Original Research

An Assessment of the Ecological Status of Diverse Watercourses of Lower Silesia, Poland

Justyna Hachoł*, Elżbieta Bondar-Nowakowska**

Institute of Environmental Development and Protection,
University of Environmental and Life Sciences, Pl. Grunwaldzki 24, 50-363 Wrocław, Poland

Received: 9 November 2010
Accepted: 23 June 2011

Abstract

This paper presents an assessment of the ecological conditions of various small and medium-sized lowland watercourses of Lower Silesia, determined in part by using aquatic macrophytes as biological indicators of the health and condition of such watercourses. Research was based on the German PHYLIB system (The German Assessment for Macrophytes and Phytobenthos), which determines ecological status based on the RI index (Reference Index). Field studies were conducted during 2007-08 on various watercourses. Research included identifying the species of aquatic macrophytes found in the streambed, as well as determining the degree of coverage; on this basis the RI index was calculated. We found the ecological status of most of the tested sections to be defined either as poor (Class 4) or moderate (Class 3). Research found that the type of streambed had little effect on the number of aquatic macrophyte species or on the ecological condition of the watercourse. We observed that time played a critical role in affecting these indicators, especially over the period that elapsed from the moment when human technical interference was first observed.

Keywords: aquatic macrophytes, ecological status, lowland rivers, maintenance works, river regulation

Introduction

In light of the EC-Water Framework Directive and in accordance with applicable water laws, any surface-water management cannot contribute to the deterioration of any aquatic ecosystem. Therefore, human technical interference in a watercourse's streambed requires careful analysis of its effects, with the ecological impact it can cause to be of primary importance. One of the elements required for such an assessment is the presence of aquatic macrophytes. They are good indicators of persistent and constant habitat features or perturbations [1-5]. In watercourses in good ecological status, any changes in their composition and abundance, in relation to what is usually found in undisturbed conditions, are relatively small. To assess these changes a variety of methods have been developed: MMOR (macrophyte method for river assessment) [6, 5], based largely on MTR (mean trophy rank) [7] and IBMR (macrophyte biological index for rivers) [8]; and RI (reference index) [9], based on the TIM index (trophic index of macrophytes) [10].

The watercourses of Lower Silesia rarely can be found in a state similar to one found in unspoiled nature. Most of the rivers have been transformed as a result of regulatory or maintenance work [11]. Such projects are complex and affect the elements of a watercourse's bed. The aim of maintenance work is to ensure free stream flow. Most conservation projects are based on the manual mowing of riverbanks and the mechanical elutriation of riverbeds along with the removal of any aquatic vegetation [12-15]. Regulatory work is characterized by intrusions larger than those of maintenance works into the riverbed, since they cause a change in a watercourse's cross-sectional parame-

*e-mail: justyna.hachol@up.wroc.pl
**e-mail: elzbieta.bondar-nowakowska@up.wroc.pl

ters, mainly the depth and slope angle and in the way the riverbanks are protected. In most cases, these regulatory works were performed using mechanical equipment [16, 17]. Not only does technical interference directly affect macrophyte growth, but also indirectly through modifying the habitat conditions of a river [1, 3, 15-18]. As an effect, such interference can directly lead to changes in a watercourse's ecological status.

Our paper analyzes the impact of these activities on the ecological status of watercourses.

Methods

Field studies were carried out during the vegetation seasons of 2007 and 2008, on eight small and medium-sized lowland watercourses of Lower Silesia (Table 1). Among the chosen watercourses, 46 one-hundred-meter morphologically homogeneous sections were selected (Fig. 1). These sections had similar climatic (moderate, transitional between maritime and continental), geological (a Foresudetic Monocline built of Permian and Trias rocks) and soil (Luvisols formed from loess and brown soil) conditions [19-21]. The hinterland was used for agricultural purposes, dominated by either grassland or farmland. In addition, almost all had little to no tree shade, nor were any of the watercourses contaminated by city or industrial sewage.

Table 1. Researched watercourses.

River Name	Length [km]	Number of Test Sections		
		N (unregulated)	C (conserved)	R (regulated)
Czarna Woda	43.8	2	5	0
Dobra	36.1	6	0	4
Oleśnica	46.6	5	1	0
Orla	95.1	2	0	1
Sąsiecznica	43.8	0	6	0
Smortawa	39.0	1	3	0
Żalina	10.9	2	4	0
Żurawka	27.5	0	4	0
	∑	18	23	5

The sections differed to a various degree by their status, due to anthropogenic activities: 18 sections were unregulated watercourses, 23 sections were subject to various maintenance works in the past decade, and 5 sections were in regulated watercourses. The low number of sections in the latter group is due to the fact that regulatory projects in Lower Silesia have been carried out only sporadically in recent years [22].

