Research for the future of our freshwaters

IGB DOSSIER

# Small standing water bodies as biodiversity hotspots – particularly valuable, but highly endangered

Options for action, protection and restoration

IGB
Leibniz Institute of Freshwater Ecology and Inland Fisheries

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# Small standing water bodies: endangered hotspots of biodiversity

Small standing water bodies[1], such as natural or artificial ponds, kettle holes, park waters and stormwater retention basins, account for more than 30 per cent of the world's freshwater surface area. Given their high abundance, biodiversity[2] and integration into the carbon and nutrient balance of their catchment areas, small water bodies are important ecosystems. Collectively, they provide valuable ecosystem services, including water retention, nutrient dynamics, recreation for people, and habitat for wildlife. However, due to their small size, their ecological and social importance is often underestimated. Small water bodies often have no protection status and are rarely taken into account in legislation and practice.

It is estimated that between 50 and 90 per cent of Europe's ponds have disappeared in the last century. Advancing climate change, with increasing water scarcity and longer periods of drought, poses a particular threat to small water bodies, leading to their further disappearance. Across Europe, the water levels of small standing water bodies are at historic lows. Many dry up completely, sometimes for years, with serious consequences for the plant and animal species that depend on them. And yet, because of their small size and important contribution to biodiversity and ecosystem services, small standing water bodies are ideally suited as nature-based solutions.

The Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Germany's largest research centre for inland waters, is publishing this *IGB Dossier*, which explains the context and identifies options for action for policymakers and authorities.

1 The definition of "small standing water bodies" varies, but they are often defined as water bodies less than 10,000 m² (1 ha) in size and generally rather shallow (maximum depth 3-5 m). For improved readability, we also use "ponds" as an umbrella term in this *IGB Dossier*.

2 The term "biodiversity" refers to the diversity of species, genetic diversity, the composition of biotic communities, the interactions within and between biotic communities, and the diversity of habitats and ecosystems. The definition is based on the UN Convention on Biological Diversity (CBD).

# 1. Small standing water bodies and their contribution to biodiversity and ecosystem services

Natural and semi-natural small water bodies are often hotspots of biodiversity within the surrounding landscape and can therefore be considered “small oases”. Their contribution to regional freshwater diversity has been shown to be the highest of all freshwater systems, supporting 70 per cent of the regional freshwater species pool in European landscapes (Williams et al. 2004; Davies et al. 2008).

## Hotspots for biodiversity

Ponds are crucial for biodiversity conservation, supporting a higher proportion of rare, endemic and threatened freshwater species than larger aquatic systems such as lakes or rivers. An important reason for this high contribution to biodiversity is the fact that small standing water bodies are not only numerous but also varied, because they are (semi-)isolated from each other and mainly influenced by very local conditions (Scheffer et al. 2006). In addition, the well-developed littoral zone with both submerged and emergent vegetation (e.g. reed belts) attracts diverse communities of flora and fauna. Small water bodies are also important stepping-stone habitats through which water-bound species can spread and re-establish themselves in the landscape. In addition to their contribution to freshwater biodiversity, small water bodies are also an important source of water and food (e.g. for birds and bats that feed on semi-aquatic insects) and their surrounding area a habitat for many terrestrial animals and plants.

## Multiple ecosystem services to human societies

Small standing water bodies provide a wide range of ecosystem services to human societies. They serve to retain water in the landscape and interact strongly with groundwater. Small standing water bodies can have a positive effect on the local microclimate by reducing local temperatures, particularly in urban areas. They can also contribute to carbon storage (Biggs et al. 2017), play an important role in nutrient dynamics and provide flood protection. Well-maintained ponds in agricultural landscapes have recently been shown to enhance pollinator richness and abundance (Walton et al. 2021a, 2021b). They also serve as water sources for livestock watering, irrigation and fire-fighting in summer or in semi-arid areas. Furthermore, they provide cultural benefits such as recreational opportunities. Small standing water bodies can provide stress relief, support for human health and quality of life, space for recreational activities, such as walking, jogging, cycling and gardening, aesthetic and inspiring experiences as well as support for educational activities, especially in urban areas.

Where they exist or are being developed as a nature-based solution as a “pondscape” (see sections 3 and 6), small water bodies can provide these ecosystem services to an even greater extent, thereby supporting climate change mitigation and adaptation.

