Calculation of damage to water biological resources during the construction of railway approaches to transport crossing through the Kerch Strait

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Abstract. The article deals with the main factors of the negative impact of the construction of railway approaches to the transport crossing through the Kerch Strait on the biota and affected aquatic ecosystems. The paper presents data on the calculation of the loss of aquatic biological resources as a result of disturbance (redistribution) of natural runoff from the deformed surface of the drainage basin. The data on the assessment of damage to aquatic biological resources due to damage to areas of the floodplain of a watercourse of fishery importance (floodplain spawning grounds) is also provided. Based on the analysis of the technical solutions of the project and the measures to protect the environment proposed in it, the main types of impact on aquatic biological resources are the following: deterioration of the conditions for fish reproduction as a result of damage to floodplain spawning grounds of the Dzharjava river; a decrease in the fish productivity of the watercourse as a result of the disturbance (redistribution) of the natural runoff from the deformed surface of the drainage basin. The paper considers compensation and environmental protection measures aimed at reducing the negative impact on the water environment during the construction and operation of railway approaches to the transport crossing through the Kerch Strait.

1 Introduction

The project "Construction of railway approaches to the transport crossing through the Kerch Strait" was provided for by the Federal Target Program "Social and Economic Development of the Republic of Crimea and the City of Sevastopol until 2020", approved by the Russian Government in August 11, 2014 No. 790 [1].

The implementation of the project makes it possible to solve the main transport, social and economic problems. These include:

• the creation of a railway component of transport corridors that pass through the Krasnodar Krai and the Republic of Crimea;

• the formation of conditions for the integrated development of the transport infrastructure of the Krasnodar Krai (Temryuksky District) and the Republic of Crimea, as

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well as adjacent regions, based on the multiple effect of the construction of a transport crossing;

- strengthening social, economic, interregional and international relations,
- increasing the level of mobility of the population and market entities;
- reducing the cost of transportation and the level of transportation costs for shippers.

The objective of the study is to assess the consequences for biota from the implementation of the project and calculate the amount of damage to aquatic biological resources during the construction of iron approaches to the transport crossing through the Kerch Strait.

2 Material and research

During the research process, a reference analytical method, theoretical analysis and synthesis were used. Calculation of damage to aquatic biological resources was carried out in accordance with the Methodology approved by order of the Federal Agency for Fisheries dated November 25, 2011 No. 1166.

3 The obtained results and discussion

Geographically, the study construction site of railway approaches is located in the southeastern part of the Kerch Peninsula. The peninsula is washed in the north by the Sea of Azov, in its western part by the Sivash Bay, in the east by the Kerch Strait, and in the south by the Black Sea.

The construction of railway approaches partially affects the water protection zone of the Kerch Strait – a water body of the highest fishery category. The beginning of the construction site – 10 m of the railway line [1, 2, 3] – covers the water protection zone of the Kerch Strait. The railway line crosses a number of low-water rivers with a catchment area from 0.1 km² to several tens of square kilometers and the length of the main log from hundreds of meters to 6.5 km. The most significant of them are a river without a name with a catchment area to the alignment of the projected crossing – 34.2 km², the Solyonaya river – 11.4 km², the Bigel river – 6.4 km², the Dzharjava river – 5.0 km² (Fig. 1).

The Dzharjava river is of fishery importance. During the period of watering, juvenile fish can enter the channel. Thus, the temporary formation of planktonic and benthic communities which are the fodder base of fish is possible. Moreover, the watercourse can serve as a spawning ground for freshwater fish species.

