Science of the Total Environment 627 (2018) 189–199

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Influence of technical maintenance measures on ecological status of agricultural lowland rivers – Systematic review and implications for river management

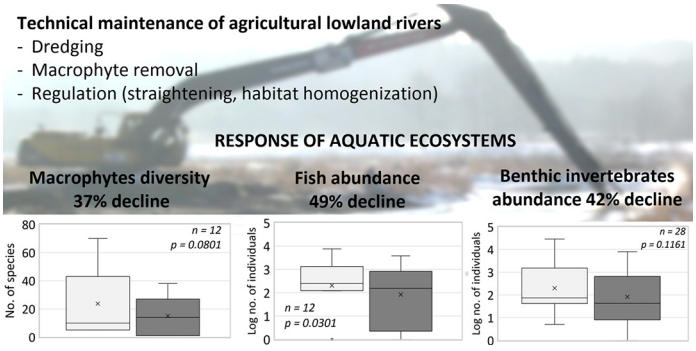
Anna Bączyk [a], Maciej Wagner [b], Tomasz Okruszko [a], Mateusz Grygoruk [a,*]

[a] Faculty of Civil and Environmental Engineering, Warsaw University of Life Sciences-SGGW, ul. Nowoursynowska 159, 02-776 Warsaw, Poland
[b] Institute of Meteorology and Water Management, ul. Podleśna 3, 01-673 Warsaw, Poland

HIGHLIGHTS

- Technical measures of river maintenance induce decline of rivers' ecological status.
- 96% of analyzed studies revealed negative responses of biota to the maintenance of agricultural rivers.
- Maintenance of agricultural rivers induces decline of abundance and species richness of biota.
- Maintenance of agricultural rivers should be revisited in science and better managed in practice.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 15 June 2017
Received in revised form 20 January 2018
Accepted 23 January 2018
Available online xxxx

Keywords:
River
Management
Agriculture
Water Framework Directive
Ecosystem

ABSTRACT

Intensification of agriculture and ongoing urban sprawl exacerbate pressures on rivers. Small rivers in agricultural landscapes are especially exposed to excessive technical actions implemented in order to allow for harvesting river water for irrigation, draining agricultural water and receiving sewage. Regular dredging and macrophyte removal strongly interfere with the global need for preserving river biodiversity that allows agricultural lowland rivers to remain refuges for a variety of species, and—accordingly—to keep water bodies resilient for the benefit of society. In order to provide a comprehensive look at the influence of agricultural lowland river management on the ecological status of these water bodies, we conducted a literature review and a meta-analysis. For the structured literature review we selected 203 papers reflecting on the response of aquatic ecosystems to dredging and macrophyte management actions. The database of scientific contributions developed for our study consists of papers written by the authors from 33 countries (first authorship) addressing dredging, macrophyte removal, status of fish and macroinvertebrates as well as the general ecological status of lowland agricultural rivers. We revealed that 96% of the analyzed papers indicated unilateral, negative responses of aquatic ecosystems, particularly macroinvertebrates, ichthyofauna and macrophyte composition, to maintenance measures. We revealed that studies conducted in the European Union on the ecological status of rivers appeared to significantly increase in quantity after the implementation of the Water Framework Directive. Finally, we concluded that day-to-day management of lowland agricultural rivers requires revision in terms of compliance with environmental conservation requirements and the recurrent implementation of technical measures for river maintenance.

* Corresponding author.
E-mail address: m.grygoruk@levis.sggw.pl (M. Grygoruk).

https://doi.org/10.1016/j.scitotenv.2018.01.235
0048-9697/

1. Introduction

Contemporary water policy in Europe is shaped by the Water Framework Directive of the European Union (WFD; European Commission, 2000). The WFD emphasizes the necessity of sustainable river management with regard to hydromorphology and biodiversity. The WFD also includes regulations on the development and implementation of ecological assessment and classification systems, using biological elements and supportive hydromorphological and physicochemical features to determine a river's ecological status (Leitão et al., 2014; Murat-Błażejewska and Sojka, 2011), providing a framework for improvement of the environmental quality of stream ecosystems, and offering ways for categorizing or measuring ecological status (Baattrup-Pedersen et al., 2008). Balancing ecological quality with agricultural use of catchments and water bodies has become one of the emerging issues during implementation of the WFD. For centuries, humans have transformed landscapes in order to produce food and forage. The extent of landscape modifications differed depending on geographical and climatic settings. A vast majority of watercourses have also become strongly modified (Dynesius and Nilsson, 1994). Water bodies located in agricultural landscapes remain local biodiversity hotspots (Chester and Robson, 2013; Clarke, 2015; Herzon and Helenius, 2008; Watson and Ormerod, 2004). However, the function and ecological status of most rivers in managed landscapes are determined by the frequency of the implementation of river maintenance measures (RMM) such as dredging (mud removal), channel straightening, macrophyte removal or hydromorphological modifications. These RMM were implemented on a regular basis across the lowland landscapes and reported as drivers of biodiversity loss (Adynkiewicz-Piragas and Drabiński, 2001; Armitage and Pardo, 1995; Hachoł and Krzemińska, 2008; Rader and Ward, 1988).

