Application of ecosystem service value assessment of water bodies in the development of future plans for the use of aquatic bioresources using the example of water bodies in the Ile-Balkhash basin

Yevgeniy Kulikov, Natalia Sadyrbayeva, Askhat Mamyshov, Kuanysh Isbekov

Fisheries Research and Production Center, Almaty, Kazakhstan. Corresponding author: Y. Kulikov, e.v.kulikov.61@mail.ru

Abstract. The current research considers possibilities of applying the assessment of the value of aquatic biological resources, natural capital and ecosystem services of a number of water bodies in the Ile-Balkhash water basin, when planning water management and fishery measures. The aim of the study was the assessment of the value of aquatic biological resources and ecosystem services of water bodies in the Ile-Balkhash water basin to identify ways of rational use of aquatic biological resources. The research objects are ecosystems and fish resources of Kapshagay reservoir, Balkhash Lake, the Ile River Delta. Balkhash Lake, the Ile River Delta and Kapshagay reservoir have the largest fish stocks among the inland water bodies of Kazakhstan: the total fish catch makes about 20% of the total annual fish production in the country. The value of biological resources, natural capital and a number of ecosystem services of water bodies is assessed. On this basis, conclusions are made about the prospects of fishery use of water bodies in terms of fishing and protection of aquatic bioresources.

Key Words: fish stock, fishery resources, natural capital, water regulation, ecosystem services.

Introduction. In environmental management in Kazakhstan, cost estimates of biological resources are so far used only to assess the potential of water bodies when planning the creation of protected areas on them (Van Zyl 2021). The application of methods for assessing the value of ecosystem services for fishing reservoirs in the Republic of Kazakhstan has not been implemented for any reservoir. Ecosystem services are the many and varied benefits that people receive freely from the natural environment and from functioning ecosystems (Tallis et al 2024). Ecosystem services can also be divided into use values and non-use values according to the concept of Total Economic Value (Dushin & Yurak 2018). Ghermandi (2011) stated that «The economic valuation of ecosystem services can proceed in different ways: using market price information or eliciting consumer preferences through a wide range of nonmarket valuation methods». The economic value of commodities produced by agroecosystems is well understood (Dominati et al 2014). However, there are very few estimates of ecosystem services for freshwater lakes and reservoirs. We see this in the generally accepted assessment of Costanza et al (2014). Freshwater food production is underestimated globally. The highest degree of direct use of natural capital is in water bodies exploited for commercial fishing, which we show in our study. For practical use, a detailed valuation of ecosystem services for the main product of environmental management is necessary. In most fishing waters this will be fish (fish products).

The real assessment of the value of aquatic biological resources and their role in the functioning of the ecosystem and in the provision of vital needs of the population in Kazakhstan is a topic rarely studied. Economic assessment of ecosystem services, as a new direction of determining the value of natural potential in monetary terms, becomes a real mechanism of justifying the various measures of nature management and of improving the efficiency of nature protection works, on the basis of specific amounts.

The objects of research are the ecosystems and fish resources of the Kapshagay reservoir, Lake Balkhash, and the delta of the Ile River in the Republic of Kazakhstan. The purpose of the work is to assess the cost of aquatic biological resources and ecosystem services of water bodies using the example of the Balkash-Ili water basin to determine ways for the rational use of aquatic biological resources. Balkhash Lake, the Ile River Delta and Kapshagay reservoir have the largest fish stocks among the inland water bodies of Kazakhstan, the total fish catch is about 20% of the total annual fish production in the country.

Material and Method

Description of the study sites. The Ile-Balkhash water basin (Figure 1) is one of the largest lake ecosystems in Central Asia. Being a transboundary basin, it is of great interest for the neighboring countries both from a scientific and economic points of view. The largest water body of the basin, the Balkhash Lake belongs to the category of drainless closed reservoirs. The area of its water surface is more than 18 thousand km^2. Its existence fully depends on the water inflow by rivers. The Ile-Balkhash basin consists of the drainless Balkhash Lake and the Ile River feeding it. In addition to the Ile River, several other watercourses flow into Balkhash Lake, but they are all significantly inferior to the Ile River, in terms of power. The main share of water inflow into Balkhash Lake belongs to the Ile River (on average, 78-80%). At the same time, a significant part of the river flowing downstream of the Kapshagay reservoir is spent annually for drawings and replenishment of the delta lakes. Over the past 10 years, the largest volume of water inflow (26.5 km^3) into the lake was observed in 2016. Balkhash Lake is the largest freshwater reservoir of Kazakhstan, being the end reservoir of the basin, whose water level strongly depends on the water consumption from the feeding river Ile, both on the territory of Kazakhstan and on the territory of the People's Republic of China.

