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Eel on the move: fish migration and the construction of "flowing spaces" on the Rhine and Weser Rivers (1880–1930)

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Abstract
Sturgeon, salmon, and eel—almost all of the fish species which guaranteed German inland fisheries a profitable living over the last centuries change habitats between oceans and rivers. The European eel follows one of the most spectacular migratory regimes: eels spend most of their lifespan in freshwater before returning to the sea to spawn and die. During their migration their motion, bodies, and nutritional value undergo a substantial transformation. This article argues that these migratory patterns were predicated upon a range of unforeseen consequences which in turn affected fishing practices, patterns of consumption, and species protection regimes along German watercourses. Retracing the migratory paths taken by the eel, it is possible to demonstrate that the variable nature of their peculiar biology served to structure "flowing spaces" of connectivity and disjunction. The empirical analysis focuses on eel migration in the river basins of the Rhine and Weser Rivers, where the resilient species gained large and growing economic importance in the early twentieth century.

Keywords Eel · *Anguilla* · Fish migration · Fishery · Fishway · Historical animal studies

Introduction

The Rhine and Weser Rivers were once the most productive inland fishing waters in Germany. For centuries, the fishermen working these rivers made a profitable living from migrating fish species such as trout, shad, eel, sturgeon, and salmon. Each spring witnessed the salmon run, as the "noble", "elegant" salmon—as contemporaries described the fish—battled the strong currents of these rivers to return from their ocean habitat to their freshwater spawning grounds at the tributaries. Although many contemporaries perceived declining trajectories from at least the High Middle Ages, the most common narratives about river fishery suggest that the onset of industrialization had the greatest impact on fish stocks. Due to pollution, river corrections, the increase in steam shipping, dam building,

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and not least overfishing as a consequence of population growth and better living conditions, all these events led to continuous decline in fish stocks in the Rhine and Weser beginning in the middle of the nineteenth century. Once common albeit expensive food items, salmon and sturgeon increasingly became a rare symbol of the past glorious times of inland fisheries. “Nothing symbolizes the changes better than the decline in Rhine fishing”, David Blackbourn writes in *The Conquest of Nature* (Blackbourn 2006, p. 107). This history is one of a gradual and irreversible disappearance of aquatic animals and a centuries-old craft tradition which reached its low point at the turn of the twentieth century. Apart from the fact that we are dealing with a long-term development, river and fishing historians have rarely asked about the further development of inland fisheries in the twentieth century. How did fishermen at rivers respond to the impacts of industrialization and the decline of certain fish species?

These overlooked aspects of historical changes in inland fisheries come to the fore when we not only follow the common narratives—which have also become the stuff of romantic legends—but also track the migrations of a specific species that has so far received less attention in historical research than the iconic species of salmon and sturgeon. Along the North Sea rivers, the European eel (*Anguilla anguilla*) gained growing economic importance in the early twentieth century; in response to the disappearance of certain fish species, many fishermen along the Rhine and Weser River turned to eel fishing. Eels are as migratory as salmon but travel in reverse: they enter freshwater as larvae to grow and mature and return to the sea to spawn and die. Meanwhile, the elongated fish undergoes a substantial transformation in its physical characteristics, including motion, bodies, and nutritional value. It is argued that his migratory regime has significantly contributed to the transformation of inland fisheries. During their journeys through their freshwater habitats, these eels on the move interacted in changing ways with sociotechnical activities along the watercourses. These human-animal relations acted to structure specific fishing practices and food cultures at particular sections of the river, spaces of conflict over access to and exploitation of eels, and spaces of species protection where efforts were made to protect the eel lifecycle.

Seeking to demonstrate these socionatural interrelations, the empirical analysis provided in this study will focus on eel migration along the Rhine and Weser around 1900, when eel fishing spread from the North Sea delta to the upper reaches of the river basins (Fig. 1). The argument will unfold in three steps. A first section will introduce the conceptual considerations that integrate perspectives drawn from environmental history, human-animal studies, and a spatial approach to fish migration. This will be followed by an overview of the history of German inland fisheries. Finally, a third section will establish the three distinct but overlapping “flowing spaces”—as I call them—structured by the eel and the migratory regime of the species.

Spaces and scales of an animated history of fish migration

Concepts of space are central to academic histories of river environments. After all, the focus of study—the river—has various spatial references. Rivers serve to delimit territories, shape landscapes, and both connect and separate places. The spatiality of rivers is expressed in a variety of forms within river histories, and historians have deployed a number of concepts to describe these spatial dimensions: from “socio-natural sites” to “riverscapes” and “national rivers” (Winiwarter and Schmid 2020; Cusack 2010;

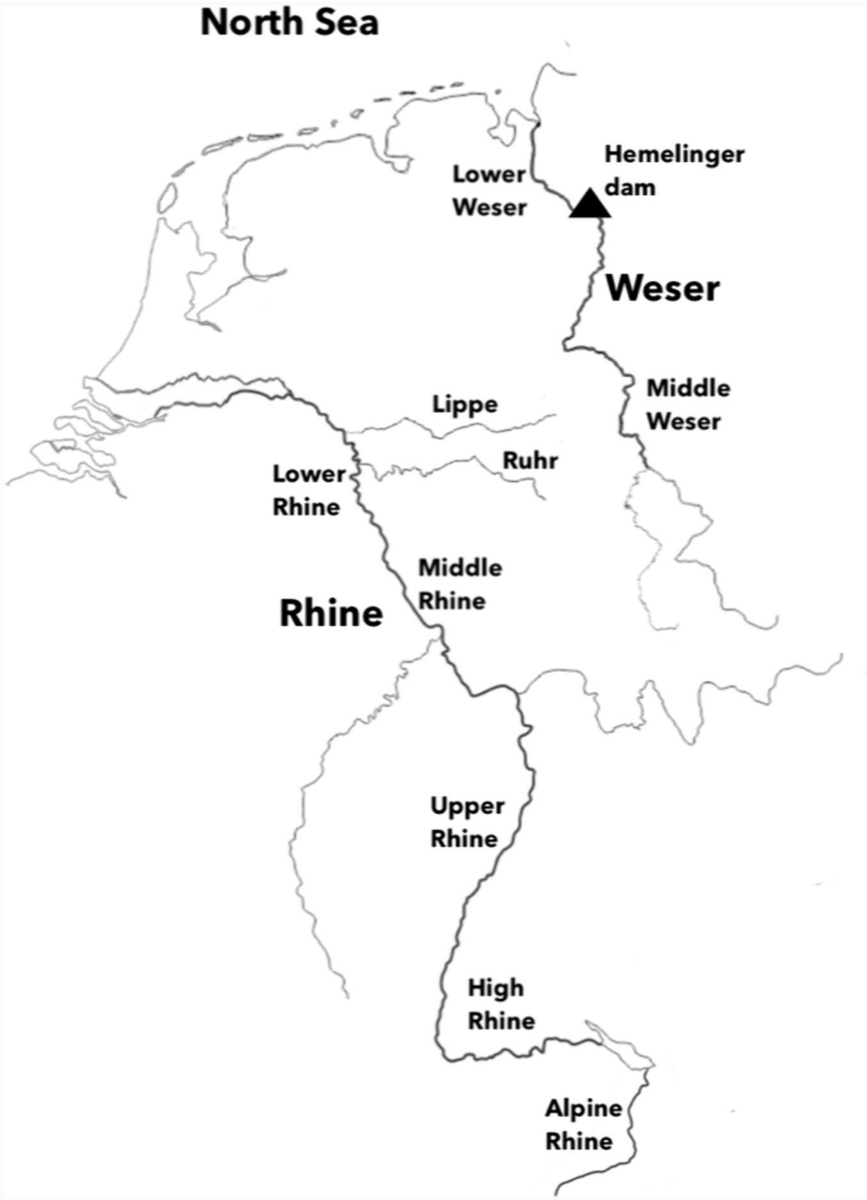

Fig. 1 Map of the study area; basins of the Rhine and Weser Rivers (cartography by the author and Charlie Fischer)

Pritchard 2011). As Paula Schönach pointed out in her thematic review from 2017: "River histories are a showcase for understanding that the intertwined nature of multiple spatial conceptions and the scales of both human action and natural processes are necessary for an adequate analysis of historical change in human-river relations" (Schönach 2017, p. 244).

In his 2010 article *Water Systems*, Terje Tvedt argued that a majority of recent studies on the spatiality of rivers have privileged human social relations, while devaluing “the role of the physical terrain” (Tvedt 2010, p. 154). An example for such a prioritization is Lucien Febvre’s study *The Rhine: Problems of History and Economics* (originally published as *Le Rhin: Problèmes d’histoire et d ‘économie*, Paris 1935). Although Febvre’s story deals with a river, he conceived of it as a human-made and formed space (Febvre 2006 [1931]; see also Rau 2016). More recent studies have demonstrated that rivers are not just a static “stage” on which the cultural history of river utilization plays out, but rather constitute complex hydrological systems. Ice jams, floods, and water shortages shaped surrounding landscapes and enabled or limited diverse forms of river utilization such as navigation, hydropower, or fishing (Knoll et al. 2017, p. 4).

A further dynamic which histories of rivers and inland fisheries must consider is the high degree of mobility exhibited by aquatic organisms. As Richard White outlined in *The Organic Machine*, these patterns of aquatic migration constitute nodal points at which the lines of human and fish intersect (White 1995, p. 20). In his account of the salmon crisis in the American Northwest, the historian Joseph Taylor wrote of “salmon spaces” which allowed some social groups access to fish while restricting others (Taylor 1999). The nuanced understanding of space deployed by historians such as White provides points of contact for analyzing the spatial configurations of the social, ecological, and hydraulic dynamics present along the course of a river.

In most fishing and river histories, however, migratory fish appear more as passive and static food resources, considered in relation to human intentionality (McEvoy 1986; van Dam 2003; Dekker 2019). This perspective reflects the worldview of contemporary fishermen; in their historical writings “much attention goes out to fish since they were (and are) an important resource of human subsistence” (Lenders 2017, p. 403). The focus on fish as a commodity offers opportunities to think critically about human-nature relationships and to trace the historical paths that have led to our problematic view of fishery today, in which we see aquatic animals only as sources to be exploited.