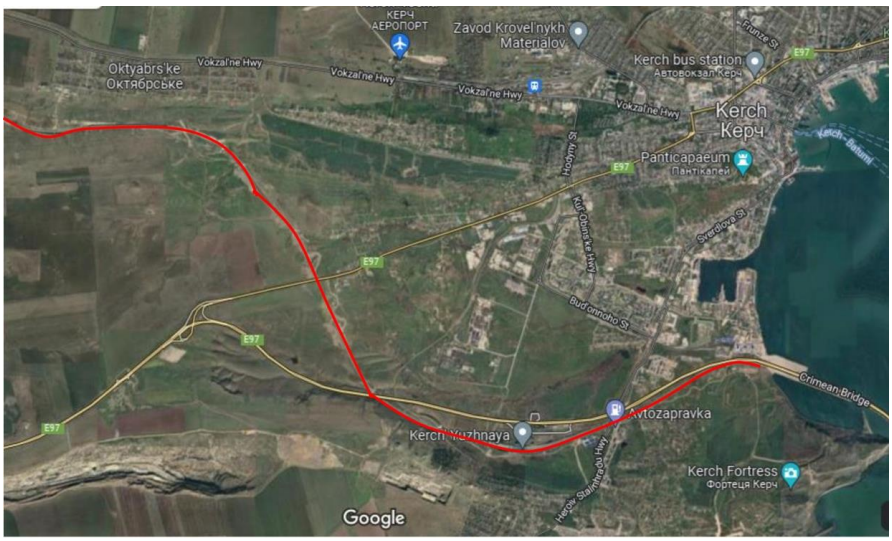

Fig. 1. Situational plan and hydrographic network in the area of approach construction

During the period of construction and installation work, one of the powerful anthropogenic factors that have a negative impact on aquatic ecosystems is the so-called "technogenic" impact associated with the use of engineering construction tools.

According to hydrological studies carried out to prepare design solutions, most of the intersected rivers are temporary runoffs. In the natural areas of the water bodies under consideration, temporary runoff is observed only during the period of snow melting and in high precipitation events. Most of the rivers do not have a permanent hydrological linkage with water bodies of fishery importance. Discharge of temporary watercourses (with the exception of the Dzharjava river) is carried out in low relief areas. Ichthyofauna is absent.

During the period of temporary runoff, hydrobiocenoses and fish food resources (phyto- and zooplankton communities, zoobenthos) fail to fully form in the watercourse areas. Thus, the formation of planktonic biocenoses occurs completely within a year, and benthic – within 3 years. Plankton communities and benthic fauna, which appear for a short time during the period of temporary watering, do not contribute to the formation of the fish fodder base due to the lack of hydrological linkage with water bodies that have ichthyofauna.

The Bigel river, despite the relative high flow, is also a temporary watercourse and has lost its hydrological linkage with the Melek-Chesme river. The discharge of the watercourse is carried out in low relief areas.

The hydrological conditions of the Dzharjava river, the right inflow of the river of the same name, (relatively gentle relief, rain flood discharge more than 7.0 m3/s, flow availability in winter at the level of 0.048-0.061 m3/s, (P 75%) and the hydrological linkage with the main watercourse provide watering of the site in the construction area during floods. The flooded areas are used for spawning of phytophilic fish (carp, crucian carp, etc.).

Thus, taking into account the possibility of the appearance of ichthyofauna during the spawning period, the Dzharjava river (PK 51 + 70) should be classified as a water body of the second category of fishery significance.

Works in the area of railway crossings through the Dzharjava river and other watercourses are planned during the low-water season, when the appearance of runoff is impossible. Consequently, the performance of works in a drained watercourse will not cause the death of plankton and benthic communities. With regard to the destruction of fish food resources, damage to aquatic biological resources is not predicted and calculated.

However, the Dzharjava river, due to the possibility of using the phytophilic group for spawning, is actually a floodplain spawning ground. When carrying out construction work in watercourses, the impact on the aquatic biota not only damages the sections of the river channel, but also disturbs the soil and vegetation cover of the floodplain. Consequently, the construction of a culvert in the Dzharjava river will lead to a negative impact on aquatic biological resources in terms of temporary damage and permanent withdrawal of spawning areas from the fishery turnover.

Fish productivity of floodplain spawning grounds of the Crimean steppe rivers, including the Dzharjava one, does not exceed 0.1 centners per hectare.

Temporary damage to the floodplain will occur due to the movement of construction equipment, the arrangement of temporary sites, etc. The constant withdrawal of floodplain spawning areas is associated with the placement of embankments and railway structures (culverts, drainage ditches) in the watercourse.

