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ECOLOGICAL RISK CLASSIFICATION IN THE REGULATED AND CONSERVED WATERCOURSES

KLASYFIKACJA RYZYKA EKOLOGICZNEGO W CIEKACH REGULOWANYCH I KONSERWOWANYCH

Abstract: The subject of the following study is ecological risk in regulatory and maintenance works conducted in small and medium-sized lowland watercourses. Risk has not been identified well enough. It results from the lack of the data to assess its level objectively. The following research presents a proposal of solving the problem.

The results of the field work conducted between 2007 and 2008 on 10 Lower Silesian lowland watercourses form a basis for this analysis. The research included hydromacrophytes identification and the degree of the bottom coverage by these aquatic plants. The following study showed that in a result of regulatory and maintenance works quality and quantity alternations in aquatic plants communities were observed. The analysis of these alternations enabled assigning measures to the factors of considered risk. It served as a basis for describing the matrix of risk classification.

Risk classification method suggested in the study may be useful in designing plans concerning ecological risk management and at the determination of the safety management rules in case of technical interferences in the watercourses.

Keywords: aquatic vascular plants, ecological risk, maintenance works, watercourses regulation

Introduction

The research on regulatory and conservation works impact on the watercourses biocenosis show it is very variable. The most often effects of the following works are quality and quantity changes in plant and animal communities in the watercourse [1–8]. The level of these changes is dependent on both technical and environmental factors [5–7, 9, 10]. All these should be taken into account when planning regulation or

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conservation. In spite of knowledge base accessible in this matter there is no method allowing for biocenosis changes forecast being a result of technical works occurring in the river bed. The lack of such a tool results in the possibility of the assessment of the project after it has been done. Decisions taken by designers and contractors are assessed after the works completion. Taking into account that the effects of some decisions are irreversible for the environment it is crucial to take fast actions on solving the problem to assure environmental safety.

The following research shows the proposal of using an assessment of ecological risk to cover the problem. The term "risk" defines a degree of exposure to harmful events and their possible consequences [11, 12]. Determination of the level of ecological risk in regulated and conserved watercourses serves a possibility of changes forecast in river beds ecosystems [13–15].

The aim of this study is the determination of the principle to assess and classify ecological risk of regulatory and conservation works basing on one element of watercourse ecosystem – hydromacrophytes. These water plants are good bioindicators of the quality of water environment [16–18]. Therefore, they are one of the basic factors considered in an assessment of the ecological state of flowing waters [19].

Study objects

Field work was performed during vegetation periods in 2007 and 2008 for 10 small and medium Lower Silesian watercourses. These watercourses were divided into 34 experimental sections 100 meters long each. Detailed characteristic of particular sections is showed in the Table 1.

The sections had similar climatic (*moderate, transitional between maritime and continental*), geological (*Foresudetic Monocline* built of Permian and Trias rocks) and soil (*Luvisols* formed from loess and brown soil) conditions [20–22]. Adjacent field was used agriculturally with a domination of arable lands and grasslands. Most of experimental sections was not shadowed. Only some of them were slightly shadowed. Water in experimental sections was contaminated neither with urban or industrial wastes.

Particular sections varied with the degree of antrophogenic transformation – 11 were located in the watercourses where conservatory works were done while other 13 were located in regulated watercourses. Each watercourse had one section where no works were conducted. In the following comparative analyses they served as reference points.

Conservation works in the examined watercourses included: manual scything of scarps and riverside zones, mechanical elutriate of the bottom with removal of the aquatic plants and reparation of the scarps' strengthening. Regulatory works showed deeper interference in the river bed itself. As a result of these works changes in parameters of vertical and cross-sections and the method of the banks protection occurred. In most cases these works were mechanically performed.

