De-stonation: The effect of restored riverbanks on the macroinvertebrate communities of the Zandmaas (Sand Meuse) in the Netherlands

Déstonation : l'effet des berges restaurées sur les communautés de macroinvertébrés du Zandmaas (Sand Meuse) aux Pays-Bas

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RÉSUMÉ

Au cours des 150 dernières années, la Meuse a subi d'importantes modifications d'origine humaine, notamment la canalisation, la régulation du débit, la pollution de l'eau et l'empierrement des berges pour prévenir l'érosion. Ces altérations ont eu un impact significatif sur les macroinvertébrés aquatiques, entraînant la perte d'espèces riveraines typiques, une augmentation des taxons tolérants à la pollution et la propagation d'espèces exotiques. Afin de restaurer les processus naturels et d'améliorer la diversité des habitats, les protections des berges de pierre sont supprimées le long de certaines sections de la Meuse. Le Zandmaas, la section sableuse de la Meuse néerlandaise, a fait l'objet de plus de la moitié des projets de dépierrage réalisés entre 2010 et 2021. Cependant, les effets de ces interventions sur la biodiversité de la macrofaune restent flous. Cette étude vise à évaluer l'effet des berges complètement dépierrées sur la biodiversité de la macrofaune dans le Zandmaas. Les macroinvertébrés ont été échantillonnés dans le cadre de cinq projets d'épierrage, variant en termes d'âge et d'étendue de l'intervention. L'échantillonnage a été effectué au niveau de l'habitat pour évaluer comment les conditions abiotiques, telles que la diversité des substrats, influencent la structure de la communauté de macrofaune.

ABSTRACT

Over the past 150 years, the Meuse River has undergone extensive man-made alterations, including channelization, flow regulation, water pollution, and stoning of riverbanks to prevent erosion. These alterations have significantly impacted aquatic macroinvertebrates, leading to the loss of typical riverine species, an increase in pollution-tolerant taxa, and the spread of exotic species. To restore natural processes and enhance habitat diversity, stone bank protections are being removed along sections of the Meuse River. The Zandmaas, the sandy section of the Dutch Meuse River, has been the focus of over half of the de-stoning projects that were performed between 2010 and 2021. However, the effects of these interventions on macrofauna biodiversity remain unclear. This study aims to assess the effect of completely de-stoned riverbanks on macrofauna biodiversity in the Zandmaas. Macroinvertebrates were sampled across five de-stoning projects, varying in age and extent of intervention. Sampling was conducted at the habitat level to evaluate how abiotic conditions, such as substrate diversity, influence macrofauna community structure.

KEYWORDS

Biodiversité, dépierrage, habitats, macroinvertébrés, berges.

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1 INTRODUCTION

Since the second half of the 19th century, the Meuse River, a 900 km river that flows through France, Belgium, and The Netherlands, suffered long-lasting man-made alterations such as the installation of weirs for flow control, channelization to improve its navigability, and stoning of riverbanks to prevent erosion [1], [2], [3]. Furthermore, around 1970, the Meuse River's water quality reached its lowest point due to the discharge of largely untreated sewage, industrial wastewater, and agricultural runoff, but gradual improvements followed with the construction of water treatment plants [3]. All these alterations affected the hydrogeological and chemical dynamics of the river and impacted the diversity of aquatic species like macrophytes, macroinvertebrates, and fish [4], [5].

Macroinvertebrates are among the most frequently monitored biological groups in European countries [6]. Macroinvertebrates are animals without a backbone that can be detected by the naked eye and their widespread use is related to their different sensitivity to environmental stressors; broad distribution; ecological functions; high abundance; simple collection methods; response to local perturbations; and their presence throughout the year [7], [8]. Research conducted in the lower Meuse (Netherlands) showcases how macroinvertebrates have responded to hydrological and morphological alterations, water pollution, and habitat degradation in the river. This is evidenced by a higher presence of macrofauna species that tolerate chemical pollution, the disappearance of typical riverine aquatic insects, and the proliferation of new exotic species of snails, mussels, and crustaceans [4], [5], [9]. Efforts to improve water quality in the 1980s had a positive but limited impact on macrofauna species richness, emphasizing the need for further measures to enhance habitat diversity [5], [9].

The Ministry of Infrastructure and Water Management of the Netherlands, Rijkswaterstaat, is restoring the Meuse to its natural state as much as possible by modifying floodplains, reconstructing dead river arms and secondary channels, as well as removing bank stone protection [1], [4], [10]. Removing bank protection can help restore natural processes, such as erosion and sedimentation, which reshape the riverbanks by creating a broader transition from water to land and reintroducing a wider variety of substrates [1]. On the local scale, these different substrates and hydrological conditions can provide a wider variety of habitats in the riverbanks for macrofauna to colonize. During the period 2010 - 2020, Rijkswaterstaat has performed de-stoning in more than 60 riverbank areas along the Meuse River, most of them located in the Zandmaas (Sandy section of the Meuse) [11]. Some of these interventions focused only on de-stoning above the waterline, while others mentioned “partial underwater de-stoning”, “bank removal 0.5 m below the waterline”, ”de-stoning up to 1 m below the waterline“ or “full underwater bank removal “[11].