However, this perspective obscures that migratory fish are living organisms with “their own drivers for action” and have not always behaved as humans want (Jørgensen 2014, p. 481). This article seeks to understand how migratory fish species interacted with, and acted to shape, their social and engineered environments over the course of their migration. In this context, it is crucial to consider fish in action and in motion, perceiving them as a in their own right rather than solely in relation to human intentionality (Brantz 2017, p. 131). Accordingly, environmental historian Anna-Katharina Wöbse argues that continuing to view nature as merely a commodity limits “human understanding of fish histories and their ecology”. She and others have called on historians to rethink human-centred perspectives in the hope of “gaining new insights by shifting the focus of their scholarly attention to the biosphere and the creatures sharing it” (Wöbse 2021, p. 293; Demuth 2024).

Ethnologists, cultural scientists, and historians working in the field of human-animal studies have long since begun to study not only the economic but also the emotional dimensions and behavioural patterns of non-human organisms, conceiving them as actors who shape history (Cabral and Lähdesmäki 2023, p. 92). With a few exceptions (Lien 2015; Balcombe 2016; Finley 2017), (historical) writings on human-animal relations have so far rarely depicted aquatic organisms as living, sentient, and even conscious beings. “Several scholars have written about […] human-animal relations, but not many have dealt with fish”, notes historian Terje Finstad, speculating: “This lack of interest in fish might be because they are seen as untamed natures that are not part of society” (Finstad 2017, p. 98). By integrating this more-than-human perspective into an environmental history of fish, this study recognizes the dynamism and resilience of non-human beings and factors in shaping the social, economic, and technological relations along German watercourses. Eels' mobile nature made them powerful agents of spatial relations that were in constant flux; their migratory paths affected fishing practices, consumption patterns, and species protection efforts along various sections of the river in different ways. The presence or absence of eels with a particular physical constitution contributed to structuring specific spatial configurations: these flowing spaces ranged from the local level of fishing sites and hydropower plants, to the regional level of food cultures and beyond, to river basins and even transnational attempts to relocate eels from England to Hamburg.

Environmental factors (geology, morphology, seasonal dynamics, etc.) along with ecological conditions and pressures on fish migration resulting from river regulation, overfishing, and damming for energy "combine differently in each river": this is how Gertrud Haidvogl and her colleagues advocate for a "detailed analysis of individual cases" (Haidvogl et al. 2015, p. 322). The present study focuses, in this spirit, on the basins of the Rhine and Weser Rivers, where archival evidence and secondary sources permit detailed analysis of the historical interrelations between aquatic organisms, natural forces, and human actions. Analyzing these sources provides a better understanding of the conditions under which the shift to eel fishing from a small-scale, local artisanal practice to a much larger industrial activity has taken place.

Sources here include journals of the fishing industry, as well as journals related to hydropower and hydroengineering, contemporary technical manuals for fishing gears and fishway construction, and fragments of a large variety of written documents from regional archives in northwest Germany. Catch statistics and other quantitative data offer some insight into the extent of eel fishing and provide limited information about the changes in fish populations. One main challenge is that these written traces of the eels are structured according to their function and specific human concerns, obscuring many relations to non-human factors, such as the living and habitat conditions of the species. In this regard, contemporary handbooks about the biology and behaviour of the eel are particularly helpful in revealing what fishers and scientists perceived and seemed to know about the species' lifecycle, its specific habitat conditions, and the many ways it has adapted to them.

These historical texts on fishing call to be interpreted with critical care (see Haidvogl et al. 2014 for an overview). As Richard C. Hoffmann notes in *The Catch*, the study of historical fishery sources "abounds with observational hazards" and "opposed delusions" (Hoffmann 2023, p. 51)—especially when it comes to historical catch data. Consistent and long-term time series of catch statistics are scarce and require careful consideration. Quantitative information on the presence of a species relied mostly on statistics provided by individual fishermen. On the Rhine the licensing conditions for eel fishing required fishermen to keep "accurate daily records" of their catch (Koch 1937, p. 35).[1] However, their statistics often provided a distorted picture of catch levels. This was partly because the fishermen often underreported their recorded catch to avoid the taxes levied on valuable species of fish (Schiemenz 1922, p. 97).

Another problem arises from the short professional lifespan of contemporary fishers and scientists. As outlined by what has been called the "shifting baseline syndrome", human perception tends to suppress trends occurring over longer periods of time than a subject could witness (Pauly 1995; Humphries and Winemiller 2009). For example, fishermen's

[1] All quotes from historical source in German were translated by the author.

catch statistics focus only on species that are of commercial interest at a given time. Catches of salmon, shad, and sturgeon were registered quite accurately for centuries on the Rhine and Weser Rivers, as these species were among the most important goods and subject to taxation; eels, on the contrary, rarely appear in fishery statistics before the turn of the twentieth century, when the species gained growing economic importance and attention. However, this should not lead us to conclude that the increase of eels in catch data indicates growing stocks, or that the eel lacked economic relevance in preindustrial times (as I show below). This data also reflects the role of human perception in determining which fish species were documented, and which were not.

Fishing, migration, and the "industrialization of rivers"

As early as premodern times, eel constituted a major share of inland fish catches across Atlantic and Mediterranean inland waters. Along the shorelines of England, expanding eel fisheries met growing demands for fish throughout the High and late Middle Ages (Hoffmann 2023, p. 58 & 198–200). The Mediterranean watersheds show similar trends. In the Rhone delta eels evidently supported local fisheries and human consumption as a common fishing resource not treated as a prestigious food item reserved for the elite (unlike salmon, sturgeon, or pike) (Berman 2010). Local eel fisheries spread along the Mediterranean coasts from Tuscany and Sicily to the mouth of the Po in the Adriatic Sea. Near the estuaries of the North Sea, too, eel fishery was a long-established tradition. Dutch fishermen were some of the first to set basket traps in front of the locks on the Lower Rhine to catch adult eels migrating downstream (van Dam 2003; Hoffmann 2008, p. 52). Across the Rhine delta of Holland and Flanders the expansion of drainage, the construction of levees and channels, and changes in the riverbed provided anthropogenically enlarged habitats, creating an environment in which eel fishing became a major resource (Hoffmann 2023, p. 200).

While eel fishing supported premodern efforts to satisfy demand for fresh and lightly processed food in the estuaries of most European river systems, fishermen further upstream concentrated on other species as the more valuable catches of salmon, sturgeon, sea trout, and shad. Salmon fishing remained by far the most important source of income for many towns and villages on the middle and upper reaches of the Rhine and Weser until well into the nineteenth century (Budai 2006; Blackbourn 2006, pp. 108–109). The profitable "king of all fish" was particularly caught between September and November, when shoals of adult salmon battled the current to reach their freshwater spawning grounds in small tributaries (Blackbourn 2006, p. 108). Some later fisheries experts claimed that Rhine salmon remained unaffected by human activity up to industrialization, when scientific observations showed a large decline of the salmon stocks (Schenk 1931, p. 76; Koch 1955, p. 230). However, there is a growing awareness in historical ecology that human impacts on river ecosystems can be traced back several centuries and that the decline of European riverine, notably anadromous, fish populations may have started much earlier. Rob Lenders and his colleagues have argued for a correlation between the preindustrial construction of water mills in the Rhine basin and the decline of natural salmon stocks (Lenders et al. 2016). Salmon primarily reproduced in smaller rivers and upper tributaries, where waterpower activities had already shaped the character of flowing waters long before the great dams were erected (Zumbrägel 2022). At the small creeks of the uplands of western Germany, where sawmills, papermills, grinding shops, and corn mills multiplied through the early modern period, dams and other barriers disrupted the ecological continuity of rivers and profoundly altered fish habitats. From the sixteenth century, reliable records along the Ruhr River (a tributary of the Rhine; Fig. 1) indicate decline of natural salmon stocks. The *Süderländische Fluß- und Schlächteordnung* from 1525 attributed the damaging of salmon runs to mill dams (*Schlächte*) and other barriers cutting off what had once been the highest spawning sites. Because "neither salmon nor [other] fish can go up," the regulation prohibited "the construction of new dams and the raising of the old ones" (Flebbe 1967, p. 163, citing the Schlächte- und Fischereiordnung no. 228; Anonymous 1799, p. 68).

Fishers, mill owners, residents, and local authorities were well aware of the damaged salmon runs long before modern industrialization. However, the effects of preindustrial economic development differed in kind and degree from region to region. When ice jams or floods damaged the dams, migrating fish were usually able to overcome the obstacles to reach their natural spawning grounds at the highest tributaries. In the uplands of western Germany, this regularly led to an "unusual abundance of fish in the small creeks" (Anonymous 1798, p. 187). Accordingly, salmon fishing remained commercially important well into the nineteenth century.

The "industrialization of rivers"—to use Eva Jakobsson's term—certainly increased the decline of fish stocks in the Rhine and Weser (Jakobsson 2002). There were many long-term anthropogenic environmental changes that dramatically altered—if not completely destroyed—the living spaces necessary for the survival of the river's non-human inhabitants. Corrections and canalizations of the river to facilitate growing steam traffic led not only to a more uniform, deeper river channel but, more importantly, to the disappearance of many promising side arms and alluvial corridors, thus effectively reducing the breeding grounds and resting points for migrating fish. Pollution by industrial effluents also had an impact on fish populations; complaints about "mass fish deaths" were registered in fishing circles beginning in the late nineteenth century (Bonne 1913, p. 145). At the turn to the twentieth century the advent of hydroelectricity also affected fish migration and transformed sections of the Rhine and Weser into energy corridors. New large-scale hydroelectric dams on the Lower Weser were built near Dörverden and Hemelingen shortly before the First World War (Schmidt 1922; Kölle 1916; Fig. 1). On the Upper Rhine, the dams and turbines of more than ten hydroelectric installations completed by the 1930s ravaged formerly productive fishing sites (Anonymous 1913; Linse 1988, p. 13). The new physical barriers not only blocked the access of the migratory shoals seeking to continue their traditional course upstream; their fast-running turbines also shredded any fish attempting to move downstream.

These were all stages of the ecological degradation of increasingly canalized rivers, but the fishing industry also contributed to the pressure on fish stocks and their depletion by intensifying daily fishing practices. Alarmed at the prospect of losing the base of its existence, the fishing industry sought to mitigate the impact of these impositions. During the second half of the nineteenth century, fishermen joined together to develop hatchery facilities, which raised and then released millions of fingerlings and smolts as an attempt to restock fish populations in the Rhine and Weser Rivers (Kinsey 2006). Nevertheless, these measures could not arrest the decline of the most important commercial migrating species—shad, sturgeon and, of course, salmon—on which fishermen depended for their livelihood.

