Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Assessment of zoobenthos communities transformation in Skurcha Lake after eco-rehabilitation measures

Nabeeva Elvira Gabdulhakovna[1*], Mingazova Nafisa Mansurovna[2], Dbar Roman Saidovich[3], Ivanova Venera Mansurovna[4], Mingazova Dina Yurievna[5]

1. Kazan Federal University, Kazan, Kremlevskaya, 18, 420008, Hibinskaya, 24-122, Russia
2. Kazan Federal University, Kazan, Chistopolskaya, 7-54, Russia
3. State Committee Republic of Abkhazia on Ecology, Republic of Abkhazia, Sukhum, 71/11 Sakharov Str.; Institute of Ecology of the Academy of Sciences of Abkhazia, Republic of Abkhazia, Sukhum, Krasnomayatskaya Str. 67
4. Kazan Federal University, Kazan, Daurskaya, 48v-78, Russia
5. Kazan Federal University Russia, Kazan, Chistopolskaya, 7-54, Russia

** Corresponding author's Email: levira_nn@mail.ru*

ABSTRACT

In this study, the results of changes in the zoobenthos community of Lake Skurcha, the Republic of Abkhazia after hydrotechnical measures for eco-rehabilitation of the reservoir are described. The Lake-Lagoon Skurcha was in adverse ecological condition (there was a shortage of oxygen, fish starvation, low species diversity). During the events, constructing channel from Kodor River, subordinate reservoirs, wetlands, tributaries have been created here to improve the water quality in the lake. The study was carried out on the species composition, abundance and biomass of organisms, indices of species diversity and similarity of zoobenthos in the period from 2009 to 2016. During this period, 56 species of zoobenthos organisms were found (Insects 32, Crustaceans 10, Hirudinea 2, Polychaetes 1, Gastropoda 9 and Bivalvia 2 species). The highest wealth was observed during the inflow period in the first years of the experiment (2011-2012), in conditions of desalination and brackish water. There is no similarity in the species composition of zoobenthos, which indicates a strong transformation of the community. During the influx period, biomass and abundance indicators increased due to insect organisms, then the proportion of brackish-water species upraised. Currently, freshwater and brackish-water species coexist in the lake, with brackish-water species dominating in the composition of zoobenthos. Improvement of water quality and diversity of zoobenthos were revealed after eco-rehabilitation measures.

Keywords: Lagoons, Lakes, Succession, Water restoration, Zoobenthos.
Article type: Research Article.

INTRODUCTION

Skurcha Lake is a reservoir formed on the site of an old quarry for the extraction of sand and gravel materials in a previously swampy area. It is located in the Ochamchira district of Abkhazia on the left bank of Kodor River, at a distance of about 1 km from the river bank. The lake is separated from the sea by a narrow coastal strip with a width of 100 to 200 m (at the narrowest point only 60-70 m). The lake stretches from east to west. From east to west, a narrow long peninsula extends along the lake, a little more than a kilometer long, dividing the eastern half of the lake into two large bays. The width of the peninsula ranges from 15 to 50 m. There are also several small islands on the lake. The reservoir was formed relatively recently, in the second half of the 1980s, after flooding (reclamation) by the waters of Kodor River of a quarry for the extraction of inert materials (sand, gravel and pebbles). Skurcha Lake like hydrochemical water structure similar to Black Sea, for example, the surface layer of water is almost fresh, while the deep layer is brackish. At great depth, there are spots of hydrogen sulfide

contamination. Until recently, the area of hydrogen sulfide contamination was increasing, and this was primarily due to poor water exchange with the nearby sea. There are also some reports about assessment of other organisms in water reservoirs around the world (Derevenskaia *et al.* 2021; Rafiee & Narimani Rad 2023; Razi Rasht Aabadi *et al.* 2023). The necessity to improve the quality of the lake's waters led to the implementation of measures for the hydrotechnical desalination of the lake, the creation of flow rate and the improvement of hydrological communication with the Black Sea.

MATERIALS AND METHODS

Studies of zoobenthos were conducted in the period from 2009 to 2016. Samples were taken in the lagoon (from 6 to 12 samples every season), in a newly-created reservoirs and water channels flowing to the lake. According to quantitative parameters, species and taxonomic diversity of zoobenthos organisms, biotic indices were calculated to assess water quality according to zoobenthos: Shannon species diversity index, Simpson dominance index, Woodiwiss index. To assess the transformation of communities, the Jacquard and Sorensen indices were used. The mathematical processing of the samples was carried out in Microsoft Excel program, space images of the Google Earth program were used for the pictures.

