Monitoring the dynamisation of the Danube floodplains between Neuburg and Ingolstadt in Germany (MONDAU II)

Barbara Stammel[1], Bernd Cyffka[1], Laura Kaiser[2], Joachim Pander[3], Klaus Mandery[4]

[1] *Floodplain Institute Neuburg-Ingolstadt, Catholic University (CU) Eichstätt-Ingolstadt, Neuburg/Danube, Germany, e-mail: barbara.stammel@ku.de*
[2] *Federal Agency for Nature Conservation, Division II 2.4 'Aquatic Ecosystems, Water Resources, Blue Belt', Bonn, Germany, e-mail: laura.kaiser@bfn.de*
[3] *Aquatic Systems Biology Unit, TUM School of Life Sciences, Technical University of Munich, Freising, Germany, e-mail: joachim.pander@tum.de*
[4] *Institute for Biodiversity Information e.V. (IfBI), Ebern, Germany, e-mail: mandery@ifbi.net*

DOI: 10.5281/zenodo.15113697

Abstract

The dynamisation measures in the Danube floodplain forest between Neuburg and Ingolstadt are among the most important floodplain restorations in Germany. Their short-term effects on aquatic and terrestrial habitats were scientifically monitored between 2009 and 2014 (5 species groups, abiotic parameters). In 2022, these studies were repeated for several parameters (hydrological and morphodynamic indicators, vegetation, molluscs, arthropods, fish) with funding from the German Federal Agency for Nature Conservation. The results indicate that even twelve years after the implementation of the measures, the ecosystem is still changing and diversifying due to the ongoing hydraulic dynamics. This change in river hydraulics resulted in a heterogenous river morphology, triggering different effects for individual species groups. The aquatic habitats continue to show greater changes than the terrestrial habitats, as was already the case in the investigations from 2009 to 2014. The repeat study resulted in a joint, spatially and temporally comparative evaluation of the monitoring data, which also generated findings that can be transferred to other nationwide projects on the dynamisation of highly degraded floodplains. The article emphasises the central role of a long-term monitoring in order to better understand floodplain ecosystems in their spatial and temporal changes and thus to be able to better manage them in the context of restoration.

MONDAU and the Danube floodplains – The Dynamisation Project

In one of the largest contiguous alluvial forests in southern Germany, along the straightened and dammed Danube between Neuburg and Ingolstadt, extensive dynamisation measures were completed in 2010 to permanently divert water into the alluvial forest even outside flood events. The aim was to induce more water level fluctuations and morphodynamics in order to preserve and promote the remaining habitat types despite the considerable disruption caused by the two barrages. The dynamisation measures consisted of three individual core measures (*fig. 1*):

1. Creation and design of the Ottheinrichbach, an 8 km long floodplain watercourse along former flood channels with different initial conditions (dry, stagnant, running and temporary watercourses). The Ottheinrichbach is fed dynamically with 1 to 5 m^3/s depending on the discharge in the Danube.
2. Ecological flooding, in which up to an additional 25 m^3/s can be discharged along the Ottheinrichbach into the floodplain in the event of higher Danube discharges (e.g. HQ1).
3. Groundwater lowering during low water in the Danube, so that the permanently high groundwater levels in the eastern area caused by the Ingolstadt barrage can be lowered during drought periods.

The first two measures were implemented by the Free State of Bavaria, represented by the Ingolstadt Water Management Office. Due to the nationwide significance and uniqueness of the project, the German Federal Agency for Nature Conservation also funded both the third measure and a monitoring programme with funds from the Federal Ministry for the Environment in a test and development project under the acronym MONDAU (Monitoring of the Danube Floodplains) (Cyffka et al. 2016). Both the Dynamisation Project and the comprehensive and balanced monitoring have led to the MONDAU project attracting a great deal of national and international attention, and since 2023 it has been considered a lighthouse project of the EU mission to protect our seas and oceans in the EU Horizon project DALIA.

