Chapter 57
Biodiversity of Indicator Biocenoses of Lotic Ecosystems of the Aral Sea Basin, Central Asia, Used in Hydrobiological Monitoring

B. K. Karimov and V. N. Talskikh

57.1 Introduction

From an ecological point of view, it is important to observe all the biological components of aquatic ecosystems, which in practice is difficult to implement due to the almost impossible task of species identification and consequently, significant time and resource costs. This dictates the need to limit the range of observations and select priority indicator biocenoses, especially when routine research covers water ecosystems over large territories.

It is generally recognized that an integral reflection of the overall well-being or disadvantage of aquatic ecosystems is the state of aquatic biota, represented by a mosaic of interconnected biocenoses occupying all possible biotopes. Their species composition and structure directly depends on the hydrological and hydrochemical regimes as well as the state of the environment (Resh and Unzicker 1975; Talskikh 1991, 1995, 2015; Johnson et al. 1993; McCormick and Cairns 1994; Gozlan et al. 2019).

During the hydrobiological monitoring, as a priority of biocenoses, we have identified periphyton and zoobenthos. The high informative capacity of the periphyton (fouling organisms) together with its high indicator capacity is primarily due to the complex species composition of organisms represented by numerous ecologically diverse species (Vis et al. 1998; Shcherbak and Semenyuk 2011; Barinova et al. 2015; Wu et al. 2017; Schneider and Petrin 2017; Kuchkarov 2018). Phytoplankton is a key indicator of ecosystem state in shallow lakes (Scheffer et al. 1993). The fouling consists of representatives of three main functional groups:

B. K. Karimov (✉)
Tashkent Institute of Irrigation and Agricultural Mechanization Engineers,
Tashkent, Uzbekistan

V. N. Talskikh
Center of Hydrometeorological Servica of the Republic of Uzbekistan (Uzhydromet),
Tashkent, Uzbekistan

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-73943-0_57

autotrophic organisms, producers (algae); heterotrophic organisms, consumers (protozoa, rotifers, worms, and others); and decomposer organisms (zoogloea, filamentous, rod-shaped bacteria, coccoids, and other forms of bacteria and fungi). The basis of biofilms of fouling is mainly due to microscopic forms, which are characterized by a high level of metabolism, short life cycles, and the ability to quickly respond to changes in the environment. The periphyton, as an integral part of aquatic ecosystems, undergoes changes due to various natural and anthropogenic factors, which is expressed in spatial and temporal successions of periphyton communities. These are the examples of very dynamic biological systems (Talskikh 1990; Vis et al. 1998; Wu et al. 2017; Schneider and Petrin 2017). In functional terms, zoobenthos is an important part of the heterotrophic component of ecosystems, and the animal organisms that represent it belong to the consumers. Due to their proximity to the substrate, periphyton and zoobenthos provide good possibility for undertaking experiments under natural conditions and allow spatial ecological assessment of aquatic ecosystems together with their classification based on the data of taxonomic analysis of their biodiversity.

The species composition and quantitative development of periphyton organisms also reliably characterize the quality of water mass in a water body. The species composition and quantitative development of zoobenthos reliably characterize the state and degree of contamination of the soil and bottom layer of water, and the population of periphytic organisms attached to aquatic macrophytes characterizes more the quality of the water mass in the water body. The composition of periphyton and zoobenthos communities is relatively constant as long as they are in the conditions in which they are formed. Various taxa and groups that are most sensitive to individual pollutants fall out in polluted waters (Talskikh 1990; Borodin and Karimov 1990; Karimov and Borodin 1990, 1991). There is a change/violation of the species and trophic structure of the periphyton and zoobenthos, sometimes catastrophic, leading to the degradation of the original biocenoses (ecological regression). The nature of distribution and intensity of development of macrophyte associations (submerged and emergent vegetation) provide important additional information when describing the general state of a water body visually. Macrophyte thickets are a kind of habitat for different groups of organisms, accordingly a source (factor) for the formation of a common biotopic and biotic diversity in a water body (Talskikh et al. 1987; Karimov and Yunusov 1990; Kolada et al. 2014; Sfriso et al. 2014).

57.2 Study Area and Data Compilation

The Aral Sea basin (ASB) is situated within Central Asia and covers an area of 2.2 million km^2 and is home to around 50 million people. Geographically it covers an extensive area, most of Tajikistan (99%), Turkmenistan (95%), and Uzbekistan (95%); Osh, Jalal-Abad, and Naryn provinces of Kyrgyzstan (59%); Kyzylorda and

South Kazakhstan provinces of Kazakhstan (13%); northern Afghanistan (38%); and a very small part of the Islamic Republic of Iran in the Tedzhen/Murghab basin.

The territory of the Aral Sea basin can be divided into two main zones: the Turan plain and the mountain zone, most of ASB is arid or semiarid. It comprises the drainage area of two major rivers, the Amudarya and the Syrdarya and the Aral Sea itself. Before a large part of the Aral Sea dried up, the Amudarya and Syrdarya rivers used to flow into it. We here mainly focus on the Syrdarya and partly on the Amudarya, by far the two largest rivers of Central Asia. The Zarafshan river, a former tributary of the Amudarya river, has a position between these two major rivers (Fig. 57.1).

The water resources in the Aral Sea region consist of renewable surface and groundwater, as well as return water from anthropogenic use (wastewater and drainage water). The territory in this region is divided into three main zones of surface runoff:

(a) The zone of flow formation – upper watersheds in the mountain areas (ZFF)
(b) The zone of flow transit, dissipation, and intensive consumption (ZFC)
(c) The delta (mouth) zones

As a rule, there are no significant levels of anthropogenic changes in the zone of flow formation, but due to construction of big dams and water reservoirs on the border of this zone, the downstream runoff regime is changing significantly. Within the zone of flow transit and dissipation, the runoff and the whole hydrological cycle are changing in consequence of interaction between rivers and territory. This

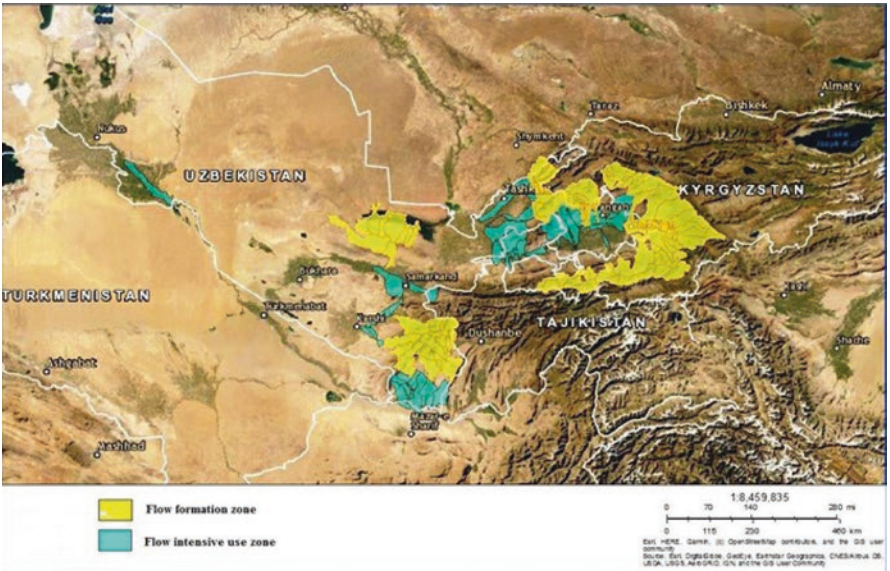

Fig. 57.1 Location of indicator lotic ecosystems in study area – Aral Sea basin, Central Asia (37°16′–42°13′N, 60°25′ 74°55′E)

interaction is characterized by the water withdrawal from rivers to the irrigated areas and the loading of return flow to the rivers with salt and agricultural chemicals (www.cawater-info.net).

Water bodies in the basin of the Aral Sea can be grouped as follows: natural water bodies (streams, rivers, and lakes); primary artificial freshwater water bodies (irrigation canals, reservoirs, and ponds); and secondary artificial brackish water bodies (drainage canals, lakes for storage of the residual non-conventional mineralized water resources of agricultural origin) (Karimov 1994). The word "Say" means the name of small mountain rivers forming further larger rivers; most of them have no or very small water discharge during the dry summer months and droughts.

There are many natural lakes in the mountainous areas and ravines of Central Asia (Egamberdieva and Ozturk 2018). The mountain lakes are of various origins. The majority of large lakes occupy basins which are the result of tectonic activity (Issyk-Kul, Song-Kul, Chetir-Kul, Karakul, Sarichelek). Lakes originating from landslides due to earthquakes are the Sarez and Yashinkul in the Pamir mountains. Numerous lakes are of glacial origin; one of the largest is the Zorkul, located at 4125 m in the Eastern Pamir. In the mountains, lakes are usually freshwater types or slightly saline (Issyk-Kul, Karakul), depending on the quality of in-flowing water. Majority of lakes located in the lowlands owe their origin to the erosion-accumulation activity of rivers in an arid climate. Generally, lowland lakes are shallow with low shores and have heavy vegetation of reeds and rushes. They are often surrounded by saline soil (solonchak) and sand. As a result of enough precipitation, many of these lakes turn into temporarily running waters, leaving behind dry river beds over time. Lowland lakes may be either saline or freshwater. Initial assessments of freshwater reserves in mountain and lowland lakes suggest a volume of 60 km^3 (www.cawater-info.net; CAWaterInfo 2020). The mountain part of the territory of Uzbekistan is rich in the river network. The largest rivers are Chirchik, Ahangaran, Kasansay, Naryn, Karadarya, Isfayramsay, Soh, Isfara, Sanzar, Zarafshan, Kashkadarya, Sherabad, and Surbandarya.

The climate is continental, determined by the landlocked position of Central Asia within the Eurasian continent (Imanberdieva et al. 2018a, b). Large daily and seasonal temperature differences are characteristic of the region, with high solar radiation and relatively low humidity. Terrain and altitude range from 0 to 7500 m above sea level (asl), leading to greatly diversified microclimates. Although this area is often subject to humid winds, the mountains trap most of the moisture, leaving little precipitation for the other areas of the Aral Sea basin (CAWaterInfo 2020). The average temperatures range from 0 to 4 °C in January and 28 to 32 °C in July. In some areas, summer temperatures may be as high as 52 °C and winters as cold as minus 16°C, with an absolute minimum of minus 38°C, creating a sharply contrasting overall climate, with hot summers and cold winters (Murray-Rust et al. 2003). Annual precipitation in the lowlands and valleys is between 80 and 200 mm, concentrated in the winter and spring, while on the foothills, precipitation is between 300 and 400 mm (www.fao.org). As one approaches the mountains, the rainfall increases, and in the highland areas the rainfall amounts to 600 and 1000 mm (UNDP 2008).