Fig. 1. Distribution of surveyed sections (developed based on Google Maps).

Field surveys were undertaken once at each site. At all of the sections the riverbed's capacity and level were measured directly in the field. For those sections where regulatory work was carried out, the parameters and date of completion were analyzed from the applicable technical documentation [15, 23-30].

To assess the ecological status of the sections the RI method was used. As MMOR had not yet been implemented as a monitoring tool in Poland when testing began, an assessment on the watercourse's ecological condition was based on the RI index [9], which had been previously used in Poland [31]. This method uses 197 species of aquatic macrophytes as indicators towards assessing ecological condition of the water. These species are divided into three groups:

A (reference species)
B (species with a wide ecological range)
C (species that thrive in degrading habitat)

Therefore, such an assessment on the ecological standing of each of the watercourses requires a controlled inventory of all discovered aquatic macrophytes; specifically identifying all water plants found as well as their degree of coverage at the bottom. All rooted plant life present for at least 90% of the growing season was taken into account, as well as all vegetation found freely floating on the water surface or beneath it. To determine the macrophytes's degree of coverage, a five-point scale was used, where:

1 plant abundance is very rare, i.e. the species covers up to 5% of the water bottom
2 rare (5% to 25%)
3 common (25% to 50%)
4 frequent (50% to 75%)
5 very frequent (from 75% to 100% coverage) [32].

The RI index was calculated by the formula [9]:

$$RI = \frac{\sum_{i=1}^{n_A} Q_{Ai} - \sum_{i=1}^{n_C} Q_{Ci}}{\sum_{i=1}^{n_g} Q_{gi}} \cdot 100$$

...where:
RI – reference index
Q_{Ai} – quantity of the i-*th* taxon of group A
Q_{Ci} – quantity of the i-*th* taxon of group C
Q_{gi} – quantity of the i-*th* taxon of all groups
n_A – total number of taxa in group A
n_C – total number of taxa in group C
n_g – total number of taxa in all groups

