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# Sunken landscapes and settlement areas. On the reconquest of underwater archaeological sites

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Prehistoric lake dwellings around the Alps have been of great interest to researchers and are now part of the [UNESCO World Heritage List](#). These sites offer challenging but favourable building locations around a lake with constantly changing water levels, which likely resulted in a lot of movement from people and nature over time. When water levels rose, these sites were taken over by aquatic plants and animals. But owing to climate change, neozoa and neophytes are spreading quickly into new habitats. It is important to document and monitor these developments in order to understand the extent and potential threat of these species in different areas.

## 1. Introduction

Prehistoric lake dwellings around the Alps play an important role in researching and understanding the past because of their special location underwater or in water-saturated environments, such as bogs. This is reflected by the fact that since 2011, they have been on the UNESCO World Heritage List as outstanding archaeological sites (Figure 1). The lakes offered favourable, but also challenging, sites for building on their shores. As the highly complex stratigraphies of many sites show, constantly changing water levels, floods and debris flows resulted in a dynamic settlement environment even in prehistoric times, which probably resulted in a constant coming and going of people and nature (Swiecinsky *et al.* [2013](#)). After the disappearance of the lake dwellings on lake shores in the first millennium BC, when the water level rose steadily and village ruins sank under thick layers of lake marl, aquatic plants and animals reclaimed the shallow water zones. The old settlements were finally left to nature and new underwater habitats were created.

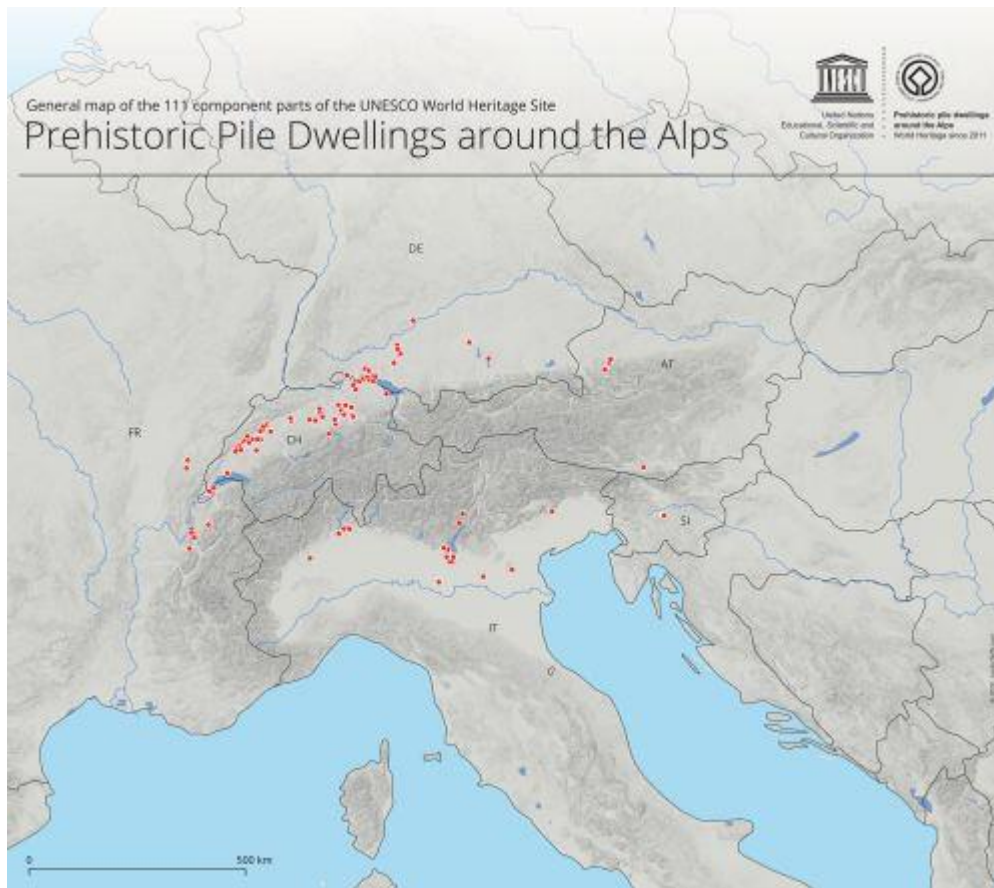


Figure 1: Map of the 111 sites inscribed as serial, transnational property at the UNESCO World Heritage list (©International Coordination Group Palafittes)

## 2. Threats

Long protected by sediments and natural shore vegetation, modern development around the lakes is increasingly threatening the preservation of the underwater cultural heritage. Since at least the mid-20th century, intensive building activity on the lakeshores and the disappearance of the reed beds have resulted in the shallow water zones being almost completely cleared in some places. This has had an enormous impact on the archaeological sites. The high pressure of development and rampant tourism compete with the preservation of the cultural heritage, which is hidden under water and therefore invisible. Additional changes to the flora and fauna make the situation even more dramatic. The shallow water zones, which also contain the remains of Neolithic and Bronze Age settlements, have become the preferred habitat for various invasive species that cause considerable damage.