RESULTS

The lake area is at least 140 hectares, the depth reaches 26 m. Until 2011, the lake was characterized by a high content of hydrogen sulfide and brackish water, did not represent fishery value. Hydrometric parameters of the lake: approximate length 2700 - 2800 m, average width 1300 m, maximum depth 16 m, average depth 7-8 m. The water surface of the lake lies about 70 cm below the level of the Black Sea. The area around the lake is flat with slight fluctuations in altitude and a general slope towards the Black Sea. Geologically, this territory is composed of alluvial river and continental, to a lesser extent marine (in the coastal strip) terrigenous deposits of the Quaternary period. Rocks are represented by unsorted terrigenous formations: boulder-pebbles, pebbles, small pebbles, sands, gravel, less often sandy clays and loams in isolated cases of clay on deep horizons (Medvedovsky 2011). The hydrochemical composition of water in the lake depends on the groundwater level, the water level in Kodor River, weather conditions (water and air temperature, precipitation, evaporation, etc.), wave hydraulic backup from the sea, the intensity of agriculture on the lands located at the north of the lake. The water in the lake is sufficiently mineralized - the total mineralization varies within 5-17 g L^{-1}, with a pH from 8.5 on the surface to 7.2 at the bottom. The water in Lake Skurcha contained substances in quantities exceeding the maximum permissible concentrations for fishery waters: Mg (12 maximum permissible standard), Na + K (23.5 MPC), Ca (2 MPC), Cl (24.5 MPC), SO_2 (2.7 MPC; Ecological Passport 2012). Nowadays, after the restoration measures, the lake is of great environmental importance, it is a reservoir rich not only in fish, but also a wintering place for a large number of aquatic and near aquatic birds. It is inhabited by various species of ichthyofaunal, from pike to catfish. Mullet and loban often come through the isthmus connecting the lake with the sea. Lots of ducks, geese, swans are living here. Lake Skurcha at present: the lake is stocked with valuable fish species by the forces of LLC "Company of Non-metallic Materials". The surroundings of the lake are a favorite vacation spot of local residents and guests of the Republic (Ecological Passport 2012).

Hydrotechnical experiment on eco-rehabilitation of Lake Skurcha

Kodor River and Skurcha Lake are located in a common hydraulic system. The lake is located on the first left-bank terrace of the river. The territory is an accumulative plain of quaternary terrigenous deposits. Skurcha Lake is of artificial origin: this is a former quarry for the extraction of inert materials, i.e., a sand-pebble mixture (Dbar & Medvedovsky 2012). The hydrotechnical experiment on Skurcha Lake began in 2011 and continued to date. The essence of the experiment is to revive the estuary - Skurcha Lake. According to surveys of local residents, there was a natural estuary here in the 1990s, but later the extraction of gravel materials deepened greatly, and due to the lack of fresh water and lack of water exchange, it began to be polluted with organic substances. This led to hydrogen sulfide contamination of the lake and oxygen deficiency (Research report 2010). In order to solve the problem of pollution and "revive" the lake, an artificial canal with a length of 380 m was dug to the eastern unnamed arm of Kodor River with a length of 5 km; water began to flow into the lake. Due to the inflow of fresh water in the lake, oxygen appeared in the upper horizons, the lake became more fresh. In 2013, it was decided to deepen the channel between Skurcha Lake and the Black Sea. The channel was deepened from 1.5-2 m to 3 m,

