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The risk as a measure of ecological safety in watercourses

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Abstract

The study analyses possibilities of PHA (Preliminary Hazard Analysis) usage in ecological risk assessment conducted within technical risk assessment. The analysis was performed based on results obtained in a study performed between 2007 and 2013 in natural and modified lowland Lower Silesian watercourses. The object of the study was communities of hydromacrophytes being good indicators of the water ecosystem quality.

The research constituted a base for the determination of ecological risk factors i.e. the probability of hazard occurrence and its effects. It allowed for the acquisition of the risk classification matrix which included three levels – low, medium and high.

Key words: *ecological risk, ecological safety, hydromacrophytes, rivers, rivers' regulation*

INTRODUCTION

Maintenance of watercourses in Natura 2000 should include both functions connected with environmental protection and river ecology. River valleys are frequently subjected to strong anthropogenic impact [POFF *et al*. 2010] which can cause numerous modifications, water contamination, biological degradation, lowered retention capacity and increased flow velocity and erosion [BONISŁAWSKA *et al*. 2013; CORTES *et al*. 2002; ŁAPUSZEK 2013; MIODUSZEWSKI 2012]. According to the Habitat Directive, each and every enterprise affecting the habitats of Natura 2000 must be subjected to the impact assessment. So far, there is no method which would allow to forecast changes in biocenoses caused by technical interference in the riverbed. The lack of such a method results in the inability of evaluation of designers and contractors decisions before the works are completed while the results of some decisions are irreversible to the natural environment. In order to increase the ecological safety it should be possible to answer the following questions:

– which hazards to the natural environment or its component ecosystems are determined by anthropogenic activities?
– what is the current effect of these hazards and what will it be in the future?
– is it possible to undertake actions limiting these threats and to repair a harmful interference to the environment?

These questions show the need of defining natural environmental safety. It is a difficult task as safety depends on many factors. It results from complexity and changeability of the natural environment [BONDAR-NOWAKOWSKA, HACHOŁ 2012]. All its component elements and necessary range of their changes should be recognized in its safety assessment. The basis of such analyses should consist in isolation of its subsystems and their elements, determination of their mutual relations and assessment of their sensitivity to an internal and external impact. The lack of information on the subject prevents from undertaking such activities. Therefore, direct observations and field research should be considered when assessing safety of natural environment.

Ecological safety in relation to ecosystems is determined as "the state of the ecosystem when the risk of its components distortion is low" [ZACHER 1991]. This definition shows that a measure of ecosystem safety may be the risk of its elements distortion. The aim of this study was to analyse this assumption using maintained and regulated watercourses as an example.

The problem of ecological risk assessment is well known to the scientists. Many ecological risk assessments were performed at very small spatial scales (e.g. estimations of a site-specific risk for a single species) or at a very large scale (e.g. global risk assessments of greenhouse gases), but rarely at the level of mesoscale [LEUVEN, POUDEVIGNE 2002]. Many authors use statistical analyses and mathematical simulation in ecological risk assessment [CIRONE, DUNCAN 2002; WILEY *et al*. 2008] while examples of ecological risk assessment methods used in technical risk valuation are rare. The following methods such as: PHA, HAZOP, FMEA and logic trees being currently used for the assessment of safety and quality of technological systems could be used for the ecological risk assessment [HACHOŁ, BONDAR-NOWAKOWSKA 2009]. This study analyses the possibility of the application of PHA (Preliminary Hazard Analysis) in the evaluation of the ecological risk during regulation and maintenance works in watercourses.

As commonly known, it is impossible to fully assess the condition of aquatic ecosystem by chemical analysis of water quality [KARAVAN *et al*. 2013]. Therefore, biological parameters are very important. The object of the analysis is one of the most crucial element of running water ecosystems – aquatic vascular plants [BONDAR-NOWAKOWSKA, HACHOŁ 2010]. These plants occur widely in rivers and their advantage is their immobility. Moreover, they are easily accessible and their reaction to anthropogenic activities is usually quick and noticeable [BOWDEN *et al*. 1994; KŁOSOWSKI 1992; SZOSZKIEWICZ *et al*. 2002]. This was the reason to use these plants in Macrophyte Method for River Assessment (MMOR) [SZOSZKIEWICZ *et al*. 2010].