Table 1

Study sections

River	Number of study section	Unmodified (U), conserved (C) or regulated (R) section	Bottom width [m]	Water-course depth [m]	Substrate	Inclination of the slope	Slope protection
Czarna Woda	1	C	5	3.5	sand/gravel	1:1.5	fascines
	2	C	3	2	gravel/stones	1:2	fascines
	3	C	3	2	gravel/stones	1:2	fascines
	4	C	3	2	gravel/stones	1:2	fascines
	5	C	3	2	gravel/stones	1:1	fascines
	6	U	7	1.5	sand	1:1	non-protected
Dobra	7	U	3	1.2	sand	1:1.5	non-protected
	8	R	3	0.6	sand	1:3	fascines
	9	R	6.8	2	sand	1:0.2	gabions
	10	R	2	2	sand	1:2	stone coating
Oleszna	11	C	2	3	organic	1:1.5	non-protected
	12	C	2.4	1.36	organic	1:0.8	non-protected
	13	U	1.5	2	organic	1:1.5	non-protected
Olesnica	14	U	7	2.06	sand	1:1.5	non-protected
	15	R	4	2.27	organic	1:1	fascines
Orla	16	U	8	1.8	organic	1:1	non-protected
	17	R	10	1.8	organic	1:0.5	fascines
Potok Sulistro-wicki	18	C	2	3.5	sand/stones	1:2	fascines
	19	U	2	3.5	sand/stones	1:2	non-protected
	20	C	2	3.5	sand/stones	1:2	fascines
Smortawa	21	C	10	2.15	sand	1:2	fascines
	22	U	5	2.15	sand	1:2	non-protected
	23	R	3	1.5	sand	1:2	fascines
	24	R	3	1.5	sand	1:2	fascines
Sleza	25	U	5	3	sand	1:1.5	non-protected
	26	R	5	3	concrete	1:0.2	stone concrete
	27	R	5	1.5	sand/gravel	1:1.5	stone coating
Zalina	28	C	1.5	1.92	sand	1:1.5	non-protected
	29	U	1.5	2.11	sand	1:1	non-protected
	30	R	2	2	organic	1:1	fascines
Zurawka	31	R	3.3	1.4	sand	1:1.5	fascines
	32	U	3	2.2	sand	1:2	non-protected
	33	R	3	2	sand	1:2	fascines
	34	R	3	2.2	sand	1:2	fascines

Methods

In the framework of the following field work macrophytes species was identified on the examined sections and the degree of the bottom coverage with them was determined. All hydromacrophytes rooted in water for at least 90 % of the vegetation period and plants flowing naturally on the water surface or under it were taken into account. Five levels Braun-Blanquet scale was used for the determination of the density degree [23].

In order to assess species variety in the examined sections Shannon-Wiener Index – H [24] was calculated, considering both number of species and their coverage regularity [10].

Statistical analysis of the results was done using Statistica v. 9.1. programme.

Risk level connected with conservation and regulatory works performance was defined according to the following formula [11]:

$$R = P \cdot S$$

In this formula:

- P – stands for the probability of change of the hydromacrophyte environment as a result of the performed works,
- S – stands for the susceptibility of changes in the aquatic plant species composition.

These factors were ascribed with different measurements. They were indicated by the field work results. In both cases 5 levels scales were used.

Product of P and S parameters formed a basis of the risk level assessment. It was followed by two parametric matrix of the risk assessment [25]. According to accepted scales, matrix was marked due to observed changes in the plants community concerning works conducted in the examined watercourse. Risk classification was based on this analysis.

Results and discussion

In the examined sections 20 species of aquatic macrophytes were determined altogether. This number is small in comparison with the results obtained from other authors in similar studies [5, 26, 27]. The small number of species of aquatic plants may be due to the fact that most watercourses underwent some kind of technical interference in the past as well as due to agricultural settings in the surroundings. Furthermore the small rivers have a lower species richness of aquatic plants than large rivers [26].

The following species were found: *Alisma plantago-aquatica* L., *Berula erecta* (Huds.) Coville., *Butomus umbellatus* L., *Callitriche* sp., *Ceratophyllum demersum* L., *Elodea canadensis* L., *Glyceria Maxima* (Hartm.) Holmb., *Hydrocharis morsus ranae* L., *Myosotis palustris* (L.) L. em. Rchb., *Lemna minor* L., *Nuphar lutea* (L.) Sibth. & Sm., *Phalaris arundinacea* L., *Phragmites communis* Trin., *Potamogeton pectinatus* L., *Potamogeton filiformis* Pers., *Sagittaria sagittifolia* L., *Sparganium emersum* Rehmann, *Sparganium erectum* L. em. Rchb. s.s., *Spirodela polyrrhiza* (L.) Schleid., *Typha angustifolia* L. According to *Method of Macrophytes Rivers Assessment* (MMOR) these species have a wide or medium wide ecological scale and low or medium index value – W measured at 1 or 2 [28].

Figure 1 shows statistic data referring to aquatic plants occurrence in the examined river sections.

