Research Article

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The concept of block organization of a water-terrestrial ecotone system

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Abstract: The proposed concept concerns determination of the parts of the coast differently affected by the water reservoir. Some parts (***blocks***) of any shore are directly affected by the flooding: ***aquatic block*** – part of the water object never exposed from the water, located on the depths more than 2.5 m; ***amphibian block*** – part of the reservoir bottom exposed periodically; ***dynamic block*** – periodically flooded coast territory. By contrast, the next ecological belt - ***distant block*** – is affected by flooding indirectly. It includes territories of coast with ground waters no deeper than 3 m. The ***marginal block*** is located on the coast with ground water level below 3 m. There the impact of the reservoir is biological and has passed through the chain of biological relations. This methodology was developed to study the influence of water objects on the lands adjacent to the reservoirs. It allows to connect elevation of the land surface with fluctuations of the water object level and with groundwater level and also to determine the boundaries of allocated blocks afield. Thus, the proposed method allows to optimize the number of field observations.

Key words: influence on the shore/coast, overflowing, water reservoir, waterlogging

Introduction

The effect of water objects on the adjoining coast is most fully revealed when considering coastline area as an “water-terrestrial” ecotone system. Therefore, the aim of this study is to clarify the peculiarities of such methodological approach and to show the features of its operation on the example of studying the influence of the reservoirs on the adjacent coastline areas. For this, features of the spatial structure of natural complexes of the shores of four reservoirs in the steppe zone in the South of the European part of Russia were analyzed and scored.

Materials and Methods

The “object” of this methodology are the natural shore complexes, and its “subject” is the assessment of the reservoir impact on them. The methodology has been designed to ensure the standardization of the procedures to assess the reservoir impact on natural shore complexes based on the algorithm of sequential actions. **The assignment of the methodology** is directly related with the problems, which it solves: (1) definition of the shore areas of a reservoir, which experience various impacts (flooding and waterlogging, or only flooding) and identification of their water regime; (2) study of the components of natural systems in areas experiencing various reservoir impacts and estimation of the depth and extent of changes in the direction of hydromorphization based on the use of a system of parameters and criteria, as well as of the especially developed scales.

The general theoretical platform of the methodology is the idea that water is the leading factor in the transformation of surrounding shore landscapes. Its complex impact on surrounding areas provides semihydromorphic and hydromorphic features and properties to the automorphic landscapes. Most of the studies (Baluk & Kutuzov 2006, Novikova & Nazarenko 2013, Novikova et al. 2014, etc.) have shown that changes in the water regime of a river area and its transformation into a reservoir activate the abrasion processes in open shore areas, that the impact of long flooding and wave action on periodically dried bottoms completely destroy initial natural complexes, that the shore areas exposed to short term flooding simultaneously experienced the erosion of upper soil horizons and surface sediment accumulation brought by water during flooding, that there hydromorphic and semihydromorphic soils and plant communities are formed, that groundwater is actively replanished and it's level rises to the surface and, that in the nonflooded areas, where groundwater is less than 3 (5) m from the surface, processes of the formation of semihydromorphic natural complexes develop. The soils, vegetation, and animal populations that existed in the initial landscape, change to varying degrees while adapting to the new water regime, depending on the hydrological and morphological conditions in different specific habitats.

The methodological approaches and **methods** used in the work include on first place the "key experience" methodological approach to compare and assess the transformation of natural shore complexes. Landscape areas unaffected by a reservoir are used as "key" areas, and the areas under its influence are used as "experimental" ones. The methodical approach considers a shore territory as a "water-terrestrial" block ecotone system in the understanding and terminology proposed by Zaletaev (1997) and ensures the assessment of a complex reservoir impact. It is this consideration of the spatial and functional structure of shores that makes it possible to assess the hydrological impact of a reservoir on adjacent land areas and their properties by the characteristics of flooding duration and frequency, degree of waterlogging and groundwater quality. The proper parameters of reservoirs, which are established to manage their functioning during their construction (e.g. the Dead Volume Level - DVL, the Normal Maximum Operating Level - NOL), are used in identifying the boundaries of different reservoir impacts on a shore (flooded and waterlogged areas).

Results

In accordance with the methodology **described above, we developed a new algorithm of the work** on the basis of specific examples, obtained from the data for four reservoirs in the south of European Russia, namely Krasnodar, Tsimlyansk, Proletarsk and Veselovsk. The algorithm contained several stages (steps) that consecutively solved the basic problems of the methodology. According to the methodology, **the first step** solved the task of identifying the spatial organization of natural complexes on reservoir shores. This task was to establish the areas exposed to various reservoir impacts (flooding duration, the presence of ground waters rising to the surface). This goal was achieved with the landscape environmental approach, based on the consideration of a shore as a block system of the "water-terrestrial" ecotone system in the understanding of Zaletaev (1997). This approach identifies five types of areas (functional blocks) that experience various reservoir impacts (Fig. 1). The first of them is the aquatic block (Fig. 1) which is the deep part of the reservoir below the DVL. The second is the amphibial block (Fig. 1), which is the flooded reservoir bottom, which is bared during drawdown of the level.