MATERIAL AND METHODS

The field study was performed in four Lower Silesian lowland rivers such as: the Dobra River – a tributary of the Widawa River, the Sąsiecznica River – a tributary of the Barycz River, the Ślęza River – a tributary of the Odra River and the Żurawka River - a tributary of the Ślęza. In these watercourses regulatory and maintenance works had been conducted a year before the study began. These works were aimed at ensuring protection against floods to adjacent areas.

There were 15 survey sites selected in the study research. According to the hydromacrophytes research methodology [SCHAUMBURG *et al*. 2006; SZOSZKIEWICZ *et al*. 2010] the length of each site was established at 100 m. There were five sites characterized in the watercourse of the Dobra river (D1, D2, D3, D4, D5), two (S1, S2) in the Sąsiecznica, four (Ś1, Ś2, Ś3, Ś4) in the Ślęza and four (Ż1, Ż2, Ż3 and Ż4) in the Żurawka.

Survey sites were located in areas of similar climate, geologic and soil conditions. Littoral zones of these sites represented agricultural land. During the field study waters were reported to be uncontaminated with any urban or industrial effluents. Sites of analysed watercourses varied in their modification level. One site in each watercourse was unmodified and showed characteristics approximate to the natural one. The range of works performed in other sites is presented in Table 1.

Table 1. Characteristics of study sites

The level of watercourse modification	The range of works in the watercourse	Symbol of the study site
Unmodified watercourse	–	D1, S1, Ś1, Ż1
I. moderate modification	– mowing flora from the litoral zone and banks, – bottom dredging and aquatic plant removal, – creation of cross sections with banks of a 1:1.5 to 1:2 slope, – bank strengthening with fascine	D2, D3, S2, Ś2, Ż2, Ż3
II. strong modification	– mowing flora from the litoral zone and banks, – watercourse deepening, – creation of cross section with banks of a 1: 2 slope – banks strengthening with stones	D4, Ś3
III. very strong modification	– mowing flora from the litoral zone and banks, – watercourse deepening – creation of the cross section with vertical banks, – banks strengthening with gabions or retaining walls	D5, Ś4, Ż4

Source: own study.

The examples of different watercourse modification are presented in Phot. 1.

The field study was performed in two cycles. The first included 2007 and 2008 vegetation periods being the first seasons after the works completion while the second study was conducted in 2011 and 2012.

The field study consisted in identification of macrophyte species in particular survey sites and in determination of the degree of their coverage. The study included all aquatic plants being rooted for at least 905 days of the vegetation periods and higher plants floating on the surface or below it. Aquatic plant species were determined directly in the field.

In order to determine the degree of water plants density, 5 degree Kohler's scale [KOHLER 1978] was

Phot. 1. Study sites presenting different level of watercourse modification: a – unmodified site (D1), b – level I – moderate modification (site Ż2), c – level II – strong modification (site Ś3), d – level III – very strong modification (site Ś4)
phot. *J. Hachoł*

used where 1 stands for 5% bottom coverage, 2 – for 5 to 25%, 3 – for 25 to 50%, 4 – for 50 to 75% and 5 – for 75 to 100% bottom coverage.

Comparative analyses were performed to assess qualitative and quantitative changes resulting from modifications in riverbeds. The basis of this comparison were:
– the number of species in the community,
– Shannon-Wiener index.

The number of species in particular survey site was determined based on field studies while Shannon-Wiener index was calculated using the following formula [SCHAUMBURG *et al*. 2006]:

$$H = -\sum_{i=l}^{s}(N_i \ln N_i) \qquad (1)$$

where:
H – index of species diversity,
s – the number of water plants in the survey site,
N_i – index calculated from the formula:

$$N_i = \frac{Q_i}{Q} \qquad (2)$$

where:
Q_i – the cube of the degree of bottom coverage by plants of the i^{th} – species,
Q – the cube of the bottom coverage by plants of all species.

In order to determine the level of risk connected with macrophyte communities the method of PHA (Preliminary Hazard Analysis) was adopted. This method requires determination of a certain level of probability of the threat occurrence and the magnitude of damage being its effect. It can be expressed by the following product:

$$R = PS \qquad (3)$$

where:
R – risk,
P – probability of the damage occurrence,
S – magnitude of the damage.