The present overview summarizes the information on the results of hydrobiological monitoring of water ecosystems in the Aral Sea basin within Uzbekistan and adjacent sections of catchment basins with a total area of more than 300,000 km^2 (37°16′–42°13′N, 60°25′ 74°55′E). This study has been carried out by Uzgidromet on the national network of observation points of background and impact levels, respectively, confined to the ZFF and ZFC zones.

The regional taxonomy of aquatic organisms, especially zoobenthos, is not well developed, and many organisms of this biocenosis are not identifiable, not only at the species level but in some cases even at the genus level. The newly recorded zoobenthos organisms, not identified before at the species level, are listed in the text only with an indication of belonging to larger taxa or with an indication of the presumably belonging to taxa ranked below the genus, but with a question mark "?". It should also be noted that the authors used the nomenclature names of algae in accordance with the definitions of algoflora for water bodies based on the classification system developed by Pecier et al. (1984), which has justified itself for decades in describing the regional algoflora of Eurasia. In accordance with this system, we used the traditional name Cyanophyta for blue-green algae, subject to the rules of the "International Code of Botanical Nomenclature" (International Cod of Botanical Nomenclature 1988).

To review the biodiversity of river ecosystems, we used the information regularly published in Hydrobiological yearbooks (Yearbooks 1986–2017). Hydrobiological research was also carried out in the course of environmental grant projects sponsored by international organizations such as the GEF, World Bank, UNESCO, and others (Borodin and Talskikh 1994; Borodin et al. 1995, Gorelkin et al. 2001; Talskikh 1995, 2003, 2015). In water courses of the region with mountain type of feeding and increased flow velocity, main biocenoses are periphyton (overgrowings) and zoobenthos abundantly and diversely presented also in littoral of lakes. Therefore, in the hydrobiological monitoring performed by Uzhydromet, these biocenoses are defined as priority bioindicators for the environment of surface waters of the region (Talskikh 1997; Kuchkarov 2018). The widespread distribution of these biocenoses and their stationary binding to specific biotopes makes it possible to carry out spatial bonitation on them, to register environmentally significant changes in the aquatic ecosystems due to the occurrence of hydrological, hydrochemical, and hydrobiological fields of heterogeneity.

57.2.1 The Classification Methodology

Basic ecological quality can be defined as a quality in which, on the one hand, the organisms are not too demanding of the environment to survive and on the other, the migration of rare species is not difficult and the organisms must be provided with an acceptable habitat to ensure, inter alia, their biological development cycles. High environmental quality is recognized when (a) dissolved oxygen in water provides normal respiration of aquatic organisms; (b) the concentration of toxic and other harmful substances in the water, sediments, and biota is below the established safe level and does not interfere with the human use of the water body; (c) the composition and structure of aquatic biocenoses correspond to a mostly intact state, and they contain key species/taxa that are usually inherent under natural conditions of this ecosystem.

On the basis of ranking of the multi-year database of information on the biodiversity of priority biocenoses, we have developed *a scale of invariant ecological statuses of indicator aquatic biocenoses* of periphyton and zoobenthos, which is used to assess the environmental situation in the system of national hydrobiological monitoring as given below:

1. *The background (reference) status is evaluated as AE(B).* This means that biocenoses are in a state of metabolic (A) and ecological (E) progress and the species composition of organisms reflects the background (B) natural state of the gene pool, which is typical for ZFF in the region. At the same time, the ecological structure of the biocenoses with known assumptions can be taken as a biosphere background (Bb), since it is largely identical to the set of dominant taxa for the ZFF of watercourses of other mountain areas of Eurasia, for example, for the watercourses of North Caucasus, Slovakia, Tuva, and many others (Butterby et al. 1991; Talskikh and Arakchaa 1993; Abakumov and Talskikh 1993). The status of the biocenoses corresponds to “high” environmental quality.
2. *Background (good) status is also assessed as AE(B),* since biocenosis is mainly represented by taxa that correspond to high ecological quality but more closely reflect the features of various hydrochemical regions and landscapes of the region in the ZFF, which allows us to consider their ecological structure as a regional background (Rb). They are characterized by a wider variation in the ecological structure associated with a wider environmental gradient of conditions that occurs in watercourses when they pass through various high-altitude zones and simultaneously increase the lateral inflow. The status of the biocenosis corresponds to “high” environmental quality.
3. *Satisfactory status is assessed as AE.* Moderate pollution of watercourses of this ecological type in ZFC has a peculiar “fertilizing effect,” which, along with a higher warming of the water mass, contributes to an increase in the level of trophic activity and, under favorable hydrological factors, a more intensive quantitative development of biocenosis, whose ecological structure is subjected to regular variation. Biocenoses are characterized by an active metabolism and a complex ecological (taxonomic and trophic) structure; there is a predominance of eurybiont organisms with a wide ecological valence. This condition is typical for most of the regulated streams of the plain zone in the ZFC and can be taken as a regional background within the anthropogenic modified zone (Bamz). At the same time, the state of the biocenosis corresponds to the “basic” environmental quality.
4. *Transitional, unsatisfactory, and poor status is assessed as AE-Ar or Ar* (r – ecological regress). An increase in the level of surface runoff pollution in ZFC and degradation of the original (background) gene pool of biocenosis occurs along

the path of noticeable (AE-Ar) or significant (Ar) changes in their ecological (taxonomic and trophic) structure, which corresponds to the transitional, unsatisfactory, and poor types of environmental condition, i.e., “bad” environmental quality.

5. *Unallowable status is evaluated as ar* (a – metabolic regress). In the case of toxic contamination, there is not only serious degradation of the ecological structure but also the suppression of metabolic processes in the ecosystem (a – metabolic regression). This extreme degree of biocenosis degradation is evaluated as an unallowable status and is indicated by the symbol ar. This characterizes the increasing level of anthropogenic impact, which is reflected, respectively, in the values of formal indices calculated, based on the results of taxonomic analysis of biocenosis indicator.

Thus, totally five main invariant ecological statuses of aquatic biocenoses are defined – AE(B), AE, AE-Ar, Ar, and ar, based on the taxonomic analysis of their biodiversity and reflecting various level of well-being or ill-being of lotic ecosystems. The proposed system of assessments reflects the actual situation in the ASB, allowing to identify the main trends in the change of biotic components in the ZFF and ZFC of the region and to give an integrated assessment of the ecological state of water bodies based on the results of taxonomic analysis of priority indicator biocenoses.

57.2.2 Retrospective Analyses of Biodiversity Studies in Lotic Indicator Biocenosis in Aral Sea Basin

The study of the biodiversity of natural surface waters (mainly river ecosystems) on the basis of systematic hydrobiological monitoring has actually been conducted since 1978 after the organization of a hydrobiological laboratory in the National Hydrometeorological Service (Uzhydromet). The main task of this organization was to conduct systematic observations of the hydrobiological status of water bodies and assess their environmental condition (including water quality) by using biological indicators. Earlier, the issues of hydrobiological monitoring in its modern sense and purpose, in particular, the issues of bioindication and assessment of the ecological status of water bodies, were practically not addressed in the ASB. Especially the study of the biodiversity of the periphyton biocenoses remained almost a white spot, and the scant information about the biocenoses of zoobenthos did not give a systematic picture and patterns of its spatial biodiversity in the aquatic ecosystems of the region. The fragmentary information available in the literature about the scientific work carried out in the region in this direction indicates that the work was not designed for long-term basis and was episodic. The data on the biodiversity of aquatic biota needed serious systematization and revision. The latter was relevant for rivers in the area of surface runoff formation, but to an even greater extent, for sections of rivers experiencing increased anthropogenic load, where under the influence of changes in hydrological and hydrochemical regimes and pollution, the original river biocenoses were degraded or transformed to various degrees.

The functions of national monitoring of aquatic ecosystem biodiversity, which are of great scientific and practical significance, include the identification of regional spatial and temporal trends in the species composition and structure of aquatic biocenoses (aquatic biota) and associated abiotic characteristics in surface waters. The peculiarity of the feeding of river ecosystems in the region, in which water flows from sources to the entrances, pass through different altitude zones, creating a natural gradient of environmental conditions, namely, the mosaic (heterogeneity) of hydrological, hydrochemical, and hydrobiological regimes in different parts of the catchment basins. The sharp continentality of the regional climate determines the pronounced seasonal contrast of hydrological, hydrochemical, and hydrobiological phases in water bodies during the annual cycle, which get disturbed under the influence of anthropogenic water overregulation, redistribution, and contamination of surface runoff.

To date, more or less satisfactory monitoring on hydrochemical and hydrobiological information has been gathered on background watercourses in the ZFF and on some flat river sections in the ZFC, which is not true for the lower reaches and deltas of rivers, as well as associated lake-type reservoirs in the zone of developed irrigation, where water bodies are under the influence of a powerful diversion of collector-drainage water (CDW).

In Uzhydromet, on a permanent basis and in accordance with the annual program, long-term monitoring of the quality and ecological status of river and partially water collectors is carried out on a network of permanent observation points using biological indicators, including invertebrates (insects, worms, crustaceans, mollusks, leeches, mites, etc.) that inhabit zoobenthos, as well as bacteria, fungi, protozoa, and algae that inhabit the periphyton (Kuchkarov 2018).

The analysis of the observed species richness of the priority indicator biocenoses monitored on the network of observation stations of Uzhydromet is contained in the primary materials (protocols of analysis), based on the results of generalization of which formal saprobiotic indices and invariant statuses are calculated. On the basis of these data, operational information on the level of pollution and the environmental conditions of watercourses at monitoring points is issued to interested agencies in the form of environmental bulletins, quarterly and annual reports (Kuchkarov 2018). Thus, the results of the biodiversity assessment of indicator biocenoses are directly used by interested agencies in the implementation of national environmental policy.

Various publications on taxonomic revisions and monographs in the study area concerning practically important systematic groups of plants, animals, and bacteria of aquatic habitats can be considered as a contribution to the mechanism of biodiversity awareness. The results of taxonomic analysis of the periphyton and partially zoobenthos biocenoses are summarized in various thematic reviews/reports and publications, which to a certain extent characterize (assess) the regional species richness and local species richness of biocenoses for certain types of water bodies, river basins, and larger landscape-geographical complexes in the ZFF, where observations covered the main biological phases of the intra-annual cycle (Karimov and Borodin 1990, 1991; Abdullaeva and Talskikh 1997; Shukurov et al. 2005; Talskikh et al. 2007; Talskikh 2008). These publications present generalized structured species lists of the periphyton and zoobenthos biocenoses with reference to various hydrological types of watercourses characteristic of the ZFF of the region, which should be considered as a basic basis for further development of background on hydrobiological monitoring and informing specialists engaged in various research activities in the region.

Such lists have not been published for ZFC watercourses and lakes, but various publications and reports provide information about the characteristic species of periphyton and zoobenthos that make up the leading (dominant) complexes for ecologically distinct types of water bodies and their individual sections (Yearbooks 1986–2017; Kamilov et al. 1994). They allow us to judge not only the observed biodiversity of priority indicator biocenoses but also to assess with a certain degree of satisfaction the ecological status (well-being) of these types of ecosystems and their spatial and temporal trends (succession) of biocenoses in a changing geophysical environment.