The industrialization of rivers thus transformed the Rhine and Weser into the habitat for a small number of tough, highly adaptable species labelled by historian Mark Cioc as the hardy "universalists" (Cioc 2022, p. 59). Nevertheless, although the large populations of bream, roach, and perch that thrived in the new, more difficult environmental conditions presented a suitable alternative catch for those engaged in subsistence fishery, these species

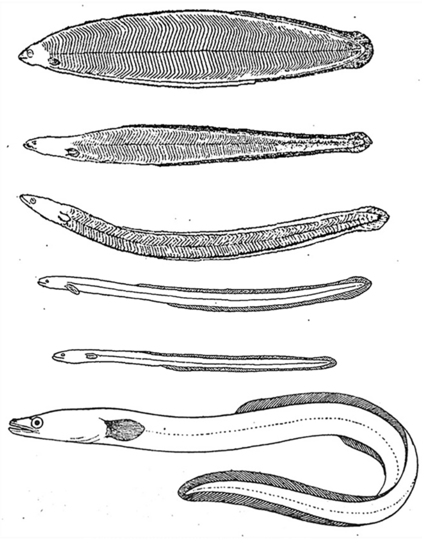

Fig. 2 Development of the eel from larva and glass eel up to the adult silver eel, as shown by Johannes Schmidt and his colleagues. These figures demonstrate the variety of body shapes and other morphological features of the eel during metamorphosis, as understood by scientists in early twentieth century. It should be noted that historical human protagonists knew only parts of the peculiar biology of the species (Schmidt 1906, p. 150; Nitsche 1886, p. 9)

were of little market value to the commercially minded fishermen. Far greater potential for economic exploitation was presented by the eel populations. Unlike the sensitive salmonids, eels enjoy broad ecological tolerances and omnivorous habits during their long maturation in inland waters. The biologist Friedrich Schiemenz, one of Prussia's most influential fisheries experts, noted how stones artificially heaped up on the riverbanks provided an ideal habitat for the prey of eels—small fish, insects, and crustaceans—and thus provided the fish with a greater source of food (Schiemenz 1930, p. 303). Industrial activities enlarged nutrient-rich stillwater habitats, with the unplanned result of much favouring the eels' living conditions. The "lake-like character" of hydroelectric installations likewise provided eels with favourable conditions (Müller 1959, p. 163; Nolte 1976, p. 37). While the hydroelectric dams blocked other migratory species such as salmon from ascending the upper courses, juvenile eels were able to circumvent the obstacles by snaking through humid moss and greenery. Not only were eels able to thrive in the changed river environment; their resilience as a species also resulted from the nature of their lifecycle. Like the ocean-dwelling salmon, which returns to its freshwater origins to reproduce, the eel follows an equally spectacular albeit inverse migratory regime. Spending most of their lifecycle in a freshwater environment, eels return to the ocean to spawn and die. The consequences of the industrialization of rivers thus had no impact on the eel's salt-water spawning ground and could only affect the spatial distribution, but not the reproductive success of the species. Eels continued to procreate in the still-untouched depths of the Atlantic.

At the beginning of the twentieth century, Danish biologist Johannes Schmidt and others discovered how eels go through different life stages as they migrate thousands of miles through rivers (Schmidt 1923; see also Poulsen 2016). These metamorphoses are accompanied by marked changes in morphology, body constitution, caloric values, and other behavioural characteristics (Fig. 2). When the leptocephali larvae reach Europe's western coasts, they metamorphosize into transparent glass eels—also known as fry or elvers—that "invade" the estuarine areas and swim up the rivers (Coates 2021, p. 102). The glass eels enter inland waters and change, through a further growing phase spent in the tributary areas, into the voracious yellow eel. When they finally return to the ocean after 6 to 20 years, the yellow eels transform into their final life stage as the silver eel. Now sexually mature, the silver eels stop feeding, at which point they present the highest calorific values, making them economically very attractive to river fishermen. These metamorphoses had an economic impact, determining the locations at which the species was fished and the types of fishing apparatus deployed. The presence of the eels also influenced the regions in which they featured, with varying degrees of popularity, in the local diet and the areas in which fishermen exhibited any interest in protecting the species. Following the migratory paths of the eel, it is possible to demonstrate how interactions between humans, nature, and living organisms served to structure flowing spaces within the watersheds of the Rhine and Weser.

Spaces of fishing

Responding to the decline of the salmon stocks, a number of Rhine and Weser fishermen turned to eel fishing. As early as 1922, the Fisheries Association of the Weser, Ems, and Coastal Area (*Verband der Fischerei-Vereine für das Weser-, Ems- und Küstengebiet*) noted that eels assured Weser fishermen the highest fishing yields "above all other fish species" (Anonymous 1922a, p. 69). Looking back in 1941 on the changes in fishing conditions along the Rhine and Weser area, Schiemenz noted that "while salmon used to be the most important fish catch […] they have been replaced by the eel, which had previously been of very little import. Today the eel is the most valuable catch; its yield represents the economic backbone of commercial fishing" (Schiemenz 1942, p. 97).

These changes also manifested in historical catch data. Despite the "insurmountable difficulties" these statistical surveys present in terms of credibility, their analysis indicates shifts in the fishing yields (see above; Schiemenz 1922, p. 96). At the Lower Weser for example, the volume of eel caught doubled from around 20,000 kg in 1900 to more than 40,000, and up 60,000 kg, in the 1930s (Nolte 1976, pp. 37–39). The high fat content of eel meat made it the eel of the most expensive freshwater fish still remaining to be caught. As the new "fisherman's bread and butter", it made for lucrative business (Kuhn 1976, p. 148). At the beginning of the 1950s, eels accounted for about 70 percent of the total takings in German inland waters (Wiehr 1950, pp. 196–198). More than 150 fishing companies were still active in the Weser River basin at the beginning of the 1950s, most of which specialized in eel fishing (Nolte 1953, p. 346). This only changed over the course of the 1960s, when increasing sewage pollution eventually resulted in a ban on the sale of eels caught from these rivers. The resilient nature of the eels meant they continued to thrive in the polluted waterways. Moreover, in acting as a carrier of the contaminants released into the water, they posed a threat to human health (Meyer-Waarden 1968, pp. 4–8; Denzer 1966, p. 253).

The early decades of the twentieth century saw eel fishing spread from the estuarine areas in which it had been pioneered to establish itself on the upstream river sections of the Rhine and Weser. Despite this trend, the forms taken by eel fishing on main rivers and their tributaries developed along different regional paths. Fishing rights along narrow tributary creeks—for example in the Weserbergland or in the Bergisches Land on

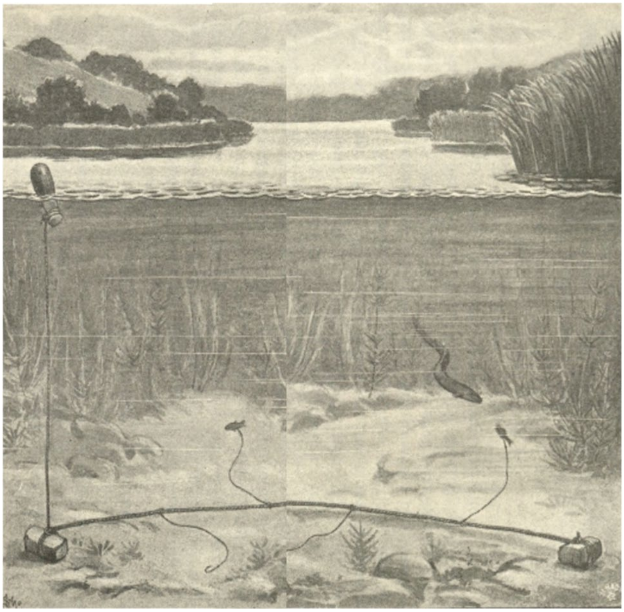

Fig. 3 The baited eel line was a common installation, deployed at river tributaries to catching the voracious young yellow eel (Walter 1903, p. 289)

the right bank of the Rhine—were held by local landowners, who either engaged in subsistence fishery themselves or granted licences to individual millers, farmers, foresters, fisheries associations, and larger fishing cooperatives.

To be an eel fisherman along the narrow tributary creeks required an intricate knowledge of the lifecycle of the eel and its migratory patterns, as the right choice of gear, place, and time determined the success of the day's work. Local eel fishermen working the tributary areas took advantage of two characteristics of the yellow eel prevalent there, i.e., their hunger and nocturnal habits. Knowing that the yellow eels were "eager to eat", fishermen cast baited rods and long-chain multi-hook eel lines before dusk (Walter 1903, p. 625; Fig. 3). In particular, mill owners were able to take advantage of the "pronounced need [of the eels] to hide themselves away" (Schiemenz 1910, p. 198). The downstream migration of adult eels gave each mill owner a seasonal opportunity to put basket traps or boxes above the dam that were used by the eels to escape daylight (Ehrenbaum 1930, p. 171). Regular fishing of eels at weirs and mills and in stillwater habitats supported heavy local consumption of fresh fish, providing protein to a larger, less wealthy consumer base. Eel catches were sold at nearby markets and served as a key subsistence good to supply fishers' households and/or the local population.

The profitable nature of this undertaking also resulted in conflict with local fishermen, who dubbed this type of eel fishing "predatory fishing" (von Staudinger 1889, p. 218; Anonymous 1911). Medieval and early modern sources are already full of conflicts provoked by water mills and their lucrative eel traps (Hoffmann 2023, p. 124). Fishermen became especially aggrieved when they thought that the millers had become greedy and took too great a catch. On one north German river course, a mill owner who had set up "a chain with eel baskets stretching from one bank of the stream to the other" in front of his dam incurred the displeasure of local fishermen because he "intensively pursued the valuable eel" (Hübner 1905, p. 126).

Such forms of small-scale eel fishing were matched by industrialized eel fishing developed on the main rivers with higher rates of water flow (Dekker 2019, p. 12). Working the lower and middle reaches of the Rhine and Weser, professional fishermen and their assistants plied a full-time trade; their wives—the original "fishwives"—sold their catch at regional markets. Such fishermen had leased the fishing rights for longer stretches of river from the state, the holder of all fishing rights in navigable waters.