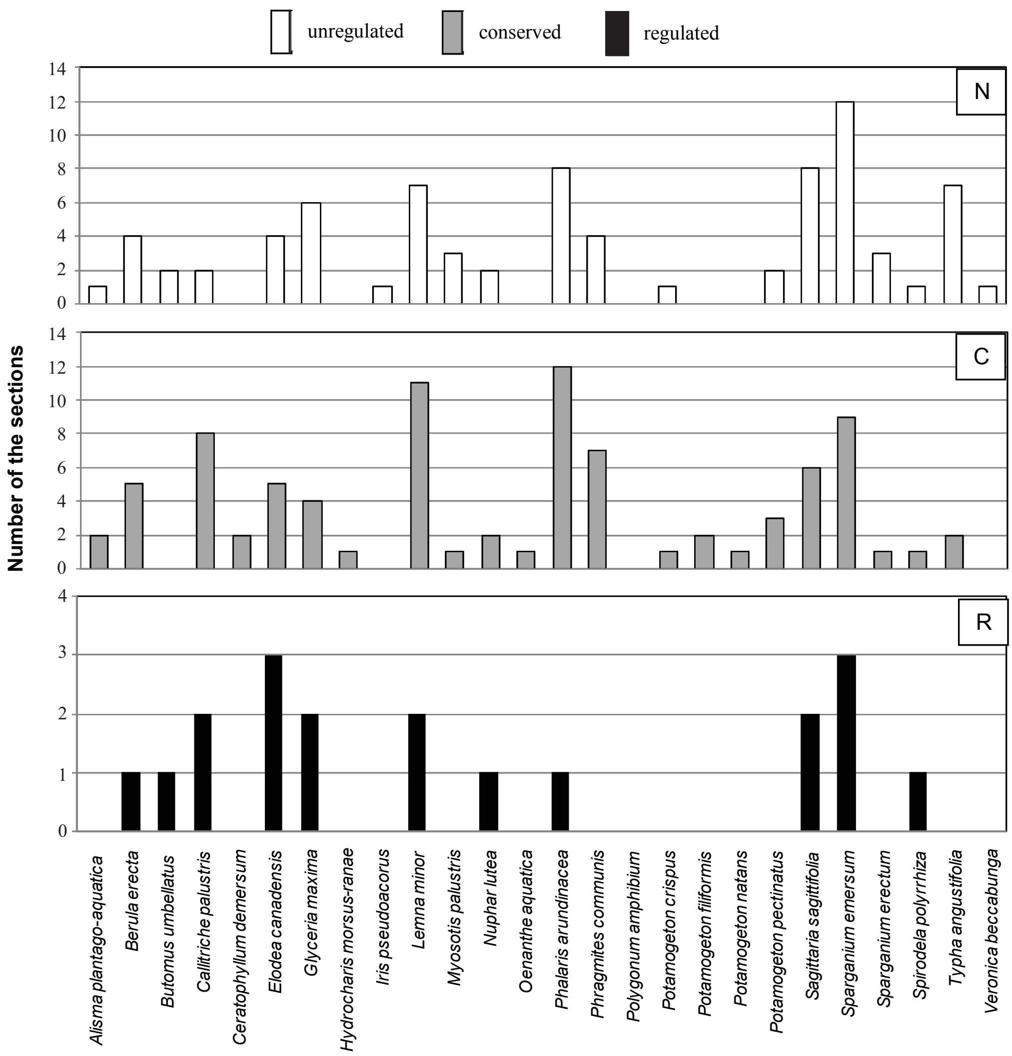

Fig. 2. Aquatic macrophytes found in the test sections: N – Natural, C – Conserved, R – Regulated.

The metric quantities (*Q*) are the converted, nominally scaled values of plant abundance:

$$Quantity = Abundance^3$$

Statistical tests, including the Kruskal-Wallis test, were used to analyze field study results.

Results

A total of 26 aquatic plant species were found among the tested watercourse bottom sections (Fig. 2). Most of them were species commonly found in watercourses, such as: *Butomus umbellatus* L., *Elodea canadensis* L., *Glyceria maxima* (Hartm.) Holmb., *Hydrocharis morsus* ranae L., *Lemna minor* L., *Myosotis palustris* (L.) L. em. Rchb., *Nuphar lutea* (L.) Sibth. & Sm., *Phalaris arundinacea* L., *Polygonum amphibium* L. f. *natans* Moench, *Potamogeton natans* L., *Sagittaria sagittifolia* L., *Sparganium erectum* L. em. Rchb. s.s., and *Sparganium emersum* Rehmann – all of which represent Group B in the RI method [9]. Four taxons, *Ceratophyllum demersum* L., *Potamogeton crispus* L., *Potamogeton pectinatus* L., and *Spirodela polyrrhiza* (L.) Schleid composed Group C, and only two – *Berula erecta* (Huds.) Coville. and *Potamogeton filiformis* Pers. – were included in Group A. The remaining species (*Alisma plantago-aquatica* L., *Callitriche palustris* L., *Iris pseudacorus* L., *Oenanthe aquatica* (L.) Poir., *Phragmites communis* Trin., *Typha angustifolia* L., and *Veronica beccabunga* L.) found during the present study were not considered within the assessment of the watercourse's ecological condition.

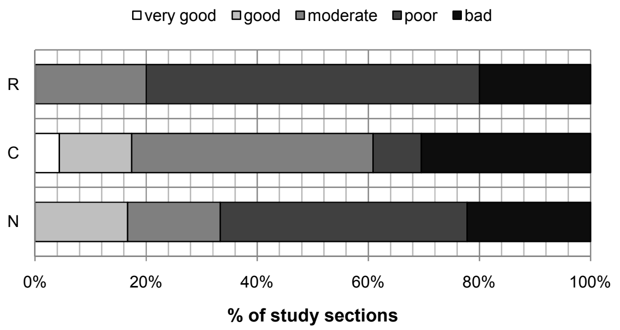

Fig. 3. The ecological condition of the test sections: N – Natural, C – Conserved, R – Regulated.

In the sections that underwent no maintenance work of any kind, i.e. sections close to reference conditions, 20 species of aquatic macrophytes were found. A higher number (22 species) was found at test sections where maintenance work was performed. It was shown that at reference sites the similar composition of species was found as in conserved ones (Fig. 2). The most common species at reference sites were *Sparganium emersum*, *Phalaris arundinacea*, and *Sagittaria sagittifolia*. The dominant species in conserved sections were *Phalaris arundinacea*, *Lemna minor,* and *Sparganium emersum* of these least amount of taxons, only 11 were found at those study sections that were part of regulated watercourses, the most common of which were *Sparganium emersum* and *Elodea canadensis*.

