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Editorial: Non-native species and biodiversity change in river ecosystems: a historical perspective

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Editorial on the Research Topic
Non-native species and biodiversity change in river ecosystems: a historical perspective

The global spread of non-native species is thought to be among the most severe pressures on biodiversity (e.g., Keller et al., 2011). Species introductions are increasing worldwide and have done so at an unprecedented rate in recent decades. There is no sign of saturation (Seebens et al., 2017). Future increases in trading and climate change can exacerbate non-native species introductions, not least because new trading routes, such as the Northern Sea Route, might reduce travel times and, therefore, the likelihood of survival for species "traveling" unintentionally on cargo ships (Hulme, 2021).

However, the phenomenon is not new, as species transfer into new regions has a long history. Recent studies have proven that intercontinental trade has been a primary driver for centuries of species exchanges. For example, the intentional and unintentional dispersal of non-native plant species was substantially shaped by European colonial empires, particularly the Spanish, Portuguese, Dutch, and British. Regions that belonged to the same empire exhibit at present more similar species compositions, and the duration of colonial influence also played a role (Lenzner et al., 2022).

Aquatic ecosystems are no exception. The presence of non-native species is considered to be a significant cause of biodiversity change there, next to land use change, eutrophication, hydrological and morphological alterations, climate change, overexploitation, and newly emerging threats such as microplastics or engineered nanomaterials (Petsch, 2016; Reid et al., 2019). Direct and indirect human interventions such as fishery, fish stocking, aquaculture, inland, and inter-sea shipping canals, or global trade – including transfers of ornamental and aquarium fish – are significant drivers of the introduction, establishment, and dispersal of non-native species in freshwater systems (Tarkan et al., 2021). Richmond et al. name the fur trade as an economic driver for introducing the American beaver (*Castor canadensis*) into the Southern California/Northern Baja California Coast Ecoregion in the 20th century. Together with hydraulic structures built for flood control since the 1940s, the new ecological engineer species had initiated habitat changes that favored other non-native species.

Fish provides a well-studied example of long-term aquatic species introductions, which allows us to trace time-dependent introduction pathways (Muñoz-Mas et al., 2023). Until the 16th century, introductions and unintentional transfers of freshwater fish species for aquaculture, followed by individuals' escape into rivers, occurred mainly at the continental scale. In Europe, the common carp (*Cyprinus carpio*) was the most significant introduced species (Hoffmann, 1996), but species movements also involved other fish and crayfish (Clavero, 2022). In the 17th century, ornamental fish of central Asian or Chinese origin, such as the goldfish (*Carassius auratus*), were introduced to ponds in aristocratic parks in Portugal (1611) and England (1665) and similar types of fish were widely introduced in Western Europe also in the 18th century (Lever, 1996).

Simultaneously, artificial inter-basin connectivity through shipping canals started to play a significant role in the unintentional spread of aquatic species. A remarkable European example is the River Rhine, which has been gradually connected to other rivers since the 1830s. The total surface area of river catchments linked to the Rhine showed a stepwise increase from 190,000 km^2 to 4.3 million km^2 (i.e., an increase by a factor of 21.6). Consequently, the average number of macroinvertebrate invasions per decade has increased from <1 to 13 species (Leuven et al., 2009).

In the 19th century, intercontinental fish introductions from North America to Europe and vice versa aimed, among others, at improving fish populations in gradually degrading rivers (Copp et al., 2005). Such purposeful intercontinental translocations were paralleled by the intentions of the so-called Acclimatization Societies. Their target was to introduce exotic plant and animal species, e.g., to enhance stocks of domestic species, or to provide food as well as new game animals (Lever, 2011). Following ideas rooted in biological and ecological knowledge of the 19th century, especially their French adherers were convinced that species could adapt to new environments (Anderson, 1992).

The spread of non-native aquatic species had long-term impacts on the native local and regional biotic communities in rivers. To date, 76 European fish species have been introduced in freshwaters, of which approximately 50 have established self-reproducing populations; in some catchments, mainly in the Iberian Peninsula and the French Atlantic coast, the proportion of non-native fish species exceeds 40% (Tockner et al., 2022). Belliard et al. used historical data and archaeological remains to investigate the deliberate and unintentional introduction of fish species to the Seine River since the 16th century. They found that 46% of the rivers' fish species are non-native, with the number increasing especially since the 19th century.

Gallardo et al. (2016) identified adverse effects of invasive aquatic species on the abundance of macrophytes, zooplankton, and fish but no generalizable significant changes in biodiversity. From these findings, they concluded that there was a certain time lag, an "extinction debt" until (native) species disappear because of competition with those not native. Another kind of time lag is the "invasion debt", the time span needed until the effects of non-native species on biodiversity become visible at a large scale (Essl et al., 2011). Acknowledging that large-scale habitat change, the climate crisis, and global commerce as pathways for the unintended spread of non-native species characterize ecosystems in the Anthropocene and the challenge to erase non-species, concepts such as "no-analog communities" (Williams and Jackson, 2007) or "novel ecosystems" (Hobbs et al., 2009) have been coined. Using an environmental history approach to describe the long-term change of biodiversity of the Don River in the UK, Rotherham argues similarly. Elucidating the interplay between riverine processes, societal river uses, and motives for species introductions, he concluded that rivers nowadays exhibit a "recombinant ecology" that has to be taken into account in river restoration.

The contributions to this Research Topic show that investigating native and non-native species is not only an ecological subject. The topic involves various societal aspects and calls for interdisciplinary research to grasp the larger picture of environmental and societal interactions. The study of Kulman and Tamïr clearly demonstrates that. They investigated the social, cultural, and ideological background of mosquito fish (*Gambusia affinis*) introduction to Palestine in the 1930s, showing this process as an endeavor of a single person, i.e., the microbiologist Israel Kligler. They highlighted, among others, the tight connection between non-native species introductions and the advance of medical knowledge.

Studies involving scholars and scientists from the humanities and the social sciences can contribute important input in investigating dispersal pathways, the specific links between the intentional and unintentional pathways, or the changing societal motives for intended introductions, their success, and failures. Finally, interdisciplinary cooperation can enrich the discussion of future management practices in conservation and restoration ecology in general and for aquatic ecosystems in particular.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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