The specific patterns of eel migration meant that particularly "favourable opportunities for catching eels" prevailed on the main streams of the Rhine and Weser (Schiemenz 1921, p. 117). Every eel which had migrated from the sea up various tributaries was now leaving its freshwater habitat ready to breed. With well-chosen techniques eel fishermen could catch eels when the sexually mature adults migrated downstream to spawn in the open ocean. The large number of eels in these migrations was matched by the peak in calorific value of the adult silver eel in the main rivers. In addition, the navigable main rivers lent themselves to the use of industrial fishing methods with larger steam powered fishing boats. Adapting their traps to the shape of the eel's body, fishermen had developed special ground nets known as *Aalsäcke* or *Aalhamen* (Walter 1910, pp. 276–284). Their wide opening and a pointed end—the meshes of which were tightly woven to fit the slim body shape of the eel—made them far more effective than the conventional trawl nets in which the eel could only be caught "very rarely", as the fish "could squeeze its slippery body […] through without much effort" (Benecke 1883, p. 90). In contrast to the tributary areas, baited fishing apparatus were not used on the main rivers because mature silver eels returning to the North Sea had a deformed digestive tract and did not eat (Walter 1903, p. 625).

The convergence of a high-value catch in an area suitable for large-scale, effective fishing methods made eel fishing in the middle and lower courses of Rhine and Weser Rivers a highly profitable endeavour. In the 1920s and 1930s eel fishing spread from the Rhine delta and established itself on the Middle and Upper Rhine, where salmon had a long status as the dominant catch. In the interwar period, more than 200 eel fishermen fished the 400 kms between the Lower Rhine and the Upper Rhine; at the Upper Rhine on the Baden side, twenty-one fishermen switched to eel fishing from the 1920s onwards (Koch 1937, p. 35). It was this change that provided the subject-matter for Willi Gutting's novel *Die Aalfischer* (1943), a publication to which historian David Blackbourn also briefly discusses in his *Conquest of Nature* (Gutting 1943; Blackbourn 2006, pp. 112–114). Gutting, a teacher and regional writer, described how the fishing villages on the banks of the Rhine sought to respond to the changing conditions of the industrialized river. Some Rhine fishermen found a solution in catching eels. In the 1920s, for example, the salmon fisherman Rud Losche built up a fleet of dozens of *Aalschokker*, steam-driven vessels specialized in eel fishing. After his death, his wife Barbara continued to run the fishing fleet and made a name for herself as the "mistress of the eel trade" (Gutting 1943, p. 308; Kuhn 1976, pp. 79–90).

Food cultures along the Rhine also shifted in response to changes in fishing. In the north, where eel fishing had a long tradition, the fat-rich fish meat of the silver eel had always been considered a delicacy. Further upstream however, there were cultural antipathies and "pronounced prejudices" against the fish (Wundsch 1949, p. 508). Some studies on the Westphalian fishing industry classified the eel as an inferior species, with some even going as far as to call it a "weed fish" and at best an affordable staple for rural communities (Walter 1907, p. 25). In Austria, Switzerland, and southern Germany, the eel was known only as marinated canned fish. In the Danube basin eels did not occur at all; and in the Swiss High and Alpine Rhine only eels of medium size appeared. These were of little interest to local fishermen, so that no *Aalschokker* were to be found at the headwaters of the Rhine. Not only did the strong river currents in this area make navigation with these craft difficult, but the small eel populations also promised poor catch prospects. The persistence of salmon breeding in the upper courses of the High and Alpine Rhine meant that the unattractive eel was not fished in this region and "often detested due to its snake-like appearance" (Steinmann 1936, Table 11). With little known about the natural lifecycle of the eel, myths continued to surround the species in southern German fishing circles. Here, cultural antipathies to its snake-like morphology and benthic habits were widespread and many fishermen believed that these slimy creatures lived from "aquatic carrion" (Schiemenz 1910, p. 198). It was not until the beginning of the twentieth century that communities at the Middle Rhine on the Rhine-Westphalia side discovered any "enjoyment of eel" (Wundsch 1949, p. 508). This was in part a consequence of the expanded supply resulting from the growth of industrial eel fishing along the Rhine. Changing ways of preparing food also improved the taste of eel meat. The development of the hot-smoking process at the end of the nineteenth century soon attracted a following and transformed perceptions of the fish as a "cheap, peasant's food" to a delicacy (Doose 1908, p. 393). The popularity of this new smoking procedure was reflected in the wide range of recipes for smoked eel prevalent in cookbooks, which displaced more traditional approaches of boiling, braising, and pickling eels (Dekker 2019, p. 8). The migratory behaviour of eels, therefore, played a crucial role in structuring spaces of fishing practices and food cultures. Variation in the body shape and caloric value over the life stages during their migration played a role in determining the attractiveness of eels to fishermen and thus the locations at which this species was fished and consumed.

Contested spaces

Patterns of eel migration also reordered relationships between different types of river utilization. Conflicts between fishing and hydropower practices had a long history on the Rhine and Weser. The advent of hydroelectric power at the end of the nineteenth century served to intensify the dynamics existing between these "age-old enemies" (Frischholz 1914, p. 467).

The emergence of the first large-scale hydroelectric plants on the main rivers around 1900 had a profound impact on the migration of eels. New hydroelectric installations and the dams built to power them acted to hinder the passage of the migratory young eels to inland waters (Heyking 1898, pp. 372–373; Baar 1903). On their return downstream towards the river estuaries, the mature silver eels encountered not just obstacles, but mortal danger, in the form of turbines which shredded whole shoals. The eels' body shape and form of movement made them highly susceptible to such a fate. The elongated eels followed the strongest river current, generated by the turbines, which drew them into near certain death (Seelig 1890, p. 236; Gerhardt 1912, p. 492). Those fortunate few eels emerging alive from the turbines were so weakened that they made easy pickings for their natural predators, such as otters and herons (Buxbaum 1889, p. 235; Liburnau 1908, p. 177).

Fisheries representatives called the hydroelectric plants "murder pits" and "machines of destruction", whose rapid rotations acted to "shred" countless eels on their way downstream (Anonymous 1910; Walter 1903, p. 750; Gerhardt 1904, p. 68; Lundbeck 1927, p. 438; Reclam 1914, p. 408). In the early 1890s eel migration at the Lippe River led to a complete shutdown of a hydropower station after the turbine chamber became "clogged with pieces of eel" (Anonymous 1891, p. 243; Fig. 1). At Hameln on the Weser, local fishermen were called to collect "dismembered eel carcasses by the hundredweight", which were found floating on the surface of the water after passing through the power plant of a papermill (Eberts 1906).

The advance of hydroelectricity and the development of the eel as economically the most important catch for the Rhine and Weser fishermen ensured that this long-standing conflict became a central concern in fishing circles. However, debates on this issue varied regionally. In areas in which the eel played hardly any role in the fishing industry—such as along the upper courses of the High and Alpine Rhine—engineers, biologists, and fisheries scientists paid little attention to the "turbine question". The attitudes of many Swiss hydraulic engineers and fisheries experts were reflected in the view of Arnold Härry, who noted in his handbook on fishways in Switzerland of 1917:

> As soon as the young eels have matured, they leave our territory [the Swiss Alpine Rhine] to return to the sea, where they are caught in large quantities along the lower river courses. Considered from a Swiss point of view, this fish consumes more in food than we extract from it, and it is therefore not appropriate to make great sacrifices to facilitate its migration in our waters. (Härry 1917, p. 10)

Views in the estuary area, by contrast, where the adult eels brought large catches for the inland fishermen, were very different. Indeed, the turbine question was the main item on the agenda at the annual meetings of northwest German fisheries associations (Anonymous 1921a; Sichler 1922). In the north, even the hydropower associations were forced to deal with the effects of their practices on eel migration (Verband deutscher Müller 1892, p. 745). Reports of "eel outrages" perpetrated by hydroelectric installations flooded the bulletins of the northwest German fisheries associations. Such intense feelings were absent further upstream, and the Journal of the Bavarian Fisheries Association (*Zeitschrift des bayerischen Fischereivereins*) or the Swiss Fishing Newspaper (*Schweizerische Fischerei-Zeitung*) had little time for eels. In their articles, fisheries experts exchanged ideas on how best to respond to the disappearance of salmon populations in their region. On the rare occasions in which eel fishing did become the focus of debate, discussions centred on proposals to restrict the use of *Aalschokker*, which also caught young salmon and trout, thereby undermining efforts to restock the upper courses of the Rhine with fingerlings and smolt (Heuscher 1899; Coaz 1900).

Conflict over the priorities in river utilization were also debated in fish exhibitions, which developed into important sites of knowledge transfer in the fishery sector at the end of the nineteenth century and offered a forum for continuing debates surrounding the turbine question (Knight 2017; Lajus 2023). In the 1880s, fisheries representatives from the Weser set up display aquariums at fish exhibitions in Kassel, showing eels with "visible injuries" and "sharp cuts […] that [had] been inflicted on them when passing through a turbine" (Anonymous 1885, p. 56; Anonymous 1889, p. 9). Counting on the shock effect, the exhibitors sought to demonstrate the damaging impact of water turbines on the eel population and engineer a consensus favourable to reforms.

By contrast, the controversy surrounding the turbine question was less pronounced along the tributaries of the Rhine and Weser Rivers. In the river basins of the right-hand Rhine tributaries Ruhr and Wupper, for example, numerous traditional watermills served the regional industry until the interwar period (Limmer and Zumbrägel 2020; Fig. 1). The old dams of these mills were "often defective, leaky, and lower" so that the small yellow eels were able to slip through and over them in great number (Hoech 1889, p. 17; Anonymous 1907, p. 187). The "cosy old wooden mill wheels" of these watermills also posed "no serious danger" to eel migration, as their spacious constructions afforded migrating eels "sufficient space to slip through" (Lundbeck 1927, p. 438). The soft wooden edges and low rotational speeds of the water wheels also caused little harm to the animals. However, it was crucial that the mills only diverted part of the river water, so that most of the eels in the main bed could "escape unharmed" (Gerhardt 1904, p. 68; Baar 1903, p. 166). The situation was different, however, with the large-scale hydroelectric plants along the main rivers of Rhine and Weser. These power plants channelled the entire river water through their machinery, giving migrating eels little chance to escape the rapidly rotating water turbines (Seelig 1890, p. 236; Borgmann 1892, p. 169).