The RI index, calculated for each section, revealed values from -100 to 50, due to a wide range of ecological conditions (Fig. 3). They represented the full spectrum of a watercourse's ecological status, from the bad (Class 5) to the very good (Class 1). This study showed that the sections in conserved watercourses, i.e. where over the years the bottom was dredged and the banks mowed, were in the best condition. The sections in very good, good, or moderate ecological status (Classes 1-3) made up over 60% of the total, with the moderate class (Class 3) the most common (Fig. 4a). Anthropologically unregulated watercourses were characterized by rather unfavorable environmental conditions. They were characterized by dense vegetative growth of two or three common species found mainly in group B [9], while other remaining species were only sparsely represented. The sections of this type dominated the fourth-class ecological status; no section was classified as "very good," and only

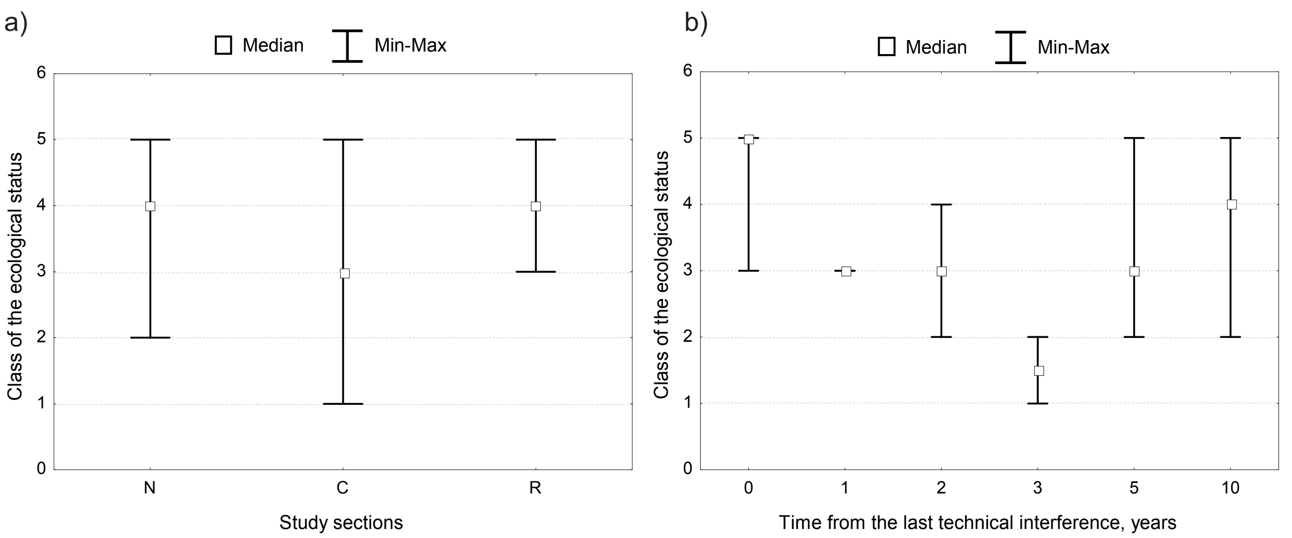

Fig. 4. The ecological condition class depending on the type of watercourse (N – natural, C – Conserved, R – Regulated) and the time that elapsed from any technical interference on the river bottom.

Table 2. The analysis of influence of technical interferences on a watercourse's riverbed as well as the time that elapsed on the number of aquatic plant species and the watercourse's ecological status, based on the H Kruskal-Wallis test.

Indicators	Maintenance or regulatory works		Time from the last technical interference	
	H	p	H	p
Number of species	2.34	0.80	8.55	0.01
Ecological condition status	3.13	0.68	13.26	0.02

33% could be classified in the good or moderate class. The worst ecological status was observed in regulated watercourses; 80% of the analyzed sections was characterized by moderate or bad ecological status.

Our study found that conserved watercourse channels, primarily those where dredging of the river bottom occurred, were in a better environmental state than those in which no such conservatory works were carried out. Therefore, it can be assumed that the thickness of accumulated silt can indirectly influence a watercourse's ecological condition. The diversity and abundance of various species generally increases with substrate stability and the presence of organic debris [33]. Therefore, the greater amount of species diversity witnessed would in all probability point to the better ecological status of a watercourse. As such this hypothesis was analyzed (Fig. 5). We showed that the thickness of accumulated silt does not correlate significantly with the ecological status, regardless of whether the watercourse was subjected to any maintenance work or not. But we found clear trends, i.e. for natural watercourses, an increase in the level of silt buildup resulted in a tendency of decreasing the ecological condition, but for those watercourses that undergo technical interference it later happens to improve. Since the level of silt buildup increases over time, the influence of this factor on a watercourse's ecological standing was considered, i.e. the time elapsed since the last technical interference. It was shown that time plays a significant impact on both the number of aquatic macrophyte species as well as the ecological condition of the watercourse (Table 2). The correlation between the watercourse's ecological condition and the time from when the riverbed was first subjected to any technical interference is illustrated in Fig. 4b. In most of the sections, immediately after any technical work, the watercourse was in poor ecological condition, but after a recovery period (three years), the conditions improved and the best status was observed.