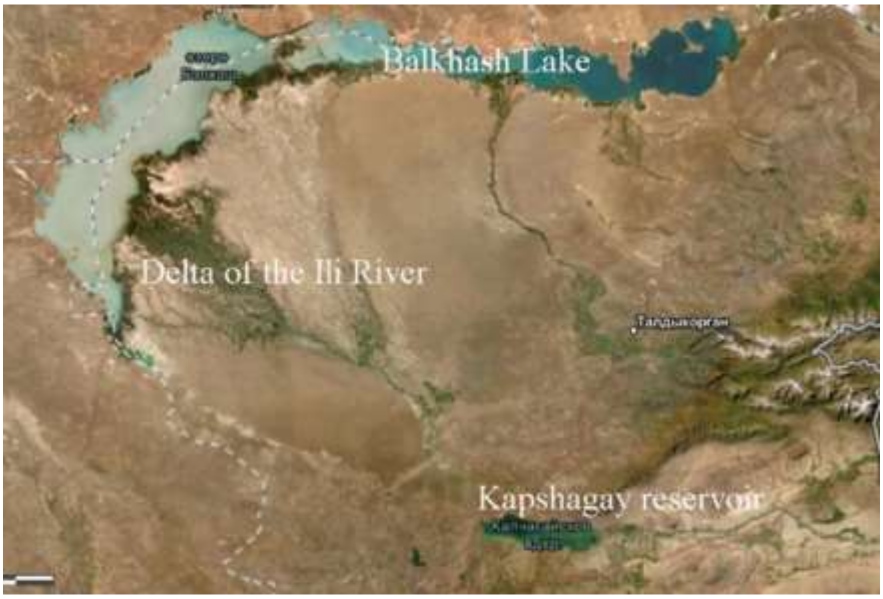

Figure 1. Ile-Balkhash basin water bodies' location.

When flowing into Balkhash Lake, the Ile River splits into a number of channels and lake systems, forming an extensive delta. The Ile River (the catchment area is 140 thousand km^2, within Kazakhstan - 77.4 thousand km^2), collecting 78.0% of the volume of surface runoff in the basin, plays a determining role in the hydrological and hydrochemical regime of the Balkhash Lake. In addition, its vast delta and the river channel itself are spawning grounds for migratory and semi-anadromous fish (Figure 2). The apex of the delta is located at 130 km (along the channels) from the Balkhash Lake. The present delta is formed by three main channels: Topar, Ile, and Zhideli. In total, the channels in the Ile Delta form six lake systems. Catfish, carp, pike-perch and other fish spawn in the delta's water bodies.

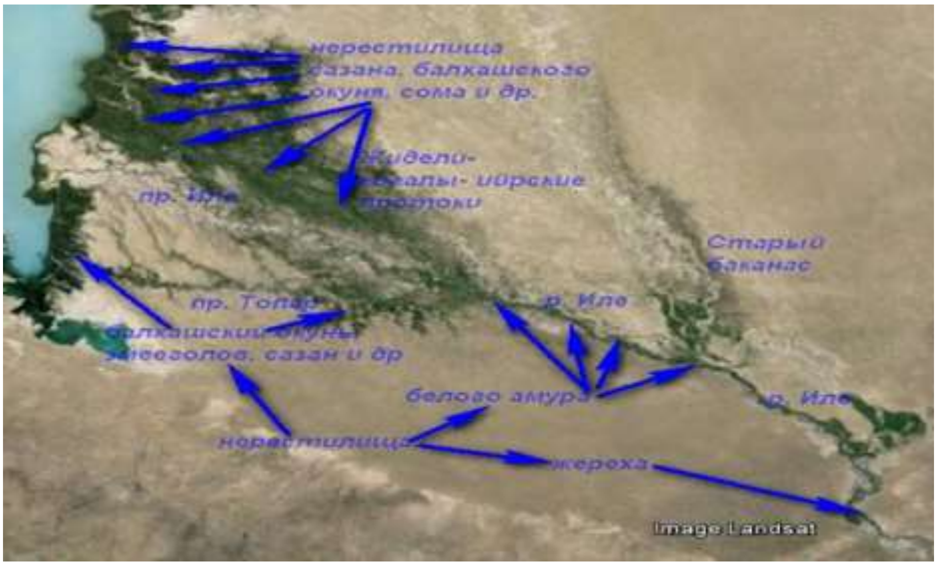

Figure 2. Lower reaches of the Ile River and its present-day delta (arrows show fish spawning grounds).