which resulted in the inflow of salt water from the sea and an increase in the salinity of the water (salinization) of the lake. Currently, the lake is brackish. The implementation of this hydrotechnical experiment was one of the elements of the soft regulation of the floodplain and the delta of Kodor River, as well as the natural environment of the lake and its coastal zone. The main network of underwater canyons is concentrated near the cape of Kodor River and Skurcha Lake. These forms are also found at the north of the Kodor River mouth, but their upper reaches are separated from the shore by a wide strip of shallow water. The presence of several small watercourses cutting through the coastal rampart of Kodor Delta, both to the northwest and northeast of the mouth of the river, shows that earlier, perhaps 200-100 years ago, Kodor River flowed into the sea with several arms (Features of formation 1990). The position of the mouth of the main channel also changed, which largely affected the dynamics of the coastal zone. In addition, in accordance with the morphology in the area of the pre-estuarine seashore, using the natural lowering of the relief, the creation of an artificial delta with the presence of small flowing reservoirs was determined (Fishery and land reclamation works 2013). This concept of management of the lower course of Kodor River was defined by the State Committee of Ecology of the Republic of Abkhazia as a guiding concept in the regulation of the riverbed and using inert material of the enterprise "Association of Non-metallic Materials", in addition, the following basic provisions were laid down in it: (i) the creation of an artificial multi-arm delta of the river; (ii) the creation of local flowing reservoirs of fishery and recreational purposes (Lake Akuna, etc.); (iii) increasing the natural productivity of reservoirs of the floodplain of the river. Codor and increase of biotopic diversity as a key ornithological territory; (iv) creation of conditions for the conservation of biodiversity.

The expediency of the soft management concept of Kodori Delta is determined by the need to maintain ecological balance in the river-sea system (Fishery and land reclamation works 2013). The main purpose of creating an artificial multi-arm delta is to divert part of the water in the river during periods of high water and flood, thereby reducing the threat of water breaking through the coastal ramparts towards the settlement. Also, the discharge of water in the main channel provides a weakening of the transporting capacity. These conditions make it possible to reduce the loss of solid runoff into underwater canyons, one of the peaks of which is located opposite the cone of the main channel of Kodor River (Medvedovsky VV 2007; Ekba & Dbar RS 2007; RA State Committee on Ecology and Nature Management 2013). This concept of regulation, adopted by the Ministry of Ecology of the Republic of Abhazia, implemented with the help of Non-Metallic Materials Company LLC, is well combined with the European concept of "Living River". In order to preserve the natural functioning of the river ecosystem, it is necessary to leave (or create in case of violations) the possibility of meandering the river, its subordinate reservoirs, wetlands, tributaries and a vast part of the floodplain. Subordinate reservoirs (floodplain lakes) preserve the gene pool of fauna and flora. The presence of subordinate (floodplain) reservoirs and wetlands enriches the river with hydrobionts during the flood. By 2012, the construction of two regulated flowing reservoirs (Akuna Canal and Akuna Lake) was completed in order to improve the conditions of natural fish farming and create favorable conditions for the habitat of waterfowl, the development of near aquatic vegetation (Fig. 1). On the other side of the lake, in 2012, the channel connecting to the sea was cleared and deepened. During 2013-2016: The period of the passage of water of Kodor River and the opening of a channel connecting the lake with the sea (inflow-outflow lake, connection with Kodor River and the Black Sea; conditions: improvement of oxygen regime, reduction of H_2S content, increased salinity, the appearance of marine species). In the studied Skurcha Lake for the period of 2009-2016, 56 species from among the organisms of zoobenthos were found, belonging to 3 types (Arthropods 42, Annelids 3 and Mollusks 11 species) followed by 6 classes (Insects 32, Crustaceans 10, Hirudinea 2, Polychaeta 1, Gastropoda 9, Bivalvia 2 species). Taxonomically for the period of 2009-2016, 13 detachments, 29 families and 41 genera were identified. Habitat conditions of zoobenthos organisms in Skurcha Lake in various periods were very different:

During 2009-2010: the period of stagnation of the reservoir (non-flowing lake, no connection with Kodor River; conditions: oxygen deficiency, content of H_2S in water bottom, low biodiversity);

During 2011-2012: the period of water supply to Skurcha Lake (tributary lake, connection with Kodor River; conditions: improvement of oxygen regime, reduction of H_2S content, reduction of salinity, appearance of new species of organisms);

From the 56 discovered species, most of the groups were represented by: Diptera 9 (16%), Dragonflies 10 (18%), Crustacea 6 (11%), Bugs 8 (14%), Gastropods 9 (16%) species. The following groups of zoobenthos organisms were less common: the order Megaloptera 1 (2%), Coleoptera 2 (4%), Bivalves 2 (4%), Plecoptera 1 (2%), Decapods 4 (7%), Hirudinea 2 species (4%), Ephemeroptera 1 species (2%), Polychaete 1 species (2%). The

distribution of species changed through years (Table 1). As the communities of Skurcha Lake were stabilized, the proportion of brackish-water species of zoobenthos was elevated, while the species richness of freshwater species decreased (Fig. 2). The highest richness was noted during the inflow period in the first years of the experiment (2011-2012), under conditions of desalination and brackish water.

