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New occurrence of reed bed decline in southern Europe: Do permanent flooding and chemical parameters play a role?

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ABSTRACT

Based on the experimental design proposed in similar studies, macromorphological and ecological traits of common reed beds were analysed at Lake Chiusi (Central Italy), together with selected chemical parameters in sediments and interstitial waters and aerial images of the site, in order to investigate reed decline and search for possible correlations among data. Typical symptoms of the reed dieback syndrome were detected, thus enlarging the occurrence of this phenomenon in southern Europe. Permanently dry, permanently flooded and partially flooded stands show different levels of decline, with the permanent flooding always co-occurring with reed dieback. Only few of the considered chemical parameters seem to play a role in reed decline (nitrates, rubidium, nickel, barium, manganese), although no clear pattern was identified. Data suggest that the co-occurrence of some chemicals with stressing conditions might affect the growth even of an efficient metal accumulator, as reed is generally considered.

1. Introduction

Phragmites australis (Cav.) Steud. is one of the most dominant and common species in wetland ecosystems from temperate regions worldwide [1–3]. It is tolerant to a broad ecological range, colonizing different habitat types, such as riverbanks, ditches, littoral zones of lakes, fens, bogs and salt-marshes. This sub-cosmopolite species can grow in oligotrophic to eutrophic conditions, but it seems to be favoured in nutrient-rich sites [4]. The common reed can also withstand different pollutants, including heavy metals. For this reason, it is often used for the treatment of industrial or agricultural wastewaters [5–9], for phytoremediation [10–12] and even for the removal of harmful microorganisms due to its allelopathic effect [13].

In some areas of the world this grass is regarded as an aggressive invasive species [14–17]. The phenomenon is prominent in the USA where the Eurasian subspecies *P. australis* subsp. *australis* outcompetes the native, recently described, *P. australis* subsp. *americanus* Saltonstall, P.M. Peterson & Soreng, displacing the authoctonous populations [18]. For this reason, in N-America and Canada *P. australis* subsp. *australis* was included among the highest priority invasive species [19–24]. On the other side, reed beds represent valuable ecosystems for biodiversity conservation, although they are both usually

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species-poor when compared with other vegetation types [25–29] and not included in any specific European list of protected habitats [30]. Reed extensive communities play important structural and functional roles in wetland ecosystems, as they work as efficient filters for pollutants and provide habitat for fauna species [31–35]. Large reed beds in Europe are considered valuable and often threatened ecosystems [36] and even in North America some scientists do emphasize the importance of both habitat and non-habitat ecosystem services provided by reed [37,38].

In the last decades, in Europe *P. australis* (in all likelihood the Eurasian subspecies, although there is often no explicit indication of the subspecies) has suffered a dramatic decline, known in literature as 'common reed dieback' [39–42]. Among the reported symptoms affecting this species, the most frequently observed are: clumped habit, weaker culms with reduced height and diameter, dead rhizomes and buds, flowering delay, abnormal lignification and suberization, presence of callus, and an evident retreat especially from deep waters [for a general overview: 39,41]. Several hypotheses were proposed to explain this process [43–46]. Increasing eutrophication and artificial changes in the water table, together with anoxic conditions and methanogenesis processes in the sediment, were regarded as primary causes of this phenomenon [47–50].

For a long-time, reed dieback was considered as a Central European issue as it was not occurring in relatively warm areas such as the Mediterranean Basin, likely due to different biogeochemical processes developing in this climatic environment [41,51,52]. However, in recent years this phenomenon was detected and described also in some Mediterranean localities, from both brackish and freshwater wetlands [53–57].

The Italian ecosystem where reed decline was most extensively detected is Lake Trasimeno, the largest lake in Peninsular Italy [27,28,54–56,58,59]. The reed-dominated macrophytic vegetation along the shores of this shallow lake showed a progressive deterioration during the last 50 years. It became evident not only for the remarkable reed retreat and dieback, but also through a progressive decline of the water conditions and a general loss of biodiversity [54,60–62]. According to a number of macro- and micro-morphologic and hysto-anatomic traits, some hypotheses were formulated in order to understand the processes driving reed decline at Lake Trasimeno [54,56].

In the wake of such a baffling detection, macroscopic symptoms of dieback were observed in other freshwater ecosystems from Central Italy, such as Lake Chiusi in Tuscany. Differently from the nearby Lake Trasimeno, Lake Chiusi has always maintained relatively good floristic conditions, preserving plant species already disappeared from Lake Trasimeno [60,63,64]. However, a visible retreat of reed beds from the waterfront in several parts of the lakeshore and an evident discontinuous, clumpy growth of the reeds could be observed.

This study is part of a general effort to understand the physicochemical processes affecting delicate ecosystems at high risk of degradation and loss, often caused by human-driven changes to land use [65–70]. Our main driving hypotheses are that:

- the reed dieback should be considered also as a Mediterranean issue;
- multiple ecologic traits might co-occur with, and concur to, reed decline, thus, suggesting that this dramatic phenomenon should be approached with an integrated, multidisciplinary investigation.

This approach takes the cue from similar outcomes in Central Italy, suggesting that permanent flooding might be associated with reed decline by inducing chemical reactions in the sediment [54,58,59]. In this light, the main goals of our survey were those to:

- verify and quantify the actual reed bed retreat at Lake Chiusi, with reference to its spatial distribution, and identify the most affected areas;
- investigate whether the observed macroscopic symptoms of decline can be related to the dieback syndrome;
- assess whether some ecological (including chemical) characteristics of sediments and interstitial waters play a major role in reed dieback and determine their relationship with the presence/absence of macromorphological symptoms.

2. Materials and methods

2.1. Study site

Lake Chiusi (surface 3.6 km^2, average depth $\sim$2.70 m, maximum depth 5.70 m) is located in the Chiana Valley (southern Tuscany, Central Italy; Fig. 1), at an average altitude of 251 m a.s.l. [71], and 10 km SW from Lake Trasimeno, the first lake in Peninsular Italy where the reed dieback syndrome was detected [54]. From a geological point of view, the study area is characterized by Quaternary sands, pebbles and muds [72]. The climate of the area is humid Mediterranean [73].

The only tributary of the lake is the Tresa Stream; waters are drained by an artificial outlet to Lake Montepulciano and from there to the Arno River. Water levels of the lake were taken into account to point out whether flooding or drought significant events took place in the past, which might have had an effect on the reed stands. Unfortunately, only the yearly maximum levels were recorded at Lake Chiusi. According to the data, kindly provided by the Hydraulic Office (Soil Protection Service) of Arezzo Province, the maximum level of the water table in the period back to 1988 was around 249.01 ± 0.11 (av $\pm$ se) m a.s.l., reaching 249.11 ± 0.08 m a.s.l. when data back to 1973 are taken into account.

Chiana Valley has been subjected to a long-time reclamation history that has deeply modified the landscape of this territory [74,75]. The Lake Chiusi and Montepulciano represent the two major wetlands of the Chiana Valley. Together with a series of human-made minor wetlands, such as ponds and canals, they are dispersed in a landscape-matrix with strong agricultural