Counting of the number and biomass of commercial fish stock was performed according to the generally accepted methods in the post-Soviet area (Pravdin 1966; Chugunova 1952; Nikolsky 1974; Babayan 2000; Malkin 1999), with the own developments of the authors of this work (Kulikov et al 2016) and of western scientists (FAO Technical Guidelines for Responsible Fisheries 2010; FAO 2006; Methot & Wetzel 2013). For the value estimation of biological resources, the market prices, trates of payment for the use of wildlife and internationally recognized prices are used. The "ArcGIS-online" program and the web application "Fishery and protection of fish stocks", developed by the LLP "Fisheries Research and Production Center", were used to link the data to the geographical location. When estimating the value of ecosystem services, recognized world estimates (Costanza et al 1997,2014) and the authors' own calculations based on the prices of water and fish in different regions of Kazakhstan were used. A total of 64 indicators of the quantitative assessment of biological resources and 120 indicators of the price evaluation of biological resources were used.

One of the first estimates of the value of different types of natural ecosystems on the planet was made by an international group of experts in 1997 (Costanza et al 1997). For this purpose, the value of the volume of ecosystem services per unit area of various biomes was calculated. In 2014, these estimates were repeated and refined (Costanza et al 2014). Many authors (Watson et al 2022; Xie et al 2017), including those in the Russian-language literature (Shirkov 2010; Rosenberg 2014; Lukyanova et al 2016), use or refer to these averaged estimates. It should be noted that this is not an original study, but a generalization of several dozens of results from studies around the world. Lakes and rivers in this study (2014) rank intermediate between deserts/tundra (0 USD ha^{-1} $year^{-1}$) and coral reefs (352 thousand USD ha^{-1} $year^{-1}$) and at the level of forests (3-5 thousand USD ha^{-1} $year^{-1}$) in terms of ecosystem service value (4,267 USD ha^{-1} $year^{-1}$). This is an objective estimate. However, the assessment of the value of certain types of ecosystem services is questionable. In our opinion, water regulation, water supply and purification (918-7514 USD ha^{-1} $year^{-1}$) are somewhat overestimated, while food production (106 USD ha^{-1} $year^{-1}$) on a global scale is underestimated, and the role of freshwater bodies as refugia is not assessed at all. Costanza himself acknowledged that while the concepts of natural capital and ecosystem services have been broadly accepted, practical applications are still limited (Costanza 2020). In our work we show the possible application of value estimates of a number of ecosystem services to determine the options for the development of territories.

Some of the terms and definitions used in the assessment were reviewed as follows. The natural capital comprises all elements of the natural resource potential (in the reproduction of which there is an objective need of society), bringing an ecological and economic effect and contributing to the increase of national wealth over a long period of time (Neverov & Derevyago 2005). R. Constanza and G. Daly define natural capital as a stock, which is the source of the flow of natural services and real natural resources (Costanza & Daly 1992).

A refugium (Latin *refúgium* - refuge) is an area of the Earth's surface or the World Ocean where a species or group of species survived or has survived an unfavorable period of geological time, during which these life forms disappeared over large areas. It is assumed that the species not only may persist in the refugium, but may subsequently spread out again from it over a wider area (understood here in terms of refuge for the conservation of endemic fish species) (Coyne & Orr 2004). The water supply is the volume of surface or groundwater provided to consumers in the required amount and in accordance with the target indicators of water quality in water bodies. The useful volume of the reservoir is the part of the full volume of the reservoir which serves to regulate the flow, to ensure the mandatory releases of water into the tailrace of the reservoir and to ensure the required drawing. The fish stock is the part of total biomass of fish population which has reached sexual maturity and is used for commercial and recreational fisheries. Biological regulation is a process of trophic-dynamic regulation of populations.

Ecosystem services are defined as the benefits to the population and businesses derived from the use of ecosystems. Natural resources valuation is the foundation of a more reasonable determination of the economic efficiency of development alternatives and can significantly influence the choice of a development option. In this study, only those types of ecosystem services of water bodies that fall within the competence of the research institute in the field of fisheries and can be counted are estimated. Of course, all the services provided by a particular ecosystem are important in human terms. But in order to develop science-based recommendations for their sustainable use, it is often important to evaluate the contribution of individual components in order to make some gradation in the value of particular types of ecosystem services.

In this case study, the water system consists of a river flowing into a lake. The river is regulated by a dam and an artificial reservoir is created. Each of these reservoirs has fish stocks, but the lake has more fish than the reservoir. At the same time, water reserves in the reservoir allow regulating the water supply to sectors of economy and population. Then, the main ecosystem service of the reservoir will be water regulation, and the ecosystem service of the lake will be of providing the population with food (fish). When implementing water management projects, in the choice of conservation of fish stocks in certain parts of the basin, the priority should be given to the lake.