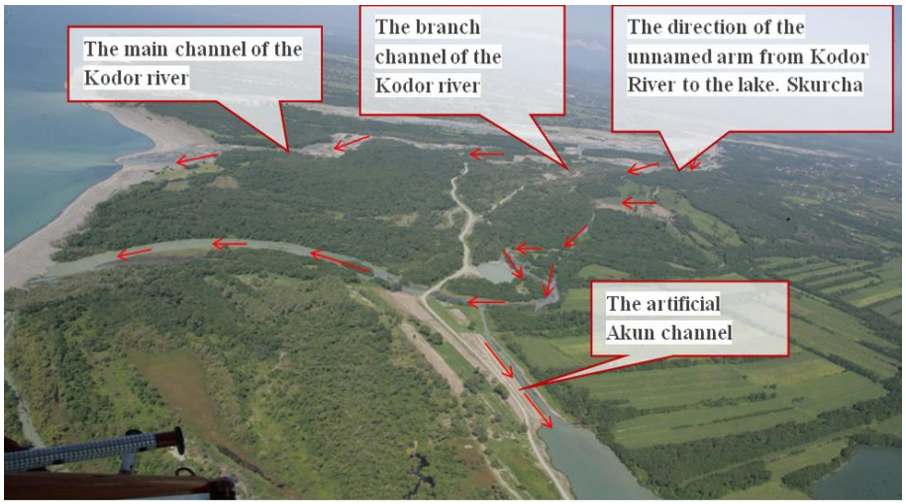
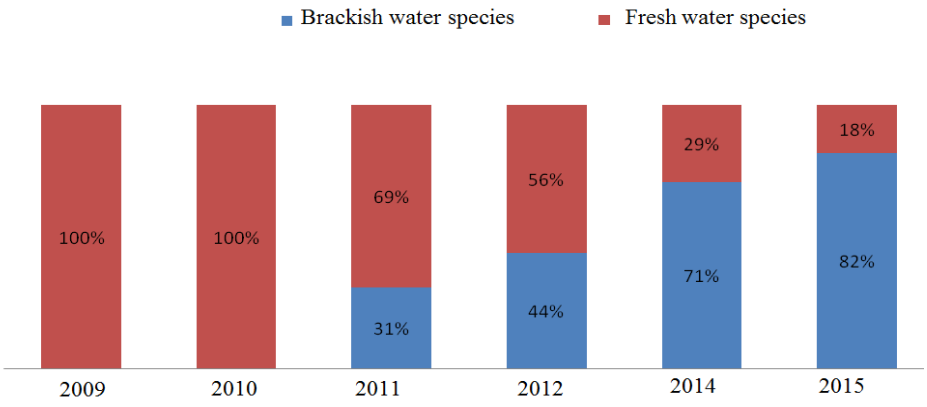


Fig.1. Aerial view of the estuarine coast of the Kodor River (materials of the Ministry of Ecology of the Republic of Abkhazia).

Table 1. The occurrence of zoobenthos species for Skurcha Lake by year (with indication of taxon)

Taxons / Periods	Types	Classes	Orders	Families	Genera	Species
2009-2010 – the period of stagnation	2	3	4	4	7	8
2011-2012 - the period of accuracy	2	4	10	21	26	28
2013-2016 - the period of communication with the Kodor River and the sea	3	5	10	19	22	24
For all years	3	6	13	29	41	56



Note: 2009-2010: The period of stagnation of the reservoir (non-flowing lake, no connection with the Kodor river).
2011-2012 - the period of water supply to the lake. Skurcha (flowing lake, connection with Kodor River and weak flow into the sea).
2013-2015: the period of the passage of the Kodor River water and the opening of the channel connecting the lake with the sea (inflow-outflow lake, connection to Kodor River and the Black Sea).

Fig. 2. Characteristics of zoobenthos species of the Kodori-Skurcha system by salinity for 2009-2015.