A three-level scale linked with the range of performed works and the degree of watercourse modification was established (Tab. 1). Particular levels represent:

1 – moderate modification,
2 – strong modification,
3 – very strong modification.

Changes in the number of species in aquatic plant communities and in the biodiversity index defined in technically unchanged sites were the basis for damage classification. Particular levels of these scales were determined based on results of the field study. In order to determine the risk dynamics, the analysis was conducted for the first and second study period.

RESULTS AND DISCUSSION

In total, twenty macrophyte species were found in study sites (Tab. 2). The number is rather low in comparison to the results of other authors [CAFFREY *et al*. 2006; PIETRUCZUK, SZOSZKIEWICZ 2009; RIIS *et al*. 2008]. A low number of aquatic plants determined during the field work may be caused by the fact that analyzed watercourses were located in relatively uniform agricultural landscape and were affected by technical interference relatively short before the examination. All the species are common and frequently occur in lowland watercourses [KŁOSOWSKI, KŁOSOWSKI 2007]. According to the Macrophyte Method for River Assessment the species were of wide or mid-wide ecological scale and of low or medium index value [SZOSZKIEWICZ *et al*. 2010].

Data presented in Table 2 indicate that a higher number of species was found in the second study period. In the latter 19 species were observed in the study sites while in the first season there were 13 species there. Four species: *Ceratophyllum demersum, Myosotis palustris, Nuphar lutea* and *Typha angustifolia* grew only in unmodified sites. These species show wide tolerance to environmental factors such as the trophy level, type of bottom substrate and depth. However, all the taxa prefer stagnant or slow flowing waters characteristic of unmodified watercourses [KŁOSOWSKI, KŁOSOWSKI 2007]. Cutting aquatic plants rooted in the bottom and escarps changes the cross section parameters and bank strengthening alter hydraulic characteristics of the river. An increase in the flow velocity may lead to the elimination of species that prefer still waters. The hydrological regime has been widely recognised as an important factor controlling colonization of streambeds by macrophytes [RIIS, BIGGS 2003]. Four other species such as *Mentha aquatica*, *Oenanthe aquatica, Sparganium erectum and Veronica beccabunga* occured only in modified sites. Modified watercourses offer completely new habitats facilitating creation of new aquatic plant communities compared with plants that occurred there before the completion of works. Similar tendencies were observed by FOX and MURPHY [1990] and HEARNE and ARMITAGE [1993]. Two species – *Elodea canadensis* and *Sparganium emersum* were noted in all the survey sites. Both species show a very wide ecological amplitude.

The number of species growing in particular sites varied. However, they were most frequent in sites never subjected to technical interference. Detailed data concerning the phenomena are presented in Table 3.

Table 2. Macrophyte occurrence in unmodified and modified sites as a result of regulatory and maintenance works

The level of watercourse modification 2007/2008				Species	The level of watercourse modification 2011/2012			
III	II	I	U		U	I	II	III
x	x		x	*Berula erecta* (Huds.) Coville	x	x	x	x
x		x	x	*Callitriche palustris* L.	x	x		
			x	*Ceratophyllum demersum* L.	x			
x	x	x	x	*Elodea canadensis* L.	x	x	x	x
	x	x	x	*Glyceria maxima* (Hartm.) Holmb.	x	x		
		x	x	*Lemna minor* L.	x	x		
				Mentha aquatica L.			x	
			x	*Myosotis palustris* (L.) L. em. Rchb.	x	x		
				Nuphar lutea (L.) Sibth. & Sm.	x			
		x		*Oenanthe aquatica* (L.) Poir.				
	x	x	x	*Phalaris arundinacea* L.	x	x	x	
		x	x	*Phragmites communis* Trin	x	x		
				Potamogeton pectinatus L.	x	x		x
				Potamogeton crispus L.	x			
		x	x	*Sagittaria sagittifolia* L.	x	x		x
				Sparganium erectum L. em. Rchb. s.s.		x		
x	x	x	x	*Sparganium emersum* Rehmann	x	x	x	x
				Typha latifolia L.		x		
			x	*Typha angustifolia* L.	x			
				Veronica beccabunga L.		x	x	
4	5	9	12	← The number of species →	15	14	6	5

Explanations: U – unmodified survey site, I – moderate modification, II – strong modification, III – very strong modification.
Source: own study.