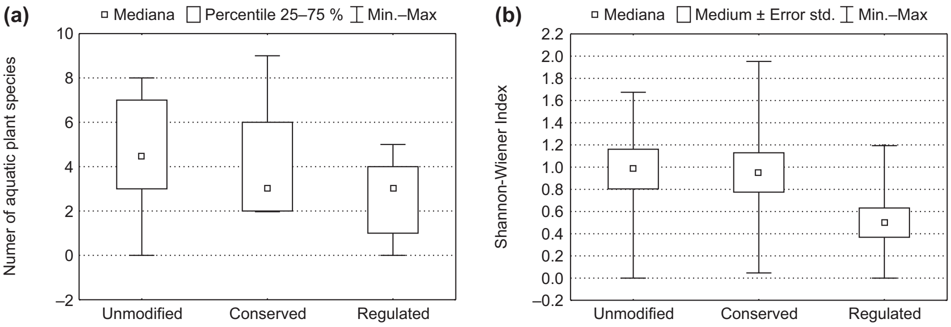

Fig. 1. Diversification of the number of species (a) and species variety Shannon-Wiener Index (b) in the examined sections

The highest mean number of species was observed in natural sections while in modified sections especially those which were regulated a lot less. It is widely believed that any technical interference within a watercourse's channel adversely affects its biocoenosis [5, 29–33]. Values of the diversity Shannon-Wiener Index determined in compared sections were slightly different (Fig. 1b). In unmodified and conserved examined sections they were similar while in regulated watercourses they were considerably lower. The mean index value in unmodified, conserved and regulated river beds was calculated at 0.98; 0.95 and 0.5, respectively.

Ecological risk factors were defined and classified using results of the following research. While assessing P factor, determining the possibility of alternations in the number of aquatic plants species, a strong relation with a range of performed works in the river bed was taken into account. Observations made during the research allowed to acknowledge a five degree scale.

Table 2

Scale of the changes occurrence probability in the aquatic plant communities in the river beds as a result of the watercourses regulation and maintenance works – P

Probability of changes occurence	
Point scale	Description scale
1 Very low	Slope mowing, river bed elutriation with the removal of aquatic plant life
2 Low	Slope mowing, river bed elutriation with the removal of the aquatic plant life, reparation and the strengthening of fascine
3 Medium	Changes in cross-section parameters, modification of the scarps incline to 1:1.5, additional strengthening of a riverbank's foundation with fascine construction
4 High	Changes in cross-section parameters, the strengthening of scarps with stone or stone mattress gabions
5 Very high	Changes in cross-section parameters, modification of watercourse's vertical plane with horizontal scarps, the strengthening of slopes with box gabions or retaining walls

Particular levels in the scale defining risk factor S – changes in the number of species as a result of works conduction were determined on the basis of comparison of species composition of macrophytes aquatic communities in the sections where technical works were and were not done. In the sections where no human interference was present 15 species (Fig. 2) were found and 10 out of 15 showed medium index value (W = 2) while other species revealed low value (W = 1). None section was defined with stenotopic species of a high index value (W = 3).

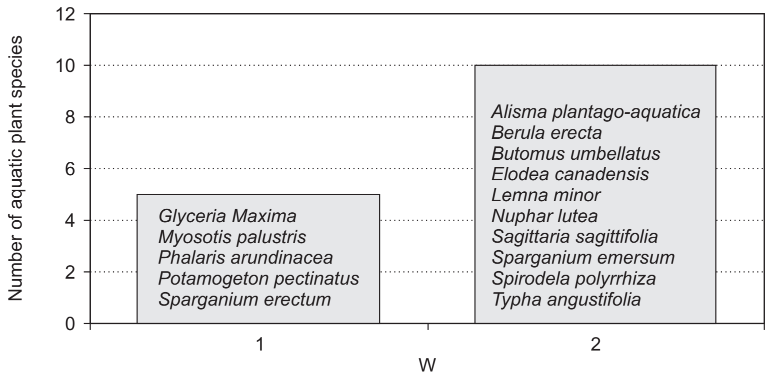

Fig. 2. Index value of the species occurring in unmodified sections

The following research enables to claim that the least severe effects of conducted works occurred in watercourses with wide ecological scale species. The more species with low index value the better they adapt to new, technically changed habitat conditions. On the basis of this relation the effects of conservatory and maintenance works were linked with aquatic macrophytes species composition in particular watercourses (Table 3).

Table 3

The scale of the consequences of the watercourses regulation and maintenance works in the river bed for the aquatic plant communities – S

Susceptibility of changes of aquatic plant species composition	
Point scale	Description scale
1 Lack	No hydromacrophytes in the watercourse
2 Mild	1–3 species of hydromacrophytes with low and medium index values of W = 1 or W = 2 in the watercourse
3 Moderate	More than 4 species of hydromacrophytes dominated with taxons of a low index value of W = 1 in the watercourse
4 Severe	More than 4 species of hydromacrophytes dominated with taxons of a medium index value of W = 2 in the watercourse
5 Very severe	Taxons with the high index value of W = 3 in the watercourse

Classifications of considered risk factors showed in Tables 2 and 3 formed a basis to compile ecological risk matrix in both maintained and conserved watercourses (Fig. 3).