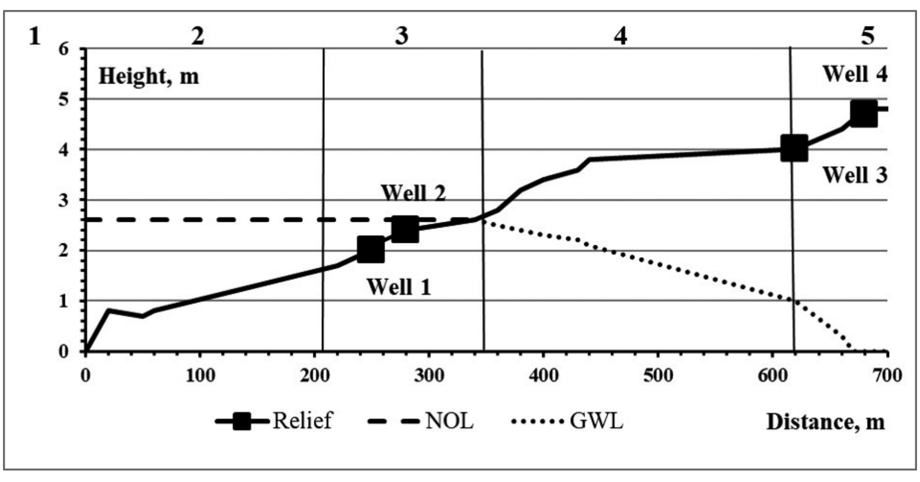

Fig. 1. Block structure of the "water-terrestrial" ecotone. Arabic numerals (1–5) designate ecotone blocks; NOL is the normal maximum water operating level; GWL is the groundwater level; Well 1-4 refers to pits for groundwater checking.

There the leading role in the open shore is played by the wavecut water action and sediments are accumulated in lagoons. This area extends from the altitude marks of the DVL to the shoreline. The third area is the **dynamic** block (Fig. 1) which is a shore territory subjected to short term flooding in spring with close standing of the groundwater level in the vegetation period. This shore area extends from the shoreline to the highest possible water level (NOL) of the reservoir. The fourth area is the **distant** block (Fig. 1) which is a non-flooded waterlogged shore territory with a groundwater depth of up to 3 (5) m. This area extends from the altitude marks of the NOL to the territories, where the groundwater depth is 3 (5) m below the surface. The last, fifth block is the **marginal** block (Fig. 1), which is not subjected to the hydrological impact of the reservoir. There, natural complexes experience the reservoir impact through biotic connections. The external boundary of the reservoir impact is determined empirically, during field studies, based on the groundwater depth of more than 3 m below the surface in spring.

The second step was to define the parameters of the flooding regime: its duration and frequency. These characteristics are calculated on the basis of standard hydrological formulas and datas of the reservoir level regime (Luchsheva 1983). **Waterlogging** is determined through the groundwater depth. This indicator can be determined only experimentally during special field works with topo-ecological instrumental leveling.

The third step was related with obtaining of additional information during experimental field studies. The topo-ecological instrumental profiling allows to make an integrated system from the obtained theoretical data on altitude marks like the boundaries of reservoir impact and all data on the real local altitude marks obtained during the field observations in the key area. Each sampling and description point is fixed with a remote geopositioning instrument.

The fourth step was to assess the transformation of natural complexes. Changes in natural complexes are scored on the basis of the degree and depth of their transformation by comparing the characteristics of the current state of natural complexes in ecotone system blocks with the characteristics of the enclosing landscape before the construction of the reservoir. The groundwater depth, the character of the biotope water regime and the signs of hydromorphism in soils and vegetation are considered as indicators.

An algorithm for a differentiated conditional scored assessment was developed to expand the assessment potential of the proposed methodological approach. A scale with gradations of the ecological value of groundwater was developed in order to assess its changes (Table 1). For example, a groundwater surge by one step (from a depth of 3 (5) m to 1.5 m and from a depth of 3–1.5 m to 0.5 m) is given 2 points. The maximal value (3 points) is

Table 1. Scale to score changes in groundwater depth with the increasing hydromorphism. The numbers within the table cells are scores that evaluate the changes in the initial groundwater level, which are indicated in the left vertical column relative to the current value in the upper horizontal row.