Table 3. The number of species in unmodified sites

Survey site	The number of species in the study period	
	2007/2008	2011/2012
D1	7	8
S1	8	7
Ś1	6	8
Ż1	3	7

Source: own study.

The field study indicated that both maintained and regulated sites of watercourses experienced a drop in the number of species. It is widely believed that any technical interference within the watercourse channel adversely affects its biocoenosis [CAFFREY *et al*. 2006; RIIS *et al*. 2000; VEREECKEN *et al*. 2006; ŻELAZO 1993). It is presented in detail in Figure 1. Black parts of each column show the number of species identified in a survey site while lighter parts present by how many species this number decreased in comparison to the number of species in watercourses not subjected to any technical interference.

Figure 1 indicates that both during the first and second study period the biggest decline in the number of species occurred in Ś4 site. In the unmodified site of the river there were 6 species in the first and 8 species in the second study period. The degree of watercourse modification in Ś4 site was qualified as very strong as a result of conducted works which totally changed the watercourse intersection. Similar range of works was also performed in D5 and Ż4 sites. However, the effects of these works were not so severe to aquatic plants.

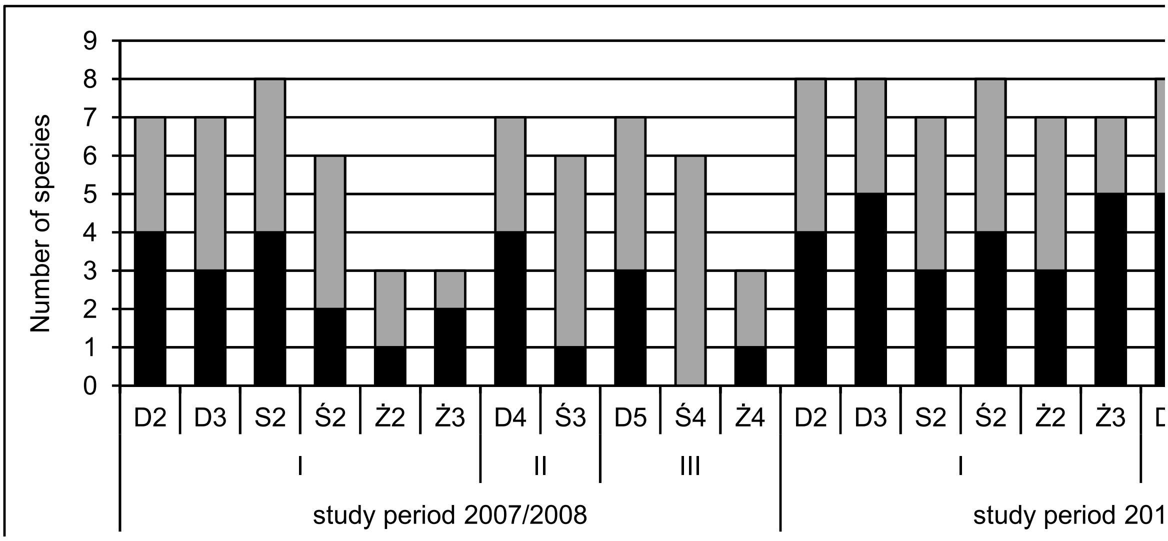

Fig. 1. Changes in the number of species in comparison to sites not subjected to any technical interference; I – moderate modification, II – strong modification, III – very strong modification; source: own study

The diversity index showed similar tendency being highest in sites that were not subjected to any technical interferences (Tab. 4). Its value decreased in the consequence of conducted works. The range of changes in relation to unmodified sites is presented in Figure 2.

Table 4. Values of the Shannon-Wiener index in unmodified sites of watercourses

Survey site	Shannon-Wiener index in the study period	
	2007/2008	2011/2012
D1	1.32	1.18
S1	1.80	1.14
Ś1	1.46	1.61
Ż1	0.61	1.34

Source: own study.