Calculation of the value of aquatic biological resources in the studied water bodies was made on the basis of a quantitative assessment of the commercial stock of fishery objects (fish) during the period of field studies in the water bodies, namely in March-September 2021, and data on internationally recognized prices for fish were extractedfrom the technical report "Implementation of fisheries and aquaculture potential in Kazakhstan" (prepared under the Joint FAO/World Bank program) (FAO-World Bank Cooperation Program 2021). The wholesale price of 1 ton of raw fish from producers was taken as the basis. Cost estimates of biological resources, natural capital and ecosystem services in this paper are given in USD.

Results and Discussion

The economic assessment of the natural resource potential of water bodies is determined by summing up the environmental and economic value of certain types of natural resources, as natural capital. Tables 1-4 provide data on the cost of aquatic biological resources, on the natural capital as a whole, and on individual types of ecosystem services of Balkhash Lake. Despite the high biomass of bream in the lake, its products have a low cost, while the biomass of catfish and pike perch is 9-11 times lower, and its cost is higher. The used part of biological resources makes up a quarter of the total commercial stock. Water reserves constitute the main part of the natural capital of the lake, but the cost of aquatic biological resources is in second place.

Table 1

Assessment of the cost of aquatic bioresources in Balkhash Lake

Type of bioresource (commercial object)	*Quantitative assessment of bioresource (commercial stock, tons)*	*Cost of the bioresource (USD ton^{-1})*	*Total cost of bioresource in the reservoir (million USD)*
Carp *(Cyprinus carpio)*	1,554	690	1.072
Bream *(Abramis brama)*	21,938	80	1.755
Asp *(Aspius aspius)*	1,292	575	0.743
Roach *(Rutilus rutilus)*	942	230	0.217
Crucian carp *(Carassius gibelio)*	441	69	0.03
Catfish *(Silurus glanis)*	1,889.5	1035	1.956
Pike perch *(Sander lucioperca)*	2,559	1495	3.826
Bersh *(Sander volgensis)*	554	690	0.382
Snakehead *(Channa argus)*	306	575	0.176
Total	31,475.5	-	10.157

Table 2

Used part of the bioresource in Balkhash Lake

Type of bioresource (commercial object)	*Annual limit (tons)*	*Price (USD ton^{-1})*	*Cost (million USD)*
Carp *(Cyprinus carpio)*	372	690	0.257
Bream *(Abramis brama)*	5,847	80	0.468
Asp *(Aspius aspius)*	285	575	0.164
Roach *(Rutilus rutilus)*	329	230	0.076
Crucian carp *(Carassius gibelio)*	159	69	0.011
Catfish *(Silurus glanis)*	352	1035	0.364
Pike perch *(Sander lucioperca)*	677	1495	1.012
Bersh *(Sander volgensis)*	120	690	0.083
Snakehead *(Channa argus)*	130	575	0.075
Total	8,271	-	2.51

Table 3

Assessment of the natural capital of Balkash Lake, mln USD

Water reserves	*Refugia*	*Cost of aquatic biological resources*	*Genetic resources*	*Total*
80.36	-	10.16	4.65	95.17

The mineralization of water reserves in Balkhash Lake in 2021 changed in the latitudinal direction from southwest to east from 1303 mg dm^{-3} to 6067 mg dm^{-3}. The water of the lake is not suitable for human drinking, but it is used for watering animals throughout the water area. The volume of water in the lake is 113.5 * 109 m^3 and multiplied by the cost of technical water in this region, 0.0007 USD m^{-3}, results in the total water capital value, as natural capital (primary data obtained through questionnaires addressed to water supply organizations).

Concerning the refugia, all endemics of Balkhash Lake (Balkhash perch, *Perca schrenkii* Kessler, 1874; Ili marinka *Schizothorax pseudaksaiensis* Herzenstein 1889) have been displaced into an adnexal system by the acclimatizers. Related to the genetic resources, since there is no available estimate for lakes, we use the estimate for forest, 16 USD ha^{-1} per year (Costanza et al 1997) times the area of the lake in ha. Balkhash perch is endemic to Balkhash Lake. Its number is unknown, but in recent years it has become more common in the coastal zone of Eastern Balkhash. The area of the littoral zone of the eastern part of the reservoir is 292,500 ha.

