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25 The Isar River: Social Pride as a Driver of River Restoration

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Summary

The transboundary Isar River is an alpine river that flows through the Bavarian Alps to join the Danube River in one of its last free-flowing sections. The Isar enables local human development and crosses the city of Munich that is the 12th largest city in Europe. The Isar largely contributes to the successful growth of Munich and highly influences the cultural development of other cities built on or close to its floodplain. The alpine riverscape is highly appreciated by the local population and is a source of civic pride. The socio-ecological degradation of the Isar River started in the late 18th century with the first morphological changes. However, it is the boom in hydro-electrical production after the First World War that caused the greatest river degradations. Because of the clear response from civil society, advocacy groups pushed for the restoration of the river. After many years of collaborative planning, intense discussion, pressure from civil society, changes in government institutions, and strong partnerships among non-government organizations, the river management trend changed from a traditional grey infrastructure-based to nature-based practices. The Isar-Plan, namely the Isar restoration project in Munich was very successful and became a worldwide symbol of hope, showing that socio-ecological restorations are possible even in metropolitan city centers. Ultimately, the Isar River is an example showing how civil society's perception of ecosystem losses can positively influence water governance.

25.1 Introduction

The Isar River is an alpine tributary of the Danube River (fig. 25.2). The name of a freshwater body is one of the first linkages between such a natural element and humanity. The etymology of river names is mostly based on language evolution theory and provides important insights on human perceptions of rivers (Muhar et al. 2019). The name *Isar* originates from the combination of two Celtic stems: *ys* meaning 'fast, torrential' and *ura* meaning 'water, river' (Schneider and Kistler 2019). Many rivers with similar natural characteristics that traversed ancient Celtic settlement areas have similar names reflecting local language evolution: the Isère River in France, the Isar and Esera rivers in Spain, the Isel River in Austria and the transboundary Jizera River, of Poland and Czech

Republic (Schneider and Kistler 2019). While the Alpine River Tagliamento (Italy) is a well-known natural alpine river with fast-flowing water and large gravel bars (Tockner et al. 2003), the Isar River was until the year 2000 almost unknown by non-Bavarians. Because of the Isar's fast-flowing water with hydro-electrical potential, its furious and repetitive flooding patterns, which are a hazard to human settlements, and the fact that it possesses a very large floodplain with gravel bars that hinders human settlement, the river has been forced into a concrete channel. In the past decades, the Isar River was managed and engineered without a broad perspective. The local authorities modified the river form to satisfy their local and short-term needs, and the river was step-wise regulated (Rädlinger et al. 2012). The major river modifications start-

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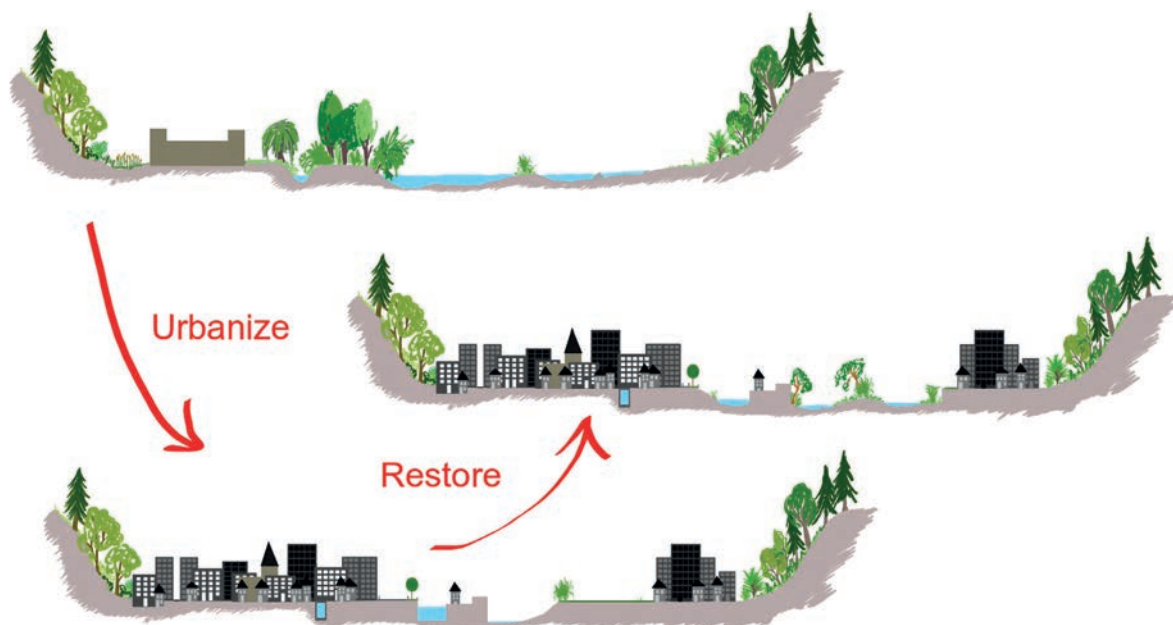


Fig. 25.1 Graphical summary: River evolution. Graph: Aude Zingraff-Hamed

ed in the 1920s with the construction of 43 hydroelectric power plants (Zingraff-Hamed et al. 2018a) including the largest storage power station in Germany (Walchensee Hydroelectric Power Station, 300 GWh). The resulting degraded morphological status of the river and related ecological and social losses triggered serious concerns and regrets from civil society (Zingraff-Hamed et al. 2019). In 1977, the Association for the Protection of the Alpine Region (Verein zum Schutz der Bergwelt e.V. formed in 1900, <https://www.vzsb.de/verein.php>) stated that the Isar is a river at the interplay between civilization and nature ("im Spannungsfeld zwischen Zivilisation und Natur") (cited in Karl et al. 1998). Ten years later, the local population finally took action to prevent further deterioration of the river-human relationship by pushing for river restoration. The Isar's history took a decisive turn as a result, with new collaborative planning that led to its restoration in Munich (2000–2011). Currently, the Isar and especially the Isar River restoration within the urban environment of Munich is a well-known example of socio-ecological river planning. Despite the fact that it is not a perfect case, it is still a strong source of inspiration worldwide helping establish the trend in ecological and collaborative river planning (fig. 25.1).

25.2 Geophysical setting

The Isar River (figs. 25.2, 25.3) starts in the Hinterau Valley near Scharnitz (Austria), in the Karwendel Mountains (elevation 1,600 m). It flows

20 km, before entering Germany at Schnarnitzer Klause. The river flows further north through Bavaria. At 145.9 km from the source, it crosses the city of Munich. The Amper River is one of its biggest tributaries and joins the Isar North of Freising. After flowing 291.5 km, the Isar River joins the Danube River in Deggendorf (elev. 310 m). The Isar drains an approximately 9,000 km² large catchment, including a part of the northern German Alps. After the Danube, the Inn and the Main, the Isar is with an average annual discharge of 173 m³s⁻¹ the largest river in Bavaria in terms of natural drainage. The Isar River has high water level variability throughout the year (table 25.1).

Historically, the river has exhibited a nival hydrological regime, which is characterized by short and violent flooding following massive snowmelts (fig. 25.4). Hydrographs show that presently, intense floods occur mostly due



Fig. 25.2 The Upper Isar. Photo: Mario Dobelmann, with permission

to extreme weather events, such as major rainstorms in the summer. Aksamit and Whitfield (2019) showed that flood pattern change indicates process changes, which may be related to climate variability and change. Because of the low water retention capacity of the geological area and of the high relief energy of the Alpine catchment, rainfall causes very strong runoff fluctuations. This means that the Isar flood pulse is greatly determined by the climatic conditions at the alpine catchment area (Neumann et al. 2011). While lowland river flooding can last over weeks, Alpine river flooding usually recedes within few days (Egger et al. 2019). Alpine-specific hydrology associated with short-term flood peaks, causes high sediment redistribution. This results in an alpine braided river

landscape. During short-term flood events, the Isar tears blocks, stones and boulders from the banks and riverbed and transports them over long distances. Afterwards the water level drops in few days (e.g., in Munich from 1,025 to 68 m³s⁻¹), the transporting power of the water decreases, gravel is sorted according to grain size by the force of the water from the alpine river shape with large gravel bars and floated pine trees of the Isar (Neumann et al. 2011). Extreme floods can also cause the relocation of the river course as a whole.

The Isar River flows within the freshwater ecoregion "Upper Danube" (<https://www.feow.org/>) but is locally divided into four sections with different landscape and ecological characteristics (table 25.2).