Spaces of species protection

By the turn of the twentieth century, the legal framework developed in the 1870s to protect the migratory pattern of eels from the encroachment of industrialization was updated to account for recent changes, in particular the introduction of turbines. For example, Sections 35 to 42 of the Prussian Fisheries Act (30 May 1874) required mill owners and dam operators to build and maintain fishways, such as eel ladders, eel channels, and eel tubes, to facilitate the upstream passage of young eels through dams (Höinghaus 1874, pp. 43–44). An amendment to this act (30 March 1880) added the requirement to take similar measures to protect downstream migratory fish. The Prussian fisheries authorities were thus authorized to compel every hydroelectric power operator to "manufacture and maintain devices (metal grids, etc.) [that] prevent fish from entering the turbines" (Heyn 1891, p. 126). The new version of the Fisheries Act of 11 May 1916 (Sect. 101) finally set the distance between the bars of these protective grids in front of hydroelectric plants at 20 mm (Görcke 1918, p. 152; Höing 1919).

This legislation indicates that contemporary fishery authorities had recognized the problems facing the decline in fish stocks and had already moved to develop measures that would address the grievances of fishermen regarding the turbine question. The mere existence of the legal requirements did not mean, however, that they ultimately achieved their purpose. A hindrance to any equitable solution was the fact that the implementation of these fish protection measures lay in the hands of hydropower operators, who had little interest in maintaining functioning fishways, especially if their upkeep interfered with energy production. The success or failure of these protective measures was therefore determined by various factors.

The physical condition of the eels also influenced efforts made to protect the species' migratory regime. The further upstream the young eels migrated, the larger and stronger the animals became. Accordingly, the protection devices also required technical adaptations to body shapes and movement behaviour. As the hydraulic engineer Paul Gerhardt noted in his 1912 manual on the construction of fishways: "the greater their distance from the sea, the larger and fatter the eel fry become. As a result, changes must be made in the construction of the eel ladders the further they are from the sea" (Gerhardt 1912, p. 496). Measures to protect the eel population were thus determined not only by the extent of industrial interventions in riverine landscapes, but also by variations in the aquatic ecosystem itself.

Along the upper courses of the High and Alpine Rhine, where eel fishing was not very profitable and hydropower conversely of considerable economic importance, dam operators were not willing to make "great sacrifices" to protect eel migration (Härry 1917, p. 10;

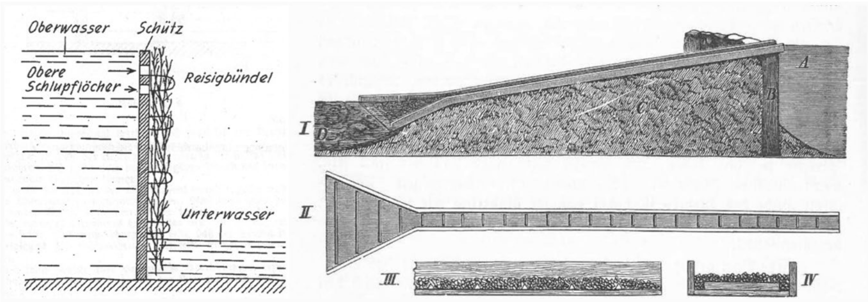

Fig. 4 Two kinds of eel ladders, implemented in different river sections with alterations reflecting the changing body shape of migrating eel. Left: simple bundles of brushwood were sufficient to support the upstream migration of juvenile glass eels in the Rhine and Weser estuaries. Right: large-scale constructions with a gravel bed were required to enable the migration of larger eels further upstream (Schiemenz 1940, p. 145; Nitsche 1886, p. 14)

Steinmann 1936, Table 11). They showed a "considerable inclination" to ignore the legal requirements or at best to implement them only sporadically (Anonymous 1900, p. 842).

Seeking to reduce costs and save space, they often built compact fish ladders that carried little water and were thus often "inefficient" and rarely used by migrating fish (Steinberg 1991, p. 175; Evenden 2006, p. 434). Steady progress was made over the course of the decades, particularly in the construction of eel ladders, but even around 1900 some mill owners continued to successfully defy the environmental regulations set out in the fisheries acts. Regulations and provisions rarely specified how an eel ladder was to be built. When ice jams or floods damaged the vulnerable structures, months often passed before they were repaired (Anonymous 1913, p. 526). In some places, however, the level of non-compliance assumed extreme forms. In southern Germany the principal offenders of protection regulations were, of course, the mill owners, who openly defied the efforts of fishery officers and continually used their political connections to gain exemptions (Zumbrägel 2021). Fishing journals published reports of mill owners who wantonly sabotaged fishways and eel ladders by plugging their openings with divots of grass. Others painted zigzag steps on their dams to simulate compliance with the law or erected simple rung ladders that neither salmon nor eel could climb (Anonymous 1914, p. 341). Even the great majority of the protective grids installed in front of water turbines failed to keep migrating eels from being drawn in, killed, or injured. Hydropower plant operators were anxious to keep the gaps in the metal grids as wide as possible to prevent backwaters caused by accumulating flotsam in front of the turbines. The prescribed minimum spacing of 20 mm distance between the bars was perhaps sufficient to prevent mature salmon from entering the turbines, but it was insufficient to keep out elongated and narrow eels (Borgmann 1892, p. 174; Anonymous 1890, p. 75).

Activities for protecting eel at the estuary of the Weser emerged in a different atmosphere. The importance of eel fishing for the local economy in this area gave local fisheries associations considerable influence, which they brought to bear on the regional government; it then urged hydroelectric operators to establish effective protection schemes. To support the upstream migration of the glass eel near the mouth of the North Sea, it was sufficient to place moistened linen sacks or bundles of brushwood in front of the dams, which enabled the tiny animals to demonstrate their "astonishing facility in climbing" (Pintner 1908, p. 122; Dallmer 1882, pp. 4–6; Fig. 4). Alternatively, millers constructed wooden channels from old boards, covered with gravel and painted black, which provided darkened routes across the dams for the photophobic animals (Hennings 1904, p. 112). Iron constructions, by contrast, were not recommended as migration aids, since the eels recoiled from "contact with metal" (Gerhardt 1912, p. 492). As these simple measures were cheap to install and did not interfere with hydropower operations, only a few hydroelectric power operators in the estuaries of the Rhine and Weser "resisted such installations" (Gerhardt 1892, p. 745; Keller 1885, p. 276).

The variations in the physiology of eels at different points along the watercourse functioned as conditions for differing requirements to facilitate eel migration and thus regional differences in technical expertise for implementation. The expert discussion of eel conservation measures in the academic and specialist literature of the time was conducted primarily by members of northwestern German fisheries associations. This regional concentration of expert knowledge was also noted in 1925 by the anonymous reviewer of a new textbook on the construction and operation of fishways (*Anlage und Betrieb von Fischpässen*; Frischholz 1925). Although the manual presented a range of models for salmon ladders, trout passes, and fish locks, the reviewer was unable to find any designs suited to eels, a fact that he attributed to the origin of the author Eugen Frischholz. Frischholz was an itinerant teacher from Upper Bavaria, where eel fishing was of little significance (Anonymous 1925, p. 403).

The intensive efforts made along the Lower Weser at Hemelingen bears out the importance attached to the facilitation of eel migration in the estuary area. At the turn of the twentieth century, plans were announced to construct a large-scale dam on the Weser near the small city of Hemelingen. This project—eventually built between 1905 and 1910—posed an insurmountable obstacle at a critical point in the migration pathways of the eels and caused uproar among those with interests in fishing. Fearing the extinction of the eel population on their river, and thus for the economic existence of its members, the Fisheries Association for the Weser, Ems, and Coastal Areas launched what would become a protracted legal dispute. The resulting ruling required the city authorities to build effective protection measures for different fish species and stipulated penalty clauses requiring the dam operator to pay serious compensation to the local fishermen if the dam obstructed the free passage of fish (Oeltjen 1912, p. 1327). As a result, the construction authorities made serious efforts to realize a "superior" and cost-intensive system to protect fish migration. Sparing no expense, the fishway system at Hemelingen cost fifteen times as much as the most expensive fish ladder ever built in the Rhine and Weser River basins (Anonymous 1909–1912, p. 42; on the construction of the facility, see Zumbrägel 2020).

Different species of fish required different kinds of installations to enable their migration through the new hydroelectric installation. A steep fish ladder installed in the middle of the dam enabled strong-swimming fish such as salmon and trout to make the climb, while a fish lock served those species less capable of climbing. Meanwhile on the left bank of the Weser, a bypass channel was built to permit the passage of adult salmon, trout, and shad from the North Sea to their spawning grounds in the upper course of the Weser. The dam also incorporated an eel ladder and other installations to facilitate the upstream migration of juvenile glass eels. Seeking to prevent the entry of mature silver eels into the rotating turbines on their way back to the sea and thus their death and injury, a metal grid was installed at the entrance to the turbine chamber. The spacing of 15 mm distance between the bars of the grid made it clear that the installation had prioritized effectiveness in fish protection over efficiency in energy production. An additional eel channel was dug to guide the fish on their downstream journey. Also indicative of the will to protect the eels was the decision to reduce the number of turbines installed in the power plant from six to five,

Fig. 5 Hundreds of juvenile glass eels crowded in front of a dam at the Weser river, willing but unable to find a way to migrate upstream (Anonymous 1909–1912)

thereby reducing the risk of striking eels (Eberts 1911, pp. 420–423). During the migration period in autumn the dam-keeper lowered the weir and opened the navigation lock of the Hemelinger dam not for ships, but to let through migratory shoals of juvenile glass eels (Anonymous 1922b, pp. 89–91).