## 2. Land use and climate change determine the occurrence and ecological status of small standing water bodies

### Less water – fewer small water bodies

Small water bodies are mostly shallow and dependent on groundwater or backwater, making them vulnerable to reduced rainfall and declining groundwater levels in the surrounding landscape. In addition, in our urbanising landscapes, land has been heavily sealed and rainfall has been channelled through sewers. As a result, the soil is often unable to recharge the groundwater. Agricultural land has been drained for decades making continuous groundwater recharge impossible in many places. As a result, small water bodies have been particularly hard hit by droughts and water scarcity in recent years. Many have disappeared altogether, both in urban and rural areas.

In urban areas, as well as in areas of intensive agriculture, small standing water bodies are often filled in with terrestrial material and built over or used to grow crops. This has had a dramatic impact on the number of ponds in our landscapes. It is estimated that across Europe, 50 to 90 per cent of the small standing water bodies have disappeared in the last century. In the UK, a historical analysis found that 80 per cent of small standing water bodies have been lost in the last 100 years (Wood et al. 2003).

### Ecological degradation due to nutrients and pollutants

Both land use and climate change also affect the ecological status of the remaining small standing water bodies in the landscape. Small standing water bodies generally have small catchment areas. It has been shown that their water quality and ecological integrity is often determined by land use in the first few hundred metres of the surrounding landscape (Declerck et al. 2006).

Standing water bodies are usually located in landscape sinks and are therefore “collection points” for substance flows. Due to their small size, ponds have a much lower ecological buffer capacity than larger water bodies such as large lakes. Pollution with inorganic and organic substances, such as fertilisers, pesticides, tyre abrasion, detergents, paint residues, flame retardants and road salt, caused by land use in the immediate vicinity of small standing waters therefore has a direct impact on their functioning and biodiversity. As a result, urbanisation (Piano et al. 2019) and intensive agriculture (De Bie et al. 2012; Ionescu et al. 2022; Bizic et al. 2022; Musseau et al. 2022) often reduce the quality and biodiversity of small standing water bodies. In agricultural landscapes, high nutrient loads that stimulate algal growth are a particularly strong driver of ecosystem degradation and altered ecosystem function (De Bie et al. 2012; Kazanjian et al. 2018). In general, “clear-water” systems with underwater vegetation have a much higher diversity than nutrient-rich, turbid systems dominated by algal blooms (Declerck et al. 2005; Usio et al. 2017; Hilt et al. 2017).

### Increased impact of droughts and extreme weather events

Extreme weather events caused by climate change can exacerbate these effects. Prolonged droughts can lead to increased concentrations of nutrients and pollutants, resulting in the loss of species sensitive to pollution. Low water levels result in a reduced dilution effect, meaning that the same pollutant load can have a much greater negative impact on the ecosystem. An increase in nutrient concentrations, combined with the fact that the reduced water volume also heats up faster, often leads to the formation of (toxic) algal blooms.

Warming also increases oxygen stress due to a combination of reduced availability and an increased need to support metabolic activity at higher temperatures. Oxygen is consumed all the more quickly, especially under a combination of warming and high nutrient concentrations, and can drastically reduce the chances of survival for all aquatic life. There is therefore a strong synergistic interaction between climate warming and pollution by nutrients and toxins – even when both are at levels where, as single stressors, each would have limited negative effects; their combined effect can be very strong.

Another important effect of climate change is that prolonged periods of drought can lead to the temporary drying up of small standing water bodies in the landscape. This has far-reaching implications because many organisms depend on water. For some, such as amphibians and insects whose larvae grow in the water, the length of the wet season is crucial to the completion of their life cycle. It is important to note that temporary water bodies also support a high diversity of taxa and often harbour rare and specialised species. It is therefore important to maintain ponds with different lengths of water retention (from ponds that hold water for only a few months to permanent ponds) in the landscape (Parra et al. 2021).

At the other extreme, heavy rain and storms can lead to massive increases in pollution from surface runoff and sewer overflows. When large amounts of rain fall in a short period of time, the parched soil or sealed urban surfaces cannot absorb it. Heavy surface runoff leads to the erosion and mobilisation of large amounts of nutrients, metals, organic pollutants, sediment and particles (e.g. plastics or tyre abrasion), which are quickly deposited in small water bodies.