Work on the construction of a railway approach at a number of sections is carried out in the water protection zone of the water bodies of the Kerch Peninsula.

Ширина водоохранной зона Керченского пролива в соответствии с ч. 4 статьи 65 Водного кодекса Российской Федерации, утвержденного Федеральным законом от 03 июня 2006 г. № 74 -ФЗ (ред. от 29.07.2017), устанавливается в размере 500 м, б. Джарджава - 50 м, р. Мелек-Чесме - 100 м.

The width of the water protection zone of the Kerch Strait in accordance with Part 4 of Article 65 of the Water Code of the Russian Federation, approved by Federal Law No. 74-ФЗ dated June 03, 2006 (as amended on July 29, 2017) is set at 500 m, the Dzharjava river is 50 m, the Melek-Chesme river is 100 m.

Based on the analysis of the project, the construction of railway approaches to the transport crossing, office buildings and structures that ensure the operation of railway transport, etc. will be accompanied by disturbance of soil cover and vegetation in the catchment area of the Kerch Peninsula water bodies (temporary watercourses in the Bigel and Dzhardzhava rivers). Violation of the water protection and water regulation functions of herbage and shrubs will lead to a reduction and redistribution of the natural surface runoff on the surface deformed by the work and, as a consequence, to a decrease in the fish productivity of the watercourse.

The calculation takes into account the total area of permanent land uptake (roadbed, drainage system and artificial structures, stations with station tracks, buildings and structures for signaling and communication, energy, track facilities, office buildings and structures that support the operation of railway transport). The transformation of the surface during the construction of the facility (preparatory work, placement of temporary roads, a site for storing inert materials, temporary construction sites, a rotational village) on the remaining area is also taken into account.

When carrying out the listed types of work and when placing the facility, for the period of complete restoration of the catchment characteristics, a permanent violation of the natural runoff is taken into account in calculating the damage to aquatic biological resources. This impact will be constant throughout the entire period of construction (29.6 months) and operation of the facility (100 years).

The period of complete restoration of the relief and filtration characteristics of soils is 30 years (the time of restoration of disturbed steppe ecosystems) [4, 5].

Other work performed in watercourses in a regular mode will not disturb aquatic biological resources, if the measures for environmental protection in the water protection zone provided for by the project are fulfilled.

The project does not provide for the intake of water from surface water sources and discharge into them. It also does not provide for the discharge of the untreated wastewater onto the relief.

According to the Methodology for calculating the amount of damage caused to aquatic biological resources [6], the calculation of losses of aquatic biological resources as a result of disturbance (redistribution) of natural runoff from the deformed surface of the drainage basin and damage from deterioration of fish reproduction conditions was made.

Losses of aquatic biological resources from disruption of runoff on a temporarily damaged area will amount to 0.648 kg, and from a violation of runoff on a permanently damaged area will amount to 169.375 kg (Table 1).

Table 1. Determination of losses of aquatic biological resources from disturbance of natural runoff within the catchment area of the considered watercourses.

Deformed surface area, km²		**Runoff module l/(s·km²)**	**Constant coefficient**	**Coefficient of depth of impact on the surface, К**	**The value of the increasing coefficient, Ɵ**	**Volume of runoff losses Q, thousand m3**	**Specific fish productivity, kg / thousand m3**	**Losses of aquatic biological resources, kg**
Temporary impact								
Temporary	0,0261279	0,1	31,536	0,3	17,467	0,431768233	0,15	0,065
Crushed stone roads	0,0777289	0,1	31,536	0,5	17,467	2,14080669	0,15	0,321
Roads made of reinforced concrete slabs	0,0087739	0,1	31,536	1,0	2,467	0,068260338	0,15	0,01
Temporary offices	0,03050559	0,1	31,536	1,0	17,467	1,680367821	0,15	0,252
								0,648
Continuous impact								
Continuous	3,0417777	0,1	31,536	1,0	117,467	1126,808089	0,15	169,021
Crushed stone roads	0,0087739	0,1	31,536	0,5	115,0	1,590988835	0,15	0,239
Crushed stone roads	0,0041484	0,1	31,536	0,5	117,467	0,768374802	0,15	0,115
								169,375