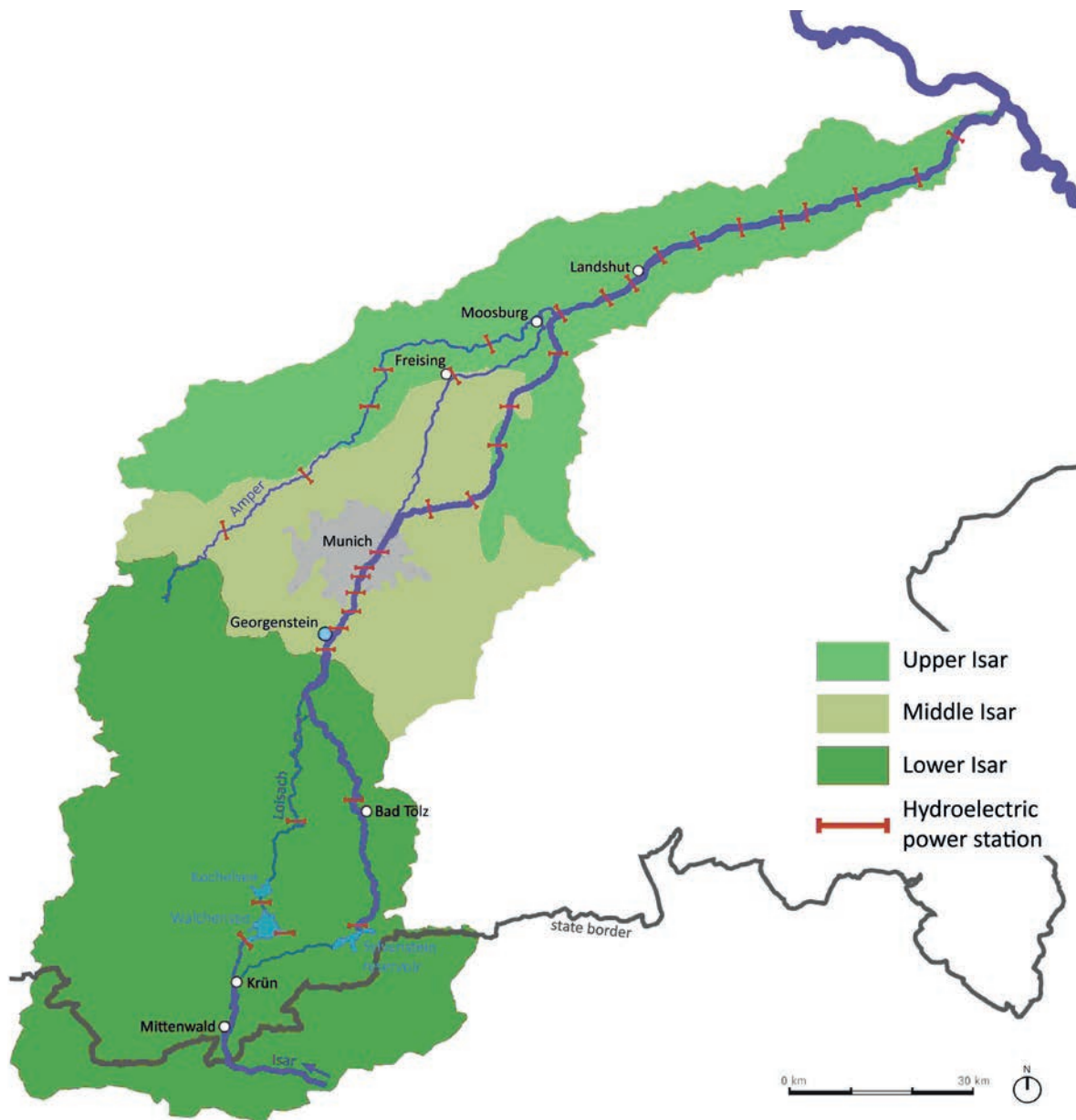


Fig. 25.3 Map of the Isar. Graph: Aude Zingraff-Hamed

Table 25.1 Overview on the discharge of the Isar River at gauging sites within each river section as identified in table 25.2. Source: <https://www.hnd.bayern.de>, accessed 26/02/2019

Discharge based on hourly discharge time series (recorded between 1959 and 2012) in $\text{m}^3 \text{s}^{-1}$	Site				
	Rißbachdüker (above the Sylvenstein Reservoir) 16001303)	Bad Tölz (16003502)	Munich (16005701)	Freising (16006500)	Landshut (16007004)
NQ: minimal annual discharge	0.131	5.36	8.63	4.64	50.9
MQ: average annual discharge	4.52	27.8	63.8	24.4	162
HQ ₁ : yearly flood event	94.5	185	350	210	450
HQ ₁₀₀ : centennial flood event	291	600	1050	950	1250
Last major floods recorded	216 (in 2013) 291 (in 2005) 275 (in 1999)	397 (in 2013) 582 (in 2005) 483 (in 1999)	761 (in 2013) 1050 (in 2005) 1440 (before reservoir construction in 1940)	664 (in 2013) 859 (in 2005) 1050 (in 1954)	1260 (in 2013) 1050 (in 2005) 1050 (in 1999)

25.2.1 The Upper Isar

The Upper Isar (fig. 25.3) is the southern section of the river, which extends from its source to the Höllriegelskreuther Dam south of Munich (Binder et al. 2001). In the Karwendel (fig. 25.2), the Isar has the characteristics of a small, wild torrent. It flows through the Northern Limestone Alps (Pfiffner 2010) and traverses a broad valley, which the Isar glacier has carved out and filled with moraine debris during the various ice ages (Neumann et al. 2011). Within the valley reach, fluvial geomorphological processes are particularly pronounced. The valley is characterized by a constantly shifting river system with large gravel bars, pioneer vegetation, and extreme water regimes that range from protracted no-flow periods (dry riverbeds) to severe flood events. The area was in 1971 classified as a nature conservation area (Zingraff-Hamed and Egger 2019). Despite its protected status, the Upper Isar has been strongly negatively affected by hydropower production and flood protection measures. In 1924, a major water diversion canal was built in Krün to supply the biggest high-pressure storage power plant in Germany. Between 1954 and 1959, the artificial Sylvenstein Reservoir was built at the upper Isar, 75 km upstream of Munich (Bäumler 1988). The natural character-

istics of the alpine river landscape of the upper Isar only partly remain. Nowadays, the natural alpine riverscape of the Isar river ecosystem and its related biodiversity are suffering the effects of constant low discharges and low sediment transport due to the construction of weirs (Binder et al. 2001). The Isar entering then the moraine landscape at Bad Tölz and displaying a branched barrel shape becomes the Middle Isar (Neumann et al. 2011).

25.2.2 The Middle Isar

The Middle Isar includes the river section from the Loisach junction to Landshut (fig. 25.3). Upon entering Munich, the Isar riverscape no longer displays the moraine landscape as upstream (Neumann et al. 2011). The river travels through a narrow valley with steep, slip-prone slopes. In the urban areas of Munich (elevation 510 m) the Isar enters the large Munich Outwash Gravel Plain shaped by the ice ages (Binder et al. 2001). Between Freising and Moosburg, the river forms the border between the pre-alpine Hügelland, consisting of low, rolling hills, and Erdinger Moos, a grassland of low-lying wetlands (Neumann et al. 2011). After Moosburg, the Isar River is joined by the Amper, one of its biggest tributaries, on the border between Upper Bavaria and Lower Bavaria.

Table 25.2 Main characteristics of the Isar river sections

Name of the River / Section	Upper Isar (upstream of the Sylvenstein reservoir)	Upper Isar (Downstream of the Sylvenstein reservoir)		Middle Isar	Lower Isar	Confluence with the Danube
Countries in the catchment	Austria and Germany					
Catchment size (km ²)	111.10	1,137.90	2,760.70	2,838.40	8,578.10	8,612.80
Length (km)	41.5	67.57	18.48	145.58	265.44	282.38
Mean min (NQ) and maximal (HQ) annual discharge (m ³ s ⁻¹)	Mittenwald (rural area) NQ 0,818 HQ 89,6	Downstream Sylvenstein reservoir NQ 1,97 HQ 353	Puppling (rural area) NQ: 10.7 HQ 575	Munich (urban area) NQ 8.63 HQ 1050	Landau an der Isar NQ 59 HQ 1150	Platting (rural area) NQ 66,3 HQ 1180
Hydrological pattern	Snowmelt hydrology and rainfall related Flood in May and July	Regulated flow regime by the Sylvenstein reservoir	Snowmelt/ Rain event Flood in May and July	Snowmelt/ Rain event Flood in May and July	Snowmelt/ Rain event Flood in May and July	Snowmelt/ Rain event Flood in May and July
Degree of naturalness	natural	heavily modified	natural	urban	modified	natural
Natural landscape types	(i) Alpine torrent section, (ii) wide river corridor with large gravel bars and (iii) a braided river	Residual alpine river characteristics with some gravel bars, and sometimes channels separated into anabranches		River mostly channelized, partly restored, with residual alpine river characteristics and riparian forest	Straightened and channelized single thread river channel. Few remaining oxbow lakes	Isar Mouth with many delta distributaries and wetlands, large delta wet forest, many oxbow lakes

25.2.3 The Lower Isar

The Lower Isar (fig. 25.3) flows through the Bavarian Hügelland in a broad valley with the geologically oldest river sediments of the entire river system resulting from an important crack during the ice age. Historically, the Isar naturally formed a network of river branches, with open gravel areas and multiple alluvial forests. On the valley floor, there are wide areas of groundwater-dominated moorland adjoining the floodplain. Today the moor area is drained and intensively used for all types of traditional agriculture (Colditz 1994). The original characteristics of the lower Isar Valley are almost non-existent right up until the river mouth (Neumann et al. 2011). This lower section of the river is heavily modi-

fied and dammed to produce hydropower and provide water for other purposes.

The hydrological character of the lower Isar River still reflects the conditions in its alpine catchment. However, it tends to a lower river system because the alpine runoff regime is naturally weakened by several factors as a decrease in precipitation from south to north and the balancing effect of the Munich gravel plain as a groundwater reservoir.

25.2.4 Confluence with the Danube

The 18 km broad Isar mouth, wrongly named Isar Delta, corresponds to the last free-flowing river section of the Danube in Central Europe (IHP 2010). Before joining the Danube main-

stream, the Isar enters the Dunggau region, which contains very fertile soil. This combined with the natural dynamics of flowing rivers and oxbow lakes, provides the mouth of the Isar with a rich floodplain. A vast variety of aquatic habitats, gravel banks, meadows and riparian forests can be found here. This delta is home to numerous species, including species of insects and migrating birds. Its international importance for nature conservation is reflected in its inclusion as nature protection areas established under the Birds Directive and Habitats Directive (Binder et al. 2001).

25.3 Historical introduction

The Isar River was used in prehistoric times as a trade route to transport goods and people from the Alps, and probably also from Italy, to the Danube River using wooden rafts (Rädlinger et al. 2012). During the Bronze Age, Munich was one of the largest raft ports in Europe. In 195 BC, Mittenwald became an important trading center at the Isar for goods when the Romans built a trade route from the Inn Valley to Augsburg (Rädlinger et al. 2012). The first bridges across the Isar River located in the current Munich and Landshut cities may date back to the Middle Ages making use of existing large gravel islands (Scheuermann 1998). In the case of Munich, Ludwigsbrücke was the nucleus of the foundation of Munich, and in 1158 the important salt trade route was moved to make use of this bridge to cross the river (Rädlinger et al. 2012). Munich and Landshut were the only safe passages across the river. As these cities grew, the need for raw materials and goods also grew, increasing raft traffic. Up until the 17th century, the Isar was used to transport goods from the Venetian market through Mittenwald and Munich, to Vienna and Budapest. At the peak of rafting transportation in the 19th century, more than 8,000 rafts landed in Munich each year (Rädlinger et al. 2012). The use of wooden rafts required only minimal river construction to aid their navigation (Neumann et al. 2011). Rafting activities still exist today, but now exclusively serve recreational uses and tourism.