The problem of land sealing, which is well known in urban areas, also affects rural areas: 20 per cent of the newly sealed areas in Germany are in the countryside, according to new research (Nguyen et al. 2022). This new sealing in rural areas has not been taken into account in calculations of nutrient inputs to water bodies. As a result, the total nutrient and pollutant load is systematically underestimated. In rural areas, much of the nutrient and pollutant input is associated with intensive agriculture, which is characterised by monocultures. Fields are often extended into the immediate vicinity of water bodies. There is then a lack of buffer zones to protect against inputs of farm sediment, fertilisers (nitrate and phosphorus), herbicides, fungicides and insecticides. In addition to surface runoff, heavy storms can cause sewers to overflow, dramatically increasing nutrient and pollutant loads in our freshwaters.

### The importance of the number and connectivity of landscapes: pondscapes

The reduction in the number and ecological quality of small standing water bodies caused by climate and land use change has important implications for their functioning and biodiversity. This is because it undermines two key drivers of their importance for biodiversity – their large number and the fact that they can be ecologically very diverse. It also undermines the extent to which small standing water bodies can act as stepping stones, forming a network that supports the (re)colonisation of habitats and the exchange of genetic material (Karnatak & Wollrab 2020). The fewer small water bodies there are and the greater the distance between them, the less likely it is that species will reach them. The density of water bodies is therefore a controlling variable, especially for passively distributed species, such as plankton organisms and macrophytes. Existing populations may become isolated and suffer from inbreeding due to loss of genetic diversity.

Comparing historical and recent data, it was recently shown that the loss of soda pans in Austria over the past 70 years has resulted in a 25 per cent loss of species (Horvath et al. 2019). These losses were mainly of the rarer and more threatened species, and were also reflected in reduced numbers of species within the remaining local habitats, indicating that the loss of biodiversity is due to a reduction in connectivity and not just to the number of habitats per se. Because of the importance of connectivity, which is mainly determined by the number and quality of the small standing water bodies in the landscape, it is important to focus not only on individual small standing water bodies, but also on the "landscape" of small standing water bodies, also referred to as "pondscapes" (pond landscapes). For effective conservation action, it is crucial to focus on a large number of small freshwater bodies in a landscape, rather than simply protecting individual sites that support the highest number of species (Musseau et al. 2022).

## Amphibians are particularly affected

Many amphibians are particularly dependent on small standing water bodies, illustrating how land use and climate change are affecting biodiversity in these systems. The disappearance of small water bodies has clearly contributed to the collapse of amphibian populations such as frogs, toads, newts and salamanders in Germany and Europe, as is reflected in the current Red List for amphibians of Germany (Redlist 2020). Most European amphibians reproduce in small water bodies and spend the rest of the year in moist terrestrial habitats. Several species need temporary water bodies because these areas have the advantage of being free from typical predators of tadpoles and newt larvae, such as fish and dragonfly larvae, which do not settle in temporary water bodies or do not survive the dry season. However, the length of time that the pond holds water is important; if it is too short, amphibians cannot complete their life cycle. The loss of small standing water bodies due to land conversion and climate change comes on top of other already existing challenges for amphibians, such as pollution, including endocrine-disrupting chemicals (Tamschick et al. 2016), and invasive species. Most amphibians have a limited ability to disperse from one habitat to another. Pondscapes with a sufficient number of small, shallow standing water bodies are therefore crucial for many amphibian species – including endangered species such as the fire-bellied

The European green toad, *Bufotes viridis*, is an amphibian species typical of smaller or ephemeral ponds.
PHOTO: AMAËL BORZÉE

toad (*Bombina bombina*), the green toad (*Bufotes viridis*) and the European tree frog (*Hyla arborea*) (Dolgener et al. 2014).