MONDAU I and further investigations in the area

Before the measures were implemented, researchers from the Floodplain Institute Neuburg-Ingolstadt, which was founded at that time by the district of Neuburg-Schrobenhausen, and other universities carried out initial investigations in the area (Cyffka et al. 2016). From 2009, one year before the Ottheinrichbach was started, a research project with eight partners was launched under the acronym MONDAU, in which the short-term effects of the measures on abiotic (hydrological, hydromorphological) and biotic parameters (forest growth, vegetation, molluscs, birds, arthropods, fish) were jointly analysed (Stammel et al. 2012). The project generated in-depth knowledge of floodplain ecological processes, in particular on their management options in a dam-regulated environment, beyond the usual efficiency control. After the initial ecological flooding and groundwater lowering, MONDAU observed an improvement in hydrodynamics and an increase in typical floodplain species (Cyffka et al. 2016). However, there were clear differences between the species groups: mobile species such as fish or birds responded very quickly (within months) to the restoration, but less mobile

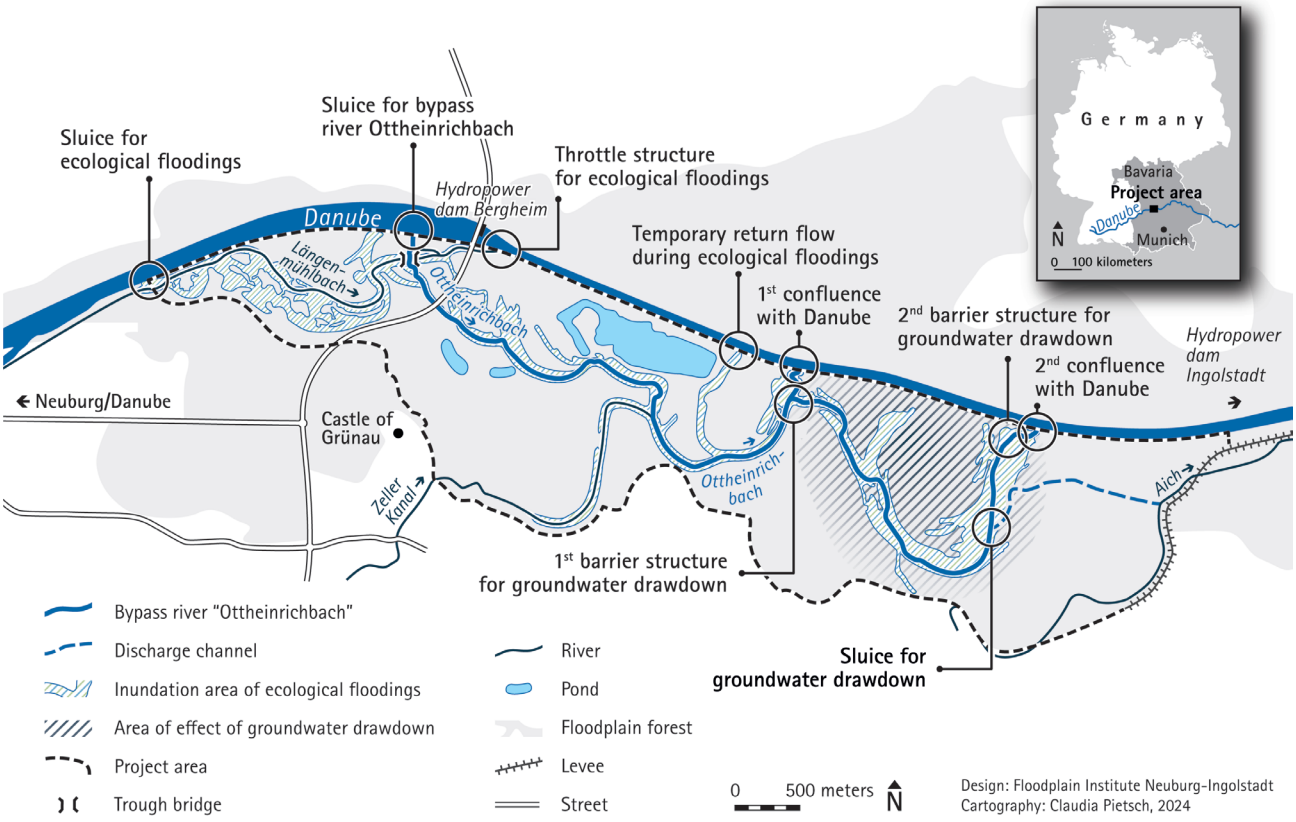

Figure 1. The location of the Dynamisation Project in Germany (small map) and the spatial impact of the measures (source: Aueninstitut Neuburg-Ingolstadt)

species groups such as molluscs also showed positive trends just two years after restoration. Plants reacted heterogeneously: while the vegetation of the water influenced sites responded quickly (within the first few years), the drier forest sites showed hardly any changes. Arthropods, on the other hand, initially reacted negatively to the restoration measures, but individual species groups began to recover in the first few years after the restoration.