Table 4

Assessment of the cost of ecosystem services of Balkhash Lake, million USD $year^{-1}$

Water supply	*Biological regulation*	*Food production*	*Rest*	*Total*
0.14	13,556	2,510.3	2,510.3	18.577

Balkhash Lake is the end reservoir of the system and does not participate in the water regulation and water distribution services. Concerning the water supply service, the water of the lake is not suitable for drinking. Water up to 2 mg dm^{-1} is suitable for irrigation and technical needs. These indicators include the water of the Western Balkhash, the volume of which is 53.3 km^3. The cost of 1 m^3 of water for technical needs is on average 0.0007 USD m^{-3}, the consumption is 164 million m^3 $year^{-1}$. Actual water consumption consists of the costs of irrigation and of the technical needs of enterprises. The cost of 1 m^3 of water for irrigation is 0.045 USD (response to a request addressed to the "Balkhash Su" enterprise), while the consumption for irrigation in 2021 amounted to 464 thousand m^3. The water treatment service was not evaluated. The cost of the service of trophic-dynamic regulation of populations is estimated at 7 USD ha^{-1} per year (for coastal ecosystems, according to Costanza et al 2014), multiplied by the area of the lake in ha. The refugia service was not calculated, since at present all native fish species and endemics have been displaced by acclimatizers into the adnexal system, which is the refugium, as previously stated. The food production service is evaluated as the annual fish catch limit in tonsmultiplied by the price of raw fish. The genetic resources service was not valued, since Balkhash perch is included in the Red Book and is not subject to catching. The recreational services was based on the following data: in 2021, 50,489 people visited the Balkhash city, while the volume of tourist services amounted to 0.975 million USD (questionnaire addressed to the "Department of Entrepreneurship and Agriculture of the city of Balkhash"), and to an average of 19.3 USD per person. According to statistics, 130,000 people visit Balkhash Lake a year (www.finreview.info). Thus, from the information processed it results that the supplying service for the provision of food (fish) is one of the main services in the structure of ecosystem services and in the system of natural capital management. The Balkhash Lake must be preserved and used as a fishing pond.

Tables 5-8 present data on the value of aquatic biological resources, natural capital in general, and individual types of ecosystem services in the Ile River Delta.

Table 5

Assessment of the cost of aquatic biological resources in the reservoirs of the Ile River Delta

Type of bioresource (commercial object)	*Quantitative assessment of the bioresource (commercial stock, tons)*	*Cost of the bioresource (USD ton^{-1})*	*Total cost of the bioresource in the reservoir (USD)*
Grass carp *(Ctenopharyngodon idella)*	23.15	1,609	37,248
Carp *(Cyprinus carpio)*	121.8	690	84,042
Bream *(Abramis brama)*	23.66	103	2,437
Asp *(Aspius aspius)*	62.61	506	31,681
Roach *(Rutilus rutilus)*	61.40	200	12,280
Crucian carp *(Carassius gibelio)*	46.03	80	3,682
Catfish *(Silurus glanis)*	70.25	1034	72,639
Pike perch *(Sander lucioperca)*	43.97	1609	70,748
Bersh *(Sander volgensis)*	56.25	690	24,469
Snakehead *(Channa argus)*	41.44	575	23,828
Total	550.56	-	363,054

Table 6

Used part of the bioresource in the Ile River Delta reservoirs

Type of bioresource (commercial object)	*Annual limit (tons)*	*Price (USD ton^{-1})*	*Cost (USD)*
Grass carp *(Ctenopharyngodon idella)*	4.30	1,609	6,920
Carp *(Cyprinus carpio)*	25.22	690	17,393
Bream *(Abramis brama)*	7.36	103	761
Asp *(Aspius aspius)*	12.96	506	6,554
Roach *(Rutilus rutilus)*	19.10	200	3,821
Crucian carp *(Carassius gibelio)*	14.32	80	1,151
Catfish *(Silurus glanis)*	13.06	1034	13,510
Pike perch *(Sander lucioperca)*	9.10	1609	14,644
Bersh *(Sander volgensis)*	17.50	690	12,069
Snakehead *(Channa argus)*	12.89	575	7,409
Total	135.81	-	84,232

Table 7

Assessment of the natural capital of the Ile River Delta, USD

Water reserves	*Cost of aquatic biological resources*	*Genetic resources*	*Total*
3,506	377.0	8,848	12,731

Table 8

Assessment of the cost of ecosystem services in the Ile River Delta, USD

Water regulation	*Water supply*	*Bioregulation*	*Refugia*	*Food production*	*Recreation*	*Total*
-	2,366	84,731	219,425	0,085	1931	308,538

The water reserves' value calculation results from the volume of water reserves, of 2.31 km^3, multiplied by the cost of technical water in the region 0.0015 USD m^{-3}. The water supply value calculation results from the total water consumption in the Ile Basin, estimated at 2.8 km^3 (of which about 0.5 km^3 is directly from the reservoirs of the Ile River Delta), multiplied by the price of irrigation water distributed through canals, which is 0.0047 USD m^{-3} (https://www.inform.kz/ru). The value of water regulation is undetermined, since the delta has no independent significance in the water regulation of the river delta basin. The biological regulation value of the Ile River Delta is the product of water body area and the cost of the bioregulation service (for wetlands), meaning 90,000 ha times 948 USD ha^{-1} (Costanza et al 2014).