### Macrophytes support biodiversity

Besides amphibians and other animals, ponds are also home to specialised aquatic plants such as macrophytes (Pätzig et al. 2012), e.g. the rare and protected water soldier (*Stratiotes aloides*) (Turner et al. 2021). Aquatic plants are important players in small standing waterbodies: During their growth, they bind carbon dioxide, which can thus be stored in the sediment for longer periods. Macrophytes remove nutrients such as phosphorus and nitrogen from the water body and can thus limit phytoplankton growth. They also release oxygen which improves the aeration of the water bodies and their sediments. Due to their diverse structure, they also promote biodiversity: a species-rich community of algae and bacteria can develop on their surface, which in turn provides habitat and food for small animals (zoobenthos). Macrophytes offer small animals protection from predators and are themselves a food source for various animal species. The lack of water leads to shrinking or complete loss of macrophyte habitats.

The water soldier, *Stratiotes aloides*, is a rare macrophyte growing in small standing water bodies.
PHOTO: LUC DE MEESTER/IGB

## 3. Social pressure of use exacerbates burdens

In addition to the threats posed by land conversion, habitat destruction and climate change, there is increasing social pressure to use water bodies, particularly in urban areas. Surrounded by sealed surfaces and unnatural spaces, small water bodies are points of attraction for recreation seekers. For many people, small water bodies are the first or even the central point of encounter and experience with nature.

But heavy use has consequences: riparian vegetation suffers and soils can be compacted by heavy foot traffic. When waterfowl such as ducks and coots are fed bread and grain, too many nutrients enter the water, which becomes heavily eutrophic. Insects, amphibians, fish and their spawn fall victim to illegally introduced fish and crustaceans. Humans also produce second-order effects that exacerbate the impact of drought: as water becomes scarcer, there is an increased risk that water will be abstracted from aquifers or directly from surface waters, further reducing the availability of water to ecosystems and their biota.

## 4. Climate feedbacks

Several of the many ecosystem services provided by small standing water bodies are linked to climate change, such as their capacity to store stormwater and interact with groundwater, their contribution to microclimate regulation, and their ability to store carbon through sediment accumulation. However, these ecosystem services depend on the quality of the ecosystem and are therefore affected by climate change itself, in addition to other threats.

Such disturbances can lead to ecological changes that cause small water bodies to contribute to further warming: polluted, nutrient-rich waters produce significantly more of the greenhouse gases methane and carbon dioxide than do less productive, clear-water habitats. In addition, when small standing water bodies dry out during prolonged droughts, the exposed sediments oxidise and release greenhouse gases. Frequent drying reduces the organic carbon burial rate of small water bodies, which is generally higher in more permanent systems such as grasslands.

## 5. Small water bodies as nature-based solutions (NBS)

Managing small standing water bodies as NBS is a promising approach because it offers synergies between environmental and human use objectives. NBS are defined by the International Union for the Conservation of Nature as: "Actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges, such as climate change, effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN, 2020).

Small standing water bodies have a particularly high potential as NBS, particularly in the context of climate change adaptation and mitigation, due to their relevant contribution to biodiversity conservation and ecosystem services (see Section 1; Cuenca-Cambronera et al. 2023). The effectiveness of ponds as NBS is also enhanced by their small size and the fact that their ecological integrity is largely determined by the land use in their immediate vicinity. This makes it easier and more cost-effective to create, improve and restore small standing water bodies.
Such creation and restoration is urgently needed, given the dramatic decline in the number of small standing water bodies over the last century and the challenges facing the remaining systems due to land use conversion and climate change.

### Consideration of networks of small standing water bodies

While small standing water bodies can be created and restored as individual units, the information presented in this IGB Dossier also points to the importance of considering networks of small standing water bodies in landscapes (also referred to as pondscapes, see Section 3). Although ponds can be considered as individual units, it is increasingly recognised that they have their greatest potential for biodiversity conservation as a network, with the density of the network being important in determining the extent to which the pondscape can support rare and specialist species. Pond creation and restoration is therefore best considered from a pondscape perspective, both to restore a high number of small standing water bodies in the landscape and to ensure their diversity. A key dimension of diversity is the extent to which ponds can differ in length of wet period – a good mix of permanent and temporary systems, and of temporary systems with relatively short or relatively long wet periods, is important for enhancing regional biodiversity.