Figures 1 and 2 indicate that when the sites were affected by any technical interference there was a decline in the number of species and in the value of species diversity index. However, it was not related to the extent of works. This may result from the fact that during both maintenance and regulatory works aquatic plants were entirely removed from the river bed and developed similarly as in the initial period after the works completion regardless of the type of technical activities. Many studies report that the range of works influences the composition of aquatic plant species after a certain time since their completion [FOX, MURPHY 1990; HACHOŁ, BONDAR-NOWAKOWSKA 2012]. The change in the number of species ranged from 1 to 8. Biodiversity index decreased in particular survey sites by 0.02 to 1.62. Based on the obtained data, S classification factor was adopted to express the damage resulting from conducted technical interference. The three-level scale was used similarly to the classification of the risk of damage occurrence. With regard to the number of macrophytes species:

1 – small damage – 0–1 species lost in the study site,
2 – moderate damage – the loss of 2–3 species,
3 – big damage – the loss of 4 and more species.

Changes in the biodiversity were classified in the following ranges:

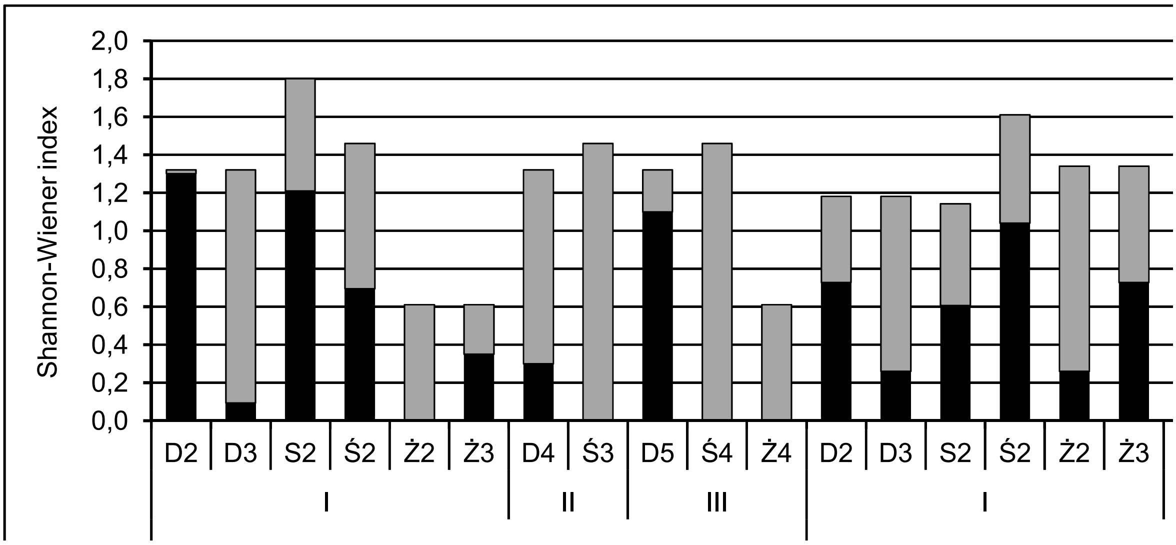

Fig. 2. Changes in the Shannon-Wiener index in relation to sites that were not subjected to technical interference; I – moderate modification, II – strong modification, III – very strong modification; source: own study

1 – small change – 0.00÷0.10,
2 – medium change – 0.11÷0.30,
3 – big change – > 0.3.

Presented classifications of P and S risk factors served as a base to create risk matrices. They are presented in Figures 3 and 4 and may help determining the risk of community impoverishment and the decline in the diversity index prior to the start of works in considered study sites.

Study period 2007/2008

The possibility of a decrease in the number of species				
	3		Ż4	D5; Ś4;
	2		D4	Ś3
	1	Ż3	D2; Ż2	D3; S2; Ś2
		1	2	3
		The extent of changes in the number of species		

Study period 2011/2012

The possibility of a decrease in the number of species				
	3		D5	Ś4; Ż4
	2		D4	Ś3
	1		D3; Ż3	D2; S2; Ś2; Ż2
		1	2	3
		The extent of changes in the number of species		

Fig. 3. The risk of changes in the number of species in macrophyte communities; source: own study

Study period 2007/2008

The possibility of a decrease of diversity index				
	3		D5	Ś4; Ż4
	2			D4; Ś3
	1	D2	Ż3	D3; S2; Ś2; Ż2
		1	2	3
		The decrease of diversity index		