Probability (P)					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	**2**	**3**	**4**	**5**
	Susceptibility of changes (S)				

Fig. 3. A matrix of ecological risk in maintained and regulated watercourses

The following matrix shows the level of risk may be placed between 1 and 25 points.

Information obtained during the field work were used for determination of point range for small risk – usually accepted, medium and high – unaccepted. Each section located in modified watercourses were defined with the area of matrix where observed changes in plants communities took place. This data was presented on both matrixes – for watercourses where conducted works comprised of the river bed conservation (Fig. 4) and for regulated watercourses (Fig. 5). Both matrixes were also marked with the direction of the observed changes referring to the number of species and Shannon-Wiener Index.

Probability (P)					
5					
4					
3					
2		= = 18, 20 + +		+ = + – – 1, 2, 3, 4, 5 + + + – –	
1	+ + 11, 12 + +	= 28 +		+ 21 +	
	1	**2**	**3**	**4**	**5**
	Susceptibility of changes (S)				

Fig. 4. A matrix of ecological risk for maintained study sections
[ ] – shows a trend of changes in the number of species: "+" – increase, "–" – decrease, "=" – no changes;
28 – the number of the examined section;
[ ] – shows a trend of changes in the Shannon-Wiener Index: "+" – increase, "–" – decrease

Observed alternations in aquatic plants communities concerned enlarging or lowering the number of species and species biodiversity index. Directions of these changes were marked in the Figs. 4 and 5 as upper and lower index given above the number. They show corresponding examined section. In case of conservatory works the most common situations were those with a growth in both values (Fig. 4). It shows that properly executed maintenance work, including mowing the banks, the removal of plant life from the river bottom and its dredging, in fact does allow the watercourse to function properly, without causing a permanent loss of aquatic plant communities [1, 5, 14, 34–38]. Maintenance works do not cause the disappearance of islands and oxbow lakes, do not change the route of the river bottom and do not restrict the watercourse's capacity during overflowing [4]. Regulated sections in most cases show that the result of river beds regulation is lowering the number of species of aquatic plants and the values of Shannon-Wiener Index. According to Gunkel [30] river regulation is a major controlling factor for the aquatic ecosystems. Conventional river control causes the changes in hydraulic characteristics of the river. The hydrological regime has been widely recognized as an important factor controlling colonization of streambeds by macrophytes [38]. If for these works risk assessment according to proposed method risk level would be contained in the right, upper matrix area (Fig. 5).

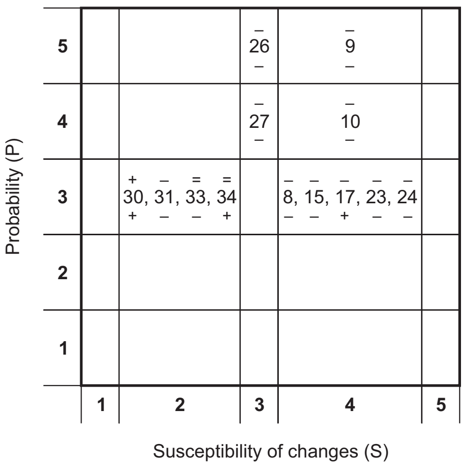

Fig. 5. A matrix of ecological risk for regulated study sections
[ ] – shows a trend of changes in the number of species: "+" – increase, "–" – decrease, "=" – no changes;
34 – the number of the examined section;
[ ] – shows a trend of changes in the Shannon-Wiener Index: "+" – increase, "–" – decrease

Figure 6 shows the matrix where both maintenance and regulatory works were considered. It was a basis for ecological risk classification taking into account its 3 levels – low, medium and high risk (Fig. 7).

The analysis of Fig. 7 reveals that the limits between fixed levels of risk are as follows:

– low risk – ≤ 4 points,
– moderate risk – 6–8 points,
– high risk – ≥ 12 points.