### Ensuring minimum environmental water needs

A prerequisite for ponds and pondscapes to serve as NBS is that the minimum ecological flow requirements of these small water bodies are met, even in the event of water shortages. Minimum ecological flow requirements describe the quantity, timing and quality of freshwater flows and levels required to sustain aquatic ecosystems (Arthington et al. 2018). Only water in sufficient quantity and quality can support biodiversity, which in turn is essential for resilient ecosystems. This is because diverse habitats and species communities provide a kind of “insurance” against external stresses, environmental changes and fluctuations, including human-induced changes such as climate change. Biodiversity increases the likelihood of survival of species and species communities and the functioning of the ecosystems on which we depend.

Given that ponds themselves contribute to water purification and recharge, this leads to the interesting situation that pond creation and restoration, together with land use management and the reduction of impervious surface, contribute to better conditions for the successful implementation of NBS through pondscapes. Increasing the number of small standing water bodies can thus indirectly enhance their functioning and ecosystem services through increased connectivity and impact on the water balance. The conservation, restoration and development of small water bodies and their biodiversity – and of freshwater ecosystems in general – is a matter of survival for both animals and humans.

## 6. Options for action: conservation, restoration and sustainable development of small water bodies

**Consistent interpretation of the legal framework:** Small water bodies receive relatively little attention in water policy and water management, partly due to their low legal status. To date, they are not covered by the reporting requirements of the European Water Framework Directive (WFD), which only apply to standing water bodies larger than 50 hectares.

As a result, their ecological status is poorly recorded and there is little political ambition to improve the situation. However, this interpretation overlooks the fact that the WFD was also adopted to protect and develop small water bodies. Spain, for example, has introduced monitoring of the ecological status of ponds as part of its WFD implementation.

The WFD, as European legislation, is implemented in Germany by the Water Resources Act (WHG), where Section 39 makes the maintenance and development of a surface water body a public obligation. This is explicitly to maintain and promote ecological functionality, particularly as a habitat for wildlife, with positive impacts on the ecosystem services described above. In addition, according to sections 28-32 of the Nature Conservation Act (BNatSchG), small water bodies are in principle legally protected biotopes. There is therefore a legal basis for the sustainable management of small water bodies.

The protection of small standing water bodies can also be implemented in the context of protection or target species, such as rare amphibians, dragonflies, damselflies and large branchiopods. In the context of the recent Convention of Biological Diversity resolution to conserve 30 per cent of terrestrial land, landscapes with many ponds and pondscapes should be an important target. Internationally, the Ramsar Convention decided to include small water bodies as targets for protection.

Irrespective of the legal context, there is a lack of practical implementation. Local authorities are often unaware of the importance of small water bodies — this is partly due to a lack of information. However, there is often a lack of public funding.

**Clarify competences and define responsibilities:** Due to the often unclear or inconsistently interpreted legal framework described above, the official responsibilities for small water bodies are not sufficiently regulated, which also results in a lack of sustainable practical water body management and maintenance. If necessary and possible, responsibility can also be transferred to civil society actors such as associations, societies, foundations and initiatives, e.g. through sponsorships, godparenthood and similar models. However, even with voluntary commitment, sufficient resources and good professional practice in water management and maintenance must be ensured. Stakeholder involvement is essential to ensure that all relevant interests and needs are taken into account in areas where ponds or pondscapes are created, restored or managed.

**Ensure minimum ecological flow requirements:** As climate change progresses, existing water scarcity will increase. It is therefore important to ensure minimum ecological flow requirements for small water bodies. In both rural and urban areas, approaches need to be developed to ensure sufficient quantity and quality of water supply to maintain small water bodies as valuable habitats. The development of pondscapes as NBS can help to create favourable conditions. This requires consideration of the ecohydrological functioning of catchments, i.e. how and when water is stored and released in landscapes. Assessing how different land uses affect the partitioning of "green" (evaporation and transpiration) and "blue" (groundwater recharge and runoff) water provides a crucial basis for evaluating how water storage and water and pollutant flux dynamics can be mediated by land management strategies to build resilience and protect water resources against future climate change.

**Develop management guidelines for small water bodies:** Depending on their type, region and location, small water bodies in Germany and Europe can have very different characteristics and management needs. For this reason, guidelines should be developed for the different types of small water bodies, which can be used as a basis for operational water management. These models should be supported by an appropriate catalogue of maintenance measures. This includes information on the proper management to maintain both the rich vegetation and the open water zone of small standing water bodies. It is important to maintain structurally rich riparian areas or transition and siltation zones. They also act as buffer zones against the influx of sediments, nutrients and pollutants. Such buffer zones should ideally be quite large (50-100 m) to be effective. They also contribute to agricultural productivity through their effect on the abundance and richness of pollinators. Wherever possible, artificial bank reinforcements should be removed and banks flattened to facilitate the development of biodiverse wetlands.