57.3 Outline of Biodiversity of Priority Indicator Biocenoses in Aral Sea Basin

The information about the biodiversity of priority indicator biocenoses and related abiotic factors is systematized and formed in the form of brief "reference," allowing to reflect their most typical (framework) regional characteristics in the form of a kind of indicator algorithms and to judge the environmental well-being of the aquatic biocenoses in the first approximation.

57.3.1 Biodiversity of BC River Ecosystems: Introductory Information

The generalized taxonomic structure of the periphyton BC biodiversity for river ecosystems is shown in Table 57.1. This is the first and so far the only structured information on the taxonomic biodiversity of the periphyton biocenoses of lotic ecosystems under the conditions of different altitudinal zoning and different levels of river runoff pollutions in the Central Asia region. It gives an idea of spatial trends in the structure of biodiversity of biocenoses of river ecosystems in the range of invariant states, AE(B), AE, AE-Ar, Ar, and ar, which have not undergone significant proportional changes to date.

Table 57.1 Taxonomic diversity of periphyton biocenoses in different ecological groups of lotic ecosystems (in parentheses, the variety of dominant species)

The taxonomic range of periphyton biocenoses	Ecological groups of lotic ecosystems							
	ZFF AE(B): background			ZFC AE: moderately polluted			ZFC (zone of flow formation) AE-Ar: polluted	ZFC (zone of flow intensive consumption) Ar/ar: very polluted
	Cold-water rivers and streams of the alpine and subalpine belts	Rivers and streams in the mountain forest belt, outflows from mountain lakes	The river sections on the foothill zone	Upstream sections of rivers in the plain zone	Midstream sections of rivers in the plain zone	Downstream sections of rivers in the plain zone	Sections of watercourses below urbanized areas	High polluted sections of watercourses
Total number of periphyton species, including:	90 (30)	337 (103)	293 (68)	317 (71)	314 (53)	252 (63)	304 (45)	107 (49)/36 (24)
***Producers*, including**	90 (30)	326 (102)	254 (67)	251 (66)	228 (49)	175 (56)	187 (34)	29 (5)/0
Cyanophyta	5 (4)	30 (17)	24 (10)	22 (9)	21 (5)	13 (5)	16 (8)	4/0
Bacillariophyta	77 (23)	263 (75)	201 (45)	186 (44)	160 (33)	133 (45)	136 (20)	18 (3)/2
Chrysophyta	1 (1)	2 (1)	1 (1)	1 (1)				
Pyrrophyta			2			1		
Euglenophyta				1	1	2	5 (2)	2 (1)/1
Chlorophyta	7 (2)	30 (9)	23 (11)	40 (12)	45 (11)	25 (8)	28 (8)	5 (1)/0
Rhodophyta		1	3	1		2 (1)	2 (2)	
***Consumers*, including:**		9 (1)	36 (1)	58 (4)	72 (3)	68 (4)	99 (8)	50 (22)/19 (11)
Zoomastigina				1	2	2	3 (1)	4 (3)/2 (2)
Sarcodina		7	6	13 (2)	12 (1)	16 (1)	23 (2)	8 (2)/0

Ciliata		1	15	21 (1)	32 (1)	28 (1)	39 (5)	24 (14)/8(8)
Rotatoria			10	17	21	17	18 (1)	10/1
Others		1	5 (1)	6 (1)	5 (1)	5 (2)	6 (1)	4 (3)/2(1)
Decomposers		2	3	8 (1)	14 (1)	9 (3)	18 (3)	28 (22)/14 (13)

In total, 738 taxa ranked below the genus were found in the periphyton biocenoses, including producers (algae) 521 (Cyanophyta, 52; Bacillariophyta, 386; Chrysophyta, 2; Pyrrophyta, 2; Euglenophyta, 7; Chlorophyta, 67; Rhodophyta, 5), consumers 177, and decomposers 40

In Table 57.1, all organisms are classified according to the large systematic taxa, as well as taking into account their various functional groups within the trophic chain – producers, consumers, and decomposers. Most of the established species are producers, of which diatoms (Bacillariophyta) are the most diverse and abundant (judging by the number of dominants). These are followed by the number of species as green (Chlorophyta) and blue-green (Cyanophyta) algae. The table shows that the taxonomic composition of both the overall diversity and the representativeness of individual taxa and functional groups in various ecological groups of watercourses and their sections is not uniform and depends on the emerging gradient of abiotic conditions in the ecological series of watercourses from the state of AE(B) to the state of AE. In the ZFF, the absolute dominance of producers is represented by North-alpine and mountain species of algae, which are replaced by eurybiont species with a wide ecological valence as they advance into the ZFC. In the watercourses belonging to the ecological groups Ar and ar, North-alpine and mountain species of algae fall from the periphyton, where the dominant position is occupied by consumers and decomposers – indicators of alphameso- and polysaprobic conditions.

In the zoobenthic communities of the background freshwater ecosystems of the region, confined to the ZFF, larvae and adult stages of insects predominate, which make up 80–90% of the total species composition. Of these, the most well-developed fauna includes chironomids, other dipterans, mayflies, caddis flies, and beetles. The benthic fauna of upstream river sections and upper tributaries has pronounced features of endemism and stenobiont nature of its constituent species, which indicates that these are of more ancient origin. Ecological and geographical analysis of the species structure of zoobenthos of the upstreams of the Boshkyzylsay river, the Young Maidantal river, and the upper reaches of the river Sarycheleksay on the territories of Chatkal and Sarycheleksky nature reserves corresponding to the ecological status of AE(B) shows that most of the species inhabiting the alpine and subalpine high-altitude zones belong to the Highland-Asian zoogeographic complex. In lower-lying areas of catchments, Mediterranean, European-Siberian, and widespread complexes of bottom organisms are more noticeably developed. In the areas corresponding to the status of Ar and ar, zoobenthic communities, as in the case of periphyton, are dominated by highly saprobic species – indicators of alphameso- and polysaprobic conditions.

57.3.1.1 Biodiversity of Biocenoses Lotic Ecosystems in ZFF

Numerous and diverse rivers and streams (locally known as says) are an integral part of the nature of mountain territories in the ASB and the most important elements of the landscape – a kind of core accumulation of life. They also give life to the lower oases. A common characteristic of most of the surveyed mountain watercourses is that they are confined to the upper sections of the catchment basins, i.e., the changes in their hydrological and hydrobiological characteristics are of a natural nature, depending mainly on the dynamics of climatic factors, which allows us to consider them as background in relation to the lower located aquatic biocenoses of the foothill and lowland belts belonging to the ZFC.

In this section, the emphasis is placed on the presence of indicator taxa corresponding to "high" ecological quality, in conjunction with the characteristics of some of the main abiotic parameters that determine the habitat conditions in the ZFF. These relationships were investigated in the framework of the regional background monitoring on the territories of Ugam-Chatkal National Park (UCNP), Chatkal, Gissar, and Nuratau nature reserves in Uzbekistan and Sarychelek reserve in Kyrgyzstan, in watercourses in the mountain frame of the Fergana valley, and in the zone of formation of the mountain rivers and says in Kashkadarya and Surkhandarya oasis as is clear from the number of publications (Abakumov and Talskikh 1987; Talskikh 1990, 1998a, b, 2008, 2015; Abdullaeva and Talskikh 1997; Bulgakov 1997; Talskikh et al. 1995a, b, 2001, 2002). These studies have made it possible to make some generalizations about the composition, structure, and diversity of priority of periphyton and zoobenthos biocenoses, as well as to evaluate the water quality class and the ecological status of the water bodies themselves in typologically different aquatic biocenoses in the ZFF, which is the main subject of consideration in this section.

In addition to assessing the spatial succession of biocenoses, an attempt has also been made to highlight some aspects of their seasonal and long-term successions. We provide comparative information mainly for the summer-autumn period, which is the "height of hydrobiological summer" in the region's watercourses, when, due to the occurrence of a temperature gradient, the characteristic typological differences between the biocenoses of different watercourses and their various sections are most contrastingly manifested. Due to the complex orography of the mountain landscape, the surveyed background watercourses or their individual aquatic biocenoses differ in water content, type of nutrition, and altitudinal location and accordingly have different sensitivity to climatic and anthropogenic factors. These differences are decisive in the formation of hydrological especially their temperature regime, the most important abiotic factor for aquatic biota. Therefore, in terms of temperature regime, all the studied background watercourses are divided into two main groups in the first approximation (Talskikh et al. 2002). In addition, two more subgroups of background watercourses were identified, for which the combination of temperature and hydrological regime dynamics leads to the appearance of slightly changed environmental conditions for biodiversity cover.

The First Main Group

It includes various cold-water oligotrophic rivers and streams/says of the alpine and subalpine zones, which are characterized by a low daily water temperature in the summer (10.1–16 °C) and relatively low amplitude of its annual and daily fluctuations. These are rivers and streams of the UCNP, Chatkal, Pskem, Akbulak, Koksu, Nauvalisay, Mazarsay, and Gulkamsay; upper course of the rivers Aktashsay, Karakiyasay, Kyzylsu, and Sukoksay; cold-water rivers and streams of

South-Maidantal plot of the Chatkal reserve, Taskesken, Tarakli, Simnansay, and Gissar nature reserve; East and West of Aksu stream of Mukhbel; upstream and upper tributaries of Bashkyzylsay on the same area of the Chatkal nature reserve; upper course of the rivers in the mountainous framing of the Fergana valley, Cadaksay, Sumsar, Kasansay, and Koksu; the upper course of the rivers Kashkadarya and Surkhandarya oases, Aksu, Tankhizidarya, Kyzylsu, Tupalang, and river Sary-Cheleksay before flowing into lake on-site Sarychelek biosphere reserve; etc. Aquatic biota develops poorly or moderately, without sharp seasonal fluctuations within quantitative and qualitative indicators. Accordingly, biocenoses are characterized by a relatively simple temporal structure, that is, "smoothed" seasonal successions (Kuchkarov 2018).

Boreal-alpine and mountain cryophilic species – indicators of xeno-saprobe-oligo-saprobe (x-o-), o- and o-β-mesosaprobe conditions predominate in these streams in the alpine zone in the periphyton and zoobenthos. Biocenoses of the periphyton develop rather poorly and species diversity is low. These are exclusively producer communities in which heterotrophic organisms from the groups of consumers and decomposers are not detected. The dominant reference taxa characteristic of these conditions are diatoms *Diatoma hiemale*, *D. hiemale* var. *mesodon*, *Cymbella stuxbergii*, *Ceratoneis arcus*, *C. arcus* var. *amphioxys*, *Didymosphenia geminata*, *Eucocconeis flexella*, *Cymbella hebridica*, *Meridion circulare*, golden alga *Hydrurus foetidus*, green colonial alga *Prasiola fluviatilis*, etc. Zoobenthos is characterized by such groups of organisms as caddis flies of the genera *Chloroperla*, *Capnia*, *Leuctra*, and *Mesonemoura*, mayflies of the genus *Iron*, and representatives of Diptera from the genera *Philorus*, *Tianschanella*, *Deuterophlebia*, and *Blepharocera*. Species diversity is generally low, there is no clear dominance of a particular species, and the food specialization of the vast majority of zoobenthos inhabitants is macro-shredders and micro-grinders. The biocenoses of periphyton and zoobenthos are in the background ecological status, designated as AE(B).