The dynamic hydrogeomorphic character of the Isar River means that it alters its course and channel form after every annual large flood event. Consequently, cities and settlements south of the Hügelland could not benefit from both the proximity to the river or from topographic protection against floods. Especially, settlements such as Munich located within the moraine landscape have required flood protection structures

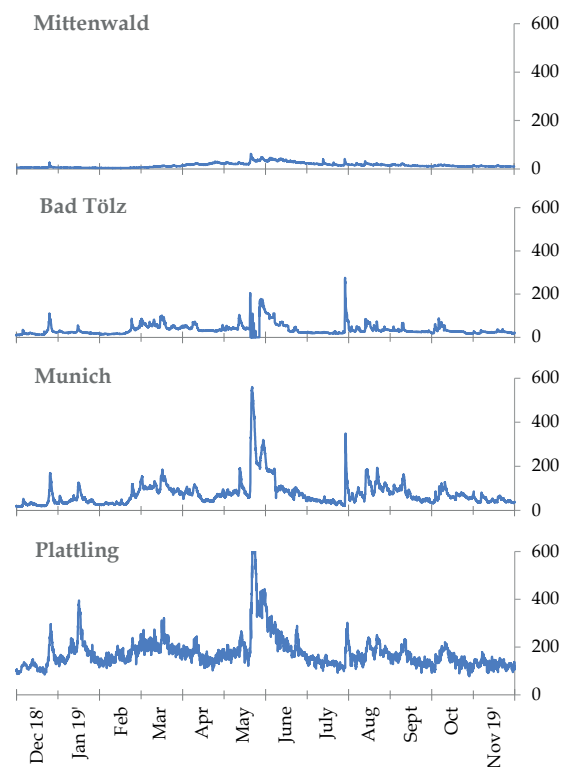


Fig. 25.4 Hydrograph ($\text{m}^3 \text{s}^{-1}$) of the Isar River between December 2018 and December 2019 at four gauging stations: Mittenwald, Bad Tölz, Munich, and Plattling. Graph: Aude Zingraff-Hamed, based on data from <https://www.hnd.bayern.de>, accessed 30/11/2018, with permission

throughout history to reduce flooding risk (Neumann et al. 2011). While past local authorities managed and engineered the Isar without considering the overall system and modified the river form to satisfy local and short-term needs, it was in the 19th century when systematic hard engineering and flow regulation of the Isar began. One impetus was the major flood in 1813 which caused the collapse of the oldest and most iconic bridge of Munich, killing more than 100 people (Rädlinger et al. 2012). Also, aesthetic considerations were used to promote governmental regulation of the river in Munich. The consideration was "[to get rid of] disadvantageous river flow [...] and ugly gravel bars that are a contrast to the beautiful arranged Englischer Garten park" (Wiebeking 1811, in Karl et al. 1998, p. 26). These new regulations set in motion a period of intensive hydraulic engineering works systematically channeled and straightened the river (Karl et al. 1998).

Since medieval times, mankind has claimed its stake in the Isar Valley, with small canals diverting water from the Isar River to supply power to mills and water for industry (Rädlinger et al. 2012). In the late 19th and early 20th centuries, this traditional use of the water took a radical turn. Between 1895 and 1923, the development

of hydroelectric power plants began with the construction of the hydropower plant Muffatwerk (1893), and Maxwerk (1895) in Munich, the last diverting Isar water into the Auer Mühlbach. The construction of the Höllriegelskreuth hydropower plant (1904) required massive river morphological changes (Neumann et al. 2011). In 1924, the first water diversion canal was built in Krün to supply additional water for the natural Lake Walchensee. From this upper lake, the water artificially flows into another lower natural lake, Kochelsee, through a hydropower plant. With an annual energy production capacity of 124 MWh, it was one of the world's biggest hydroelectric power plants at the time of the construction. Even today, with a mean annual production of 300 Gigawatt hours, it is the largest high-pressure storage power plant in terms of energy generation in Germany. Since 1983, it has been a protected industrial monument. Water diversion for its operation has resulted in the Upper Isar riverbed being almost 30-year long dry most of the year before inclusion of minimal residual flow (Bäumler 1988, Döring and Binder 2010, Karl et al. 1998, Küster et al. 2011, Zingraff-Hamed and Egger 2019).

Between 1954 and 1959, the Sylvenstein Reservoir (fig. 25.5) was built on the Upper Isar River, downstream to the Isar diversion at Krün and 75 km upstream of Munich, to avoid downstream river bed dryness (Bäumler 1988). The reservoir enables snowmelt water storage and a constant all-year minimal flow through an outlet in the Isar river bed. The water released from the reservoir also operates two small hydroelectric power plants with 3.8 Megawatt hour capacities. To accomplish this, the small village of Fall was flooded and a new settlement was built on higher ground. The reservoir has a sur-

face area of approximately 6 km², the average water level is approximately 752 m above sea level, and the storage capacity is approximately 125 million m³. The watershed for the reservoir is 1,138 km², and the dam volume is 1.03 million m³. The yearly amount of precipitation in this area is approximately 1,750 mm y⁻¹. The design of the reservoir considered not only technical feasibility, but also landscape aesthetics. The reservoir is the result of a dam built at a natural bottleneck in the upper Isar Valley and is mostly filled by two small tributaries of the Isar, the Dürrach and Walchen. This created a fjord-like lake that appearing to be a natural fit into the mountain landscape, reminiscent of relics from the Ice Age such as the Tegernsee and other lakes in the surrounding area.

In the present-day, it may be hard to conceive that the Sylvenstein Reservoir was originally built as a nature conservation measure to ensure minimum water flows in the Isar River (Binder et al. 2001); the reservoir's role as flood protection infrastructure was secondary. With climate change, extreme rainfall events in alpine regions are becoming more intense. According to climate scenarios, the Isar catchment will face a change in rainfall pattern, especially a 25% increase in intense rainfall events and an increase of 12% in the 100-year return period maximum discharge (DKRZ 2017, Wagner et al. 2017). Consequently, additional measures were taken in the 1990s at Sylvenstein to serve also flood protection goals. Between 1999 and 2001, the dam wall was raised by 3 m to increase retention capacity. However, as dam safety could not be ensured in the case of a 1,000-year flood event in combination with congestion problems at the bottom outlet, a new relief tunnel for the reservoir was constructed. Today, the dam is 44 m high and 180 m long.

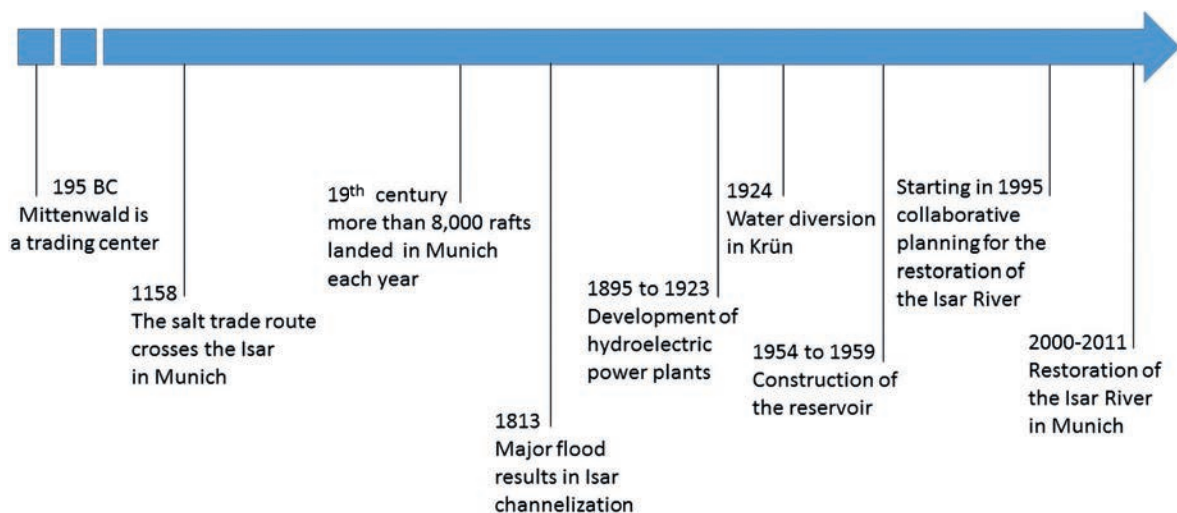


Fig. 25.5 Timeline showing main changes in the history of the Isar. Graph: Aude Zingraff-Hamed

Nowadays, more than 100 years after the start of electricity generation using the hydropower capacity of the Isar River, the water is used to generate energy along almost the entire river. Forty-three hydroelectric power plants are currently in operation. In Munich, most of the water from the Isar (93% of the mean annual discharge) is diverted into a side channel to supply hydroelectric power plants (Zingraff-Hamed, et al. 2018b). In the context of climate change, in light of the Kyoto Protocol and the focus on renewable energy portfolios, the remaining hydro-electrical potential of the Isar River along with that of other alpine fast-flowing rivers, is gaining political attention.

25.4 Key elements of biotic diversity

Alpine rivers, including their riparian zones, are hotspots for biodiversity (Muhar et al. 2019). As a result of geological and riverine settings, as well as the extreme, short-term, and frequent floods, plant and animal species have to be highly specialized in high and frequent perturbation resistance and nutrient-poor growth strategies (Egger et al. 2019). While high levels of water can have destructive effects on the riparian and floodplain habitats, it is also an opportunity to create new habitats. This is particularly true for Isar typical species that are gravel bar dependent. The mosaic of various physical habitats at the Isar is dynamic (in space and time) and result in the coexistence and succession of a broad spectrum of different species in the river valley (Küster et al. 2011).

The typical vegetation assemblage composition of the Isar varies between the upper and lower reaches of the river (fig. 25.6 and table 25.3). The hydrodynamics of the Isar River highly affect the flora. During low water levels, large parts of the floodplain are naturally dry, causing high water stress that requires special adaptation strategies. Short-term, high water levels are a common occurrence, resulting in natural patterns of erosion and sedimentation, as well as the turnover of successions and creation of pioneer habitats (Egger et al. 2019). The floods result in oxygen stress that also requires adaptation strategies. The flood height, duration, frequency and season are all critical factors influencing floodplain vegetation structure. Small repeated floods throughout the year provide a disturbance mechanism that prevents pioneer vegetation from evolving into a flood-resistant, shrub-dominated community. The powerful 100-year floods transform the riparian zone, removing whole trees and entirely covering vegetation with new sediments. Some typical riparian plant

species along the Isar River (Egger et al. 2019) are listed in table 25.3. They and their physical habitats require the natural flood pulse and the related natural processes characteristic of this alpine river to survive. Artificial hydro-morphological modification of the river, for example for energy production, locally destroys river habitats (Egger et al. 2019, Karl et al. 1998). For example, population loss of *Myricaria germanica* reached 70% between 1945 and 2016 (Müller et al. 2019).