As common and widespread as eels were on the north German dinner table, comparatively little was known at the turn of the century about their migratory behaviour. This lack of understanding soon became apparent through the construction of the Hemelinger fishway system. Eschewing the eel ladder installed for their upstream migration, the glass eel instead attempted to climb the gate of the navigation lock (Häpke 1913, p. 196). Since in most cases the eels failed to climb this ladder, "starved eel fry" were regularly found in the water in front of the dam (Henking 1920, pp. 118–119; Fig. 5). Prompted by the eels' migratory behaviour, the hydraulic engineer Johannes Oeltjen, who was responsible for these installations, prioritized the completion of the bypass channel originally intended for other migrating fish, repurposing it for eels by installing clay eel tubes at the transitions between the water basins and scattering dark gravel in the channel and thus providing the eels with the cover that they preferred. His technological adaptations had the desired effect and many glass eels could be observed using the new route (Henking 1920, p. 119; Häpke 1914, p. 451).

The initial failure of those facilities designed to assist juvenile glass eels ascend to inland waters triggered a second strategy that increasingly supplanted previous efforts to protect the natural migratory regime of the species. Seeing that the encroachment of industry and hydropower on the river had significantly reduced the natural eel migration along its course, the German Fisheries Association (*Deutscher Fischerei-Verein*) felt forced to take more direct action to ensure the migratory paths (Anonymous 1922a, p. 69). By the start of the interwar period at the latest, the dams at Hemelingen and Dörverden became the most important glass eel depots in the basin of the Weser (Schiemenz 1921, p. 117). At Hemelingen, the Bremen Fisheries Association (*Fischereiverein Bremen*) was commissioned to take millions of juvenile glass eels from the river in front of the dam and release them on the other side so that the animals could continue their upstream migration. At the Dörverden dam, forty kilometres upstream from Hemelingen, this was the task of the fisherwoman Otte—one of the few female fisheries experts in the Weser basin (Anonymous 1921b, p. 25; Anonymous 1921a, p. 98). The German Fisheries Association also acted to redistribute large numbers of glass eels by rail, transporting them from these areas of highest abundance at German river mouths to underpopulated waters in the South. This redistribution has become commonly known as "stocking" or "restocking". The intervention to ensure the mobility of these juvenile eels wrought new spatial interconnections, creating contact zones between the upstream and downstream sections of the watercourse and thereby connecting the segmented spaces of fishing within the river basins.

That such extensive and targeted measures were taken to protect eels was a result of many factors. Technological advances in transportation making possible new practices in storing and packing live fish coincided with increased pressure on fisheries from the industrialization of rivers in general and threats to eel populations in particular. Moreover, the eel's far greater tolerance of a much broader range of environmental conditions meant that it was far better suited for transport over long distances than other aquatic organisms. The eels were moved in wooden crates topped with ice, the water of which condensed and dripped onto the eel fry during transport and kept them "fresh for 12 to 24 h" (Walter 1910, p. 231). This mass transport was made economical by the highly profitable nature of eels as a commodity and the rapid and considerable growth which they displayed in the rich southern German feeding grounds to which they were transported.[2]

The first tentative attempts to transport glass eels as a means of restocking in other rivers began in the 1870s, when the German Fisheries Association initiated a programme to introduce glass eels into the Danube to replace the disappearing huchen or Danube salmon (Elsner 1899). In another, less successful move, the glass eels released into the Black Sea failed to reproduce (Haack 1881). These efforts were followed by the first transnational attempts to relocate glass eels from the banks of the Severn estuary near Epney in England to the eel depot in Hamburg, where they were refreshed, repacked, and shipped by rail to various destinations throughout Germany, including regions as far away as the High Rhine. The World Wars interrupted these international relations in eel trading, so that German coastal locations such as Herbrum on the Ems, Dörverden and Hemelingen became more significant for obtaining glass eels (Dekker and Beaulaton 2016, pp. 273–275; Lübbert 1927, pp. 209–211). When international cooperation in eel restocking was resumed in the second half of the twentieth century, the international interventions of researchers and fishermen to maintain eel migration transformed this species into what many have called a "eurofish". Since the 1970s European countries have struggled to develop a common policy for protecting this shared species. Environmental historian Peter Coates has gone as far as to interpret these transnational efforts to protect eels as the nucleus of a European conservation movement (Coates 2021).

[2] The crucial factor explaining the lengths to which fisheries associations were prepared to go to maintain the eel population, however, was the failure by fisheries scientists to develop a successful large-scale and economically viable artificial breeding program for the eel. To this day, the continued existence of eels in rivers and hatcheries remains entirely dependent on wild eel stocks.

Conclusion

Fishing practices, efforts towards species protection, and local food cultures were influenced by a complex mix of socio-natural interactions—hydrological conditions, local working traditions, human intervention in the river environment, and the migration patterns of the eel. The latter has so far received little to no attention from historians working at the junction of river and fishing history. This article has not sought to establish a new concept of environmental determinism which overstates the agency of non-human life in historical narratives. Rather, the goal has been to present an analytical approach to conceptualize the interactions of aquatic organisms with natural forces and human actions in the process of constituting spaces. Drawing on perspectives from environmental history, human-animal studies, and spatial theory, it has broadened resource-centred approaches to aquatic animals by considering the biological and behavioural patterns of fish migration as an influential factor. This was shown by the example of the fishway system at the Hemelinger dam. The migrating glass eels co-structured and challenged sociotechnical activities, rarely interacting with eel ladders and other technical devices as hydraulic engineers expected. Attempts to control organisms can have unintended consequences, since the reactions of animals produce contingencies and uncertainties. Writing fisheries histories from the animals' point of view, as suggested by scholars from the human-animal studies, reveals that migrating eels are "agents capable of developing distinct forms of resilience when facing human power" (Duarte et al. 2023, p. 9). In this case, the living agency of the eel has shown the limitations of hydroengineering planning processes. This perspective can also increase our awareness of the fragility and contingency of historical processes and enlarge our understanding of how technological change has been shaped by the non-human world. Through their ability to make their own choices about whether to use a given fish pass and in what way, migratory fish have co-produced sociotechnical activities along our rivers and creeks.

The application of a more-than-human perspective to understanding fish migratory patterns has enabled us to develop an alternative storyline that brings out the multifarious and complex interrelations between animals, humans, and the environment—a narrative that goes beyond the traditional view of declining inland fisheries resulting from industrialization. Eel fishing represents an interesting example of this kind of continuity that was particularly significant in the Rhine and Weser Rivers until well into the twentieth century. This transformation of eel fishery from a local artisanal practice to a much larger industrial activity occurred within historical contexts marked by regional depletion of earlier migratory salmon stocks, increased scientific understanding of eels, spatial differentiation of species behaviour in river systems, conflicts with contemporary construction of hydroelectric facilities, and efforts to mitigate those impacts. Another example is the persistence of traditional eel fishing methods in many tributary areas, handed down through local fishing practices and specific knowledge of the life stages of the eel and its behavioural patterns. Eel fishing was a highly complex craft that required not only knowledge of the diverse river ecologies and long personal experience but also the ability to make and use various kinds of devices—eel lines, basket traps, boxes, and *Aalschokker*; many of these were designed to catch eels during a specific stage of the life cycle. Tracing the path of migratory eels through their freshwater habitats thus also foregrounds widely neglected aspects in the twentieth-century history of German fisheries, expanding historical knowledge about the commonly ignored freshwater fisheries of Europe in the twentieth century.

The approach taken here also contributes conceptually to the history of rivers by addressing a core question of spatial theory: how can complex dynamic phenomena such as rivers—which are always in flux, and in which historical processes overlap at different scales—be understood in spatial terms? River histories typically circumvent these methodological challenges by tailoring their analysis to a single level of scale, emphasizing a micro, meso or macro approach (Schönach 2017, pp. 240–244). In this respect, there is also no right or wrong choice. As the environmental historian Richard White noted in 1999: "each scale reveals some things while masking others" (White 1999, p. 977). The history of fish migrations makes it possible to switch between these scales, thereby combining different aspects of fisheries history at the micro, meso, and macro levels. The spatial scale of connectivity may span localities and regional specificities to encompass processes that merge into larger scales and affect the entire river basin or—as shown by the example of eel restocking—go even further to national or transoceanic contexts. A historical analysis that follows migrating fish allows us to conceptualize the multispatiality of river dynamics, contributing to a more nuanced and comprehensive understanding of flowing spaces.

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References

Anonymous (1798) Ueber Thierfang und Jagd, mit Rücksicht auf die Grafschaft Mark und deren Geschichte. Magazin für Westfalen 2:164–222

Anonymous (1799) Anleitung zur Anwendung der Wasserbau-Gesetze auf die Fabriken-Gebäude und Ströme der Grafschaft Mark. Magazin für Westphalen 1:63–125

Anonymous (1885) Ausstellungs-Bericht über die Fischerei-Ausstellung in Kassel im November 1884. Mittheilungen an die Mitglieder des Vereins zur Förderung der Fischzucht im. Reg. Bez. Kassel II 2:56–58

Anonymous (1889) Kurzer Führer durch die Fischerei-Ausstellung. Cassel, Kassel

Anonymous (1890) Ueber Aalpässe. Circulare des Deutschen Fischerei-Vereins 20:71–76

Anonymous (1891) Report of the annual meeting of the Westphalia Fisheries Association, 27 May 1891 [Regional Archives North Rhine-Westphalia, Oberpräsidium Münster, no 1856, vol 1 – Fischereiverein für die Provinz Westfalen (1886–1894), p 243]

Anonymous (1900) Aale in den Turbinen. Allgemeine Fischerei-Zeitung 3:842

Anonymous (1907) Die Wirksamkeit der Fischwege. Allgemeine Fischerei-Zeitung 32:186–191, 212–215

Anonymous (1909–1912) Bau des Weserwehrs [State Archives Bremen, Nr. 4,33/2, Wasserstrassendirektion, 83]

Anonymous (1910) Turbinen und Fischzucht. Allgemeine Fischerei-Zeitung 35:269–270

Anonymous (1911) Ausübung der Fischerei im eigenen Mühlgraben. Zeitschrift für die gesamte Wasserwirtschaft 6:107

Anonymous (1913) Die Schädlichkeit der Rheinkraftwerke. Allgemeine Fischerei-Zeitung 38:526