In the subalpine zone, in addition to this complex of organisms, representatives of other genera develop abundantly, due to which the species diversity of the periphyton increases somewhat. The dominant complex also develops o-saprobic diatoms *Cymbella delicatula*, *C. affinis*, *C. cistula*, *C. helvetica*, *C. microcephala*, *Synedra goulardii*, *Achnanthes linearis*, *A. minutissima*, *Fragilaria leptostauron*, *Gomphonema intracatum*, some blue-green colonial algae *Phormidium ambiguum*, *P. favosum*, green filamentous alga *Ulothrix zonata*, etc. In zoobenthos, the complex of alpine forms is mostly preserved with the only difference that mayflies develop more noticeably, which include species from the genera *Ephemerella* and *Ameletus*. In the trophic structure, along with shredders, various types of organisms – gatherers and filtering ones – also begin to play a significant role. The environmental condition is assessed as AE(B).

The Second Main Group

This group can be conditionally merging of downstream sections of rivers and streams in the mountain forest belt of snowmelt-rain-fed type, which in most cases (with the exception of some constantly cold-water rivers and says) are a continuation of the above streams in their middle course, for example, river Bashkyzylsay and its tributaries in the middle reaches in the Chatkal nature reserve; in UCNP mid- and downstreams for rivers Aktashsay, Karakiyasay, Kizilsu, Sumxy, and Chimgansay; in the Akhangaran river basin mid- and downstreams of the river Dukentsay; mountain and piedmont sections of river Ahangaran; and others. They are characterized by much higher amplitude of annual and daily fluctuations in water temperature in the summer, when the daily warming of the water mass can reach 18.5–24.7 °C.

Allochthonous organic matter in the form of leaf litter enters the biocenoses of rivers and streams of the forest belt in a noticeable amount, which, in combination with increased water warming, leads to an increased level of trophic activity and abundant development of aquatic biota during summer and autumn compared to the first group of watercourses. During this period, there is an active drift of periphyton algae, which can cause the water to acquire a greenish hue. In some dry and low-water years, mass development of green filamentous algae of the periphyton from the genera *Ulothrix* and *Cladophora* can be observed (50–60% of the projected bottom cover), which, for example, has been observed as typical for the Boshkyzylsay river in 2000.

In most of the background "warm-up" watercourses, the summer-autumn linear stratification of biocenosis is clearly traced. This is a consequence of the occurrence of an ecological gradient of conditions in them from the upper to the lower stream, during the passage of various high-altitude zones. In the mountain forest zone, the species diversity of the periphyton during the period of linear stratification increases almost twice compared to the biocenoses of previous high-altitude zones. Some boreal-alpine algae species, such as *Diatoma hiemale*, *D. hiemale* var. *mesodon*, *Cymbella stuxbergii*, *C. arcus* var. *amphioxys*, *Meridion circulare*, and *Prasiola fluviatilis*, fall out of the dominant summer-autumn complex and are partially replaced by mountain-foothill o-β- and β-mesosaprobe eurybiont species. Here diatoms from the genera *Achnanthes*, *Cymbella*, *Synedra*, *Fragilaria*, *Gomphonema*, and *Navicula* develop more abundantly and variously, and species of the genus *Phormidium* are found from blue-green algae, where representatives of desmidium and protococcal algae of the genera *Cosmarium* and *Scenedesmus* are first discovered. In small tributary streams with a higher trophic level, blue-green algae from the genera *Nostoc*, *Calothrix*, and *Tolypothrix*; filamentous green algae from the genera *Spirogyra*, *Zygnema*, *Oedogonium*, and *Draparnaldia*; as well as diatoms from the genera *Eunotia*, *Amphipleura*, *Rhopalodia*, *Denticula*, and *Epithemia* are characteristic of littoral biotopes with clusters of plant matter (detritus). In the periphyton, individual heterotrophic organisms from the group of consumers (nematodes, shell amoebas, infusoria, tardigrades) are also found.

Zoobenthos has the highest species diversity compared to the alpine and subalpine zones, which is explained by the increase in the number of ecological niches. With the changes in temperature conditions from spring to summer-autumn, the composition and structure of zoobenthos changes due to the appearance of eurybiont species in them: mayfly larvae of the genera *Baetis* and *Caenis*; beetles from the genera *Helmis* and *Stenelmis*; dragonflies; crustaceans; oligochaetes from the family Naididae; stoneflies of the genera *Hydropsyche*, *Agapetus*, *Dinarthrum*, and *Cheumatopsyche*; chironomids of the genera *Eukiefferiella* and *Orthocladius*; and others are observed. Trophic (ecological) structure is usually complex, and trophic chains are long and branched. Trophic dominants include detritophagous shredders, gatherers, filterers, zoo- and phyto-phagous, and omnivores. In winter, these differences are to a certain extent smoothed out mainly by equalizing the water temperature along the length of the stream, which allows boreal-alpine species to dominate the middle and even lower course in them, which is not observed in the height of hydrobiological summer. Intra-annual cyclical changes in the trophic structure of zoobenthos look like this: during high biological summer, detritophagous gatherers predominate; by autumn the role of predatory stoneflies increases, replaced in winter by predatory caddis flies and macro-shredders, which by summer give populations of early age stages that are detritophagous gatherers; and the cycle repeats (Bulgakov 1997).

In the second group of aquatic biocenoses, seasonal succession of periphyton and zoobenthos biocenoses is clearly expressed, which is characterized by a complex time structure, including several phases that regularly and consistently replace each other during the annual cycle. In the periphyton biocenoses of middle reaches of the river Bashkyzylsay in the 1980s stood out well two main biological phases, labeled as phase *Hydrurus foetidus* and phase of *Didymosphenia geminata*. These phases are distinguished according to the dominance of these types of algae, respectively, in the cold winter-spring and warm summer-autumn periods, when they formed characteristic fouling on underwater rocks, clearly visible even visually. These two phases, in turn, included six more fractional categories – subphases, reflecting the most characteristic intra-annual changes in the composition and structure of the periphyton. However, in the late 1990s and in 2000, the noticeable development of *H. foetidus* was observed only during the transitional winter-spring period, without any mass development of this golden alga, so characteristic of the 1980s. The same can be said about *D. geminata*, whose colonies in recent years have mostly been found only in the upper reaches of the controlled section of the Boshkyzylsay river, also with a low abundance. It has almost disappeared from the summer-autumn subphases, previously characteristic species of diatoms from the genera *Frustulia*, *Rhopalodia*, *Denticula*, and *Amphipleura*. Less pronounced was the summer drift of the periphyton, when well-formed films of fouling, breaking off from stony substrates and breaking up with the current, formed a powerful drift of genetic material into the lower current, which gave the water mass a greenish hue in the summer and autumn period. In recent years, there has been a massive development of green filamentous algae. The abovementioned environmentally significant modulations in the biocenoses structure in the absence of direct anthropogenic impact indicate changes in hydrological and hydrobiological processes that may be associated with changing climatic conditions. The ecological state is also assessed as AE(B), but with a more complex time structure of biocenoses, which in this group of aquatic biocenoses are more sensitive to the dynamics of changes in climate factors.

In general, the diatomic complex of algae of the periphyton of background watercourses in the ZFF is characterized by absolute dominance of autotrophic freshwater organisms from the group of producers and among them diatoms, with simultaneous weak development of diatoms from the genera *Navicula* and *Nitzschia*. It is characterized by a diverse and abundant development of north-alpine species, which together with freshwater species make up from 55 to 85% of the total diversity of diatoms. The highest percentage is typical for high-altitude and cold-water rivers and streams, such as Tashkesken, Terakli, and Zimnansay rivers, upper reaches of the Akhangaran river, upper tributaries of the Boshkyzylsay, upper reaches of the rivers Akbulak, Serkali, Mazarsay, Aksu West, Aksu East, Tankhizidarya, Gelandarya, and others, with the advancement from the upper river sections of the alpine and subalpine forest. In the foothill zone, the diversity and abundance of brackish- and freshwater eurybiontic species increases, for example, it is typical for biocenoses of rivers Ugam (mouth), Tankhizidarya (village Kattagon), and Kashkadarya (village Varganza).

In the periphyton, along with mountain alpine diatoms and from the genera *Cymbella*, *Ceratoneis*, *Achnanthes*, *Synedra*, and *Diatoma*, eurybiont species from the genera *Navicula*, *Gomphonema*, and *Cocconeis* appear. As part of zoobenthos, there are both mountain species of caddis flies of the genera *Filchneria* and *Amphinemura*, mayflies of the genera *Ecdyonurus* and *Ephemerella*, mayflies of the genus *Cheumatopsyhe*, Diptera of the genera *Atherix* and *Eriocera*, and beetles of the genus *Helmis* and eurybiont species of mayflies of the genera *Baetis* and *Caenis* and stoneflies of the genus *Hydropsyche*, oligochaetes family Naididae.

The most striking regional feature of the zoobenthos of background watercourses is the predominance of cryophilic and oxyphilic species with a pronounced adaptation to rapid flow. There are various species of caddis flies, mayflies of the genera *Ephemerella* and *Ameletus* of the family Heptageniidae, and dipterous of the family Tipulidae, Blepharoceridae, and Simuliidae. To a lesser extent, larvae of stoneflies, beetles, and dragonflies are typical, which tend mainly to streams and lower, more eutrophicated sections of rivers in the forest zone. With the advance to the foothill zone, the main functional load in zoobenthos passes to mayflies of the genera *Baetis* and *Caenis*, stoneflies of the genus *Hydropsyche*, as well as to chironomid larvae and oligochaetes. In the trophic structure of zoobenthos, the role of shredders decreases and the leading position is gradually occupied by gathering collectors and scrapers.