While Bavarian river bodies altogether host 86 fish species, the Isar River alone (excluding tributaries) is home to 34 of them (Hiernis 2008). Isar fish species are well adapted to the demanding alpine conditions such as low temperatures and fast-flowing water. The upper reach species benefit from the high volumes of sediment transported which create new, well-oxygenated gravel spawning habitats. Species characteristic of the Upper Isar, and all of which are dependent on cold waters and gravel substrata, are the Danube salmon (*Hucho hucho*), grayling (*Thymallus thymallus*), common nase (*Chondrostoma nasus*) and burbot (*Lota lota*). For example, burbot embryos require a temperature between 2 and 6°C to grow. Almost all of these species migrate up to 30 km upstream to their spawning grounds and, therefore, their populations are negatively affected by hydroelectric power plants that represent major migration obstacles. The overall fish population has decreased by at least 50% during the last 50 years and in the upper Isar the number of fish species dropped to seven (Kinshofer 2019). The Middle and Lower Isar reaches offer warmer waters and support fish species such as common barbel (*Barbus barbus*), European chub (*Leuciscus cephalus*), European perch (*Perca fluviatilis*), and zander (*Stizostedion lucioperca*).

There is a high bird diversity along the Isar River, especially at the Isar mouth. In the upper catchment, the iconic species of golden eagles (*Aquila chrysaetos*) hunt in the open Isar Valley and enclosed hardwood forest and reproduce on the cliffs of the Alps. More common to the Isar River corridor are the common sandpiper (*Actitis hypoleucos*) and little ringed plover (*Charadrius dubius*) which require open gravel areas near freshwater for breeding (Karl et al. 1998). Two warblers (*Phylloscopus bonelli* and *Sylvia borin*) and the tree pipit (*Anthus trivialis*) inhabit pioneer shrub groups of German tamarisks and willows. Habitat destruction cause population decrease. For example, only 18 common sandpiper couples were observed at the Upper Isar in 2006 compared to c. 50 in 1982 (Zintl 1988). Located in the middle river reaches, the Ramsar site Ismaninger Reservoir is a prime breeding area for

Table 25.3 Key elements of biodiversity of the Isar River

Key element	Link to the natural flow regime	Ecosystem services	Human use and threats
Pioneer grassland species on open gravel and sand bars: <i>Chondrilla chondrilloides</i> , <i>Epilobium dodonaei</i> , <i>E. fleischeri</i> , <i>Calamagrostis pseudophragmites</i> , <i>Typha minima</i> , <i>Erigeron angulosus</i>	Stress-tolerant species (mechanical, flood and drought stress) with high regeneration rates and relatively short life cycles. They mostly colonize sand-gravel bars for short periods	Ecosystem engineers (pioneer species, stabilizing sediments, developing soil)	These species are generally poor competitors in stable landscapes, therefore they are threatened by river regulation, hydraulic engineering, flood protection infrastructure, and hydro-electrical power plants
Pioneer shrub species on open gravel and sand bars: German tamarisk (<i>Myricaria germanica</i>), willows (<i>Salix daphnoides</i> , <i>S. eleagnos</i> , <i>S.x purpurea</i>)	These species are established on newly formed gravel bars and use floods for seed dissemination, e.g. German tamarisk is able to germinate within a few hours.	Landscape-engineer species stabilizing gravel bars. Source of nutrients for herbivores. Breeding area for birds	Species are threatened by river regulation, hydraulic engineering, flood protection infrastructures and hydro-electrical power plant construction
Softwood floodplain forest: White willow (<i>Salix alba</i>), Grey Alder (<i>Alnus incana</i>), Black-poplar (<i>Populus nigra</i>)	Fast-growing tree species (1–2 my ⁻¹), able to germinate without humus. Vegetative reproduction from broken branches.	Architect species stabilizing river morphodynamics. Food source for herbivorous insects and beaver	as above
Hardwood floodplain forest	Shade-tolerant species slowly replace the softwood forest that has a shorter life span (< 60–70 years) where river dynamics are reduced.	Support a high diversity of animal species. The dry and light forest society allow growth of understorey with grasses and herbs	Species are exploited for wood. Wood was transported by raft to city settlements. Threats by overexploitation, and habitat loss
Common sandpiper (<i>Actitis hypoleucos</i>) and little ringed plover (<i>Charadrius dubius</i>)	Their breeding habitat is open gravel areas near freshwater. Their existence is highly dependent on the flood pulse	Predator of insects	River regulation reduces availability of breeding habitats. Breeding habitats are suffering from recreational usage
Danube salmon (<i>Hucho hucho</i>), grayling (<i>Thymallus thymallus</i>), common nase (<i>Chondrostoma nasus</i>) and burbot (<i>Lota lota</i>)	Species are adapted to low, unstable thermal regimes and flash-flowing water. They require floods to transportation the sediments needed for creation of suitable spawning habitats	Predator roles in alpine river trophic cascades	Popular angling activities. Hydropower plants present physical barriers to migration and altered pattern and timing of geomorphologically critical events
Wolf spider (<i>Arctosa cinerea</i>)	Species hunt on open gravel bars. During flood events, the spiders close their burrow openings and survive in air bubbles	Predators on various terrestrial insects and other spiders, important food item for birds	River regulation decreases morphological processes, causing loss of its main habitat

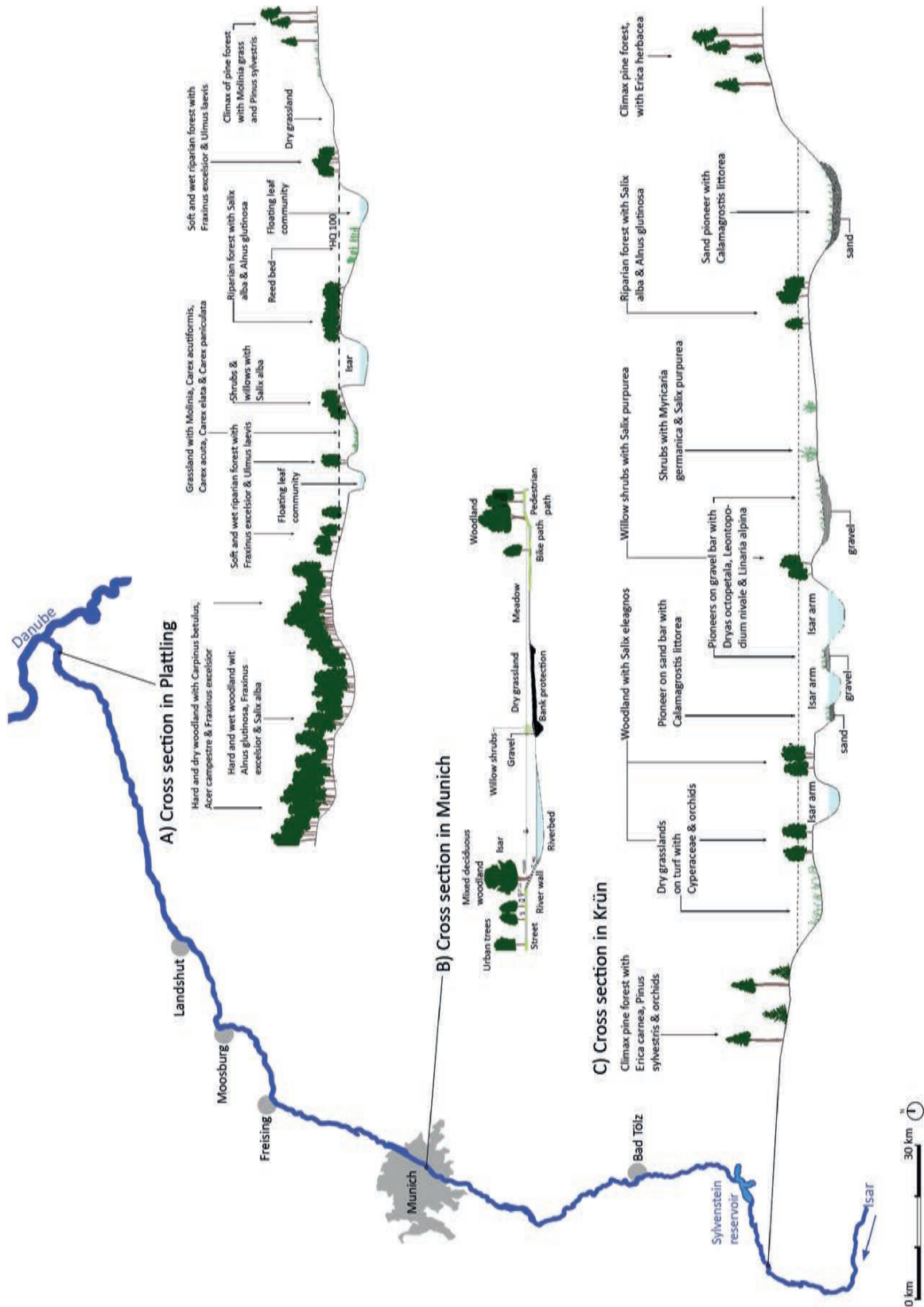


Fig. 25.6 Vegetation structure along the Isar river. Graph: Aude Zingraff-Hamed

roseate tern (*Sterna dougallii*). The confluence of the Isar to the Danube and its wide riparian forest offer habitats for more than 100 bird species (e.g., *Nycticorax nycticorax*, *Ixobrychus minutus*,

Asio flammeus, *Lanius minor* and *Alcedo atthis*) than the alpine area.