MONDAU II – What is new and what has remained the same?

After 2014, the Aueninstitut Neuburg-Ingolstadt and the Technical University of Munich carried out further studies (e.g. Stammel et al. 2021, Pander et al. 2017). During this period, the development of the habitats was not only influenced by the dynamisation measures but above all by the warm and dry years 2014 and 2018 to 2020 and the large-scale ash dieback (*fig. 2*). Twelve years after the implementation of the measures, renewed funding from the Federal Agency for Nature Conservation provided the opportunity for MONDAU II to record the development after the initial phase with a joint study in 2022. In this way, the medium-term, hypothetically less dynamic development could be separated from the short-term effects of restoration. Experience from other projects shows that the initial positive effects of (construction) measures can disappear again after just a few years if there is a lack of hydraulic dynamics (e.g. Januschke et al. 2014). In principle, the study design used in MONDAU I was repeated. However, individual parameters (birds, tree species vitality) for which a very small change was expected were not surveyed again; for other parameters, the original survey effort was reduced (e.g. reduction of forest vegetation surveys due to revision of the stratification). The surveys were mostly carried out by new employees; in the case of arthropods and molluscs, continuity could not even be achieved at the level of research partners. For the studies on aquatic biodiversity, the monitoring of MONDAU I was carried out with the identical sample design and the same core team, resulting in a very high degree of consistency in data collection and analysis (Pander et al. 2024).

Results of the individual sub-projects

A comprehensive presentation of the results of MONDAU II can be found in the final report of the project, which is published in the publication series of the German Federal Agency for Nature Conservation (Stammel et al. 2025). The most important findings for the individual study objects are summarised as follows:

Abiotic site parameters: Since 2011, a total of 30 ecological floods with an average duration of 3.6 days have been carried out, but no flooding took place in the study year 2022 due to the low discharge of the Danube. This is probably one of the reasons why only minor erosion and accumulation processes were observed in MONDAU II compared to MONDAU I. In contrast, no changes in groundwater and discharge dynamics and the extent of flooded areas could

be documented during an ecological flood in 2023. Only the increased deadwood dynamics and the resulting backwater effects caused locally larger flooding in small areas. The investigations of soil moisture showed that the water content in the soil increases almost parallel to the water level during ecological flooding. In contrast, the uppermost soil layer (25 cm) does not appear to be directly affected by the runoff dynamics due to an interruption of the capillary rise.

Floodplain vegetation: Twelve years after restoration, the initial increase in species diversity in the aquatic and riparian vegetation had declined again, as some of the new species in MONDAU I did not establish permanently. The often-steep banks and the low morphodynamic processes provided hardly any dynamic areas for the germination and establishment of riparian plants. The few positive exceptions emphasise the need for more intensive flow dynamics and measures to create suitable site conditions, such as flattening the banks and adding gravel. The forest vegetation also showed a decline in the initial increase in species, but a greater differentiation along the analysed moisture gradient. In particular, the 2013 flood event led to a decline in species not adapted to floodplains and resulted in a change in the vegetation on the subsequently litter- and vegetation-free soils.

Floodplain fauna: The mean species numbers of molluscs had more or less returned to the pre-restoration level by 2022, while the mean numbers of individuals continued to increase significantly. Overall, a mollusc fauna dependent on higher humidity had established itself compared to the pre-restoration period – but still with clear differences to the species inventory of the surrounding more natural floodplains. After the initial decline, species numbers in the arthropod groups studied also returned to levels similar to those before re-dynamisation. The species composition in the various layers analysed (soil, shrub layer and canopy) changed considerably over the years, probably due to the changed conditions in the floodplain, but also to the respective weather conditions. However, with the exception of the dry year 2022, the diversity of beetles typical of floodplain forests was consistently positive, which can certainly be considered a success. The gravel banks further expanded the range of species studied and provide information on the quality of the riparian habitats of the Ottheinrichbach. With proper conservation management, these areas provide habitat for many species relevant to nature conservation, such as ground beetles.