Related to the refugia, the Ile Delta is a wetland. Thus, the water bodies of the Ile River Delta should be considered a refugium, the value of which is defined as the product of the area of the water body and the cost of the ecosystem service (for wetlands) of 90,000 ha multiplied by 2,455 USD ha^{-1} (Costanza et al 2014). Concerning the food production, in 2022, the annual limit in the Ile River Delta is estimated at 135.81 tons of fish, with a total value of 84.2 thousand USD. The value of the genetic resources for the water bodies of the Ile River Delta is the product of the area of the water body and the service cost (for wetlands), meaning 90,000 ha multiplied by 99 USD ha^{-1} (Costanza et al 2014). Concerning the recreation and tourism, about 40,000 tourists a year unofficially visit the Ile River Delta, at a cost of about 16 USD per tourist, for 3 days a year. Thus, the ecosystem services of providing shelter for rare endemic fish species and of bioregulation provision in the form of breeding grounds for vulnerable commercial fish species of Balkhash Lake are the main ones in the structure of ecosystem services of the Ile River Delta, therefore, it is recommended to partially remove the delta water bodies from human economic activity.

Tables 9-12 present data on the cost of aquatic biological resources, natural capital in general and certain types of ecosystem services of the Kapshagay reservoir.

Table 9

Assessment of the cost of bioresources in the Kapshagay reservoir

Type of bioresource (commercial object)	*Qualitative assessment of the bioresource (commercial stock, tons)*	*Cost of the bioresource (USD ton^{-1})*	*Total cost of the bioresource (million USD)*
Bream *(Abramis brama)*	2896.8	218	0.63
Pike perch *(Sander lucioperca)*	263.0	966	0.254
Catfish *(Silurus glanis)*	172.4	529	0.091
Carp *(Cyprinus carpio)*	155.1	621	0.096
Silver carp *(Hypophthalmichthys molitrix)*	249.0	575	0.143
Asp *(Aspius aspius)*	187.7	345	0.065
Grass carp *(Ctenopharyngodon idella)*	91.7	667	0.062
Roach *(Rutilus rutilus)*	245.4	92	0.023
Crucian carp *(Carassius gibelio)*	72.0	92	0.007
Snakehead *(Channa argus)*	46.4	414	0.019
Total	4379.5	-	1.39

Table 10

Used part of the bioresource in the Kapshagay reservoir

Type of bioresource (commercial object)	*Annual limit (tons)*	*Price (USD ton^{-1})*	*Cost (million USD)*
Bream *(Abramis brama)*	724.2	218	0.158
Pike perch *(Sander lucioperca)*	61.5	966	0.059
Catfish *(Silurus glanis)*	46.8	529	0.025
Carp *(Cyprinus carpio)*	40.4	621	0.025
Silver carp *(Hypophthalmichthys molitrix)*	38.9	575	0.022
Asp *(Aspius aspius)*	41.3	345	0.014
Grass carp *(Ctenopharyngodon idella)*	21.5	667	0.014
Roach *(Rutilus rutilus)*	76.8	92	0.007
Crucian carp *(Carassius gibelio)*	23.3	92	0.002
Snakehead *(Channa argus)*	46.4	414	0.019
Total	1121.1	-	0.306

Table 11

Assessment of the cost of natural capital of the Kashagay reservoir, million USD

Water reserves	*Refugia*	*Cost of aquatic biological resources*	*Genetic resources*	*Total*
22	no	1.39	no	23.39

Table 12

Assessment of the cost of ecosystem services of the Kapshagay reservoir, million USD

Water regulation	*Water supply*	*Bioregulation*	*Refugia*	*Food production*	*Genetic resources*	*Restoration and tourism*	*Total*
10.07	4.73	1.29	no	0.35	no	12.07	28.51