The Isar hosts insects that are highly adapted to the flood pattern. A particular challenge for

Table 25.4 Key elements of cultural diversity of the Isar River

Key element	Link to the natural flow regime	Ecosystem services and social importance	Threats and recovery
Aquatic trade route (rafting)	The fast-flowing water enable the rapid transport of goods and people from Italy to the rest of the Danube Basin	Cultural exchange. Flood events have low duration (few days) and did not allow continuous navigation	Hydroelectric power production and river regulation have left only 28 km of the Isar River navigable
Fishing	Fishing activities follow the migration calendar of the breeding life cycles of several fish species	Food seasonality	Fish species, especially those historically fished, are endangered by hydro-morphological changes
Participatory planning and polycentric governance	The socio-hydrological setting (flood protection, water use) of the Isar have brought upon specific, collaborative planning and management practices	Social cohesion to face natural risks	The construction of grey solutions to prevent flood risks, negate the need for collaboration
Spirituality and legends	Natural hazards related to the river have been incorporated into popular legends	Social identity	Loss of cultural history

terrestrial insects and spiders is short-term flood rise (often only for a few hours). To survive, they have developed a range of different strategies that consist of escaping, resisting, or submerging (Egger et al. 2019). The wolf spider (*Arctosa cinerea*) populates the open gravel and is highly adapted to flood events (table 25.3). The terrestrial insect herbivores, cicadas and tree bugs, settle on pioneer vegetation along the riverbed. A common grasshopper, *Bryodemella tuberculata*, can be found on open gravel bars. This grasshopper species has adopted this habitat type over time since its native habitat, the German Steppe, has largely disappeared (Karl et al. 1998). However, the species is now disappearing also at the Isar, due to anthropogenic hydromorphological changes in the gravel bars and the high volumes of human traffic they experience (Karl et al. 1998). Other insect populations are decreasing. For example, between 2006 and 2016 the number of species of wild bees nesting at the Isar decreased from 58 to 14 species (Stamm 2018).

25.5 Key elements of cultural diversity

Rivers supply many goods and services for the survival and development of mankind (Böck et al. 2018) such as food, gravel for construction, drinking water and energy. Rivers are an im-

portant environmental component that are able to maintain the earth in a biophysically suitable condition for human beings to live in. Moreover, rivers make the world a more attractive place to live and offer many cultural benefits such as recreational possibilities and aesthetic, intellectual, and spiritual inspirations. Furthermore, the type and quality of a river's cultural contributions influence local culture.

Since the earliest stages of local settlements (around 195 BC), the Isar has been a source of goods and services that has highly influenced local culture (table 25.4). The Isar River has provided people with food. Migratory fish species, such as the Danube salmon and common nase, were highly valued food species, but the availability of supply was dictated by their migration calendar. Fish migration thus had an important effect on the seasonality of fishing activities. When the water temperature reaches seven degrees Celsius, fish species from the Danube start to migrate to the headwaters in the Alps to spawn. While the Bavarian cuisine is not based on fish, in comparison with marine regions such as the Mediterranean, Steckerlfisch, grilled on an open fire on a wooden stick, is famous in Bavaria (*Stecken* is Bavarian for 'stick'). This delicacy can be found year-round, but is traditionally eaten during Easter. Nowadays, most of the Isar fish

species are included in the red list. Consequently, fish is sourced from aquaculture.

Since the Bronze Age, the Isar has been an important trade route that enabled the economic development of cities. In particular, the city of Munich benefitted from being in a strategic location for the market for salt produced in Italy (Rädlinger et al. 2012). Because of its high-gradient sections, navigating the Isar was only possible on timber floats and rafts. The transport of goods and people brought much wealth but also enabled the cross-fertilization of cultures, e.g. language and architecture (Muhar et al. 2019). With the construction of railways, the demand for the Isar River for trade and transport was entirely lost. Instead, timber rafting rapidly became a very popular leisure activity among locals and tourists (von Brunn 2017). Timber rafting on the Isar River was recognized in 2014 by UNESCO as immaterial cultural heritage. Today, rafting on the Isar is a major touristic attraction, with 15 rafting companies permitted to offer on average around 700 rafting tours on the river between May and September every year (von Brunn 2017). In addition, private rafting is allowed and popular among the citizens of nearby areas. Currently, wooden rafts can transport around 60 people over 28 km downstream in five hours. In the last decade, anthropogenic morphological modification of the Isar River and water diversions have put recreational rafting at risk. There are several stretches of the river that are no longer navigable, because of man-made barriers such as weirs (Renner 2019). Only a few river constructions, such as raft ramp slides in weirs, ensure the survival of this cultural heritage. The longest raft slide in Europe is located on the Isar River. With the huge demand for recreational rafting, from 2018 individual rafting activities have been strictly regulated and limited to reduce the pressure of recreational activities and their impacts on natural habitats (especially gravel bars used as bird nesting sites).

The Alps are a hotspot for tourism, offering domestic and international visitors many recreational opportunities. Alpine rivers are an important component of this attractiveness and are especially accessed by residents from surrounding areas (Muhar et al. 2019). The dynamics of running water has a certain aesthetic appeal, offering opportunities for reflection and contemplation of nature, and recreation (fig. 25.7). The river also opens up access to the limitlessness of nature that carries with it a feeling of liberation. Along the Isar, this human relationship with nature is especially relevant. There are many types of swimming activities and people who practice

a free body culture. Nude swimming is consequently very popular, and recognized by domestic and international visitors as a part of Munich's local identity (e.g., many postcards show nude swimming in the Isar) (Bäumler 2019). In the late 20th century, swimming in the river became a health risk, because of the poor water quality (Bäumler 2019). In many reaches, such as within Munich, swimming was not even possible, because of water diversion for hydropower. Since the start of activities by NGOs (e.g., Isar Allianz, WWF, 'Rettet die Isar jetzt' initiatives) to protect the cultural and natural heritage of the Isar River, swimming is becoming safe in more places again. It is now possible even in the city center of Munich, and ultraviolet radiation (UV) techniques in wastewater treatment plants ensure that the water quality is adequate for contact recreation activities including swimming activities according to the EU Bathing Water Directive (EC 1975).

Hydropower production is also culturally linked with the river. Alpine rivers are particularly energy-rich water bodies because of the high river slope and the force of the water (Muhar et al. 2019). The earliest documented watermills on the Isar River date back to 957 AD. Mills were built on secondary channels of the Isar. As mills require a regulated constant water supply, the natural river channels had to be channelized or separate millraces constructed. In the 19th century, only influential, affluent families could exploit hydropower. As a result, they established strong relationships with local government, to discuss water management strategies (Hickethier 2000). In this way, water use for hydropower triggered the first participatory planning for the Isar River (Zingraff-Hamed et al. 2019). Throughout history, the natural extreme hydrological variability of the Isar also drove collaborative planning between users, including raftsmen, fishermen, farmers and millers (Rädlinger et al. 2012). Furthermore, because the Isar was a wild-flowing river with sudden flood events that triggered relocation of the main river channel, local water governance had to adapt accordingly. Dramatical changes in river course location due to flood events (HQ5) have resulted in villages becoming cut off from the river on which they depend for their survival (Rädlinger et al. 2012). To maintain a close connection with crucial water resources, cities like Munich developed a high level of cooperation with governments of the surrounding villages (Freudenberger 1927). This communication network of local water governance has evolved into the current complex, polycentric river governance scheme (Zingraff-Hamed et al. 2019).

Since the early stages of human settlement, the Isar has also been a source of natural disasters that have affected the local culture and river management practices. In particular, two types of natural hazards have greatly impacted local culture: flooding and rockfalls. A multitude of legends about the Isar River and its hazards exists (Gisela Schinzel-Penth 2017). The two most popular legends, *Isarnixe* and the *Schnarchermannndl*, illustrate how the river was perceived as a source of great fear. The *Schnarchermannndl* was a malicious cave-goblin, who settled in caves at cliffs close to Munich, between Menterschwaige and Pullach. He would threaten and yell at travelers along the river. Those who dared to intrude upon his caves would suffer greatly, as the goblin was reputed to kill his victims by throwing rocks (Gisela Schinzel-Penth 2017). Just like the mermaids of the sea, rivers like the Isar were said to be home to mythological inhabitants. According to legend, the *Isarnixe* lived in the section of the Isar River close to Munich. The *Isarnixe* is described as a "beautiful woman with big green eyes and long hair" (Schinzel-Penth and Schuch 2010, p. 219) but her tempting songs was a source of great danger. Especially at the Georgenstein, the *Isarnixe* sang a mysterious bird-like song that caused many raftsmen to drown. It is also rumored that the *Isarnixe* walked in the riparian forest during flood events, to lead people to the turbulent Isar and drown them there. The *Isarnixe* is still today a source of inspiration. Later, Catholic influences were aimed at erasing these mythological beings and circulating the concept that God will protect people from the river. For example, the Chapel Marienklause was built in 1866 on the banks of the Isar in Munich, to thank Holy Mary for saving lives during flood events (Rädlinger et al. 2012).



Fig. 25.7 Recreational uses at the Isar. Photo: Christian Erfurt, with permission

25.6 Current trends

With decades of river management to achieve hydroelectric production and the safety of the local population, by means of grey flood protection infrastructure, the Isar River gradually lost its original characteristics, its unique biodiversity, and many cultural aspects that were linked to the river. Hydroelectric power plants have blocked the passage of people traveling in wooden rafts, prevented the upstream spawning migrations of fish (e.g., Danube salmon) and hindered the hydrochorous seed dispersal of plants like the German Tamarisk (*Myricaria germanica*). The extensive diversion of water into secondary channels, without the provisioning of sufficient environmental flows causes the main river to run dry most of the year, to the detriment of most natural habitats and cultural activities, such as swimming.