Discussion

In the 46 test sections surveyed, 26 species of macrophytes were found. This number is small in comparison with the results obtained from other authors in similar studies [34-36]. 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. The low diversity combined with the dominance of a few very common species resulted either in a moderate or poor ecological status in most sections.

It is widely believed that any technical interference within a watercourse's channel adversely affects its biocoenosis [16, 17, 34, 37-39]. Our study revealed that this is not always right. We showed that the riverbeds of conserved watercourses were in better shape than those without maintenance works; this is maybe characteristic for small watercourses. Streambeds of waterourses where no maintenance work was carried out were almost completely dominated by two to three plant species, such as *Sparganium emersum* and *Phalaris arundinacea*. The remaining species found in these unregulated watercourses were represented by a few lone individuals. Overall, conserved watercourses featured a lower abundance of macrophytes while diversity levels were higher.

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

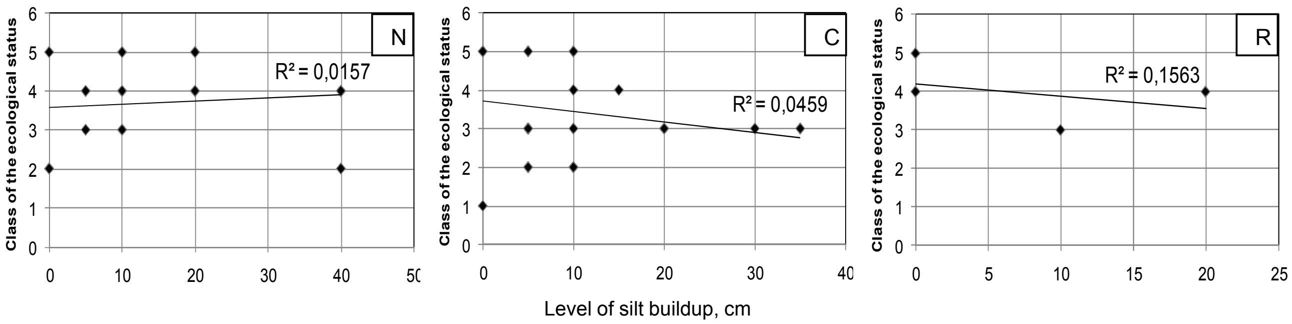

Fig. 5. The correlation between ecological condition class and the level of silt buildup in natural (N), conserved (C), and regulated (R) watercourses.

function properly, without causing a permanent loss of aquatic plant communities [3, 12, 14, 34, 40-43]. This is due to the fact that most aquatic plants have very efficient mechanisms for vegetative reproduction and dispersal, such as budding, the re-rooting of plant fragments, fast-growing stolons, and winter buds, tubers, and turions [44]. 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 overflow [15].

Research has found that time is the most important factor on a watercourse's ecological condition. The best environmental conditions were found in those watercourse sections where maintenance work had been performed more than 3 years previously. These findings are of great practical importance since maintenance projects should be cyclical, so that a watercourse can continually fulfill its technical, economic, recreational, and aesthetic functions. A period of 3 years could designate the frequency of such monitoring programs.

Conclusions

1. Research carried out on 46 sections of small and medium-sized lowland watercourses in Lower Silesia showed that the RI method is applicable to assess the ecological status of these watercourses.
2. The ecological condition of the surveyed watercourses was diverse. It covered all five classes, from Class 1 (very good) to Class 5 (bad ecological status), this gradient is due to morphological status and the technical modification gradient within the 46 sections.
3. The effect of construction works on ecological condition was dependent on their scope. We showed that regulatory works were largely harmful, while conservatory works had a positive effect.
4. The ecological condition of a watercourse that underwent some form of maintenance work was dependent on the time elapsed after such work. This factor has to be considered when assessing the impact of anthropogenic activities on a watercourse's ecological condition. This means that any research conducted on such an issue should stretch over a longer period of time (at least 10 years). The results of such monitoring programs would be useful for developing plans and schedules for any future maintenance works on a watercourse. In addition they could serve a practical function in arranging ecological risk management plans of conservation works on the watercourses by taking into account the aquatic flora present.

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