Study period 2011/2012

The possibility of a decrease of diversity index				
	3			D5; Ś4; Ż4
	2	D4		Ś3
	1			D2; D3; S2; Ś2; Ż2; Ż3
		1	2	3
		The decrease of diversity index		

Fig. 4. The risk of changes in the biodiversity index in analysed sites; source: own study

The use of Preliminary Hazard Analysis method for risk assessment should allow its gradation in three categories: low risk level, medium risk level and high risk level with the low risk level showing acceptable values. The level itself should also include the safety index. It pertains to considered biological indices and both study cycles. Performed study showed that any technical interference in the watercourse, even of minor extent, results in a high risk of impoverishment in macrophyte communities and related diversity indices. The results show that the maintenance or regulation of watercourses requires activities that would decrease the level of ecological risk [BONDAR-NOWAKOWSKA 2010].

Risk classification in an appropriate range allows to compare different project solutions and choose the most appropriate one. This study does not unambiguously indicate the difference between low, medium and high risk of changes in macrophyte communities caused by regulatory and maintenance works. The problem may be resolved using observations of water ecosystems. It should be the subject of subsequent studies.

CONCLUSIONS

1. The level of safety of each system requires risk analyses. These analyses determine hazards and choices of efficient ways of prevention.

2. Technical interference in the river bed is always associated with the high risk of impoverishment of macrophyte communities. The risk shows a tendency to increase in time.

3. Changes in species composition of aquatic plant communities in the first two years after the works completion are rather not related to the range of these works.

4. Creation of an effective and universal method of ecological risk assessment in maintained and regulated watercourses requires further studies and analyses also in the form of controlled experiment.

REFERENCES

BONDAR-NOWAKOWSKA E. 2010. Reagowanie na ryzyko ekologiczne w konserwowanych ciekach [Responding to ecological risks in maintained watercourses]. Zeszyty Problemowe Postępów Nauk Rolniczych. Z. 548 p. 33–44.

BONDAR-NOWAKOWSKA E., HACHOŁ J. 2010. Zmiany w składzie gatunkowym naczyniowych roślin wodnych po konserwacji cieków [Changes in the aquatic plant species composition after the maintenance works on water courses]. Woda-Środowisko-Obszary Wiejskie. T. 10. Z. 3 p. 41–48.

BONDAR-NOWAKOWSKA E., HACHOŁ J. 2012. Proces technicznego utrzymywania koryt cieków nizinnych a bezpieczeństwo środowiska przyrodniczego. W: Bezpieczeństwo systemu. Techniczne, organizacyjne i ludzkie determinanty bezpieczeństwa pracy [The technical maintenance of lowland watercourse beds and the environmental safety. In: The safety of a system. Technical, organizational and human determinants of the safety]. Ed. Sz. Salamon. Częstochowa. Sekcja Wydaw. PCz. p. 307–317.

BONDAR-NOWAKOWSKA E., HACHOŁ J. 2011. Zmiany w zbiorowiskach naczyniowych roślin wodnych jako czynnik ryzyka ekologicznego w regulowanych i konserwowanych ciekach [Changes of aquatic vascular plant communities as an ecological risk factor in the watercourses after regulation und maintenance works]. Infrastruktura i Ekologia Terenów Wiejskich. Nr 1 p. 263–273.

BONISŁAWSKA M., TAŃSKI A., MOKRZYCKA M., BRYSIEWICZ A., NĘDZAREK A., TÓRZ A. 2013. The effect of effluents from rainbow trout ponds on water quality in the Gowienica River. Journal of Water and Land Development. No 19 p. 23–30.

CAFFREY J.M., MONAHAN C., TIERNEY D. 2006. Factors influencing the distribution of aquatic plant communities in Irish canals. Hydrobiologia. Nr 570 p. 133–139.

CIRONE P.A., Duncan P.B. 2000. Integrating human health and ecological concerns in risk assessments. J Haz Mater. 78 p. 1–17.

CORTES R.M.V., FERREIRA M.T., OLIVEIRA S.V., OLIVEIRA D. 2002. Macroinvertebrate community structure in a regulated river segment with different flow conditions. River Research and Applications. Vol. 18 p. 367–382.