Damage from deterioration of fish reproduction conditions. Determination of damage to aquatic biological resources due to damage to areas of the floodplain of a watercourse of fishery significance (floodplain spawning grounds) is carried out according to formula 1 [6]:

$$N = P_0 \times S \times \frac{F_1}{F_0} \times q \times \Theta \times 10^{-3}, \quad (1)$$

where:

N are the losses (amount of damage) of aquatic biological resources, kg or t;

P_o is the fish productivity (annual) of the water body, g/m², kg/km², kg/ha;

S is the area of the water body, m², km², ha;

F_0 are the areas of breeding, feeding, wintering grounds in a water body of fishery significance before the negative impact of the planned activity, m², km², ha;

F_1 are the areas of breeding, feeding, wintering grounds in a water body of fishery importance after the negative impact of the planned activity, m², km², ha;

q is a correction coefficient for the different quality of breeding, feeding or wintering grounds, defined as the ratio of their quality indicators to the same average indicators of all parts of a water body of fishery significance (for feeding grounds, biomass indicators of food organisms are used, for breeding grounds – the number of reproductive juveniles, for wintering areas – the number of individuals per unit area);

Θ is the value of the increasing coefficient, taking into account the duration of the negative impact of the planned activity and restoration to the initial state of aquatic biological resources.

Formula 1 is applied to small water bodies when considering the ratio of indicators F_1/F_o as a coefficient showing the direct dependence of the decrease in bioproductivity (fish productivity) of a water body of fishery value on the proportion of losses in breeding, feeding or wintering grounds, if such a relationship is established. In these calculations, the specified ratio is assumed to be equal to one. At the same time, the calculations take into account the annual losses of aquatic biological resources during the period of restoration of disturbed habitats (reproduction, feeding, wintering), if the time of their restoration is more than one year, by introducing an appropriate coefficient.

Fish productivity of floodplain spawning grounds in the lower reaches of the Dzharjava river is estimated at 0.1 centner per hectare (10 kg/ha) [5].

The area of *temporary* damage to the floodplain is 0.0167 ha (116.7 m^2).

The area of *continuous* damage to the floodplain is 0.07903 ha (790.3 m^2).

Due to the fact that crossing watercourses are temporary, damaged spawning grounds are considered floodplain. The recovery time of floodplain spawning grounds (overgrowth with vegetation, perennial grasses, and shrubs) is 3 years.

The value of the increasing coefficient Θ for the period of construction of the culvert in the Dzharjava river (13.7 months) and restoration of floodplain spawning grounds will be:

$$13,7/12+1,5 = 2,642$$

Temporary damage to aquatic biological resources from losses of floodplain spawning grounds of the Dzharjava river for the period of construction and restoration of fish reproduction conditions will be:

$$N_{\text{floodplain temporary}} = 10 \text{ kg/ha} \times 0,01167 \text{ ha} \times 2,642 = 0,308 \text{ kg}$$

When calculating the value of the increasing coefficient **0** to determine the amount of permanent damage to aquatic biological resources from the placement of the culvert in the floodplain of the Dzharjava river, the period of operation of the facility (100 years) is also taken into account.

$$\Theta = 13,7/12 + 100 + 1,5 = 102,642$$

Continuous damage from withdrawal of floodplain spawning grounds of the Dzharjava river under the solid constructions of the bridge will be:

$$N_{\text{floodplain continuous}} = 10 \text{ kg/ha} \times 0,07903 \text{ ha} \times 102,642 = 81,118 \text{ kg}$$

The total one-time losses of aquatic biological resources from damage to floodplain spawning grounds and disruption of runoff in the temporarily damaged area will be:

$$N_{\text{total one-time}} = 0,648 \text{ kg}_{\text{ runoff temporary}} + 0,308 \text{ kg}_{\text{ floodplain temporary}} = 0,956 \text{ kg}$$

The total continuous losses of aquatic biological resources for these components will be:

$$N_{\text{total continuous}} = 169,375 \text{ kg}_{\text{ runoff continuous}} + 81,118 \text{ kg}_{\text{ floodplain continuous}} = 250,493 \text{ kg}$$

The average annual damage to aquatic biological resources during the exploitation

period (100 years) is estimated at 2.505 kg.