Traditional agricultural water management focuses on reducing the natural variability of river flows to achieve stable water supply and mitigate extreme hydrological events such as floods and droughts. Economic and social motivation for RMM is driven by the need of more intensive landscape productivity; however, a question arises if there are any limits for this activity, taking into account the need to preserve abundance and diversity of riverine communities. A majority of small rivers used as drains/irrigation canals in agricultural landscapes (hereafter referred to as agricultural rivers, ARs) have been modified in terms of their flow regime, in-stream habitat diversity and hydromorphology (Harrison et al., 2004; Johnson, 1988). Similarly, nearly 80% of all water discharge of the largest river systems in both North America and Europe is affected by agriculture and industry-related stressors (Alexandre et al., 2013; Dynesius and Nilsson, 1994). As observed nearly 30 years ago, reducing the diversity and patterning of aquatic habitats in agricultural rivers results in the degradation of river ecosystems (Hellawel, 1988) and endangers the biodiversity of approximately 65% of the world's river habitats, putting thousands of aquatic wildlife species at risk of extinction (Guti and Berczik, 2014). Although legislation systems and knowledge have quickly moved forward in the last decade, and nature-based solutions in RMM have been developed (e.g., Prus et al., 2017) and mandated (*vide* WFD), available scientific observations allow to put a hypothesis that river maintenance has largely remained "traditional" in terms of its scale and continues to influence riverine and riparian ecosystems negatively and across scales (Adynkiewicz-Piragas and Drabiński, 2001; Biereżnoj-Bazille and Grygoruk, 2013; Hachoł and Krzemińska, 2008).

The negative influence of technical RMM on particular elements of riverine and riparian ecosystems of ARs has been repeatedly reported in the worldwide scientific literature since the 1980s (e.g., Murphy et al., 1987; Rader and Ward, 1988; Swales, 1982a, 1982b). However, river-management authorities responsible for implementation of RMM and—at the same time—implementation of the WFD seem not to deal with these actions as with critical stressors for these ecosystems (Smokorowski and Pratt, 2007).

The main goals of the paper are:

- to summarize the most up-to-date basic research on the influence of river maintenance measures on particular elements of riverine ecosystems,
- to identify research gaps and issues related to AR maintenance in terms of compliance with the WFD and claims about sustainability in water-resources management in lowland river basins.

The research goals were formulated in order to provide an opportunity for future development of best management practices which would reduce the threats to the biodiversity of ARs and would ensure their agricultural and ecological functions. Even though the study is driven by a Central European perspective on water management and the status of ARs in the landscape and mesoscale lowland geoecosystems, we believe it provides insights into the international context.

2. Meta-analysis and publication search criteria

This study is based on results of literature meta-analysis. The first step of our approach was oriented at selecting the most comprehensive set of scientific contributions possible. To ensure the highest possible quality of the input data and the conclusions discussed in our analysis, only international peer-reviewed papers listed in the Web of Science Core Collection, SCOPUS and EBSCO databases were analyzed. The research reviewed was published in English. We are aware that results of the query did not cover all research results published in the given field and in national languages, but in order to perform the analysis based on homogeneous criteria, we decided to limit the database to items that have been peer-reviewed and published in recognized books and journals. These databases were subjected to two structured queries. The first query included combinations of keywords: TI = fish* OR macrophyte* OR macroinvertebrate* AND dredg* OR removal OR regulat* AND TS = water management. The second query included combinations of keywords: TI = (fish OR macrophyt* OR macroinvertebrate*) AND TS = water management AND TI = lowland river. This query allowed to select relevant studies addressing the issues of ecological status of managed lowland agricultural rivers. The asterisk inserted at the end of the search terms enabled all variations of the key word to be included in the search. As the research was aimed at revealing a general influence of RMM on fish, macroinvertebrates and macrophytes, the set of papers retrieved by these queries was filtered with the inclusion and exclusion criteria indicated in Table 1. Studies retrieved with the use of an automated query that clearly did not match the criteria referring to lowland rivers (e.g. studies done in upland and mountainous streams) were removed from the database. The resulting database of papers and their features (year of publication, author's origin, number of citations) was used as a set of input data for the meta-analysis (see References and additional literature presented in Appendix 1).

In order to address the research questions, we conducted quantitative analysis supported by standard statistical testing of differences with a *t*-test, with special focus on before-after and control-impact (BACI) studies dealing with the response of aquatic ecosystems to RMM such as dredging, macrophyte removal and broadly considered channel regulation. We searched for publications providing information on four basic RMM, namely channel regulation, mechanical dredging, macrophyte removal (weed cutting) and removal of debris jams, and describing impacts of these RMM on aquatic ecosystems (Table 2).

3. Results and discussion

3.1. Trends in publications

For the review and meta-analysis, we selected 203 papers which met inclusion criteria given in Table 1. Among the selected papers