After the hydro-electric boom at the Isar in the 1930s, the local population formulated strong critic on the negative evolution of the hydro-morphological status of the Isar. Many residents recalled the river as a means of recreation and inspiration during their childhood. In 1946, the Bavarian Constitution added Article 141 (Bayern 1946), which outlines the obligation of protecting the social function of nature, rivers and lakes for recreational usage. One of the resulting measures was the construction of the Sylvenstein Reservoir in 1954 (see section 25.4), to enable the regulation of a minimum instream flow in the Isar. In the late 1960s and early 1970s, the ecological and environmental movement had begun to grow in Europe, followed by major river governance changes (Zingraff-Hamed et al. 2017b). For instance, in 1970, the Bavarian State Ministry for the Environment and the Environmental Protection Department of Munich were created (Bäumler 2019). At this time, active advocacy groups found new partners in these government institutions. In 1975, the European Bathing Water Directive (EC 1975) further reinforced popular opinion, giving the public another reason to pressure local governments. Despite these legislative improvements, the public remained dissatisfied by the lack of actions and further lobbied local government. At the beginning of the 1980s, public outcry became stronger, especially after the dramatic Sandoz chemical accident and spillover into the Rhine River, killing almost all aquatic life (see chapter on the Rhine, this volume). The extremely poor ecological condition and water quality of most rivers in Germany could no longer be ignored. In 1984, Article 141 of the constitution was modified to define environmental and natural protection as a



Natural Wetland. Photo: Aude Zingraff-Hamed



Recreational uses. Photo: Aude Zingraff-Hamed



Salix purpurea. Photo: Aude Zingraff-Hamed



Open air restaurant at the Isar. Photo: Gerd Lupp



Myricaria germanica. Photo: Aude Zingraff-Hamed



Isar as love watcher. Photo: Aude Zingraff-Hamed

Fig. 25.8 Left column: iconic examples of biological diversity, right column: iconic examples of cultural diversity



Intensive hydro-electric power production. Photo: Aude Zingraff-Hamed



Isar Restoration in Munich. Photo: Aude Zingraff-Hamed



Water diversion. Photo: Aude Zingraff-Hamed



Fish pass. Photo: Fritz George, with permission



Channelization. Photo: Aude Zingraff-Hamed



Honeycomb solution. Photo: Aude Zingraff-Hamed

Fig. 25.8 (continued) Left column: iconic examples of threats, right column: iconic examples of sustainable management

constitutional goal of the State. As a result, practices that are damaging to the environment are now regulated. In 1987, the Bavarian water law was also changed to provide for minimum water flows in rivers. On a larger scale, the European Union (EU) adopted a fauna and flora directive in 1992 (EC 1992), which further reinforced the movement that was already gaining momentum for the Isar River. Advocacy groups demanded the restoration of the Isar and targeted different locations on the river to force ecological measures, e.g., Mühlthal and Munich.

Restoration efforts at Mühlthal were met with very strong confrontation. In 1907, energy suppliers obtained authorizations to deviate river water without any limits and without any restriction on the lowest discharge that could be left in the main river channel. In 1985, an advocacy group known as the Mühlthal Initiative started to lobby for more water in the Isar River. In 1997, the original energy suppliers conceded the Mühlthal hydroelectric power plant, after 70 years of exploitation, and were forced to adhere to minimum flow limits for the river.

In Munich, civil society outcry for the restoration of the Isar River, to allow for more cultural activities and to improve its ecological health benefitted from the Mühlthal initiative success story. Between 1987 and 1999, energy producers, state offices for water management, nature conservationists, fishers, as well as consultants in the field of forestry, hydraulics, biology, ecology, river morphology and landscape architecture collaboratively planned the design of the new design for the river (fig. 25.8). The NGO community and Isar Allianz were also heavily involved. The opinion of civil society was represented and integrated into the decision process through the Münchner Forum (<https://muenchner-forum.de/>). In 2005, the Bavarian Water Agency published a report 'The Isar in Munich - an urban river landscape adapts to the winds of change', that presented the ongoing restoration project in Munich to the international community (Arzet and Joven 2005).

The Isar River restoration project is an example of the evolution of urban river development and the importance of quality standards established by civil society (Kiss 2018, RESTORE 2013). An increasing number of people is living in cities, and attractive waterscapes provide recreational opportunities to enjoy nature and a higher quality of life. People are becoming more aware of the value of high quality riverscapes and are starting to reclaim them. The Isar restoration highlighted the fact that planning objectives for the river and surrounds are dynamic and have changed

over the past decades. Previous planning objectives applied technical solutions that narrowed the space for rivers and provided space for the city, different kinds of hard infrastructure, and agriculture. The objectives have now changed to incorporate the enhancement of ecosystems and their functions, the prevention and mitigation of floods through nature-based solutions, and the functionality of the riverscape for public use. For instance, the application of concept of nature-based solutions (NBS) growth rapidly. NBS are "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions" (EC 2015, 2017). The main challenges at present are to provide more space for the river, and to balance historical heritage and future needs. Furthermore, the role of landscape planners and architects has changed. They have become the mediators among water and nature conservation authorities, the public, media, government administrations, energy suppliers and interest groups.

25.7 Isar River Restoration in Munich

25.7.1 Introduction of the 'Isar Plan'

The restoration of the Isar River was launched in 1995 by the Bavarian Water Management Agency in Munich and the City of Munich, and implemented between 2000 and 2011, under the slogan "New Life for the River Isar." The restoration project focused on the 8-km stretch of the Isar River in Munich, starting from the southern city border at the Großhesseloher Bridge to the Deutsche Museum (Museum Island) (fig. 25.9). The reference site used for the restoration was the iconic *Flaucher* area. This area is a several 100 m long river reach near the inner city that has maintained much of its natural character and offers attractive recreational opportunities, despite some weirs and other hydrological structures in this area (Arzet and Joven 2005). While project implementation took 11 years, the planning process had started early on in 1970 (Bäumler 2019 and see previous section). The project cost approximately 35 million Euros and was funded by the State of Bavaria and the City of Munich (Arzet and Joven 2005). Eighty years after the channelization of the Isar River, its concrete corset in Munich was removed and the river's natural shapes provided a highly efficient means of flood protection. The Isar River restoration was a prototype in many aspects and has inspired many

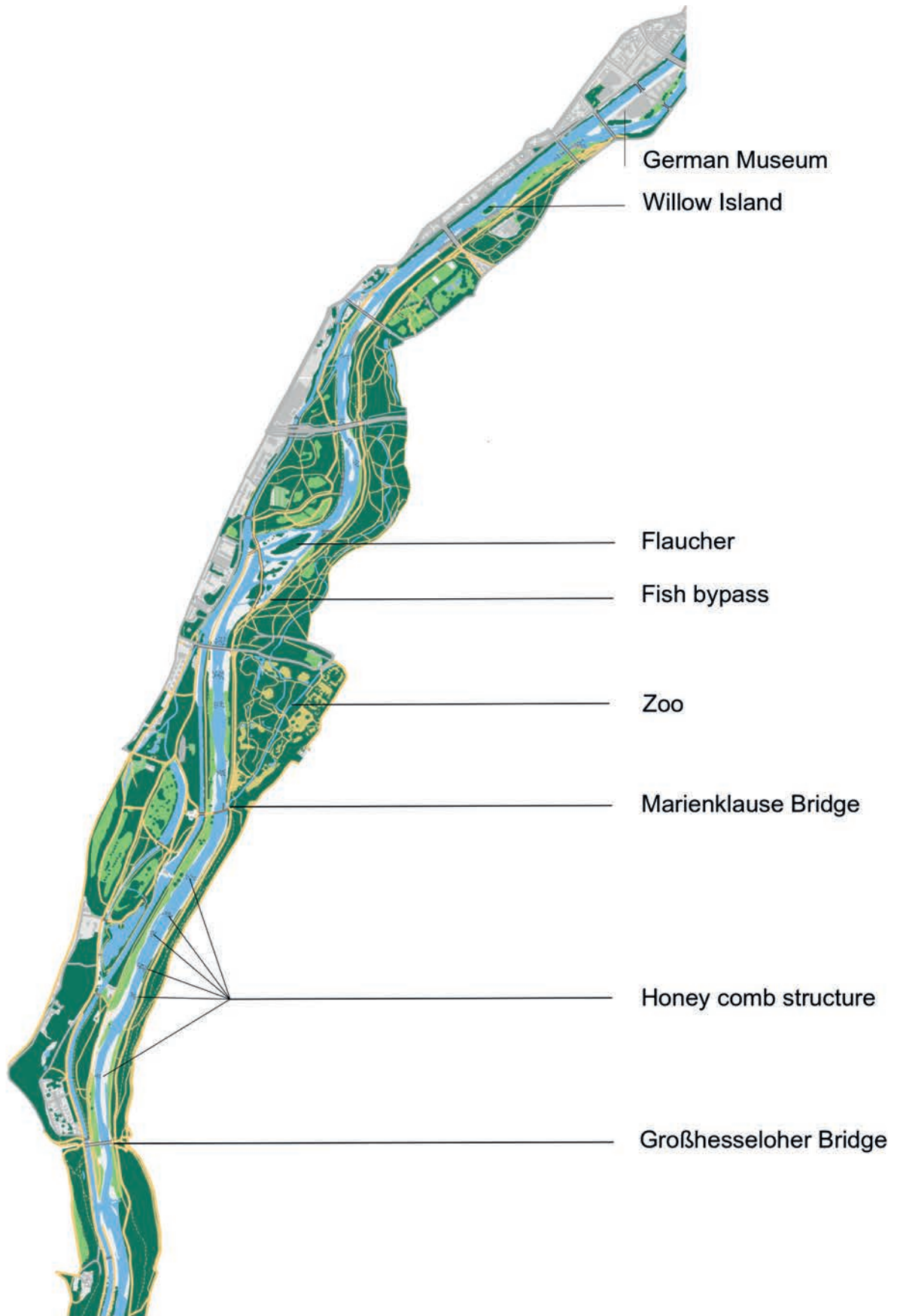


Fig. 25.9 Overview of the Isar restoration. Graph: Aude Zingraff-Hamed

other restoration efforts. It is still the center of attention for many people, because it is an example of socio-ecological restoration initiated by public concern for the environment and the need for urban populations to be in touch with nature.

25.7.2 Project drivers

Many factors worked together to enable the restoration of the project.

25.7.2.1 The need for better flood protection

The construction of Sylvenstein Reservoir helped to reduce flood risks that were mainly due to flood peaks (Wasserwirtschaftsamt Weilheim 2009). However, it quickly became evident that the dam could not eliminate all hydrometeorological risks in Munich, since it only controlled 35% of the local catchment area. Therefore, the dam could not protect Munich against the estimated 100-year flood (HQ100) (Zech 1988). Hydraulic calculations proved that there was a freeboard deficiency of over one meter. In the case of a HQ100 flood, the riverine area in Munich (before restoration) can support only $800 \text{ m}^3 \text{ s}^{-1}$, but the discharge may be up to $1,150 \text{ m}^3 \text{ s}^{-1}$. Studies of climate change scenarios suggested an increase in precipitation of 25% during summer which would potentially generate the largest flood events in the Isar River. Consequently, flood waves could increase by 12% (DKRZ 2017, Wagner et al. 2017). Furthermore, traditional hard engineering measures, such as dam construction, have already led to negative effects on the riverscape, biodiversity, and recreational potential. Many problems arose as a result of past river regulations. Narrowing and accelerating the water flow led to increased riverbed erosion, which threatened the foundations of the iconic bridges that brought prosperity to Munich in the past (Rädlinger 2011). In the interest of public safety, the Bavarian State government urged regional water agencies to implement a more efficient flood protection design for the city of Munich.