Since the Kapshagay reservoir is an artificial reservoir, the value of its natural capital is less than the value of its ecosystem services. Concerning the water reserves value, the volume of water is 14.5 km^3 multiplied by the cost of technical water in this region 0.0015 USD m^{-3} (https://www.inform.kz/ru). Related to the water supply, the water from the Kapshagay reservoir is used for various needs, both drinking and technical. Initially, this is technical water that needs to be cleaned. The total water consumption in the Ile basin is estimated at 2.8 km^3, of which about 1.0 km^3 directly from the Kapshagay reservoir. The price of irrigation water through canals is 0.047 USD m^{-3} (https://www.inform.kz/ru). Concerning the water regulation, the useful volume of the reservoir is 6.64 km^3 multiplied by the cost of water for technical needs 0.015 USD m^{-3}. This water body is not a refugium, as native valuable rare fish species have been displaced from it by acclimatizers and invasive species. The bioregulation value is the product of the area of the reservoir and the cost of the service (for coastal ecosystems according to Costanza et al 2014), meaning 184,700 ha multiplied by 7 USD ha^{-1}. The recreation and tourism services refer to ecological tourism, sport fishing and other recreational activities in nature. In 2021, Kapshagay was visited by 250 thousand tourists, according to the Almaty Region Tourism Department, and the cost per tourist was about 16 USD per day, for an average of 3 days per year. Thus, water regulation in the Ile River basin and water supply (apart from energy supply, which is not assessed in the current study) are the main ecosystem services of the Kapshagay reservoir.

Conclusions. Ecosystem services are defined as the benefits to population and businesses derived from the use of ecosystems. Taking into account the cost (assessment) of resources makes it possible to more reasonably determine the economic efficiency of the development alternatives and can significantly influence the choice of a development option. At the same time, all water bodies in one basin are interconnected, and the impact on one water body will inevitably affect other water bodies in the basin. Balkhash Lake is the final water body of the system and takes almost no part in water regulation and water allocation. The water in the lake is not directly suitable for drinking, but it is of great importance as one of the largest reservoirs of fresh water in Central Asia. The basis of the value of Balkhash Lake's natural capital is its water reserves. The basis of the value of ecosystem services of Balkhash Lake is the biological regulation of fish populations, but no less important is the providing service of supplying the population with fish products, because it is the largest fishery reservoir in the east and south of Kazakhstan with catches of over 8 thousand tons of fish per year. It is extremely important to preserve Balkhash Lake as a fishery reservoir, given that the value of individual fish species in the lake is determined only by their use value, as almost all of these species are acclimatizers. Maintenance of the refugium and related services of biological regulation are the main part of the plan for the conservation of fish resources in the Ile River Delta and are the main ecosystem services of this water body, so it is recommended to partially remove water bodies of the delta (channels, floodplain lakes) from human economic activities, which has already been done in the form of a ban on commercial fishing and is planned as a specially protected natural area (the Ile-Balkash Nature Reserve planned for creation). Since Kapshagay reservoir is the second largest reservoir in the country, water regulation in the entire basin and water supply (in addition to energy supply, which we do not evaluate here) are its main ecosystem services, in accordance with the overall strategy of sustainable management of nature. And although the Kapshagay reservoir is a fishery reservoir, when implementing fishery and water management projects, the choice of conservation of fish stocks in certain parts of the basin should give priority not to the reservoir, but to Balkhash Lake.

Acknowledgements. This research was funded by the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (Grant No. BR 10264205).

Conflict of interest. The authors declare no conflict of interest.

References

Babayan V. K., 2000 [The precautionary approach to estimating the total allowable catch (TAC)]. VNIRO Publishing House, Moscow, 191 p. [In Russian].
Chugunova N. I., 1952 [Methodology of studying the age and growth of fish]. Soviet Science, Moscow, 115 p. [In Russian].
Costanza R., 2020 Valuing natural capital and ecosystem services toward the goals of efficiency, fairness, and sustainability. Ecosystem Services 43:101096.
Costanza R., d’Agre R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P., van den Belt M., 1997 The value of the world’s ecosystem services and natural capital. Nature 387:253–260.
Costanza R., Daly H. E., 1992 Natural capital and sustainable development. Conservation Biology 6(1):37–46.
Costanza R., de Groot R., Sutton P., van der Ploeg S., Anderson S. J., Kubiszewski I., Farber S., Turner R. K., 2014 Changes in the global value of ecosystem services. Global Environmental Change 26:152–158.
Coyne J. A., Orr H. A., 2004 Speciation. Sinauer Associates Inc., Sunderland, ISBN 0-87893-091-4.
Dominati E. J., Robinson D. A., Marchant S. C., Bristow K. L., Mackay A. D., 2014 Natural capital, ecological infrastructure, and ecosystem services in agroecosystems. Encyclopedia of Agriculture and Food Systems, pp. 245-264.