In the studied newly created water bodies (Kodor River, Akuna Canal, Lake Akuna-1) for the period of 2009-2016, 48 species from among the organisms of zoobenthos were found, belonging to 3 types (Arthropods 42, Annelids 4, Mollusks 2 species) and 5 classes (Insects 41, Crustacea 1, Hirudinea 2, Polichaeta 2, Gastropods 2 species). The largest average number of zoobenthos organisms was recorded in 2009 in Skurcha Lake (1122 examples/m^2). High abundance values were achieved due to the Chironomids *Pseudodiamesa gr. nivosa* (Goetghebuer, 1928) (475 examples/m^2). High values were also observed in Skurcha Lake in 2014 (9.6 examples/m^2). The following dominant groups were identified: insects (marked in 4 stations), Heteroptera (in 4 stations). Rare groups were Amphipoda, Molluska, Brachyura, Ephemeroptera. The largest average biomass in 2014 was recorded on the lake. Skurcha, due to a large individual Brachyura *Potamon tauricum* (Czerniavsky, 1884) Brachyura, Insecta and Heteroptera made the greatest contribution to the biomass in the studied lake Skurcha at the stations. During the experiment, the quantitative indicators changed: during the influx period, the indicators of biomass and abundance increased due to insect organisms. By the deepening of the channel connecting the lake to the sea, the number and biomass of brackish-water crustaceans were elevated, with insects dominating. During assessing the biotic indices of species diversity, alterations in values for different stations were revealed. In 2012, the highest index values were revealed in Kodor River (Simpson index 0.65; Shannon index 1.28; Woodiwiss index 6; Hmax 2). In Lake Akun-1, the highest values (Simpson index 0.85; Shannon 2.92; Woodiwiss 6; Hmax 3.17) and in Akun Channel (Simpson index 0.77; Shannon index 2.39; Woodiwiss index 6, Hmax 3) were revealed in 2015. As a result of sustainability of the community and the degree of contamination research by zoobenthos indicators using biotic indices, it was revealed that in 2012 the water in Akun Canal was very polluted, and the communities were unstable. In 2013, communities the Akun Canal were stabilized in some areas, communities remained unstable at the confluence with the lake and the water was classified as moderately polluted - dirty waters. To assess the transformation of the community, the Jacquard and Sorensen indices were used (Tables 2-3). Tables reflect the index of species similarity of Jacquard and Sorensen. It is shown that there is no similarity between the years, indicating a strong transformation of the community during the studied periods.

Table 2. The index of the species similarity of the Jacquard in Skurcha Lake.

Years	2009	2010	2011	2012	2014	2015
2010	0	-	0.04	0	0	0
2011	0	0.04	-	0.07	0	0.05
2012	0	0	0.07	-	0.04	0.03
2014	0	0	0	0.04	-	0.13
2015	0	0	0.1	0.04	0.2	-

Table 3. Sorensen Species Similarity Index.

Years	2009	2010	2011	2012	2014	2015
2009	-	0	0	0	0	0
2010	0	-	0.08	0	0	0
2011	0	0.08	-	0.13	0	0.11
2012	0	0	0.13	-	0.09	0.06
2014	0	0	0	0.09	-	0.24
2015	0	0	0.11	0.07	0.3	-

DISCUSSION

There is a strong process of transformation of benthic fauna in Skurcha Lake as a result of the action of two measures:

1) The passage of the waters of Kodor River for the purpose of desalination (since November 2011 and continues to date) led to a drop in electrical conductivity, saturation of the bottom layers with oxygen, and a decline in the content of hydrogen sulfide;

2) The entry of the Black Sea waters during the deepening of the channel connecting the lake to the sea (since 2013). In 2013, the channel connecting Skurcha Lake in its eastern part to the Black Sea was significantly deepened and expanded. In 2009, the depth of the channel was small, 1.5-2 m, and there was no entry of seawater in a large volume. In 2013, after deepening, it was higher than 3 m. The entry of seawater and backwater led to the stratification of the lake, an upraise in the mineralization of the bottom layers. The influx of seawater into the

lake has changed the species composition of benthos and water quality. The strong transformation of benthos is also confirmed by the fact of the mass death of the freshwater crab *Potamon tauricum* (Czerniavsky, 1884) in 2013. After the arrival of the salty waters of the Black Sea, the nature of water exchange altered, the salinity of the bottom layers of water increased, and conditions for the habitat of euryhaline species of zoobenthos were appeared, leading to the displacement of freshwater fauna. Due to the stratification of waters, conditions for the joint existence of biotopes with different salinity indices were created in the lake, leading to the coexistence of hydrobionts living in different environmental conditions in one ecosystem.