Aquatic biodiversity: As in MONDAU I, the fish communities in the aquatic habitats of rivers, oxbow lakes or floodplain ponds continue to differ significantly from each other, and in general, in MONDAU II more fish were recorded across all age classes. The greatest changes in the fish community composition occurred in the rivers and narrow oxbow lakes of the Ottheinrichbach. Only one new fish species, the invasive blackmouth goby, could be detected in the project area. Individual species such as the rheophilicbarbel have increased in number overall size classes and now comprise a fully established

Figure 2. Impressions of changes over time – 30 ecological floods have passed through the study area since 2010 (cf. upper left photo); in some places the water level is so high that the trees in former alluvial forest areas have died (cf. upper right photo, middle part); a lot of deadwood has been introduced into the Ottheinrichbach (cf. lower left photo, and photo on title page), particularly as a result of the ash dieback, which has a strong impact on the morphodynamic development and the habitats in the watercourse.

population after twelve years. Rare species, such as the *Zingel streber,* were caught with significantly more individuals and age classes, indicating a longer period needed for colonisation by these specialised species (Pander et al. 2024).

Despite the different development of the individual species groups, the joint evaluation of the results of the sub-projects showed the ongoing change of the ecosystem and the dwindling influence of the hydrological initial conditions prior to the restoration (formerly dry, standing, running or temporary floodplain waters). Even though the total number of species and the Red List species of most species' groups (*fig. 3*) decreased significantly, the typical floodplain species increased, and a greater moisture gradient developed. In particular, the increased productivity, expressed by the number of individuals (molluscs, arthropods, fish), was attributed to the changed hydrological conditions. The dynamisation measures together with the natural flooding caused a moderate change in the terrestrial floodplain ecosystem and a significant change in the aquatic ecosystem. The extensive monitoring with its spatial, temporal and species-specific dimensions showed that the initially strong dynamisation effects often diminish over time. The significant importance of hydrological dynamics and longitudinal and lateral connectivity for the floodplain ecosystem confirms the need to bring as much water as possible to the remaining floodplain forests, especially during climatically dry years.

Conclusion for monitoring and floodplain dynamisation

The Ottheinrichbach and its newly created floodplain is a successful example of how an important habitat can be restored, also as a substitute for the heavily modified habitat in the dammed Danube and its floodplains. The management required after the implementation of the measures is based on monitoring results. Such success control offers the opportunity to learn from observations in a timely manner and to derive possible improvement measures for the area itself (e.g. subsequent shaping of banks, adjustment of discharge volumes) in an evidence-based adaptive management process, but also to transfer the knowledge gained to other areas.

The key findings from the two MONDAU projects for efficient and scientifically sound monitoring are:

- Long-term effects: Many measures take years to take effect; in some cases, an extreme event is needed as a catalyst to initiate dynamic processes. Meaningful floodplain monitoring, particularly in the context of expected climatic and hydrological changes, must therefore be designed for the long term (e.g. 10 or 20 years).
- Recording and evaluation standard: The various target species of floodplain restoration projects occur in diverse sub-habitats and at different trophic and functional levels but also require dynamic processes and changes in abiotic parameters. The selected species groups and study parameters should be recorded in a standardised manner, following a common spatial study design wherever possible, in order to allow comparisons between restoration projects. The BACI design (before, after, control, impact) has proven to be the standard for site selection, allowing the effects of both the temporal change and the measure to be analysed.
- Adaptive management: Monitoring is important as part of adaptive management in order to identify potential for improvement in long-term operations. The great importance of hydrological dynamics for the floodplain ecosystem became clear, confirming the need to divert as much water as possible to the remaining floodplain forests.

