyan, S.Kh., Malkhasyan, A.H., 2014. Ichtyofauna of the state Armenia reserves and national parks. *Biological Journal of Armenia* **1** (66), 18–25.

Seliger, C., Scheikl, S., Schmutz, S., Schinegger, R., Fleck, S. et al., 2016. Hy: Con: a strategic tool for balancing hydropower development and conservation needs. *River Research and Applications* **33** (2), 1438–1449.

Shannon, 1948. A mathematical theory of communication. *The Bell System Technical Journal* **27** (3), 379–423.

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A. et al., 2010. Global threats to human water security and river biodiversity. *Nature* **467**, 555–561.