25.7.2.2 Poor water quality

Despite that Sylvenstein Reservoir was constructed to maintain a minimum amount of water in the river to provide for ecological river functions during dry periods, the Isar River in Munich was barely flowing for most of the year (fig. 25.10). In 1970, the river was reduced to a dry riverbed in this reach. Since 1907, Public Utility Munich has been discharging fully 100% of the Isar River water on the Großhesseloher weir into the side canal to supply hydroelectric power plan on a side channel (Bäumler 2019). At this time, water deviation for water use and hy-

droelectric energy did not take into account minimum) flow requirements in the main channel, which resulted in hygiene problems. Furthermore, urban runoff and sewage flowed directly into an almost dry river providing unsafe conditions for bathing (Rädlinger 2011). Instream water quality fell deep below the standards defined by the European Bathing Water Legislation (1975). Local municipalities and the district authorities that were responsible for public health were concerned about citizen health and safety. Together they urged Munich and the Bavarian water agencies to implement measures to ensure water quality that would be safe for contact recreational use (Nico Döring and Binder 2010).

25.7.2.3 Lack of biological diversity

In 1970, the Isar River flowed in a concrete channel through the city, and the optimal use of hydropower had absolute priority over ecology (Bäumler 2019). With its double-trapezoidal shape, species-poor recreational grassland in the floodplain and willows at the edges of the fortified riverbanks and high river walls, the Isar did not provide physical habitats for typical species for such alpine rivers. Furthermore, numerous transverse construction such as weirs and hydroelectric power plants hindered fish migrations (Karl et al. 1998). At this time, the EU Water Framework Directive (EC 2000) had not yet been ratified. However, nature conservation NGOs were concerned and engaged in negotiations with the authorities, shedding light on the State's irresponsible and unethical use of resources (Bäumler 1988).

25.7.2.4 Insufficient recreational potential

The Isar corridor has been defined by Munich's Planning Department as a key asset for improving quality of life (Rossano 2016). The city of Mu-



Fig. 25.10 Historical photography showing the dry gravel bed of the Isar. Photo: Klaus Bäumler

nich experienced a population boom between 1950 and 1975, when the number of people doubled, and reached almost 1.5 million inhabitants in 2015. Furthermore, due to rapid urbanization, most of the open spaces in the inner city were built up, putting increasing recreational use pressure on fewer and fewer urban green spaces. On the other hand, public demand for urban greening and recreational spaces increased (Oppermann and Pauleit 2005). The unused engineered riverine area was formally designated as floodplain and consequently, while it offered great potential as a large public park, was not able to be developed. In 1983, the greening of the Isar riverscape reached the top of the local political agenda and was integrated into the 1983 Urban Development Plan (München 1983).

25.7.2.5 Destruction of the alpine riverscape

As explained in section 25.4, the regulation of the Isar River and hard engineering measures caused major modification of the hydro-morphological dynamic of the river. Natural processes were stopped and sediments were filtered out by dams, causing the loss of typical alpine riverscape characteristics. The large gravel bars that facilitated closer access by people to the waterbody were replaced by high artificial embankments with slopes of about 45 degrees. In comparison with other major river centered European cities, such as Paris with the Seine River, Munich's fortified waterfront was not perceived an element of local identity (Döring and Binder 2010). The public lobbied for the recovery of the Isar as an element of Bavarian identity and pride, and suggested to the city department the removal of the Isar river's concrete corset (Sartori 2010). In 1984, a municipal bill labelled 'Nature in the city' (*Natur in der Stadt*) supported the restoration of the Isar River (Rossano 2016). This bill was the first of 30 bills passed by the city council that made the implementation of the Isar River restoration plan possible (Schaufuß 2016).

To plan, design, and implement Isar restoration, a comprehensive planning framework had to integrate policy demands from various water governance viewpoints (Kiss 2018, Reichholf and Arzet 2011). The management of the Isar River in Munich benefitted from long-term experience in polycentric governance (Zin-graff-Hamed et al. 2019) and stakeholders were able to work together for the future design of the river. One example of this is in the application of a new financing scheme. While normally, the Bavarian State water agency funds 75% of building costs related to flood protection measures, here the state funded 55% of the Isar restoration and

the remainder was funded by the city of Munich (Kiss 2018). Finally, the restoration project was successful not only because of a good cooperative governance scheme, but also because of an intensive collaborative planning process where civil society and NGOs played important roles.

25.7.3 Collaborative planning process and a Living Lab

"It took forty years of intense effort of the civil society before the Isar river change from a mere trickle back to a living river" (Bäumler 2019). Civil society was significantly involved in all phases of the long road of transforming the Isar River into an entity something that could enable people to be closer to nature. The high degree of collaborative planning with all stakeholders and, in particular, the in-depth involvement of NGOs and the public, were key success factors for the project (Schaufuß 2016). However, the process was not easy.

Ex-post analysis of the Isar story enabled to identify three steps of the collaborative planning process. First, from 1970 to 1985, civil society learned that their opinion is important and can lead to major changes. In 1970, after the memorandum of the landscape architect, Alwin Seifert, titled 'The Isar North, Within, and South of the city of Munich - A Plan for Recovery', civil society started to inform and pressure politicians (Bäumler 2019). Then, some local "champions" formed groups, at the request of the politicians and government administration, to carry out the Isar restoration (Döring and Jochum 2006). At the same time, the enforcement of environmental protection laws necessitated a reorganization of state and municipal authorities. In 1973, the city government appointed its first environmental officer, a direct contact who even joined some protests (Bäumler 2019). Later, in 1974, Theo Fischer, an environmental protection officer of Munich, further roused public opinion regarding the future of the Isar River. The period 1970 to 1974 marked the start of civic intervention. Citizens, municipalities and environmental associations joined forces across regional boundaries in numerous initiatives, such as the 'Emergency Community Save the Isar Now' (*Rettet die Isar jetzt e.V.*) (Bäumler 2019). The first document written by the Bavarian Ministry of the Environment and presented to the public in 1980 brought hope and reinforced the idea that if civil society cares, politicians will take the problem seriously. This document presented planning objectives to improve river water quality and increase the minimum discharge to assure socio-ecological quality. Other new legal regulations in favor of environmental protection enabled the people of Munich to legally demand re-

storative measures (Bäumler 2019). In 1980, a new urban wastewater management plan was ratified and implemented, greatly improving the water quality of the Isar River within the urban environment. In 1985, after strong pressure on the city government, the Munich City Council enforced a minimum annual outflow of $5 \text{ m}^3\text{s}^{-1}$ of the Isar at southern Munich entrance, for all months of the year. Regular MQ should be of $68 \text{ m}^3\text{s}^{-1}$. For our understanding at the time this chapter is written, it suggests the water is coming out of a pipe, and it is true. However, this small increase of the water quantity flowing into the river, was perceived as a great improvement of the river quality in 1985. The resistance of energy suppliers was tremendous, because they had a legal right dating back to 1907, to exploit the water resources of the Isar River without limitation. However, public opinion was even stronger. This was the first time in the history of the river that social and ecological advocates worked together side-by-side. Civil society had won its first fight of the war and this gave them the courage to propose an even greater objective: the morphological restoration of the urban river.

Second, between 1985 and 1990, civil society gradually gained more responsibility in the restoration design. In 1985, a representative member of the two most influential political movements wrote a request to the city council to address unsatisfactory recreational provisions for the Isar River (Bäumler 2019). They requested the removal of all kinds of built infrastructure not necessary for the production of hydroelectric power, such as concrete channels. Furthermore, they demanded greater accessibility to the riverine area (water, gravel bars and riparian forests), to experience the natural environment. The president of the city council was facing such requests from the leading party and the even stronger opposition party. As a result, the president assigned a collaborative working group to identify planning goals for the Isar River under the lead of the planning department. The Münchner Forum was assigned to collect public opinion. In 1989, over 100,000 participants drew their requests on maps and elaborated a plan for the Isar River. In 1990, the Münchner Forum presented to the city council five main goals for the Isar River: more water, better water quality, more recreational uses, the possibility for swimming and rafting, and accessibility to the natural riverscape. Additionally, the 'Isar-Allianz' (an alliance of environmental NGOs) presented the result of their assessment and pleaded for an improvement of river ecological quality. These considerations were integrated into the project objectives and the

water protection goals of the water agency. The final formulation of the goals is as follows (Wulf and Schaufuß 2013):

- Improvement of flood protection, by increasing the water retention capacity of the river section in Munich (nature-based solution);
- Improvement of the ecological status of the river, by providing habitats for wild species, improving river condition, activating morphological processes, insuring longitudinal and lateral continuity, recreating natural habits for animals and plants, and improving biodiversity and water quality.
- Improvement of recreational quality, by recreating an attractive and natural alpine riverscape, such as the Flaucher, and enabling water and nature accessibility in a dense urban area.

Third, in 1995, an interdisciplinary working group called the 'Isar-Plan' was initiated. It was lead by both the State Office of Water Management and the City of Munich (Department of Public Construction, Department of Urban Planning and Building Regulation and Department of Health and Environment). This phase was characterized by a cooperative partnership between Munich and the Free State of Bavaria. This cooperation was a prerequisite for the successful realization of the Isar Plan. In 1995, work groups composed of experts and government administrations started collaborating under the direction of the Water Management Office in Munich. The working groups designed a river with near-natural conditions inspired by the Flaucher reference site and optimized its recreational potential. They incorporated innovative nature-based solutions for flood protection and mitigation (rather than traditional grey infrastructure/hard engineering practices, e.g. increasing dam number). The 'Isar Allianz' was not formally involved in the 'Isar Plan' working group, although all the NGOs in the 'Isar Allianz' were involved. All important planning and implementation steps were transparently communicated within the framework of cooperation of the Münchner Forum (Bäumler 2019). Public participation was maintained through internet platforms, information brochures, excursions, workshops, television and press, roundtable discussions, information points, and telephone (Schaufuß 2016).

The Isar Plan was a pioneer effort in collaborative planning, which started with advocacy groups and rapidly evolved into a Living Lab approach (Zingraff-Hamed et al. 2019). The plan included the quadruple helix actor system (viz. public sector, academia, private sector and government) in project planning and implementa-

tion (Leminen 2013, 2015). Experts have identified the high level of cooperation as the principal project success factor (Schaufuß 2016).