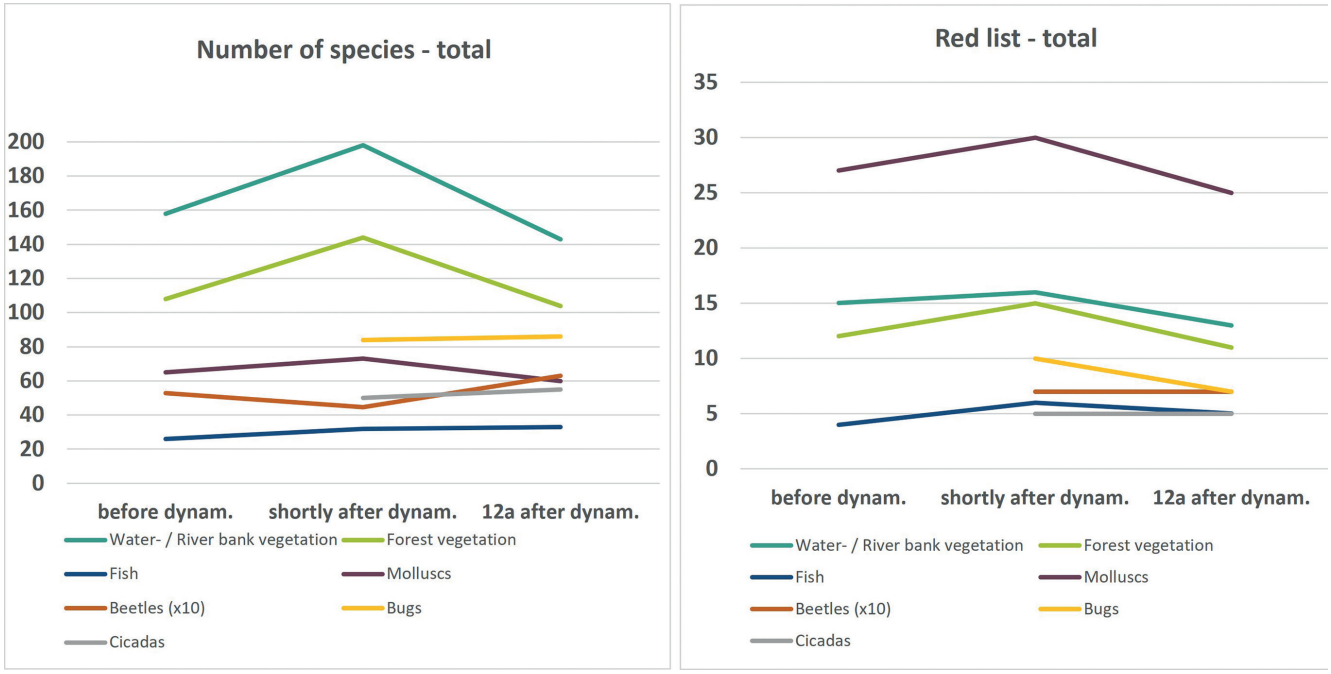

Figure 3. Change in the total number of species recorded on the permanent monitoring plots and the number of Red List species of the individual species groups before the measures were implemented, shortly afterwards and twelve years later (source: Stammel et al. 2025).

Accordingly, discharge volumes and times that are as flexible as possible and orientated towards ecological functionality, should be granted at the approval planning stage. This is the only way to react promptly to monitoring results without further authorisation procedures.

Even in heavily anthropogenically modified floodplain landscapes, as presented herein on the Danube, dynamisation measures were able to induce positive effects in terms of structural diversity (especially deadwood), lateral and longitudinal connectivity and the dynamics of discharge volumes. The monitoring showed that the improvements were only effective for some species groups or in some sections, not in the entire watercourse or across the entire floodplain. The positive experience and knowledge gained from the dynamisation project along the impounded Danube should be applied to other impounded floodplain areas. Of course, the specific local hydrological and ecological conditions and situations must always be taken into account when planning dynamisation measures. However, the large-scale expansion of successful measures of this kind is essential in order to achieve a significant turnaround in the biodiversity crisis in rivers and floodplains.

References

Cyffka B, Binder F, Ewald J, Geist J, Gruppe A, Hemmer I, Kiehl K, Mosandl R, Schopf R, Zahner V (eds.) (2016). Neue dynamische Prozesse im Auenwald – Monitoring der Auenrenaturierung an der Donau zwischen Neuburg und Ingolstadt, Naturschutz und Biologische Vielfalt 150, 370 S.