In accordance with paragraph 52 of "Methods ..., 2011" [6], permanent damage to aquatic bioresources (long-lasting and multi-year) can be reduced to a one-time damage determined given the recovery time of the amount of directly lost aquatic biological resources used for fishing.

Consequently, *the total amount of damage to aquatic biological resources* (total lost biomass of fish products) for the object: "Construction of railway approaches to the transport crossing through the Kerch Strait" is estimated at 251.449 kg:

$$N_{totsl} = N_{total\ temporary} + N_{totsl\ continuous} = 0{,}956\ kg + 250{,}493\ kg = 251{,}449\ kg$$

To reduce the negative impact on aquatic biological resources during the period of construction work, the following measures should be taken:

– stoppage of construction work on the installation of culverts during the period of maximum precipitation (from April 1 to June 30) on the Dzharzhava river;

– restoration of disturbed areas on completion of work;

– development of a schedule, taking into account the low-water period, when the beams are not flooded (July-August);

– implementation of compensatory measures to replenish fish stocks at the end of construction work.

As a compensation measure, additional reproduction of juveniles of one of the following species of aquatic bioresources (indicated in order of preference) is proposed at fish hatcheries in the Krasnodar Krai: Black Sea salmon (brown trout), Russian sturgeon and starry sturgeon.

The calculation of the amount of juvenile fish required to restore the disturbed state of aquatic biological resources through their artificial reproduction is performed according to formula 2 [6]:

$$N_m = N/(p \times K_1) \times 100\% , \quad (2)$$

where:

N_m is the number of reproducible aquatic biological resources (larvae, juvenile fish), ind .;

N is the loss of aquatic biological resources (amount of damage), kg or t;

p is the average mass of one reproduced individual of aquatic biological resources in yield to the fishery, kg;

K_1 is the coefficient of replenishment of the yield to the fishery,%.

In accordance with [7], biotechnological indicators for fish breeding enterprises in the Krasnodar Krai and the Republic of Crimea are used in the calculation.

The average weight of producers is calculated from the sex ratio when receiving reproductive products.

The number of juveniles of Black Sea salmon (trout), Russian sturgeon, and starry sturgeon required for the performance of compensatory measures is presented in Table 2.

There are currently no fish-breeding enterprises for the release of juveniles of these species on the territory of the Republic of Crimea. It is proposed to carry out compensation measures at fish breeding enterprises of the Krasnodar Krai.

Table 2. The volume of compensation measures for the additional release of juveniles at fish breeding enterprises in the Krasnodar Krai.

Type of reproduced juveniles	**Average weight of juveniles, g**	**N (lost biomass of fish products), kg**	**P (average weight of producers), kg**	**Sex ratio females: males**	**K_1 (coefficient of the yield to the fishery), %**	**Number of reproduced juveniles, ind.**
Black sea salmon	3,0	251,449	3,5	3:1	0,5	**14369**
Russian sturgeon	2,5	251,449	15,0	1:1	0,6	**2794**
Starry sturgeon	1,5	251,449	9,5	1:1	0,5	**5294**

Thus, compensation measures can be carried out through additional reproduction at fish breeding enterprises in the Krasnodar Krai with the subsequent release of juveniles of the following species into the water bodies of the Azov-Black Sea basin:

- Black Sea salmon – 14369 individuals weighing not less than 3.0 g
- Russian sturgeon – 2794 individuals weighing not less than 2.5 g
- Starry sturgeon – 5294 individuals weighing not less than 1.5 g

Compensation measures for the reproduction of one of the proposed species of juveniles should be coordinated with the Azov-Black Sea territorial administration of the Federal Agency for Fishery. These measures are determined by the capabilities of fish farms for additional (unscheduled) release of juveniles for the period of implementation of the measures.