**Promote the restoration and creation of small water bodies:** The creation of new small standing water bodies is important, as it increases regional diversity and contributes to the conservation of rare species and the general stepping stone function of small water bodies. Secondly, to increase the ecological function, biodiversity and ecosystem services of small standing water bodies, it is necessary to improve their water quality and structure (e.g. presence of underwater and riparian vegetation). The implementation of such NBS is relatively cost-effective as it can be done at a very local scale. The success of the measures should be monitored, combined with continuous and qualified biotope management and maintenance. In addition, small water bodies should be given a higher priority for development and support through public programmes. One measure that can promote the ecological development of small water bodies – also in the sense of NBS – is that they can be increasingly taken into account in compensation and replacement measures for interventions in the natural balance, as required by nature conservation legislation. Overall, effective conservation measures should focus more on achieving a large number of different small freshwater bodies in a landscape ("pondscape") than on protecting individual sites with the highest number of species.

**Reduce emissions and create riparian strips and buffer zones:** Policymakers should consider whether substance emissions should be more tightly regulated as water scarcity increases and pollutant and nutrient loads interact with the effects of warming and reduced dilution. Given the importance of water quality for biodiversity and ecosystem services, it is essential that nutrient, sediment and pollutant inputs to small standing waters are reduced as much as possible. This can be achieved by managing land use in the immediate vicinity of the ponds. In practice, this may often mean establishing sufficiently large buffer zones (50-100 m), in which vegetation is either protected or very extensive farming is practised without the use of fertilisers or pesticides. In both rural and urban areas, sufficiently large riparian strips should be established to act as a physical barrier and reduce hazardous inputs to water bodies through retention or chemical transformation. The establishment and maintenance of these riparian strips should be monitored by the authorities at sufficiently frequent intervals.

**Give more consideration to small water bodies in urban and settlement planning:** The concept of the "sponge city" offers great potential for small water bodies, where rainwater is not discharged directly into the sewerage system, but infiltrates into the urban soils and, in the best case, is purified by biogeochemical processes. Precipitation can thus contribute to the recharge of backwater and groundwater, which in turn supports small water bodies. For this reason, urban and settlement planning must increasingly promote the reduction of sealed surfaces in the catchment area, including the requirement for roof drainage in new and existing buildings to be directly infiltrated on site. In addition, social pressures on urban small water bodies often require policies on access and visitor management.

**Better protect small water bodies in rural areas:** Many current agricultural practices and products are not sustainable in the wake of ongoing climate change. Landscapes and soils need to be designed and managed to absorb and store water better and to release it more slowly. Increased water retention in the area can then benefit both agriculture and small water bodies. Again, the creation and protection of small standing water bodies and wetlands can contribute to this. In agricultural areas, the development of sufficiently large buffer zones around small standing water bodies will be essential for their quality and functioning.

**Make information and data publicly available to experts:** All existing small water bodies should be listed in an up-to-date and complete manner in accessible environmental databases and be easily identifiable and findable through stored geodata. Their respective subtypes, characteristics and, where appropriate, existing protection status and official responsibilities should also be recorded. This will also enable the organised civil society, such as NGOs, to contribute to the protection of small water bodies. The economic, social and environmental benefits of small standing waterbodies can only be assessed through long-term and systematic monitoring, which requires both resources and commitment.

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Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB)
in the Forschungsverbund Berlin e. V.
Müggelseedamm 310
12587 Berlin, Germany
Phone: +49 30 64181-500
Email: info@igb-berlin.de
Internet: www.igb-berlin.de/en
X: https://twitter.com/LeibnizIGB
Newsletter: www.igb-berlin.de/en/newsletter

**Responsible authors** (in alphabetical order)
Hans-Peter Grossart, Sabine Hilt, Luc De Meester, Thomas Mehner, Michael Monaghan, Camille Musseau, Stephanie Spahr, Matthias Stöck, Sabine Wollrab

**Coordination**
Johannes Graupner

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