CONCLUSION

1. As a result of the hydrotechnical experiment, a decrease in the concentration of hydrogen sulfide in the bottom layer was observed, the oxygen content upraised and the temperature regime changed, which subsequently leads to an elevation in the species diversity of hydrobionts.
2. The mineralization of the Kodora, the canal and Akuna Lake ranged around 100 mg L^{-1} allowing us to determine the water in these water bodies as poorly mineralized and attribute it to fresh water types. The water in Skurcha Lake increased mineralization to the level of 1929 mg L^{-1} at the bottom layers of water.
3. Two types of waters were distinguished in the composition of the Kodor-Skurcha system water: bicarbonate-calcium (Kodor River, Akuna Canal and Lake Akuna) and sodium chloride (Skurcha Lake).
4. In Skurcha Lake in the period of 2009-2016, 56 species among the organisms of zoobenthos were found, belonging to 6 classes: Insects, Higher crayfish (crustaceans), Leeches, Polychaete worms (polychaetes), Gastropods, Bivalves.
5. The consequence of the events was a strong transformation of zoobenthos communities during the studied periods. When creating a channel diverting water from Kodor River, the proportion of freshwater species was elevated. After the arrival of the sea waters of the Black Sea, the freshwater community was replaced by brackish-water species of zoobenthos. Currently, freshwater and brackish-water species coexist in the lake, with brackish-water species dominating in the composition of zoobenthos.

ACKNOWLEDGMENTS

This paper has been supported by the Kazan Federal University Strategic Academic Leadership Program. The authors express their gratitude to the staff of the Institute of Ecology of the Abkhazian Academy of Sciences, colleagues from the Department of Environmental Management and Water Use for their assistance in organizing research.

REFERENCES

Dbar RS & Medvedovsky VV 2012, Problems and prospects of lake arrangement. Skurcha. Sat. Construction in coastal resort regions. Materials of the 7th International Scientific and Practical Conference in Sochi on May pp. 14-19.

Derevenskaia, OI, Borisova, NI & Unkovskaia, EN 2021, Zooplankton indices in the evaluation of the ecological state of the eutrophic lake (Case study: Karasikha Lake, Russia). *Caspian Journal of Environmental Sciences*, 19: 701-708

Ecological Passport of the Reservoir 2012, Lake Skurcha. RA State Committee for Ecology and Nature Management, Sukhum, 7 p.

Ekba, YaA & Dbar RS 2007, Ecological climatology and natural landscapes of Abkhazia. Sochi: "Papyrus-M-Design", 324 p.

KFU 2011, Research report: Hydrobiological study of the water bodies of Abkhazia (based on the results of the Russian-Abkhazian expedition in 2010). Kazan, 2011, 99 p.

Keonjian VP *et al.* 1990, Features of formation and the current state of the shores of the eastern part of the Black Sea. Practical Ecology of Marine Regions: The Black Sea, Kiev, Naukova dumka.

Medvedovsky VV 2007, Influence of changes in anthropogenic load on the nature of the stability of the ecological system coast-sea on the example of the coast of Abkhazia. Collection: Reports of the jubilee international conference in honor of the 75th anniversary of the OEU (OGMI). Odessa.

Medvedovsky VV 2011, Engineering note on the survey of the surroundings of the lake. Skurcha. Foundation of the Hydrophysical Institute of ANA. 2011 Sukhum.

Rafiee, G & Narimani Rad, F 2023, Assessment of three Different Recirculating Tilapia Culture Systems Using Biological Filters and Mineral Nutrient. *Aquatic Animals Nutrition*, Vol. 9, No. 1, pp: 63-75.

Razi Rasht Aabadi, A, Imanpour Namin, J, Sattari, M 2023, Species diversity of macrobenthos as live food in the ecosystem of Fusheh River, Northern Iran. *Aquatic Animals Nutrition*, Vol. 9, No. 2, pp: 9-24.

RA State Committee on Ecology and Nature Management 2013, Fishery and land reclamation works in the floodplain of the Kodor River and on the Lake Skurcha. Sukhum, 10 p.