The cost of compensation measures depends on the price of juveniles with a certain weight, set depending on their cost at fish farms with different forms of ownership. Such calculations are carried out during the development of compensation measures and the preparation of an agreement with fish farms.

4 Conclusion

According to the data of hydrological studies, which were carried out during the period of preparation for construction, it was established that most of the crossing rivers are temporary watercourses.

One of the main anthropogenic factors that have a negative impact on aquatic ecosystems during the period of construction and installation work is the technogenic impact associated with the use of engineering construction tools. These impacts include disturbance of soil cover and vegetation, disturbance of water protection and water regulation functions of grass stand and shrubs, noise and vibration produced by operating equipment, and possible emergency situations as a result of accidents.

It is planned to construct railway approaches partly in the water protection zone of the Kerch Strait – a water body of the highest fishery category.

The projected track crosses a number of water bodies – temporary watercourses (rivers). In accordance with the order of the Federal Agency for Fishery of 17.09.09, No. 818 "On the establishment of the categories of water bodies of fishery significance and peculiarities of harvesting (catch) of aquatic biological resources inhabiting them and classified as fishing

objects", most of the water bodies under consideration cannot be attributed to any category of fishery significance.

The exception is the Dzharjava river. Considering the possibility of periodic appearance of ichthyofauna during the spawning period, the Dzharjava river (PK 640 + 30.36) should be attributed to water bodies of the second category of fishery significance.

Work in the area of the railway crossing through the Dzharjava river, as in other watercourses, is planned during the low-water period, when runoff is impossible. Work in a drained watercourse will not cause the death of plankton and benthic communities.

Based on the analysis of the technical solutions of the project and the measures proposed in it for environmental protection, the main types of impact on aquatic biological resources from the implementation of the project will be:

- deterioration of fish reproduction conditions as a result of damage to floodplain spawning grounds of the Dzharjava river
- a decrease in the fish productivity of the watercourse as a result of the disturbance (redistribution) of the natural runoff from the deformed surface of the drainage basin.

The total one-time losses of aquatic biological resources from damage to floodplain spawning grounds and disruption of runoff in the temporarily damaged area will amount to 0.956 kg.

The total continuous loss of aquatic biological resources will amount to 250.493 kg.

When summing continuous damage and one-time total amount of damage to aquatic biological resources (total lost biomass of fish products) we will get the following value – 251.449 kg.

Additional impact on aquatic biological resources and their habitat during work in the water protection zone of the water body (loading and unloading operations, movement of construction equipment and vehicles) will be insignificant if the technical solutions and environmental protection measures adopted in the project are fulfilled [14-17]. Other possible sources of negative impact on watercourses and their biological resources, such as littering of catchment areas and channels with construction and household waste, pollution with fuels and lubricants, will be eliminated or minimized with full compliance with the environmental protection measures provided for by the project.

Compensation measures can be performed through additional reproduction at fish breeding enterprises in the Krasnodar Krai with the subsequent release of juveniles (underyearlings) of the following species into the water bodies of the Azov-Black Sea basin:

- Black Sea salmon – 14369 individuals weighing not less than 3.0 g
- Russian sturgeon – 2794 individuals weighing not less than 2.5 g
- Starry sturgeon – 5294 individuals weighing not less than 1.5 g

To minimize the possible negative impact on the aquatic environment during the construction and operation of the facility, the project provides for the necessary environmental protection measures. As an additional measure to minimize damage to aquatic biological resources, a prohibition on work should be recommended during the period of possible watering of river's watercourses and spawning of fish in the Dzharjava river, namely from April 1 to June 30.

To minimize the impact on the environment during the work, it is necessary to comply with the requirements of the Water Code of the Russian Federation regarding economic activities in water protection zones and implement the program of industrial environmental control (monitoring) of the facility condition provided for by the project.

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