Anonymous (1914) Wie sich ein schwäbischer Müller eine 'Fischleiter' vorstellt. Allgemeine Fischerei-Zeitung 39:341
Anonymous (1921a) Vereinsnachrichten. Fischerei-Verein Bremen, Generalversammlung. Fischerei-Zeitung für das Weser- und Emsgebiet 1:39
Anonymous (1921b) Das Aufsteigen der Aalbrut. Fischerei-Zeitung für das Weser- und Ems-Gebiet 1:25
Anonymous (1922a) Letter from the office of the Fisheries Association of the Weser, Ems and Coastal Area to the governments of the Prussian States, 23 February 1922 [Regional Archives North Rhine-Westphalia, L 79 No 4906: Fischerei. Verschiedenes, pp 69–70]
Anonymous (1922b) Dritte Sitzung des Fischereiausschusses für die Unterweser am Sonnaabend den 29. Juni 1922. Fischerei-Zeitung für das Weser- und Ems-Gebiet 2:89–91
Anonymous (1925) Bücherschau. Allgemeine Fischerei-Zeitung 50:403
Baar F (1903) Ein Beitrag zur Schädigung der Aale durch Turbinen und Mühlräder. Fischerei-Zeitung 6:166–167
Balcombe J (2016) What a fish knows. The inner lives of our underwater cousins. Scientific American, New York
Benecke B (1883) Der Aalfang im süßen Wasser. Bayerische Fischerei-Zeitung 8:89–129
Berman CH (2010) Reeling in the eels at la Trinquetaille near Arles. In: Scott B (ed) Ecologies and economies in medieval and early modern Europe. Brill, Boston, pp 149–164
Blackbourn D (2006) The conquest of nature water. landscape and the making of modern Germany. Norton, London
Bonne G (1913) Die Verunreinigung unserer deutschen Gewässer und ihre Verhütung. Zweite Gemeinsame Tagung für Denkmalpflege und Heimatschutz. Dresden, 25. und 26. September 1913. Wilhelm Ernst & Sohn, Berlin, pp 163–197
Borgmann H (1892) Die Fischerei im Walde Ein Lehrbuch der Binnenfischerei für Unterricht und Praxis. Julius Springer, Berlin
Brantz D (2017) Assembling the multitude: questions about agency in the urban environment. Urban History 44:130–136. https://doi.org/10.1017/S0963926816000304
Budai J (2006) Die Fischerei am Oberrhein. Historischer Verein für Mittelbaden, Rheinau
Buxbaum L (1889) Der Zug der Fische im Main im Frühjahre 1889. Der Zoologische Garten 30:233–236
Cioc M (2022) The Rhine. An Eco-Biography, 1815–2000. University of Washington Press, Seattle
Coates P (2021) Protecting eurofisch: an environmental history of the European Eel and its europeanness. In: Wöbse AK, Kupper P (eds) Greening Europe: environmental protection in the long twentieth century—a handbook. De Gruyter, Oldenbourg, Berlin, pp 101–128
Coaz J (1900) Etwas über Fischstege. Beilage zur Schweizerischen Fischerei-Zeitung, No 1 to No 3, Vol. VII
Cusack T (2010) Riverscapes and national identities. Syracuse University Press, New York
Dallmer E (1882) Ueber Errichtung von Aalbrutleitern. Circulare des Deutschen Fischerei-Vereins 4:4–6
de Cabral D, Lähdesmäki H (2023) Multispecies cultures and environmental change the animal (agency) turn. In: San Martín W, Carey M, Swart S (eds) The Routledge handbook of environmental history. Routledge, London, pp 91–106
Dekker W (2019) The history of commercial fisheries for European eel commenced only a century ago. Fisheries Management and Ecology 26:6–19. https://doi.org/10.1111/fme.12302
Dekker W, Beaulaton L (2016) Faire mieux que la nature—the history of eel restocking in Europe. Environment and History 22:255–300. https://doi.org/10.3197/096734016X14574329314407
Demuth B (2024) On the agency of environmental history. Journal of Social History 57:398–403. https://doi.org/10.1093/jsh/shad057
Denzer HW (1966) Beiträge über die Schädigung der Berufsfischerei am Rhein im Lande Nordrhein- Westfalen. Fischwirt 16:253–264
Doose W (1908) Eine Wenig Bekannte Aalfangmethode. Allgemeine Fischerei-Zeitung 33:393–394
Duarte R, Swart S, Soluri J (2023) Introduction: new geographies in animal history. Global Environment 16:7–11. https://doi.org/10.3197/ge.2022.160101
Eberts H (1906) Die Fischpässe der Weserwehre. Fischerei-Zeitung. Wochenschrift für Interessen der gesamten Deutschen Binnen-Fischerei 32:315–319
Eberts H (1911) Wasserwirtschaftliche Rundschau. Jahresbericht der 27. Hauptversammlung des Westdeutschen Fischereiverbandes. Zeitschrift für die gesamte Wasserwirtschaft 6:418–423
Ehrenbaum E (1930) Der Flussaal. In: Demoll R, Maier HN (eds) Handbuch der Binnenfischerei Mitteleuropas. Schweizerbart, Stuttgart, pp 160–217
Elsner B (1899) Ueber die Besetzung der Binnengewässer mit Aalen. Allgemeine Fischerei-Zeitung 24:107–111

Evenden M (2006) Fish vs. power: salmon, science and society on the fraser river. In: Tvedt T, Coopey R (eds) A history of water. Cambridge University Press, London, pp 430–443
Febvre L (2006) [1931] Der Rhein und seine Geschichte. Campus, Frankfurt a. M.
Finley C (2017) All the boats on the ocean: how government subsidies led to global overfishing. Chicago University Press, Chicago
Finstad T (2017) Naked gene salmon: debating fish, genes, and the politics of science in the "age of publics." Technology and Culture 58:97–120
Flebbe H (1967) Schlächte- und Fischereiordnung Nr. 228. In: Flebbe H (ed) Quellen und Urkunden zur Geschichte der Stadt Altena (Westf.), Bd. 1: Von den Anfängen bis 1609. Eigenverlag Stadt Altena, Altena
Frischholz E (1914) Fischwege. Allgemeine Fischereizeitung 39:467–470
Frischholz E (1925) Anlage und Betrieb von Fischpässen. Schweizerbart, Stuttgart
Gerhardt P (1892) Anlage von Aalpässen. Anlage 2. Die Mühle 29:745–746
Gerhardt P (1904) Fischwege und Fischteiche. Die Arbeiten des Ingenieurs zum nutzen der Fischerei. Wilhelm Engelmann, Leipzig
Gerhardt P (1912) Die Fischwege. In: Rehbock T et al (eds) Handbuch der Ingenieurwissenschaften. Wilhelm Engelmann, pp 454–499
Görcke H (1918) Das Preußische Fischereigesetz vom 11. Mai 1916 (nebst der Fischerei-Ordnung vom 29. März 1916 und den sonstigen fischereigesetzlichen Vorschriften für Preußen. HW Müller, Berlin
Gutting W (1943) Die Aalfischer. Gauverlag Bayreuth, Bayreuth
Haack H (1881) Bericht über die erste größere Aussetzung von Aalen in das Gebiet der Donau. Circulare des Deutschen Fischerei-Vereins 11:123–125
Haidvogl G, Lajus D, Pont D, Schmid M, Jungwirth M, Lajus J (2014) Typology of historical sources and the reconstruction of long-term historical changes of riverine fish: a case study of the Austrian Danube and northern Russian rivers. Ecology of Freshwater Fish 23:498–515. https://doi.org/10.1111/eff.12103
Haidvogl G, Hoffmann R, Pont D, Jungwirth M, Winiwarter V (2015) Historical ecology of riverine fish in Europe. Aquatic Sciences 77:315–324. https://doi.org/10.1007/s00027-015-0400-0
Häpke L (1913) Über das Weserwehr und seine Fischpässe. In: Brauer A (ed) Verhandlungen der Deutschen Zoologischen Gesellschaft auf der dreiundzwanzigsten Jahresversammlung zu Bremen vom 13. Bis 15. Mai 1913. Gustav Fischer, Berlin, pp 195–197
Häpke L (1914) Fischpässe und Aale am Weserwehr bei Bremen. Allgemeine Fischerei-Zeitung 39:450–451
Härry A (1917) Die Fischwege an Wehren und Wasserwerken in der Schweiz. Rascher, Zurich, Leipzig
Henking H (1920) Neue Wanderwege für die Fische der Unterweser. Mittheilungen des Deutschen Seefischereivereins 36:112–122
Hennings (1904) Fischpässe und Aalschutzvorrichtungen. Allgemeine Fischerei-Zeitung 24: 112–113
Heuscher J (1899) Fischereiverhältnisse in Der Aaare. Schweizerische Fischereizeitung 7:49–67
Heyking H (1898) Turbinen und Aale. Fischerei-Zeitung 1:372–373
Heyn J (1891) Betreffend Rechenfrage bei Turbinen. Circulare des Deutschen Fischerei-Vereins 21:164
Hoech T (1889) Einrichtungen an Wassertriebwerken zum Schutze der Fische. Circulare des Deutschen Fischerei-Vereins 19:16–20
Hoffmann R (2008) Medieval Europeans and their aquatic ecosystems. In: Herrmann B (ed) Beiträge zum Göttinger Umwelthistorischen Kolloquium 2007–2008. Universitätsverlag Göttingen, Göttingen, pp 45–64
Hoffmann R (2023) The Catch. An Environmental History of Medieval European Fisheries. Cambridge University Press, Cambridge. https://doi.org/10.1017/9781108955898
Höing A (1919) Das preussische Fischereigesetz von 1916 in seiner Bedeutung für die Industrie. Buchdruckerei Hans Adler, Greifswald
Höinghaus R (1874) Fischereigesetz für den Preußischen Staat vom 30. Mai 1874. Nach den amtlichen Motiven und den Kommissionsberichten des Landtages. Wiegandt Hempel & Parey, Berlin
Hübner A (1905) Die Meinung der Praktiker. In: Hübner A (ed) Fischwirtschaft. Gesammelte Arbeiten aus 25jähriger öffentlicher Tätigkeit und 40jähriger Praxis. Emil Hübners, Bautzen, pp 122–131
Humphries P, Winemiller KO (2009) Historical impacts on river fauna: shifting baselines and challenges for restoration. Bioscience 59:673–684. https://doi.org/10.1525/bio.2009.59.8.9
Jakobsson E (2002) Industrialization of rivers: a water system approach to hydropower development. Knowledge, Technology and Policy 14:41–56. https://doi.org/10.1007/s12130-002-1014-0
Jørgensen D (2014) Not by human hands. Five technological tenets for environmental history in the anthropocene. Environment and History 20:479–489. http://www.jstor.org/stable/43299700