FOX A.M., MURPHY K.J. 1990. The efficacy and ecological impacts of herbicide and cutting regimes on the submerged plant communities of four British rivers. P. II. A multivariate analysis of the effect of management regimes on macrophyte communities. Journal of Applied Ecology. Vol. 27 p. 541–548.

HACHOŁ J., BONDAR-NOWAKOWSKA E. 2009. Wykorzystanie metody analizy przyczyn i skutków wad (FMEA) do oceny ryzyka ekologicznego w regulowanych i konserwowanych ciekach [The use of failure mode and effects analysis method (FMEA) for evaluation of ecological risk in regulated and maintained watercourses]. Nauka Przyroda Technologie. T. 3. Z. 3 pp. 83.

HACHOŁ J., BONDAR-NOWAKOWSKA E. 2012. Tendencies in the development of hydromacrophytes after the completion of regulatory and maintenance works in a river bed. Ecological Chemistry and Engineering A. Vol. 19 p. 997–1013.

HEARNE J.W., ARMITAGE P.D. 1993. Implications of the annual macrophyte growth cycle on habitat in rivers. Regulated Rivers: Research and Management. Vol. 8 p. 313–322.

KARAVAN J., SOLOVEJ T., YUSCHENKO Yu. 2013. Determination of anthropogenic impact on the Siret River and its tributaries by the analysis of attached algae. Journal of Water and Land Development. No 19 p. 53–58.

KŁOSOWSKI S. 1992. Ekologia i wartość wskaźnikowa zbiorowisk roślinności szuwarowej naturalnych zbiorników wód stojących [Ecology and indicative value of rush communities in natural stagnant water bodies]. Fragmenta Floristica et Geobotanica. Vol. 37 p. 563–595.

KŁOSOWSKI S., KŁOSOWSKI G. 2007. Rośliny wodne i bagienne [Aquatic and bog plants]. Warszawa. Multico Oficyna Wydawnicza. ISBN 978-83-7073-248-6. pp. 336.

KOHLER A. 1978. Methoden der Kartierung von Flora und Vegetation von Süßwasserbiotopen [Methods of mapping the flora and vegetation of freshwater habitats]. Landschaft und Stadt. Vol. 10(2) p. 73–85.

LEUVEN R.S.E.W., POUDEVIGNE I. 2002. Riverine landscape dynamics and ecological risk assessment. Freshwater Biology. Vol. 47. Iss. 4 p. 845–865.

ŁAPUSZEK M. 2013. Wpływ czynników antropogenicznych na równowagę koryt dopływów górnej Wisły [The effect of anthropogenic factors on the equilibrium of riverbeds of the upper Vistula River tributaries]. Woda-Środowisko-Obszary Wiejskie. T. 13. Z. 41 p. 75–88.

MIODUSZEWSKI W. 2012. Small water reservoirs – their function and construction. Journal of Water and Land Development. No 17 p. 45–52.

PIETRUCZUK K., SZOSZKIEWICZ K. 2009. Ocena stanu ekologicznego rzek i jezior w Wielkopolsce na podstawie makrofitów zgodnie z wymaganiami Ramowej Dyrektywy Wodnej [Macrophyte-based assessment of the ecological status of river and lakes in Wielkopolska according to requirements of the Water Framework Directive]. Nauka Przyroda Technologie. T. 3. Z. 3 pp. 96.

RIIS T., BIGGS B.J.F. 2003. Hydrologic and hydraulic control of macrophyte establishment and performance in streams. Limnology and Oceanography. Vol. 48 p. 1488–1497.

RIIS T., SAND-JENSEN K., VESTERGAARD O. 2000. Plant communities in lowland streams: species composition and environmental factors. Aquatic Botany. Vol. 66 p. 255–272.

RIIS T., SUREN A.M., CLAUSEN B., SAND-JENSEN K. 2008. Vegetation and flow regime in lowland streams. Freshwater Biology. Vol. 53 p. 1531–1543.

SCHAUMBURG J., SCHRANZ C., STELZER D., HOFMANN G., GUTOWSKI A., FOERSTER J. 2006. Handlungsanweisung für die ökologische Bewertung von Fließgewässern zur Umsetzung der EU-Wasserrahmenrichtlinie: Makrophyten und Phytobenthos. München. Bayerisches Landesamt für Umwelt pp. 120.