25.7.4 Restoration measures

The goals of the Isar-plan being identified, it was clear that restoration measures would not follow the conventional approach of heightening of dams and dykes for flood protection. Instead, the solution employed was widening the riverbed within the dykes and lowering the alluvial zones, thereby eliminating the artificial double-trapezoidal river channel form. Moreover, sewage treatment plants along the Isar River were upgraded, to meet instream water quality requirements for water-based recreation (Döring and Jochum 2006).

Reshaping the section of the river between Grosshesseloher Brücke and Museum Island with lowered and modeled sides as a polyfunctional riverscape allowed for water-based recreation activities and areas for leisure. New riparian gravel structures, instead of linear concrete embankments, were intended to provide dynamic habitats with changing shorelines (Arzet and Joven 2005).

25.7.4.1 Dynamization of river banks

From the city boundary at Großhesseloher Bridge to Braunauer railway bridge, the artificial stone bank edges were removed, the riverbed was widened by about 45 m to a total of 90 m, and the river banks were flattened. In this upper part of the Isar section to be restored, some riverside sections were left to self-development (Arzet and Joven 2005). The largely unrestrained process led to the establishment of a mix of steep banks and flat gravel slip-off slope banks, especially in the outer curves. Such sites should allow 'true' nature to enter the urban areas over time, providing a more natural riverscape for inspiration and spirituality.

25.7.4.2 Structural measures in the riverbed

Concrete floor sills were replaced by rough, flat ramps of block stones to ensure fish migration. The implemented honeycomb design of the rough ramps supports a more natural scenery. It also eliminates migration obstacles for aquatic biota, e.g., *Chondostoma nasus* and *Hucho hucho* and better supports recreation activities, such as canoeing. This new design also locally re-oxygenates the water. The structure of the ramps was intended to be non-homogeneous, with raised and steeper sections providing a variety of structures for fish and other aquatic organisms to facilitate connectivity and passage. The

diversity of the river shapes e.g., pools, stone steps, and gravel banks and bars which formed downstream is intended to reinforce the morphological dynamic of the riverbed (Arzet and Joven 2005).

These ramp structures also influenced the stream velocity downstream and the formation of gravel stone banks and islands. Additional gravel was unloaded into the river, and gravel islands were created, providing habitats for pioneer plants and highly specialized fauna (see section 25.5). Despite the natural appearance of the gravel islands, they had to be fixed to prevent any risk of dynamic displacement in the urban zone. Dead wood, tree trunks and rootstocks embedded in the banks and the riverbed, as well as driftwood, served as refugia for young fish and habitat for other biota (Arzet and Joven 2005).

25.7.4.3 Nature-based solutions in limited space

Further downstream from Hellabrunn Zoo, possibilities for river restoration were restricted due to urban infrastructure and main roads close to the river. For that reason, the western river embankment had to be left fortified and channelized, while on the eastern side, the riverbed could be widened and redeveloped (Arzet and Joven 2005). The flat, species-poor, recreational grassland in the dammed-up floodplain was removed out to increase the water volume retention capacity. The riverbank was flattened, terraced, modeled, and public river access was created in many places. Mixtures of indigenous seeds from wild herbs were then sown and cut hay (that originated from glacial relicts and nearby nature conservation areas) was spread to quickly revegetate the area (Arzet and Joven 2005). The old existing dykes, with their old and culturally important tree populations, were raised, widened, reinforced and stabilized with a sealing wall. During severe flooding events, the Isar River can reach this level without causing damage. Reinforcing the dykes with a diaphragm wall enabled dyke rehabilitation maintaining tree populations as attractive scenery for recreation. In some areas, new dykes were created in front of the old ones. Extra care was taken so that the sealed embankments with their thin soil layers would provide habitats for species of dry grassland.

25.7.4.4 An alpine river experience in the inner city - Willow Island

The design of the section of the river in the innermost part of the city was more difficult, because of the limited availability of space and the

existence of important heritage buildings. Several technical challenges to enhance both flood protection and recreational use had to be met. A competition was held to find the best solutions to merge the seemingly unquenchable demands for urbanism and the need for a more naturally functioning and wilder, and recreational riverscape (Armonat 2010). A variety of different solutions were suggested, ranging from island structures and meandering rivers, to highly linear interpretations (Arzet and Joven, 2005). A nature-oriented design doubled the width of the river in some places. Rough ramps were built in the riverbed for connectivity. Planted, flattened shorelines, gravel banks and step-like rock arrangements replaced paved, steep concrete embankments along this reach. Also the passage to the 'Small Isar', a EU Natura 2000 protected area south of the Deutsche Museum, was newly constructed. The implemented design included the construction of 'Willow Island' (fig. 25.11) which is not intended to be accessible to people, but rather, is designed to develop into an undisturbed habitat for animals and plants, including German Tamarisk. The island should also recreate alpine river scenery and safeguard existing trees.

25.7.5 Restoration results

The 'Isar Plan' is an internationally renowned example of urban river restoration and the use of nature-based solutions to mitigate flood risk. In 2007, the Isar Plan won the first German award ever given by DWA (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V.) for river development (*Gewässerentwicklungspreis*). The Isar-Plan is recognized as a good example and a learning case for multiple projects, for networks, practitioners, researchers, including the River Network, the European Centre for River Restoration (<https://www.restorerivers.eu/>), the European Climate Adaptation Platform (Climate-ADAPT, Schaufuß 2016), the NATURVATION project (<https://naturvation.eu/>, Kiss 2018), the PHUSICOS project funded by the European Union's Horizon 2020 research and innovation program (<https://phusicos.eu/>, Fohlmeister et al. 2018), and SEE-River project funded by the European Union's South-East Europe Transnational Cooperation Program. The international acclaim of the Isar Plan is mainly due to

- its innovative socio-ecological approach to urban river restoration (Kiss 2018);
- its pioneering governance constellation within a polycentric governance context and Liv-



Fig. 25.11 Willow Island at the Isar in Munich. Photo: Gerd Lupp

ing Lab approach, namely a co-design procedure (Fohlmeister et al. 2018) for designing nature-based solutions (Zingraff-Hamed et al. 2019); and

- its successful example of civil society engagement to achieve an improvement of the ecological status of the river for ethical and recreational purposes.

The implemented multifunctional riverscape is perceived as a 'return to the wild' and has surpassed many previous urban river restorations in terms of its socio-ecological benefits. While the grey flood protection infrastructure had a capacity of only $900 \text{ m}^3 \text{ s}^{-1}$, the socio-ecologically functional restored river has a capacity of $1,200 \text{ m}^3 \text{ s}^{-1}$ and can sustain a HQ100 flood risk ($1,150 \text{ m}^3 \text{ s}^{-1}$) (Lang 2019). Furthermore, the restored river has been able to meet high recreational demands, by offering large gravel bars and direct access to water, as well as a way for the public to experience a near-natural riverscape in the city center. The Isar in Munich is also an example of fairness, since it is freely and safely accessible by women, men, children and handicapped people. The restored Isar river has also shown an improvement in its ecological status, e.g. increase of water quality, macro-zoobenthos quantity and diversity, increase of fish population and elevation of oxygenation level (Orlamünde 2013).

25.7.6 Current conflict between intensive recreational usage and nature conservation

The Isar riverscape is not included as one of Munich's urban parks area, because of its natural characteristics and its classification as a non-man-made design. However, it is undeniably one of the most valued green spaces in the city by recreational users (fig. 25.8). No official numbers exist, but an independent study showed that during sunny days in June 2013, 774 people were observed with in a 100 by 20-meter sampling area of a gravel bar (Zingraff-Hamed et al. 2017b). In this small area, the number of visitors per day was 600 on each of 10 days between April and early October (Zingraff-Hamed et al. 2018a). This high user density is a clear indicator of the success of the project with respect to the increase of recreational usage of the area. While improving the recreational potential of the area was a goal of the restoration, nobody had foreseen this great increase of intensity of the recreational uses. It also introduces a conflict with nature conservation goals.

Model-based estimation of the conflict between recreation usage and habitat suitability and availability show a direct correlation for human beings and fish species (Zingraff-Hamed

et al. 2018b). However, this study also suggests that a recreation management plan could be implemented to limit pressure on sensitive species. While restrictions could be implemented for an immediate and short-term protection of species (e.g., restriction on swimming activities within 100 m of a spawning area to avoid destruction of eggs), long-term restrictions decrease acceptance for restoration measures. Public use of the natural environment could be an educational opportunity to raise awareness. The indirect impact on nature due to recreational usage may represent a higher risk for plant and animal species than natural competition. For example, nitrate pollution caused by repetitive and massive urine spill into the nutrient-poor habitat causes long-term competition between highly specialized species and nitrogen-loving ubiquitous and the eventual dying out of the specialized species (Zingraff-Hamed et al. 2017a). On the other hand, a byproduct of intensive use of recreational areas is trash. This is a major concern of the local authorities in terms of expensive cleaning costs (€ 40 million per year), and more so, plastic litter resulting in micro-plastic pollution.

25.7.7 Lessons learned

The Isar case provides us with many lessons:

- The nature-oriented river landscape designed in the city center of Munich demonstrated that a near-nature urban river development can be achieved
- Civil society can influence major socio-ecological changes in the riverscape
- When the citizens care, the politicians take care
- Mutual trust and understanding among different stakeholders is a key of successful collaborative planning
- Processes and negotiations need time and patience
- Long-term collaboration helps to avoid planning mistakes or pitfalls
- Importance of understanding how to take advantage of the 'windows of opportunities' to re-establish hydromorphological process
- Socio-cultural and ecological needs should be balanced to achieve resilience
- Flood protection does not mean ecological degradation
- Better management of recreational usage and raising awareness among citizens for nature and river conservation is needed

Moreover, the project demonstrated that public participation and active co-design are not only possible, but can even promote innovations. Collaborative processes may be more time-con-

suming, but increase project acceptance and resilience. The Isar Plan emphasizes that societal demand for ecological values and high quality of life have already occurred (Zingraff-Hamed et al. 2019) and proves that when citizens care, politicians will take care. The example of the Isar Plan collaborative planning process mirrors the socio-ecological principle that self-organizing users and leaders will develop the effective and sustainable management of a resource (Ostrom 2009). The Isar case shows how civil society can drive socio-ecological planning, and as such is an example of a statement by the UNESCO chair on River Culture: "*only if the people develop a feeling of care for the river, they will take action*" (Wantzen et al. 2016). The authors of Rivers of the Alps also stated that "*No law can replace or even surpass the protection that comes from the hearts of committed people*" (Muhar et al. 2019, p. 277).

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