Januschke K, Jähnig SC, Lorenz AW, Hering D (2014). Mountain river restoration measures and their success(ion): effects on river morphology, local species pool, and functional composition of three organism groups. Ecological Indicators 38, 243-255. DOI: 10.1016/j.ecolind.2013.10.031

Pander J, Mueller M, Knott J, Egg L, Geist J (2017). Is it Worth the Money? The Functionality of Engineered Shallow Stream Banks as Habitat for Juvenile Fishes in Heavily Modified Water Bodies. River Research and Applications 33, 63-72. DOI: 10.1002/rra.3065

Pander J, Winter E, Geist J (2024). Ecological indicators for restoration success: Development of fish diversity in a large, restored floodplain over twelve years. Ecolocial Indicators 169, 112920. DOI: 10.1016/j.ecolind.2024.112920

Stammel B, Cyffka B, Geist J, Müller M, Pander J, Blasch G, Fischer P, Gruppe A, Haas F, Kilg M, Lang P, Schopf R, Schwab A, Utschik H, Weißbrod M (2012). Floodplain restoration on the Upper Danube (Germany) by re-establishing back water and sediment dynamics: a scientific monitoring as part of the implementation. River Systems, 20, 55-70. DOI: 10.1127/1868-5749/2011/020-0033

Stammel B, Assel M, Borgs T, Geist J, Groh K, Mandery K, Pander J, Rumm A, Steffens M, Ullmann V, Winter M, Cyffka B (2025). 12 Jahre auenökologische Prozesse im Donauauwald bei Neuburg – Ergebnisse eines abiotischen und biotischen Monitorings. BfN-Schriften 717, 180 S.

Stammel B, Stäps J, Schwab A, Kiehl K (2021). Are natural floods accelerators for streambank vegetation development in floodplain restoration? International Review of Hydrobiology 107, 76-87. DOI: 10.1002/iroh.202102091

45th IAD Conference 'Innovative solutions and cooperation to protect and restore biodiversity and ecosystems in the Danube River Basin'

The conference held from 9 –12 April 2025 in Sofia, Bulgaria, was, after those in 1966, 1976, 1990 and 2014, the 5th IAD Conference hosted by the Bulgarian section of IAD, represented by the institutes of the Bulgarian Academy of Sciences. The conference was organised by the Institute of Biodiversity and Ecosystem Research, BAS (IBER-BAS), Climate, Atmosphere and Water Research Institute, BAS (CAWRI-BAS), the General Secretariat of IAD, Danube Region Invasive Alien Species Network (DIAS) and Union for Conservation of Nature Bulgaria (UCNB). The conference was funded by IAD and co-funded by IBER-BAS and the projects DANUBE4all, DaWetRest and DANSER, in the frame of the EU Mission 'Restore our Oceans and Waters' Danube and Black Sea Lighthouse.

The event was attended by 120 participants from 15 countries. The majority of participants came from the host country, Bulgaria (more than 70 participants), followed by Romania, Serbia, Ukraine, Austria, Hungary, Germany, Czech Republic, North Macedonia, and participants from Croatia, France, Ireland, Slovakia, Slovenia, and Türkiye. About 35 of them were young scientists, PhD- and undergraduate students. A total of 83 communications (nine keynote, 39 oral presentations, 35 posters) were given and allowed insights into the rich and diverse research on the Danube River Basin and the Danube and Black Sea Region.

The conference provided an exchange forum for long-term multidisciplinary research and activities on various topics, highlighting the importance of building innovative solutions and cooperation to protect and restore biodiversity and ecosystems in the Danube River Basin. This year's IAD Conference aimed to showcase the significant achievements made in the Danube and Black Sea Lighthouse by scaling up sustainable solutions related to the main threats to the Danube River Basin as hydromorphological alterations, water pollution, ecosystem degradation, invasive alien species and effects of climate change. The Conference objectives were covered by, but not limited to, 12 scientific

Figure 1. Co-chairs of the Organising and Scientific Committees; from left to right: Cristina Sandu, IAD Vice-President, Teodora Trichkova, IAD Country representative Bulgaria, Katrin Teubner, IAD General Secretary, and Bernd Cyffka, IAD President. Photo: Milcho Todorov.