More detailed characteristics that take into account, among other things, the individual features of the taxonomic structure and regional and local biodiversity of the selected indicator biocenoses for different types of watercourses are given in different publications (Talskikh 1990, 1998a, b, 2005, 2008, 2015; Abdullaeva and Talskikh 1997; Shukurov et al. 2005; Talskikh et al. 2007; Abakumov and Talskikh

1987; Talskikh et al. 2002; Bulgakov 1997). According to these sources of regional biodiversity for aquatic ecosystems, biocenoses of Western Tien-Shan mountains are as follows: in the periphyton, there are 569 taxa below the genus rank (species, subspecies, forms), belonging to 7 orders, 97 genera; in the zoobenthos, 478 taxa are below the rank of genus, belonging to 204 genera. Local biodiversity for the streams of the Chatkal nature reserve includes 300 taxa of periphyton ranked below the genus, belonging to 5 orders, 71 genera, and for zoobenthos 176 taxa ranking below the genus, belonging to 124 genera. The taxa with a rank below the genus have been registered on certain sections of rivers in the alpine and forest zones of the South Maydantal section of the reserve as 37 and 82 taxa in the periphyton and 34 and 38 taxa in the zoobenthos, respectively. On the Boshkyzylsay section of the reserve in the upper and midstream sections of the Boshkyzylsay river, taxa with a rank below the genus are registered as 59 and 160 taxa in the periphyton, and in zoobenthos – 66 and 142 taxa. In the upper and lower tributaries of the Boshkyzylsay river, taxa with a rank below the genus are in the periphyton 73 and 183 taxa and in the zoobenthos 75 and 118 taxa. The observed diversity of taxa with a rank below genus in a separate one-time samples of periphyton is as follows: in the alpine and forest zones of South-Maidantal part of the reserve 8–40, in the up- and midstream sections of the river Bashkyzylsay 18–53, and in the up- and midstream tributaries of Bashkyzylsay – 20–83.

At the separate background monitoring points covering the upper sections of the Ugam, Chirchik, Akhangaran, and Akbulak rivers in the ZFF the records are in periphyton, from 67 to 183, and in zoobenthos – from 41 to 64 taxa with a rank below the genus. The observed species diversity for these sites in different years for periphyton is in some single samples, 32–141 taxa ranked below the genus, and for zoobenthos – in some single samples – 7–19 taxa ranked below the genus (Kuchkarov 2018).

The Third Subgroup

In a separate third subgroup among the "warmed up" watercourses of the ZFF, it is possible to conditionally allocate aquatic biocenoses in the areas of outflow from lakes on the territory of the Sarychelek mountain biosphere reserve (Jalal-Abad region of Kyrgyzstan). From these watercourses, with the passing heated water masses planktonic organisms are also carried out, which leads to natural increase in trophic level (Talskikh 2005, 2008). The temperature regime of the river Sarycheleksay, first from lake Sarychelek and then lake Kylakel, drain the lakes twice, change under the influence of these lakes. The maximum summer water temperature in Sarycheleksay, recorded at the confluence with the lake of the same name, was 11 °C. After leaving the lake Sary-Chelek (duct Tuskaul), summer daily maximum water temperature was up to 20.4 °C. After leaving the lake Kylakel, where the river has the name of Khojaata, located 23 meters lower (abs), the warming is 21.5 °C. After a level drop of 600 m, the summer daytime water temperature in the river below village Arkit reaches 22.6 °C, while entering the foothill plain below Kyzyltuu (with a decrease in the height of the riverbed by about 50 m) is −24.2 °C. A characteristic feature of the river nutrition causes a lower turbidity of the water of river Khojaata, compared to the Karasu river that receives it during the spring flood. From the methodological point of view, a comparative linear description of the BC biodiversity characteristics along the entire segment of the considered mountain stream is of interest.

The Sarycheleksay river, which belongs to the first group, before entering the lake of the same name, is a rapid stream with clear, transparent, cold water, and a predominance of laminar flow type. Macrophytes do not develop, except for some small sod of water moss *Fontinalis*, which covers no more than 1–2% of the riverbed area. Periphyton communities in the form of light brown deposits, colorless gelatinous clusters of diatoms, and dark brown strands of cryophilic x-o-saprobic golden algae *Hydrurus foetidus* mosaically cover 15–20% of stony substrates and do not have significant differences in the spring and summer-autumn seasons. The dominant and subdominant complex, along with the *H. foetidus*, includes the north-alpine x-, x-o-, and o-saprobic species of diatoms *Diatoma hiemale*, *D. hiemale* var. *mesodon*, *Ceratoneis arcus*, *C. arcus* var. *amphioxys*, *Cymbella hebridica*, *C. stuxbergii*, *Meridion circulare*, as well as mountain and boreal species *C. delicatula*, *C. helvetica*, *C. cistula*, *C. ventricosa*, *Eucocconeis flexella*, *Synedra vaucheriae*, *Fragilaria leptostauron*, *Didymosphenia geminata*, *Gomphonema angustatum*, *Gomphonema intracatum* and its var. *pumilum*, and various species of the genus *Achnanthes*, and in some (drought) years, subdominants were also o- and o-β-mesosaprobes *Ulothrix zonata*, *Spirogyra* sp., *Vaucheria* sp., *Zygnema* sp., *Phormidium favosum*, and characteristic of mountain forest and cold-water rivers and streams *Chamaesiphon polonicus*, *Ch. incrustans*, settling on the threads of *Vaucheria*. The number of species found in the periphyton at different dates of the spring-summer-autumn season (observed species richness) is 8–38, and the local species richness is 91 taxa ranking below the genus.

A peculiar complex of zoobenthos organisms forms on the cold-water section of the stream in the lake, in which 21 species (70%) out of 30 discovered species are specific to this section. The bottom fauna is mainly represented by x-o-saprobic species of caddis flies, mayflies, stoneflies, dipterous, and chironomids, such as *Xanthoperla curta*, *Ameletus alexandrae*, *Baetis* sp. *(lunulatus?)*, *Baetis (Baetiella) oreophilus*, *B.(B.) stipposus*, *Epeorus (Iron) montanus*, *Apatania* sp., *Pagastia* sp. *(orientalis?)*, *Eukifferiella* sp. *16*, *Thienemanniella* sp. *8*, and *Tvetenia* sp. *2 (paucunca Saether* ?), etc. The basis of zoobenthos in qualitative and quantitative terms is the larvae of mayflies and chironomids. The biocenoses of periphyton and zoobenthos are in the background ecological state, designated as AE(B).

On the hydrobiological regime of the two sections located below: "heated" outflows of water from the lake Sarychelek (the middle part of the ducts of Tuskaul), and from lake Kylakel (the beginning of the Khojaata river), are significantly influenced by lakes, from the surface horizon of which well-warmed and plankton-rich water masses are carried out. Therefore outflows from lakes can be considered in the classification series as a separate type of aquatic biocenoses. A favorable hydrological regime without sharp fluctuations in the water level, combined with the above factors, causes an increased level of trophic activity and abundant development of aquatic biota throughout the year.

A stimulatory effect of the influence of lakes is visually noticeable in the development of macrophytes – pondweed (*Potamogeton pectinatus*) in the form of spots-clusters along the riverbed, reeds (*Phragmites australis*) along the shore, and powerful turf water moss *Fontinalis*. Both sites are very similar in the composition of periphyton organisms. Here 50–70% of the surface of the rocky bottom is covered with moss turf, in the intervals between which fouling almost completely covers all the underwater rocks and forms a very colorful mosaic of richly developed green filaments (from the genera *Vaucheria*, *Zygnema*, *Spirogyra*, *Mougeotia*, *Draparnaldia*, *Oedogonium*) and variously colored calcareous crusts and films formed by blue-green algae from the genera *Schizothrix*, *Calothrix*, *Tolypothrix*, *Homoeothrix*, *Plectonema*, and *Phormidium*, which are especially abundant in the summer and autumn period. Various mountain, boreal, and eurybiont x-o-, o-β-, and β-mesosaprobe diatoms develop abundantly and variously, which in different combinations make up a dominant and subdominant complex – *Eucocconeis flexella* and *E. lapponica*, various species from the genera *Achnanthes* and *Cocconeis*, *Didymosphenia geminata*, *Cymbella affinis*, *C. cistula*, *C. cymbiformis*, *C. delicatula*, *C. helvetica*, *C. lanceolata* var. *notata*, *C. ventricosa*, *C. microcephala*, *C. turgida*, *C. aequalis*, *Diatoma elongatum* and its variations var. *tenuis* and var. *capitellatum*, *N. cryptocephala* and its variations, *Epithemia sorex*, *Eunotia arcus*, *E. praerupta*, *Eunotia* sp., *Fragilaria pinnata*, *F. pinnata* var. *lancettula*, *F. construens* and its variations, *F. leptostauron*, *F. intermedia*, *F. crotonensis*, *F. capucina*, *Gomphonema intracatum* and its var. *pumilum*, *Navicula radiosa*, *Nitzschia denticula*, *N. angustata* var. *acuta*, *N. sinuata* var. *tabellaria*, *Synedra acus* and its variations, *S. capitata*, *S. amphicephala*, *S. ulna* and its variations, *Rhopalodia parallela*, from planktonic lake forms not found in other water courses, *Cyclotella kuetzingiana* var. *planetophora*, *C. ocellata*, *Asterionella formosa*, and *A. gracillima*. The north-alpine rheophilic species listed above for the periphyton on the cold-water stream of the Sarycheleksay river are not found here. On the other hand, filamentous green, blue-green algae, and, especially, diatoms from the genera *Cyclotella*, *Denticula*, *Cymbella*, *Fragilaria*, *Epithemia*, *Eunotia*, *Navicula*, *Nitzschia*, and *Synedra* develop much more abundantly and variously on the outflows from lakes, which brings them closer to the composition of the periphyton with the lakes that feed them. On the outflows from lakes in the periphyton, there are characteristic colonies of freshwater sponge *Spongilla lacustris*. Constantly, but with a low abundance in biofilms of fouling and turf of water moss, there are certain species of consumers – naked and shell amoebas, rotifers, nematodes, chironomids, and tardigrades. The observed species richness of the periphyton at different dates of the spring-summer-autumn season is 51–72, and the local species richness is 131–151 taxa ranked below the genus.

The specific appearance of the benthos of Tuskaul channel and the beginning of the Khojaata river, which is formed under the influence of lakes, retains its features further. For example, on the site located below in the area of the village of Arkit, which is expressed in its great similarity, for caddis flies 100% of the general species; for mayflies for different river cross-sections 50–80%; for stoneflies 43-75%; for chironomids 55–70%; etc., most of which belong to o- and o-β-mezosaprobic organisms with a wide ecological valence. Mayflies *Baetis (Acentrella) putoranicus* and C*heumatopsyche* sp. (*capitella?*), *Hydropsyche ornatula*, *H. gracilis*, dipterous family *Simuliidae* sp., chironomids *Eukifferiella* sp. 3, *E. quadridentata*, *Micropsectra* sp. *2*, and *Rheotanytarsus* sp. *2.* were found in the dominant and subdominant groups. Among the common species of zoobenthos of these two sites, we also noted the caddis flies *Amphinemura* sp. *(sulcicollis Stephens?*), *Agnetia* sp., mayfly *Baetis (Nigrobaetis) muticus*, *B.(Baetiella) ursinus hissaricus*, *B.(B.) buceratus*, *B.(B.) stipposus*, *chironomid Tvetenia* sp. 2 *(paucunca Saether?)*, the water mites *Hygrobates calliger*, and the gammarids *Gammarus* sp. *(lacustris Sars.*?). Hydra – *Hydra* sp. – are also found in these areas and nematodes, *Nematoda* gen. sp.