Meanwhile, we have to consider a multitude of neozoa (alien animals) and neophytes (alien plants) as potential enemies of our underwater heritage. Depending on the local conditions, different animals and plants conquer a new habitat. In the maritime field, shipwrecks are well known to serve as artificial reefs for fish and plants (Asner *et al.* 2022). In inland waters, archaeological relics are utilised e.g. at eroded pile fields, where wooden remains protrude from the seabed. In the UNESCO World Heritage Site Keutschach am See, the pikeperch (*Sander lucioperca*) finds a



refuge between the piles in the middle of the lake (Figure 2) (Poppenwimmer [2020](#); Billaud [2021](#)). However, owing to the legal situation - the water is privately owned - and the economic importance and popularity of the pikeperch as an edible fish among sport anglers, the originally non-native pikeperch cannot simply be removed. Also in Keutschach, the native European noble crayfish (*Astacus astacus*) had made a home in the lake dwellings until recently (Petutschnig [2001](#)). There are numerous crayfish dens and corridors in the settlement area which are eroding the site in places and above all creating leverage points for erosion. However, these constructions seem to have been abandoned as a result of crab plague. Fortunately, the disease-resistant invasive signal crayfish (*Pacifastacus leniusculus*) and spiny-cheeked crayfish (*Faxonius limosus*) have not yet been able to establish themselves here. These two species are a serious threat to the lake dwellings in France and are widespread in Lake Constance (Hagmann and Köninger [2022](#)).



Figure 2: Pikeperches at the UNESCO World Heritage site of Keutschacher See in Carinthia/Austria (©Kuratorium Pfahlbauten)

Invasive mussels are also a growing problem. Native mussel species have disappeared owing to poor water quality and other factors, such as the Great Swan Mussel (*Anodonta cygnea*) or the Thick-shelled River Mussel (*Unio crassus*) and have not yet been able to establish new populations (Patzner [2019](#)). Species from the robust triangular mussel family Dreissenidae (e.g. the quagga mussel), which are thought to originate from the Black Sea region, are increasingly being found. They sometimes adhere to the lake bottom over large areas and in some places directly to archaeological finds such as wooden piles (Figure 3) (Hagmann and Köninger [2022](#)). Formerly autochthonous species, such as beavers, which are returning to their natural habitats along the riverbanks, are also contributing to the deterioration of lake dwellings by building their structures in the area of the archaeological reserves (Gschwind [2020](#)).



Figure 3: Dense coverage of the lake bottom with Zebra Mussels (*Dreissena polymorpha*) at the Iron Age site of Traunkirchen in Upper Austria (©Kuratorium Pfahlbauten)

Neophytes are also spreading in the circum-Alpine waters, and the coverage of sites with aquatic macrophytes can have different effects. On the one hand, there is the risk of greater destruction in the upper layers owing to a stronger root system within the lake sediments. On the other hand, there are also positive effects, as less sediment is removed in the calm area of algal carpets, and plants can even act as sediment traps.

The monitoring of archaeological sites at Lake Constance since 2012 shows a strong increase in macrophytes such as Swiss pondweed (*Stuckenia helvetica*) and, more recently, stonewort (*Chara globularis*) (Ebersbach *et al.* [2019](#)). The stonewort itself, which is native to Austrian lakes, is a protected species in the Attersee and Mondsee Natura 2000 sites and, like the beaver, raises the issue of potential conflicts of interest between nature conservation and the protection of cultural heritage. However, in line with the UNESCO World Heritage concept, which considers natural and cultural heritage as a whole, joint solutions must be found for the protection of both.

Documenting the spread of neozoa and neophytes and their new habitats is all the more important as they can also be seen as harbingers of climate change. In this context, the rapid establishment of effective and comprehensive monitoring of shallow water zones is urgently needed, as the extent and potential threat in many areas cannot be assessed at present.





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