SZOSZKIEWICZ K., KAROLEWICZ K., ŁAWNICZAK A., DAWSON F.H. 2002. An assessment of the MTR aquatic plant bioindication system for determining the trophic status of Polish rivers. Polish Journal of Environmental Studies. Vol. 11 p. 421–427.

SZOSZKIEWICZ K., ZBIERSKA J., JUSIK S., ZGOŁA T. 2010. Makrofitowa metoda oceny rzek. Podręcznik metodyczny do oceny i klasyfikacji stanu ekologicznego wód płynących w oparciu o rośliny wodne [Macrophyte method for river assessment]. Poznań. Bogucki Wydaw. Nauk. ISBN 8361320814 pp. 77.

VEREECKEN H., BAETENS J., VIAENE P., MOSTAERT F., MEIRE P. 2006. Ecological management of aquatic plants: effects in lowland streams. Hydrobiologia. Vol. 570 p. 205–210.

WILEY M.J., PIJANOWSKI B.C., STEVENSON R.J., SEELBACH P., RICHARDS P., RISENG C.M., HYNDMAN D.W. KOCHES J.H. 2008. Integrated Modeling of the Muskegon River: tools for Ecological Risk Assessment in a Great Lakes Watershed. In: Wetland and Water Resource Modeling and Assessment: A Watershed Perspective. London. Taylor & Francis. p. 247–258.

ZACHER L. 1991. Bezpieczeństwo ekologiczne – wymiary polityczne, międzynarodowe i globalne. W: Międzynarodowe bezpieczeństwo ekologiczne [Environmental security – political, international and global aspects. In: International ecological safety]. Ed. Z.J. Pietraś, M. Pietraś. Lublin. Wydaw. UMCS p. 95–124.

ŻELAZO J. 1993. Współczesne poglądy na regulację małych rzek nizinnych. W: Ochrona przyrody i środowiska w dolinach nizinnych rzek Polski [Nature conservation and environmental protection in lowland river valleys of Poland. In: Current views on the regulation of small lowland rivers]. Ed. L. Tomiałojć. Kraków. Wydaw. IOP PAN. p. 145–154.

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Ryzyko jako miara bezpieczeństwa ekologicznego w ciekach

STRESZCZENIE

Słowa kluczowe: *bezpieczeństwo ekologiczne, regulacja rzek, rośliny wodne, ryzyko ekologiczne, rzeki*

W pracy przeprowadzono analizę możliwości wykorzystania metody wstępnej oceny zagrożeń (ang. Preliminary Hazard Analysis – PHA), stosowanej w ocenie ryzyka technicznego, do oceny ryzyka ekologicznego. Analizę przeprowadzono na podstawie wyników badań wykonanych w latach 2007–2012 w czterech nizinnych rzekach Dolnego Śląska. Na rzekach tych wyznaczono 15 odcinków badawczych, zróżnicowanych pod względem stopnia ich przekształcenia. Przedmiotem badań były zbiorowiska naczyniowych roślin wodnych. Badania terenowe obejmowały identyfikację gatunków roślin występujących na poszczególnych odcinkach badawczych oraz określenie stopnia pokrycia przez nie dna. Na tej podstawie dla każdego odcinka obliczono wskaźnik różnorodności Shannona-Wienera. W celu oceny zmian jakościowych i ilościowych w rozpatrywanych zbiorowiskach, wynikających z przekształcenia koryt cieków, wykonano analizy porównawcze. Podstawę do klasyfikacji wielkości szkód zaistniałych w wyniku przeprowadzonych robót stanowiły zmiana liczby gatunków w zbiorowiskach naczyniowych roślin wodnych oraz wskaźnika bioróżnorodności, określone w stosunku do odcinków nieobjętych ingerencją techniczną.

Na podstawie wyników badań określono czynniki ryzyka ekologicznego, tj. prawdopodobieństwo wystąpienia zagrożeń oraz skutki tych zagrożeń. Umożliwiło to opracowanie macierzy klasyfikacji ryzyka, w której przyjęto trzy poziomy ryzyka – niskie, umiarkowane oraz wysokie. Zakwalifikowanie ryzyka do odpowiedniego przedziału pozwala na porównanie różnych rozwiązań projektowych oraz na podjęcie decyzji, które z nich przyjąć do realizacji.