At the same time, each of the river sections has its own characteristics. Only at the first site in zoobenthos, we found the mayflies *Ecdyonurus* (*Afghanurus) rubrofasciatus*, stoneflies *Rhyacophila obscura*, chironomids *Cricotopus bicinctus*, *Conchapelopia* sp. *(Larsia curticalcar* Kieff.*?)*, and water mites *Megapus* sp. and *Sperchon plumifer*. In the second section (more eutrophic), from dipterous *Melanochelia* sp. *(riparia* Fall.?), from beetles *Helmis* sp., from dragonflies *Agrion splendens*, from leeches *Herpobdella octoculata*, and representatives of oligochaetes *Nais barbata*, *Eiseniella tetraedra*, and *Tubificidae* gen. sp. The observed species richness of zoobenthos at different dates of the expedition survey was 42–45 taxa ranking below the genus.

In the specific conditions of outflows from lakes, macrophytes (pondweeds) and powerful turf of water moss develop abundantly, which is usually not typical for "unregulated" rivers belonging to the category of mountain streams. The structure of the periphyton biocenoses here has its own individual features related to the type of nutrition, stabilization of the hydrological regime, and settlement of some planktonic lake forms. Here, unlike most mountain streams, diatoms from the genera *Fragilaria*, *Synedra*, *Cymbella*, *Cyclotella*, *Achnanthes*, *Cocconeis*, *Navicula*, *Nitzschia*, *Eunotia*, *Anamoeoneis*, *Denticula*, *Gomphonema*, *Epithemia*, and *Rhopalodia* develop extremely diverse and abundant in the periphyton – planktonic or littoral species – that enter the biotopes with clusters of vegetable detritus. In the zoobenthos biocenoses, there are mayflies *Baetis putoranicus*, stoneflies *Hydropsyche ornatula*, *H. gracilis*, dipterous family Simuliidae, and chironomids of the genera *Eukiefferiella*, *Micropsectra*, *Rheotanytarsus*, and *Cricotopus*, the presence of leeches *Herpobdella octoculata*, oligochaetes of the families *Naididae* and *Tubificidae*. An interesting feature of these biocenoses is the development of planktophagous dragonflies *Agrion splendens*, dipterous of the genus *Melanochelia*, hydra, water mites, and a number of predatory chironomids. The trophic structure of zoobenthos biocenoses is characterized by a good development of second- and third-order consumers, which indicate the complexity and branching of food chains and the predominance of detritus and pasture ways of utilization of autochthonous and allochthonous organic matter. At the same time, the role of phytodetritophages-scrapers and shredders decreases, and the role of phyto-zoophagous, detritophagous filterers, and zoophagous-grabbers increases. The taxonomic composition of the periphyton and zoobenthos biocenoses indicate a more mature stage of natural succession of biocenoses of outflows from lakes (higher trophic level), which are nevertheless in the background ecological state, designated as AE(B).

The Fourth Subgroup

A very special fourth subgroup of aquatic biocenoses is found typical for shallow says/streams draining the slopes of the Nuratau range (Jizzakh region of Uzbekistan) in the Nurata mountain nature reserve (Alychak, Khayatsay, Tikchasay, Ukhumsay, Shoxchinansay, Fargunsay, Madjerumsay, etc.), which can serve as analogs to other shallow watercourses of ZFF (Talskikh et al. 1995b; Talskikh et al. 2001). The low water content and predominance of the groundwater nutrition of these watercourses determines their increased sensitivity to changes in climate factors and the close dependence of the aquatic biocenoses on the status of adjacent landscapes and anthropogenic factors. Water from the main says, as in most other small rivers and says of the ZFF, is already in the nature reserve territory intensively used by a network of artificial ditches for irrigation and drinking needs of settlements located downstream outside the reserve. The channels of the shallowest streams in their midstream may dry up, as in Khayatsay, and then reappear downstream as a result of local wedging of springs on the surface and losses from the irrigation ditch network. The water content of streams varies significantly by season and year. The highest water runoff is typical for the spring rainy period, and in the summer-autumn low-water period, it can get reduced by 20–34 times. For example, in hydrological post Madjerumsay in the period from 1983 to 1995, the maximum average monthly spring water discharge varied in the range of 0.33–4.06 m^3/s and the minimum average monthly summer water discharge – in the range of 0.013–0.12 m^3/s.

In the periphyton biocenoses of these ecological groups in the up- and midstream sections of says, constantly present are *Melosira arenaria*, *Fragilaria brevistriata*, *Fr. intermedia*, *Frustulia vulgaris*, *Gomphonema angustatum* var. *productum*, *G. bohemicum*, *G. intracatum* var. *pumilum*, *Cymbella helvetica*, *Nitzschia linearis*, *N. hantzschiana* (diatoms), and, characteristic of mountain forest streams, blue-green algae from the genera *Pleurocapsa* and *Chamaesiphon*. The diatoms *Amphora ovalis*, *Achnanthes lanceolata* and its variations, *Cymbella sinuate*, and *C. microcephala* are also constantly found in the turf of water moss from this ecological group. An interesting fact is the discovery of a rare freshwater diatom *Campilodiscus noricus* var. *hibernicus*, not found in other mountain streams of the Central Asian region, in the periphyton of Khayatsay, Madjerumsay, and in the spring stream of Yangokliksay. Individual boreal-alpine species of diatoms, such as *Diatoma hiemale* var. *mesodon* and *Cymbella hebridica* develop noticeably in the stream sources in the sod of water moss. During the high-water spring period, the development of the cryophilic x-saprobic golden alga *Hydrurus foetidus* is observed in larger says (Tykchasay, Madjerumsay).

In general, the periphyton biocenosis is characterized by the predominance of species with a wide ecological valence and the presence of individual pronounced dominants. Almost everywhere, blue-green filamentous colonial algae from the genera *Phormidium*, *Lyngbya*, and *Nostoc* dominate and give mass development, and in the lower unshadowed areas, in addition to these, separate species of filamentous green algae from the genera *Cladophora*, *Oedogonium*, and *Spirogyra* develop abundantly. Eurybiont and halophilic species of β-mesosaprobe diatoms *Diatoma vulgare* var. *productum*, *D. elongatum* var. *tenue*, *Melosira* variations, *Synedra ulna*, *Cocconeis pediculus*, *C. placentula* var. *euglypta*, *Navicula gracilis*, and *N. cryptocephala* var. *veneta*, *N. salinarum*, and *Cymbella affinis* constantly and abundantly develop in the middle and lower sections of watercourses, which develop even more abundantly in low-water years, while reducing the abundance and diversity of the mountain forms of algae mentioned above.

The local species diversity of the periphyton biocenoses for the hydrographic network of the nature reserve is characterized by the following indicators: a total of 220 taxa have been registered with a rank below the genus, among which diatoms (Bacillariophyta) predominate – 168 taxa. Blue-green algae (Cyanophyta) account for 32 taxa. The total species diversity of algae in individual locations covered by 3-year observations varied in the range from 59 to 92, and the observed species biodiversity in individual single samples ranged from 13 to 63 taxa. The observed species diversity of algae from spring to summer in most cases increased by 1.5–2.0 times. There is also a trend in increasing species diversity from the source to the lower sections, but it is less pronounced than inter-seasonal changes in species diversity.

In the zoobenthos biocenoses during the survey period, 118 taxa were found with a rank below the genus, of which 49.2% of the taxa are dipterous larvae. Of the dipterous, chironomids predominate, 33% of the total number of taxa, 11% of taxa are represented by stoneflies. Mayflies, beetles, and water mites each account for 8.5% of the total taxonomic diversity. Other species (caddis flies, amphipods, turbellaria, dragonflies, mollusks, water bugs, oligochaetes, nematodes) account for a total of about 16% of the taxonomic diversity of zoobenthos (Kuchkarov 2018). The total taxonomic diversity in individual localities varies between 13 and 41 taxa over the period of 3-year surveys.

It is possible to distinguish three most typical subgroups of aquatic biocenoses in the first approximation, namely, (a) cold-water sources of says in their upstream and zones of spring wedging in the midstream; (b) shaded forest areas of riverbeds with a large amount of coarse plant detritus on the bottom; and (c) more open and warmed areas of riverbeds with a predominance of fine detritus, which alternate in different combinations in different river basins of the Nurata reserve. In subgroup (a), taking into account the landscape and ecological features of the territory under consideration, the ecological status of the biocenoses in this group is estimated as AE(B). In the biocenoses of subgroups (b) and (c) with an increased level of trophic activity due to autochthonous and allochthonous organics, especially in low-water hydrological phases on shallow forested areas and in places of illegal livestock stands, where destruction processes clearly predominate, the biocenoses are in a state of "ecological stress," their ecological status is estimated as AE, typical for ZFC.

Most of the watercourses in the middle part of the Nurata reserve are in a state of unstable ecological balance, which is reflected in the structure of the biocenoses. The biological mechanism works with "overload" and is aimed at processing and mineralization of allochthonous organic material, the volume of which is comparable to the capacity of the watercourses themselves. Zoobenthos plays a leading role in maintaining the ecological balance and forming water quality in the streams of the reserve – as the main destructor of allochthonous organic matter coming from coastal phytocenoses and illegal stands of livestock, as well as in the mass die-off at the end of vegetation of filamentous and colonial algae of the periphyton (Kuchkarov 2018).

In such a situation, it is important to prevent further increase in the organic load on the reserve's aquatic biocenoses and try to preserve the natural grassy cover of mountain slopes that regulate the intensity and uniformity of underground spring water supply, since violation of their buffer capacity can lead not only to the loss of their landscape and aesthetic value – it will turn these into semi-stagnant pools with "blooming" water, but also to the loss of an important source of clean water for the population living nearby (Talskikh et al. 1995b, 2001). A similar situation is already observed in the lower reaches of some mountain rivers of anthropogenic and recreational zones in the UCNP (the second group), whose channels are subject to "hydrological eutrophication" due to excessive water withdrawal (Talskikh 2001; Talskikh et al. 2002).

57.3.1.2 BC Biodiversity in River Ecosystems ZFC

In moderately polluted river ecosystems of ZFC, compared with their background sections of ZFF, there is a linear downstream increase in water mass salinity (up to 368–374 mg/l), average concentrations of ammonium nitrogen (up to 0.021–0.240 mg/l), nitrite nitrogen (up to 0.006–0.039 mg/l), mineral phosphorus (up to 0.009–0.020 mg/l), and average COD values (up to 14.8–16.1 mgO/l) (Talskikh 1995, 2015; Kuchkarov 2018). Large amplitudes of annual and daily fluctuations in water temperature and its increased warming up in summer – up to 21–27 °C – are typical for the streams of the plain belt (Fig. 57.2). Moderate pollution with dissolved organic and mineral nutrients has a peculiar "fertilizing" effect, which, along with the warming of the water mass, contributes to further increase in the level of trophic activity and under favorable hydrological factors a more diverse and intensive development of the periphyton and zoobenthos biocenoses, whose ecological structure naturally changes.