Due to the decrease in water pollution and the initiatives to develop more natural river ecosystems, macrofauna communities in the Meuse are expected to recover over time. However, currently, the ecological status of macrofauna in the Dutch Meuse remains inadequate [4] and does not meet the Water Framework Directive expectations [12]. The most recent multiyear study [12] on Rijkswaterstaat's riverbank restoration efforts along the Meuse (2008-2017) found no clear effect on the macrofauna communities, but they highlighted that species richness responded positively to the interventions only after 4 to 5 years [12], [13]. Furthermore, despite the high proportion of de-stoned riverbanks in the Zandmaas region, no monitoring program is in place to track macrofauna adaptation to these interventions.

This study aims to assess the effect of completely de-stoned riverbanks on macrofauna biodiversity in the Zandmaas and to determine whether this relationship is influenced by the presence of different habitats. Also, factors such as the age and the length of the de-stoning interventions will be considered. More specifically, this research seeks to explore how de-stoning characteristics (length and age) influence the abiotic habitat conditions of riverbanks in the Zandmaas, and to investigate how these altered abiotic conditions subsequently affect the macroinvertebrate community composition along the riverbanks in this region.

2 METHODOLOGY

2.1 Study area

In the Netherlands, the Meuse river has a catchment area of 6000 km^2 and a length of 239 km. Upon entering the Netherlands, the Meuse flows through the Grensmaas, a free-flowing, non-navigable gravel section. Due to the steeper terrain in this region, the water flow in the Grensmaas is faster compared to the downstream sections. As the river continues into the Zandmaas, the slope becomes much gentler, and its flow is regulated by weirs [2], [3]. The Zandmaas is typically described as the sandy Meuse, flowing from Maasbracht to 's Hertogenbosch [3].

Between 2010 and 2021, more than 30 de-stoning projects were carried out in the Zandmaas. This study focuses on the lower segment of the Zandmaas, between Velden and Cuijk. This area was chosen due to the range of full underwater de-stoning projects carried out in different years, which also varied in length, allowing us to address our research questions.

2.2 Sample collection

Taking into account full underwater bank removal or 1 m underwater de-stoning, 5 projects were selected in the study area, considering a balance between their age of intervention (2015 and 2019) and their length (short, medium and long) (Table 1). Overall, 18 locations were sampled between October and November of 2024, 11 locations from the selected projects, and 7 control locations where stone protection remained. Locations were selected based on criteria like accessibility, distance from other interventions, and distance to sources of variability.

The selected projects have lengths that range from 400 m to 2800 m. In the longest interventions (>1500 m), 3 sampling locations were selected (start, middle, and end); in the middle ones (<1500 m but >500 m), 2 locations (start and end); and in the shortest (<500 m), only one location (middle). Because habitats are expected to change greatly in longer riverbanks, two controls are selected for the projects with longer interventions.

Table 1. Sampling locations per de-stoning project

Name of the project	Last intervention	Length (m)	Sampling locations	Control locations
Lomm	2015	700	2	1
Oeffelt- St. Agatha	2015	2800	3	2
Aijen	2019	400	1	1
Afferden	2019	1200	2	1
Vierlingsbeek	2019	1900	3	2

On the selected locations, a traject of 50 meters of riverbank was observed to identify the presence of the different habitats in the area. Samples were collected using a 0.3 m wide macroinvertebrate net with a 0.5 mm mesh size [14]. Each habitat in each location was sampled separately, taking a minimum of 0.5 m stretch per habitat and adding to a total of 2.5 meters per location. Meaning that a maximum of 5 habitats could be sampled per location. Substrates as rock or gravel were gently brushed into the net to collect the organisms. The material collected in the net per habitat was transferred into 200 ml plastic containers and preserved with 75% ethanol. Turbidity, dissolved oxygen and pH were measured in the water before sampling for macrofauna. All samples were transported to the Aquatic Ecology and Water Quality Management (AEW) laboratory located at Wageningen University. Individuals were first sorted into groups and then identified and counted to the lowest possible taxonomic level.

2.3 Data analysis

Species found will be taxonomically standardized to determine the species richness and diversity indices. The total species richness per location will be plotted against habitat diversity. For a more specific analysis, species richness will be compared between habitat categories. The importance of de-stonation on abiotic habitat richness and on taxonomic richness will be analysed through generalised linear models (GLM). Additionally, because the macrofauna in the Meuse is species-poor and dominated by exotics, special attention will be paid to the presence of native species or typical good-quality riverine species, like EPT families (Ephemeroptera, Plecoptera and Trichoptera).

Significant differences (P<0.05) in species richness or habitat diversity in samples will be tested based on presence of de-stoning, age of the intervention or length. Multivariate analyses will be performed. An explorative indirect analysis will be used to find the similarity or difference between the community composition of the samples. A direct analysis will be performed considering composition and abundance of macrofauna as the response variables, and 1) presence of de-stoning, 2) age of the intervention, or 3) length, as explanatory variables.

3 EXPECTED RESULTS

Preliminary results suggest that de-stoning efforts influenced abiotic factors. Control locations were predominantly characterized by shallow and deep artificial substrates, whereas de-stoned areas often presented silty or sandy surfaces, with occasional vegetation on the edge and sporadic gravel accumulation. Ongoing analysis is examining the relationship between habitat formation (abiotic variables) on the riverbanks and macrofauna composition (biotic variables).

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