Groundwater depth (in the initial landscape, before flooding), m	Groundwater depth (current), m			
	>3 (5)	3-1.5	1.5-0.5	0.5-0
>3(5)	0	1	2	3
3-1.5	1	0	1	2
1.5-0.5	2	1	0	1
0.5-0	3	2	1	0

Table 2. Scale to score the hydrogenic soil transformation

Parameter	Indicators of modern hydromorphism						Meadow formation process		Swamping process	
	effervescence	secondary gypsum	ochre tint	bluish gray tint	soil peas Fe + Mn	$CaCO_3$ mold	subtype	type	subtype	type
Initial type (automorphic zonal)	1	1	1	1	1	1	6	8	9	10

Note: In the amphibian block in the open shore conditions, soils are eroded and receive the maximal score, which indicates the greatest degree of transformation

Table 3. Scale to score the hydrogenic vegetation transformation in the direction of increasing moisture

Zone	Ecology of plant communities in functional ecotone blocks			
	Amphibian	Dynamic	Distant	Marginal
Steppe	hydrophilic and hygrophilic	hygrophilic and mesophilic	mesophilic, mesoxerophilic	xerophilic, mesoxerophilic
Score	6	4	2	0

Note: In the absence of dense aboveground vegetation in the amphibian block, the change is given two more points. As a result, the score is 8 points.

Table 4. Score of the ecosystem transformation in a zone influenced by reservoirs based on the indicators of modern hydromorphism in the functional blocks. * - The numbers in the brackets are landscape indices according to the Landscape Map (1987); the indices of topoecological profiles for each reservoir are under them.; ** - Roman numerals designate the blocks of the shore ecotone system: II—amphibian; III—dynamic; IV—distant; V—marginal.

Sub-zone	Landscape index, profile number*	Ecotone block	Ground water	Humus layer thickness	Soil inclusions	Vegetation	Salinization	Score
Steppe (true steppes)	Krasnodar reservoir – **6.6**							
	(239 v) KP	II**	1	0	2	6	0	9
		III	1	0	3	4	0	8
	(239 e) KP 8	II	1	0	1	6	0	8
		III	1	0	1	4	0	6
		IV	0	0	0	2	0	2
	Tsimlyansk reservoir – **8.5**							
	(239 b) TP 6	III	2	0	2	4	1	9
		IV	2	0	0	2	0	4
Dry steppe	**(251 a) TP 21**	III	2	0	3	4	2	11
		IV	1	0	2	2	1	6
	(255 o) TP 18	III	2	0	2	4	3	11
		IV	1	0	0	2	1	4
	(255 ch) TP 1	III	2	6	4	4	0	16
		IV	1	0	3	2	0	6
		V	0	0	1	2	0	3
	(255 ts) TP 11	III	2	6	2	4	2	16
		IV	1	0	3	2	1	7
	Proletarsk reservoir – **11.3**							
	(249 b) PP 5	II	2	6	2	4	3	17
		III	1	0	2	4	3	10
		IV	0	0	3	2	2	7
	Veselovsk reservoir – **12.4**							
	(249 b) VP1	II	3	10	0	6	3	22
		III	2	0	3	4	3	12
		IV	0	0	1	3	2	5
	(255 i) VP 5	III	1	6	3	4	3	17
		IV	1	0	1	2	2	6

given to a groundwater surge from a depth of 3 (5) almost to the daylight surface (0.5–0 m).

In addition, a scale that binds the parameters and assessed values was developed to estimate the soil transformation (Table 2). For this purpose, a different "point weight" was adopted. The absence of the hydromorphism signs indicates the absence of hydrogenic soil transformation and is given "0" points. Changes in the vegetation from an aboriginal shore to a shoreline due to an increased moisture supply to biotopes are directed towards the replacement of moisture resistant species and plant communities by hydrophilic ones. To make it easier to perceive the assessment scale, a conditional ecological series that reflect the essence of changes during an increase in biotope hydromorphism from the zonal to the semiaquatic and aquatic level, rather than specific communities, were given (Table 3).

The salinization of shore soils under the reservoir impact is estimated on the basis of the content of watersoluble salts in the solid residue of the water extract. This indicator varies from less than 1 to 3%. The scale was built with a step of 0.25% for the two lower levels (zero or weak salinization) and 0.05% for the upper levels (medium and high salinization). The developed scales (Tables 2–3) were used to estimate the degree of the transformation of natural complex components (groundwater, soils, and vegetation) in the ecotone system blocks of enclosing landscapes on the shores of the studied reservoirs in the steppe zone of European Russia (Table 4).

Then the transformation depth was calculated as their sum, separately for each block of the enclosing landscape (Table 4). The higher the score was, the deeper was the transformation of the natural complex in a given block. In addition, the transformation depth of natural complexes in different blocks was based the calculation of the average transformation depth of natural complexes for the reservoir (Table 4).

Discussion

The application of the described methodological approach, represented in Table 4, showed that the lowest average score (6.6) was estimated for the Kransnodar reservoir, but the values grew according to the gradient of environmental aridization towards south. The soil salinization in the Kuma-Manych Depression at the Proletarsk and Veselovsk reservoirs supplemented the transformation of ecosystems, and the values turned out to be the highest (11.3 and 12.4, respectively). These results prove the possibilities for use of the applied algorithm in accordance with the proposed methodology. On the other hand, the results obtained allow to state that the developed procedure is still restricted by the geographical scope of the steppe zone, but further development of studies in other zones will possibly allow the expanded use of the proposed procedure.

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