This process is reflected in the regular change of o- and o-β-mezosaprobic conditions to β-mezosaprobic conditions and the transition of water quality to the class of moderately polluted waters. In the last parts of the lower stream the water quality changes into polluted levels due to an increase in the salinity of waters up to 1000

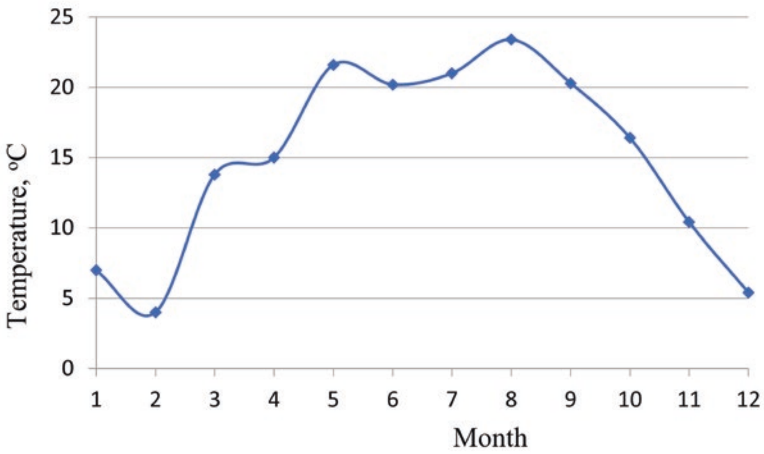

Fig. 57.2 Temperature profile for downstream of Chirchiq river, Hydropost Chinaz within ZFC zone in 2017

mg/l or even above this level (Rubinova 1987; Karimov et al. 2014, 2019) followed by a noticeable development in the indicator biocenosis of brackish-water species.

In comparison with Rb in moderately polluted ZFC watercourses, the average values of biological oxygen demand BOD5 are 2.5 times higher, COD 2.1 times, mineralization 1.5 times, mineral phosphorus and ammonium nitrogen 7.0 times, and nitrite and nitrate nitrogen 2.0–2.7 times. The transformation of the taxonomic structure of biocenoses is even more noticeable in the lowland river mouths, due to an increase in the salinity of the water mass under the influence of discharge of collector-drainage runoff from agriculturally irrigated lands (Chembarisov et al. 2004, 2013; Yakubov et al. 2011; Karimov et al. 2014). In such areas, along with eurybiont species, the brackish water complex of aquatic organisms often develops noticeably. Water quality (especially in the summer-autumn low-water hydrological phase) passes from the class of moderately polluted waters to the transition class of moderately polluted waters, as well as to the transition invariant ecological status AE-Ar, since the change in the gene pool in comparison with the background exceeds 50%.

The results of taxonomical analysis reveal that the following rivers and their sections with good or abundant biocenoses development belong to moderately polluted watercourses: the Akhangaran river (the transition section below city Angren; the downstream section from the Tuyabuguz reservoir to the village Soldatskoe); Chirchiq river (downstream section from city Chirchiq to Village Novomikhailovka); Zarafshan river (downstream above and below the city of Samarkand to the division of the river into two branches, Akdarya and Karadarya); Aksu river (village Miraki, tail-bay of Hisarak reservoir); Kashkadarya river (tail-bay of Chimkurgan reservoir); river Sherabad (village Derbent); river Surkhandarya (tail-bay of the South

Surkhan reservoir); river Amudarya (tail-bay of the Tyuyamuyun reservoir), river Syrdarya (within the Tashkent oasis), Salar and Karasu canals (on the sections above city Tashkent) (Kuchkarov 2018).

Moderately polluted-polluted watercourses with weak development of aquatic biota due to the increased natural turbidity of their water and unstable loose clay-sand soils include the Karadarya river (within the Ferghana valley) and the Syrdarya river (within the Ferghana valley). Weak development of aquatic biota is also characteristic of the river Surkhandarya (in the Denau-Shurchi section), Kashkadarya river (from Chirakchi to Chimkurgan reservoir), and Zarafshan river (mid- and downstreams after city Navoi), where the water quality is reduced to a transitional class of moderately polluted-polluted waters, and the ecological invariant status is classified as AE-Ar (Kuchkarov 2018).

In the up- and midstream sections of rivers on the plains, depending on the hydrological situation and the season of the year, the quality of the combined hydrobiological characteristics may vary from a transitional class of clean-moderately polluted to moderately polluted water invariant ecological status – AE.

In downstream, the water quality can vary from moderately polluted to intermediate moderately polluted-polluted water (in some cases, up to the class of polluted water). Invariant ecological status changes from AE to AE-Ar.

The observed species diversity for the up- and midstream river sections reveals that: in zoobenthos in different years, 20–66 (in some single samples 5–30) taxa ranked below the genus; in periphyton, in some single samples, 36–181 taxa ranked below the genus. The observed species diversity for downstreams is as follows: in zoobenthos in different years 31–74 (in some single samples, 5–34) taxa ranked below the genus; in periphyton – in some single samples – 30–167 taxa ranked below the genus (Kuchkarov 2018).

In rivers with a weak development of aquatic biota, due to the increased turbidity of their water and unstable alluvial clay-sand soils, during the flood period, the biocenoses of periphyton and zoobenthos are not formed; in summer-autumn single samples, the observed biodiversity for periphyton is 10–48 and for zoobenthos, 2–14 taxa with a rank below the genus (Kuchkarov 2018).

The description of the biodiversity of priority lowland watercourses biocenoses for ZFC in the considered ecological series is completed by water bodies of the lowland zone under anthropogenic impact with highly modified ecosystems (Talskikh 1990, 1995, 2015; Yearbooks 1986–2017; Talskikh et al. 1987). This is the Karasu canal (below city Tashkent), the Salar canal (below Tashkent), river Kalgan-Chirchik (below city Yangiyul), and downstream of drainage canal Siab (below city Samarkand), which in different periods of their monitoring on the Uzhydromet observation network were qualified as polluted, dirty, and very dirty water courses based on the results of taxonomic analysis of priority indicator biocenoses.

57.4 Conclusions

In the ASB lotic ecosystems, periphyton and zoobenthos are the most significant indicator biocenoses. Their widespread development makes it possible to conduct a spatial comparative assessment of all types of water bodies within the catchment areas of rivers, both in the zone of surface runoff formation (ZFF) and in the zone of its intensive consumption and pollution (ZFC). For the periphyton and zoobenthos of background freshwater lotic biocenoses, the most informative biological phases of their development usually occur during the summer-autumn transition period. The analysis of the taxonomic composition and bioindication of the summer and autumn phases (intra-annual temporal patterns of biocenoses) has identified the emerging threat of the transition of water quality class "clean" water to intermediate class "clean-moderately polluted" waters in the small rivers of mountain and foothill areas where the border of ZFC and gradually expanding urban areas shifted to ZFF.

In the watercourses of the ZFF zoobenthos, biocenoses have a complex branched trophic structure, in which groups of scrapers, shredders, gatherers, predators, and filterers are well represented. In the lowland areas, the watercourses of the ZFC zone are under the impact of anthropogenic pollution. There is an increase in the pasture path of the functioning of the biocenoses, and food chains are shortened and straightened. In polluted areas, the biocenosis biomass reaches its maximum values compared to clean and moderately polluted areas. In the biocenosis, detritophagous (swallowers and filterers) develop in the mass, and the role of predators decreases. The biocenosis "works" with an overload for utilization of allochthonous organic matter.

The analysis of the biodiversity of indicator biocenoses in ZFC watercourses revealed that moderate pollution of the midstream of rivers maintains their eutrophicated state throughout the year, activates the metabolism of the periphyton, which in this case is caused first by increasing the diversity (total number of species) of the autotrophic component, and then, with increasing pollution load, by complicating the polyfunctional structure of the periphyton. The latter is expressed in a more abundant and diverse development of not only autotrophic but also heterotrophic organisms. When a certain and sufficiently high level of pollution is reached, the biocenoses transition to a new qualitative status with the predominance of destructive processes characterized by simplification of the taxonomic structure of producers or their complete suppression. The list of dominant and subdominant species of indicator biocenoses in the long-term aspect of the ZFF zone watercourses under conservation conditions will remain essentially unchanged, undergoing only certain fluctuations related to the dynamics of climate factors, which, for example, may have a known impact on the water content of rivers and streams and, accordingly, on their temperature and hydrobiological regimes.

Summarizing up the data from the section "biodiversity of river ecosystem biocenoses" of the ZFF, it should be noted that such studies belong to the category of background monitoring. In the future, their regular implementation is extremely important from the point of view of studying biosphere processes, inventory, and assessment of the status of the gene pool of large landscape complexes (nature reserves) and entire regions, studying the dynamics of natural processes and their response in the form of biological trends associated with global and local changes in the geophysical environment under the influence of anthropogenic or natural factors, including global climate change.

References

Abakumov VA, Talskikh VN (1987) The temporal structure of periphyton communities of background ecosystems. In: Problems of background monitoring of the state of the environment, vol 5. Leningrad Gidrometeoizdat, Leningrad, pp 97–107

Abakumov VA, Talskikh VN (1993) Ecological modifications of periphyton in various types of Czechoslovakian watercourses. In: Problems of ecological monitoring and modeling of ecosystems, vol 15. Gidrometeoizdat, St. Petersburg, pp 37–62

Abdullaeva LN, Talskikh VN (1997) The current state of periphyton communities of the Chatkal nature reserve – Trudii Nature reserves of Uzbekistan, vol 2. Printing House "Mehnat", Tashkent, pp 6–17

Barinova SS, Klochenko PD, Belous YP (2015) Algae as indicators of the ecological state of water bodies: methods and prospects. Hydrobiol J 51(6):3–21

Borodin VE, Karimov BK (1990) Changes in phytoplankton communities in the discharge reservoirs of the UzSSR due to their pollution. Tez. docl. All union symposium "Rational use and protection of water resources from pollution", Kharkov, pp 15–16

Borodin VE, Talskikh VN (1994) Hydrological, hydrochemical and hydrobiological regime in flat water bodies in the Aral Sea Region (Subproject 14). Aral Sea project seminar, UNESCO, Tashkent, pp 10–13th May, (1992–1993 Reports), pp 63–65

Borodin VE, Ruziev IB, Rakhmanov BA (1995) Impact of the Amu Darya water content on the hydrochemical regime and pollution of water bodies of the Southern Priaralie. In: Proceedings of the conference "Fresh Water", Uzbekistan, pp 111–115

Bulgakov GP (1997) Macrozoobenthos of the Bashkyzylsay river and its tributaries (Chatkal nature reserve). Proc Nat Reserv Uzbekistan 2:27–29

Butterby RV, Talskikh VN, Yalovitskaya NI, Budaeva LM (1991) Hydrobiological characteristics of water bodies of the Central Caucasus in terms of periphyton and phytoplankton. In: Ecological modifications and criteria for environmental rationing. Proceedings of the international symposium, Gidrometeoizdat, pp 101–123

CAWaterInfo (2020) The Aral Sea Basin. http://www.cawater-info.net/aral/water_e.htm. Accessed 22 May 2020