Keller H (1885) Die Anlage der Fischwege. Zentralblatt der Bauverwaltung 5:259–278
Kinsey D (2006) "Seeding the water as the earth". The Epicenter and Peripheries of western aquacultural revolution. Environmental History 11:527–566. http://www.jstor.org/stable/3986030
Knight W (2017) Fish out of water fish exhibition in late nineteenth-century Canada. In: Ingram D, Sethna C (eds) Animal metropolis. Histories of human-animal relations in urban Canada. University of Calgary Press, Calgary, pp 115–138
Knoll M, Lübken U, Schott D (2017) Introduction. In: Lübken U, Schott D (eds) Rivers lost—rivers regained. Rethinking city river relationships. University of Pittsburgh Press, Pittsburgh, pp 3–22
Koch W (1937) Entwicklung und Stand der Fischzucht in Baden. Beith, Adelsheim
Koch W (1955) Von den Existenzkämpfen der Rheinfischerei. Badische Heimat 25:228–237
Kölle J (1916) Die Wehranlage in der Weser bei Bremen. Zeitschrift des Vereines Deutscher Ingenieure 60:81–107
Kuhn G (1976) Die Fischerei am Oberrhein. Ulmer, Stuttgart
Lajus J (2023) Fish as a resource and a curiosity in international exhibitions at the end of the nineteenth century. Global Environment 16:57–74. https://doi.org/10.3197/ge.2023.160104
Lenders R (2017) Fish and fisheries in the Lower Rhine 1550–1950: a historical-ecological perspective. Journal of Environmental Management 202:403–411. https://doi.org/10.1016/j.jenvman.2016.09.011
Lenders R, Chamuleau T, Hendriks A et al (2016) Historical rise of waterpower initiated the collapse of salmon stocks. Scientific Reports 6:29269. https://doi.org/10.1038/srep29269
Liburnau HRL (1908) Die Forstlichen Hilfsgegenstände, Wien
Lien M (2015) Becoming salmon. Aquaculture and the domestication of a fish. California University Press, Oakland
Limmer A, Zumbrägel C (2020) Waterpower Romance. The cultural myth of dying watermills in German hydro-narratives around 1900. Water History 12:179–204. https://doi.org/10.1007/s12685-020-00252-6
Linse U (1988) "Der Raub des Rheingoldes". Das Wasserkraftwerk Laufenburg. In: Linse U et al (eds) Von der Bittschrift zur Platzbesetzung. Konflikte um technische Großprojekte. Laufenburg, Walchensee, Whyl, Wackersdorf, Dietz, Berlin, pp 11–63
Lübbert H (1927) Die Versorgung Deutschlands mit Aalbrut in der Zeit nach dem Kriege. Der Fischerbote 19:205–211
Lundbeck J (1927) Untersuchungen über die Beschädigung von Fischen, besonders Aalen, in den Turbinen des Kraftwerks Friedland (Ostpr.). Zeitschrift für Fischerei 25:438–465
McEvoy A (1986) The fisherman's problem. Ecology and law in the California fisheries, 1850–1980, Cambridge University Press, Cambridge
Meyer-Waarden P (1968) Die Lage der Flußfischerei. In: Meyer-Waarden P (ed) Die deutsche Aalwirtschaft. Wege zu ihrer Intensivierung. Westliche Berliner Verlagsgesellschaft Heenemann KG, Wilmersdorf, Berlin, pp 1–16
Müller K (1959) Fischpässe in regulierten Flüssen. Weser. Monatsschrift des Weserbundes e.V. 12:161–163
Nitsche H (1886) Der Flussaal und seine wirtschaftliche Bedeutung, Dresden
Nolte W (1953) Versuch einer Statistik des Landesfischereiverbandes Niedersachsen. Neues Archiv für Niedersachsen 7:332–350
Nolte W (1976) Die Küstenfischerei in Niedersachsen. Kommissionsverlag Göttinger Tageblatt, Göttingen
Oeltjen J (1912) Jahresbericht der Bauinspektion für die Unterweserkorrektion über die Ausführung der Wehr-, Schleusen- undTurbinenanlage in der Oberweser bei Bremen für das Jahr 1911. Verhandlungen zwischen dem Senate und der Bürgerschaft inden Jahren 1901–1910:1326–1329
Pauly D (1995) Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution 10:430. https://doi.org/10.1016/s0169-5347(00)89171-5
Pintner T (1908) Die Aalfrage. Vortrag gehalten den 20. November 1907. Schriften des Vereins zur Verbreitung naturwissenschaftlicher Kenntnisse 48:119–143
Poulsen B (2016) Global marine science and Carlsberg: the golden connections of Johannes Schmidt (1877–1933). Brill, Leiden, Boston
Pritchard S (2011) Confluence. The nature of technology and the remaking of the Rhone, Harvard University Press, Cambridge
Rau S (2016) Fließende Räume oder: Wie läßt sich die Geschichte des Flusses schreiben? Historische Zeitschrift 291:103–116. https://doi.org/10.1524/hzhz.2010.0035
Reclam E (1914) Turbinenrechen. Fischerei-Zeitung 17:405–409

Schenk U (1931) Die Wasserwirtschaft im Niederschlagsgebiet der Ruhr. Eine volkswirtschaftliche Untersuchung. Lechte, Emsdetten
Schiemenz P (1910) Was frisst der Aal? Der Fischerbote 1:197–200
Schiemenz P (1921) Die wirtschaftliche Bedeutung des Aals im Weser-Ems-Gebiet. Fischerei-Zeitung für das Weser- und Ems-Gebiet 12:115–119
Schiemenz P (1922) Bildet Fischereigenossenschaften [Regional Archives Lower Saxony Osnabrück, Rep 335, Nr. 14935: Anlage von Aalbrutleitern an den Emswehren zu Rheine, Listrup-Mehringen und Hanekenfähr, pp 97–98]
Schiemenz F (1930) Wasserbauliche Forschungen Zugunsten der Fischerei. Fischerei-Zeitung 33:301–307
Schiemenz F (1940) Abänderungen und neue Formen der Aaltreppe. Verlag J. Neumann, Neudamm and Berlin [Regional Archives Lower Saxony Osnabrück, Rep 675, Mep, Akz. 2000/029, Nr. 14]
Schiemenz F (1942) Arbeiten aus dem staatlichen Fischereiamt für die Binnengewässer der Provinz Hannover. Jahresbericht der Naturhistorischen Gesellschaft zu Hannover 92/93:92–106
Schmidt J (1906) Contributions to the life of the eel. Rapports Et Procès-Verbaux Des Réunions 5:137–274
Schmidt FW (1922) Die Stauanlage in der Weser bei Dörverden. Zeitschrift Für Bauwesen 72:362–384
Schmidt J (1923) Die Laichplätze des Flußaals. Internationale Revue der gesamten Hydrologie und Hydrographie 11:1–40
Schönach P (2017) River histories: a thematic review. Water History 9:233–257. https://doi.org/10.1007/s12685-016-0188-4
Seelig FW (1890) Ueber die Anwendung und den Nutzen der Fischwege. Allgemeine Fischerei-Zeitung 15:221–224, 233–237
Sichler R (1922) Bericht des Braunschweigischen Fischerei-Vereins über die Arbeit im Interesse der Fischerei im Weser-Ems-Gebiet. Fischerei-Zeitung für das Weser- und Ems-Gebiet 2:103–105
Staudinger V (1889) Aus dem Gebiete des Fischereirechts. Das Recht auf Selbstfänge und besonders Aalkörbe. Allgemeine Fischerei-Zeitung 19:217–219
Steinberg T (1991) Nature incorporated. Industrialization and the waters of New England. University of Massachusetts Press, Cambridge
Steinmann P (1936) Die Fische der Schweiz. Sauerländer, Aarau
Taylor J (1999) Making salmon. An environmental history of the northwest fisheries crisis. University of Washington Press, Seattle
Tvedt T (2010) Water systems. Environmental history and the deconstruction of nature. Environment and history 16:143–166. http://www.jstor.org/stable/20723773
Van Dam P (2003) Eel Fishing in Holland. The transition to the early modern economy. International Journal of Maritime History 15:163–175. https://doi.org/10.1177/084387140301500211
Verband deutscher Müller (1892) Anlage von Aalpässen. Die Mühle 47:745–756
Walter E (1903) Die Fischerei als Nebenbetrieb des Landwirtes und Forstmannes. J. Neumann, Neudamm
Walter E (1907) Die Fischereiliche Bewirtschaftung der Talsperren. Die Talsperre 6:25–28
Walter E (1910) Der Flußaal. Eine biologische und fischwirtschaftliche Monographie. J. Neumann, Neudamm
White R (1995) The organic machine. The remaking of the Columbia River. Farrar, Straus and Giroux, New York
White R (1999) The nationalization of nature. Journal of American History 86:976–986
Wiehr H (1950) Binnenfischerei. Jahresbericht über die deutsche Fischerei:196–204
Winiwarter V, Schmid M (2020) Socio-natural sites. In: Knoll M, Mares D, Haumann S (eds) Concepts of urban-environmental history. Transcript, Bielefeld, pp 33–50
Wöbse AK (2021) Environmental history. In: Roscher M, Krebber A, Mizelle B (eds) Handbook of historical animal studies. De Gruyter Oldenbourg, Boston, pp 293–308
Wundsch HH (1949) Die Veredelungsnamen bei Fischen. Abhandlungen aus der Fischerei und deren Hilfswissenschaften 1:505–514
Zumbrägel C (2020) How a fishway from Norway reached the Weser River in Germany (1905–1912). Arcadia. https://doi.org/10.5282/rcc/9052
Zumbrägel C (2021) Der Lachs auf der Leiter. Fischwege und Fischwanderungen an norddeutschen Flüssen um 1900. Traverse 2:71–90. https://doi.org/10.5169/seals-953614
Zumbrägel C (2022) Hydropower and dams. An entangled history of academic engineers, local knowledge and environmental features (1880–1930). In: Heine EC, Meiske M (ed) Beyond the lab and the field: infrastructures as places of knowledge production since the nineteenth century. Pittsburgh University Press, Pittsburgh, pp 63–84. https://doi.org/10.2307/j.ctv2fwfz3h.7

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