Dushin A. V., Yurak V. V., 2018 Total economic value concept: essence, evolution and author's approach. Advances in Economics, Business and Management Research 47:91-97.
Ghermandi A., Nunes P. A. L. D., Portela R., Rao N., Teelucksingh S. S., 2011 12.11 - recreational, cultural, and aesthetic services from estuarine and coastal ecosystems. Treatise on Estuarine and Coastal Science 12:217-237.
Kulikov Y. V., Isbekov K. B., Assylbekova S. Z., 2016 [Finding of withdrawal rates for fish populations that have reached critical values of the biomass of the commercial stock]. Fishery Issues 17(3):368-374. [In Russian].
Lukyanova O. N., Volvenko I. V., Ogrodnikova A. A., Anferova E. N., 2016 [Assessment of the value of bioresources and ecosystem services of the Sea of Okhotsk]. Proceedings of TINRO 184:85-92. [In Russian].
Shirkov E. I., 2010 [Ecological and economic efficiency of the use of the natural resource potential of the Sea of Okhotsk]. Spatial Economics 3:49-67. [In Russian].
Malkin Y. N., 1999 [Reproductive and numerical variability of commercial fish populations]. VNIRO Publishing House, 144 p. [In Russian].
Methot J. R. D., Wetzel C. R., 2013 Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86-99.
Neverov A. V., Derevyago I. P., 2005 [Natural capital in the system of sustainable development]. Belarusian Economic Journal 1:121-132. [In Russian].
Nikolsky G. V., 1974 [Theory of fish herd dynamics]. Food Industry, Moscow, 448 p. [In Russian].
Pravdin I. F., 1966 [Guidelines for the study of fish]. Food Industry, Moscow, 376 p. [In Russian].
Rosenberg A. G., 2014 [Estimates of ecosystem services for the territory of Samara region]. Povolzhsky Ecological Journal 1:139-145. [In Russian].
Tallis H., Guerry A., Daily G. C., Pascual U., 2024 Ecosystem services. Encyclopedia of Biodiversity 3:753-763.
Van Zyl H., 2021 Kazakhstan Biodiversity Offsets Guideline (BIOFIN). Technical Report, 116 p.
Watson S. C. L., Watson G. J., Beaumont N. J., Preston J., 2022 Inclusion of condition in natural capital assessments is critical to the implementation of marine nature-based solutions. Science of the Total Environment 838:156026.
Xie G., Zhang C., Zhen L., Zhang L., 2017 Dynamic changes in the value of China's ecosystem services. Ecosystem Services 26A:146-154.
*** FAO-World Bank Cooperation Program, 2021 Realizing the growth potential of fisheries and aquaculture in Kazakhstan: A demand side assessment. FAO, 82 p.
*** FAO, 2006 Stock assessment for fishery management. A framework guide to the stock assessment tools of the Fisheries Management Science Programme. FAO fisheries technical paper 487:263.
*** FAO Technical Guidelines for Responsible Fisheries, 2010 Russian version of FAO. Aqua-culture development. Ecosystem approach to aquaculture. FAO Technical Guidelines for Re-sponsible Fisheries, 53 p.
*** http://finreview.info/ru/review/dohodnost-turisticheskogo-sektora-mozhet-uvelichitsja-do-200-mlrd-tenge-v-god
*** https://www.inform.kz/ru/novye-tarify-na-podachu-vody-po-kanalam-utverzhdeny-v-kazahstane_a3781946

Received: 17 April 2023. Accepted: 12 December 2023. Published online: 28 December 2023.
Authors:
Yevgeniy Kulikov, Candidate of Biological Sciences, Leading Researcher, Fisheries Research and Production Center, 89A Suyumbay ave., 050016 Almaty, Kazakhstan, e-mail: e.v.kulikov.61@mail.ru
Natalia Sadyrbayeva, Balkhash branch, Senior Researcher of the Integrated Fisheries Laboratory, Fisheries Research and Production Center, 89A Suyumbay ave., 050016 Almaty, Kazakhstan, e-mail: natasadyr@mail.ru
Askhat Mamyshov, Information innovation manager, Fisheries Research and Production Center, 89A Suyumbay ave., 050016 Almaty, Kazakhstan, e-mail: mamyshov@fishrpc.kz
Kuanysh Isbekov, Doctor of Biological Sciences, General Director, Fisheries Research and Production Center, 89A Suyumbay ave., 050016 Almaty, Kazakhstan, e-mail: isbekov@fishrpc.kz

How to cite this article:
Kulikov Y., Sadyrbayeva N., Mamyshov A., Isbekov K., 2023 Application of ecosystem service value assessment of water bodies in the development of future plans for the use of aquatic bioresources using the example of water bodies in the Ile-Balkhash basin. AACL Bioflux 16(6):3378-3389.