Basing on the research it was impossible to determine the risk level for 5, 9 and 10 points. Therefore, it is necessary to conduct further research, including study objects

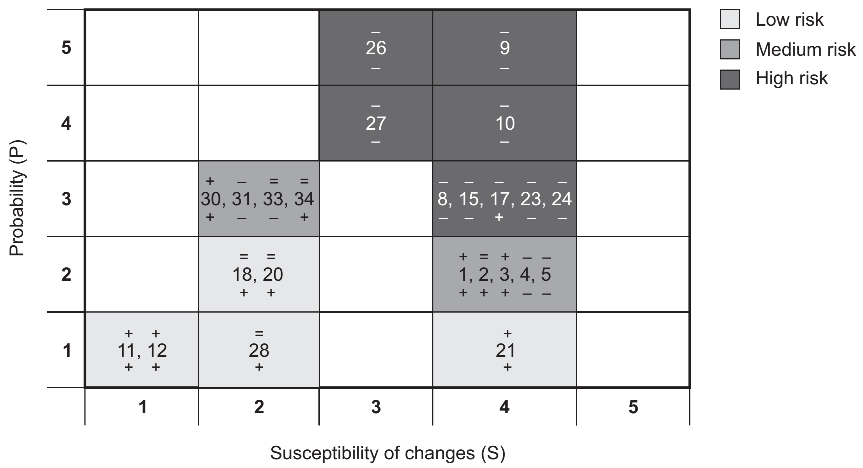

Fig. 6. The ecological risk classification based on the alternations of aquatic plants communities of maintained and regulated watercourses
[ ] – shows a trend of changes in the number of species: "+" – increase, "–" – decrease, "=" – no changes;
28 – the number of the examined section;
[ ] – shows a trend of changes in the Shannon-Wiener Index: "+" – increase, "–" – decrease

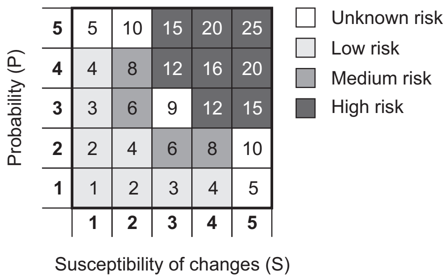

Fig. 7. A matrix showing the three ecological risk levels of maintained and regulated watercourses

with various composition of aquatic plant communities and the different degree of anthropogenic transformation.

Conducted research and analyses should be considered as pilotage for the following project. Better recognition requires further observations performed in the communities of plants and animals in watercourses being a subject to water works.

Conclusions

1. The research conducted on 10 lowland watercourses found in Lower Silesia, where maintenance and regulatory works were done, showed these works resulted in alternations in the number of aquatic plants species and the index of their biodiversity. The range of performed works and ecological tolerance of the plants occurrence in watercourses had a big influence on the size of these changes.

2. The results of the following research allowed for determination and classification of ecological risk factors in five level scales – the possibility of alternations in species in the communities of hydromacrophytes and the level of these changes.

3. Based on the risk matrix, the ecological risk was then classified in three different levels. Low risk was determined for those values ranging from 1 to 4, medium risk was found between 6 and 8, while high risk was determined at values of 12 points or more.

4. The performed analysis found that maintenance works are connected with low or moderate risk, whereas regulatory works comprise of moderate or high risk area.

5. In order to limit adverse alternations of the aquatic plants community, a risk assessment should be performed when planning any maintenance or regulatory works. It requires a detailed environmental assessment of the river bed and a detailed analysis of the range of the planned works.

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KLASYFIKACJA RYZYKA EKOLOGICZNEGO W CIEKACH REGULOWANYCH I KONSERWOWANYCH

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Streszczenie: Przedmiotem pracy jest ryzyko ekologiczne w robotach regulacyjnych i konserwacyjnych wykonywanych na małych i średnich ciekach nizinnych. Ryzyko to nie jest jeszcze dobrze rozpoznane. Wynika to m.in. z braku podstaw do obiektywnej jego oceny. W pracy przedstawiono propozycję rozwiązania tego problemu.

Podstawę analizy stanowią wyniki badań terenowych prowadzonych w latach 2007–2008, na 10 nizinnych ciekach Dolnego Śląska. Badania obejmowały identyfikację występujących w korycie gatunków naczyniowych roślin wodnych oraz określenie stopnia pokrycia przez nie dna. Wykazały one, że w wykonanych prac zachodzą zmiany jakościowe i ilościowe w zbiorowiskach naczyniowych roślin wodnych. Analiza tych zmian pozwoliła na przypisanie miar czynnikom rozpatrywanego ryzyka. Stanowiło to podstawę opracowania macierzy klasyfikacji ryzyka.

Zaproponowana w pracy metoda klasyfikacji ryzyka może być przydatna w opracowywaniu planów zarządzania ryzykiem ekologicznym oraz przy określaniu zasad zarządzania bezpieczeństwem środowiska przyrodniczego w przypadkach ingerencji technicznych w korytach cieków.

Słowa kluczowe: ryzyko ekologiczne, naczyniowe rośliny wodne, roboty konserwacyjne, regulacja cieków