Chembarisov EI, Lesnik TY, Chembarisova EI (2004) Hydrochemistry of river and collector-drainage waters of the Syr Darya river basin. Prob Desert Develop 2:20–24

Chembarisov EI, Lesnik TY, Nasrulin AB, Rakhimova MN (2013) Modern hydrological and hydrochemical regime of the Syr Darya river. In: Monitoring of changes in soil moisture pressure to adjust irrigation modes and reduce crop losses, Uzbekistan

Egamberdieva D, Ozturk M (eds) (2018) Vegetation of Central Asia and Environs. Springer Nature, Cham, 381 p

Gorelkin NE, Goroshkov NI, Nurbaev DD, Talskikh VN (2001) Assessment of the state of water collectors and lakes on the right bank of the Amu Darya. Intl Sci Pract J 2:49–57

Gozlan RE, Karimov BK, Zadereev E et al (2019) Status, trends and future dynamics of freshwater ecosystems in Europe and Central Asia. Inland Waters 9(1):78–94

Imanberdieva N, Severoglu Z, Kurmanbekova G et al (2018a) Plant diversity of Ala-Archa Nature Park in Kyrgyzstan with emphasis on its economic potential. In: Egamberdieva D, Ozturk M (eds) Vegetation of Central Asia and Environs, Chapter 16, Springer Nature, Cham, pp 365–381
Imanberdieva N, Imankul B, Severoglu Z et al (2018b) Potential impacts of climate change on plant diversity of Sary-Chelek Biosphere Reserve in Kyrgyzstan. In: Egamberdieva D, Ozturk M (eds) Vegetation of Central Asia and Environs. Chapter 15, Springer Nature, Cham, pp 349–364
International Cod of Botanical Nomenclature (1988) Adopted by fourteenth international botanical congress, Berlin, July–August 1987. Koeltz Scientific Books, Koenigstein, 328 p
Johnson RK, Wiederholm T, Rosenberg DM (1993) Freshwater biomonitoring using individual organisms, populations, and species assemblages of benthic macroinvertebrates. Freshw Biomonit Benthic Macroinverteb 1:40–158
Kamilov GK, Karimov BK, Hakberdiev B (1994) Water bodies of Uzbekistan and their fishery importance. Tashkent State University Press, Uzbekistan, p 135
Karimov BK (1994) Ecological classification of hydroecosystems in the Aral Sea Basin. Uzbek Biological Journal 3:35–37
Karimov BK, Borodin VE (1990) Phytoplankton communities of drainage collectors, discharge reservoirs and treatment facilities of the UzSSR, assessment of the possibility of their use for bioindication. Collect Sci Papers GosNIORH 313:205–217
Karimov BK, Borodin VE (1991) Hydrobiological and hydrochemical characteristics of water bodies in the southern Aral Sea region. Collect Sci Works NPO SANIIRI 2:25–37
Karimov BK, Yunusov I (1990) The influence of water quality on the formation of plant communities in the Eastern Arnasai lakes. Collect Sci Works NPO SANIIRI 1:59–67
Karimov BK, Matthies M, Kamilov BG (2014) Unconventional water resources of agricultural origin and their re-utilization potential for development of desert land aquaculture in the Aral Sea basin. In: Bhaduri B et al (eds) The global water system in the Anthropocene: challenges for science and governance, Springer, Cham, pp 183–201
Karimov BK, Matthies M, Talskikh V et al (2019) Salinization of river waters and suitability of electric conductivity value for saving freshwater from salts in Aral Sea basin. Asian J Water Environ Pollut 16(3):109–114
Kolada A, Willby N, Dudley B et al (2014) The applicability of macrophyte compositional metrics for assessing eutrophication in European lakes. Ecol Indicat 45:407–415
Kuchkarov BT (2018) Sixth national report of the Republic of Uzbekistan on the conservation of biological diversity. Tashkent, Uzbekistan, 207 p
McCormick PV, Cairns J (1994) Algae as indicators of environmental change. J Appl Phycol 6(5–6):509–526
Murray-Rust H, Abdullaev I, Hassan M, Horinkova V (2003) Water productivity in the Syr Darya river basin, no. 616-2016-40979, Uzbekistan
Pecier V, Cervenka M, Hindak F (1984) Zaklady sestemu a evolucie vytrusnych rastlin. SPN, Bratislava, p 588
Resh VH, Unzicker JD (1975) Water quality monitoring and aquatic organisms: the importance of species identification. J (Water Pollut Contr Fed) 1:9–19
Rubinova FE (1987) Impact of water melioration on discharge and hydrochemical regime of rivers in the Aral Sea Basin. Trudii SANIGMI 124(205):159
Scheffer M, Hosper SH, Meijer M-L et al (1993) Alternative equilibria in shallow lakes. Tree 8:275–279
Schneider SC, Petrin Z (2017) Effects of flow regime on benthic algae and macroinvertebrates – a comparison between regulated and unregulated rivers. Sci Total Environ 579:1059–1072
Sfriso A, Chiara F, Daniele B et al (2014) Using phytoplankton and macrophytes to assess the trophic and ecological status of some Italian transitional systems. Continent Shelf Res 81:88–98
Shcherbak VI, Semenyuk NE (2011) The use of phytomicroperiphyton to assess the ecological status of anthropogenically altered aquatic ecosystems. Hydrobiol J 47(2):27–42

Shukurov EJ, Mitropolsky OV, Talskikh VN et al (2005) Atlas of Biodiversity of the Western Tien Shan – GEF/WB Central Asian transboundary project for the conservation of the biodiversity conservation of the Western Tien Shan. Regional Department of the Project. Astana-Bishkek-Tashkent, 101 p

Talskikh VN (1990) Natural and anthropogenic changes in periphyton biocenoses in the water-courses of the Central Asian region. Trudii SANIGMI 138(219):56–78

Talskikh VN (1991) The use of the concept of invariant states of biosensors in environmental monitoring and rationing of river pollution in Central Asia. In: Ecological modifications and criteria for environmental regulation. In: Proceedings of the international symposium, Gidrometeoizdat, pp 163–184

Talskikh VN (1995) Methodology for assessing the ecological status of water bodies of the Aral Sea coastal area using hydrobiological indicators. In: Conference proceedings. SANIGMI, Glavhydromet, pp 87–95

Talskikh VN (1997) Methods of hydro biological monitoring of water bodies in the region of Central Asia. Recommendations – RU 52.25.32-97. Glavgidromet RU, Tashkent, 67 p

Talskikh VN (1998a) The concept of biodiversity conservation in the Western Tien Shan. Trudii SANIGMI 155(236):35–44

Talskikh VN (1998b) Biological scale for assessing the quality of water and the ecological status of Central Asian watercourses based on the ranking of the “biological response” of periphyton biocenoses. Works of V.A Bugaev Issue 155(236):57–60

Talskikh VN (2001) The problem of eutrophication of river systems of the Central Asian region. In: Problems of protection and rational use of biological resources of water bodies of Uzbekistan. Materials of the Republican scientific and practical meeting. . Institute of Zoology, Publishing House “Chinor ENK”, Tashkent, pp 92–96

Talskikh VN (2003) Surveys of periphyton and zoobenthos in Sudochie wetland lakes: Main results and lessons learned. Environmental sustainability and advanced approaches to water management in the Aral Sea Basin: In: Proceedings of the international conference, Almaty-Tashkent, pp 369–375

Talskikh VN (2005) Preliminary results of comprehensive expeditionary studies of biohydrocenoses of the lake-river complex of the Sary-Chelek reserve and adjacent territories. In: Proceedings of the reserves of Kyrgyzstan. State Forest Service of the Kyrgyz Republic. Kyrgyz NORP of the Central Asian GEF/WB Cross-Border Project on the Conservation of Biodiversity of the Western Tien Shan, Bishkek, pp 68–84

Talskikh VN (2008) Essay on the study of periphyton biocenoses, their spatial and belt distribution in the waterways of the Western Tien Shan. In: Biodiversity of the Ugam-Chatkal National Park. UCH GPNP, Tashkent-Gazalkent, pp 14–37

Talskikh VN (2015) Ecological modifications of biocenoses of transformed aquatic ecosystems of the region of Central Asia under conditions of drought. Bulletin number 9. Climate change, causes, consequences and adaptation measures. Uzhydromet/UNEP, Tashkent, pp 53–63

Talskikh VN, Arakchaa KD (1993) Assessment of the ecological state and quality of water in water bodies of Tuva by hydrobiological indicators. In: Environmental protection and man – proceedings of the III Republican scientific practical conference. “News of Tuva”, Kyzyl, pp 94–97

Talskikh VN, Bulgakov GP, Zagryazhsky SV, Svidova LV (1987) Sanitary and hydrobiological characteristics of the biocenoses of Uzbekistan’s surface water bodies. Trudii SANII 2:63–97

Talskikh VN, Bulgakov GP, Taraskin AA, Gerasimova OD (1995a) Biohydrocenoses of the basin of the Bashkyzylsay river of the Chatkal reserve. Proc SANIGMI 151(232):84–92

Talskikh VN, Bulgakov GP, Taraskin AA, Gerasimova OD (1995b) The current hydrobiological state of the Nurata Reserve watercourses. Proc SANIGMI 151(232):93–101

Talskikh VN, Taraskin AA, Abdullaeva LN et al (2001) Ecological state of background water-courses of the Nurata Reserve. In: Proceedings of reserves in Uzbekistan, vol 3. Publishing House “Chinor ENK”, Tashkent, pp 5–17

Talskikh VN, Mustafayeva ZA, Gerasimova OD (2002) Background monitoring and assessment of the freshwater biohydrocenosis of the Western Tien Shan. In: Western Tien Shan biodiversity, protection and rational use. Publishing House “Chinor ENK”, Tashkent, pp 207–213

Talskikh VN, Gerasimov OD, Matmuratov MA, Mirabdullaev IM (2007) Taxonomic diversity of the biocenoses of the zoobenthos of the wetland Sudochie. Bull Karakalpak Branch Acad Sci Repub Uzbekistan Nukus 3(208):31–33

UNDP (United Nations Development Program) (2008) Environmental profile of Uzbekistan based on indicators, 88 p

Vis C, Hudon C, Cattaneo A, Pinel-Alloul B (1998) Periphyton as an indicator of water quality in the St Lawrence River (Quebec, Canada). Environ Pollut 101(1):13–24

Wu N, Dong X, Liu Y et al (2017) Using river microalgae as indicators for freshwater biomonitoring: review of published research and future directions. Ecol Indic 81:124–131

www.cawater-info.net. Accessed 16 Feb 2019

www.fao.org. Accessed 14 Feb 2019

Yakubov XE, Yakubov MA, Yakubov SX (2011) Collector-drainage waters in Central Asia and estimation of their use for irrigation. IWP AS Uzbekistan, SIC ICWC, Tashkent, p 189

Yearbooks (1986–2017) Yearbooks of the quality and ecological status of surface waters by hydrobiological indicators in the territory of Uzhydromet's activities. Uzhydromet, Tashkent