

Influence of sample location and livestock numbers on *Sporormiella* concentrations and accumulation rates in surface sediments of Lake Allos, French Alps

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Abstract Spores of coprophilous fungi, especially *Sporormiella*, are often well preserved in lake sediment cores. It has been hypothesized that such spores can be used to quantify past livestock abundance. The quantitative relationship between fungal spore abundance and livestock populations, however, is not well established, nor are the mechanisms of spore transport and deposition in lacustrine systems. Multiple cores from Lake Allos, a large high-elevation lake in the French Alps, were used to map the modern abundance of *Sordaria* and *Sporormiella* spores throughout the lake. We observed high spatial heterogeneity with respect to spore numbers. No correlation with the distance from shoreline was found. There was,

however, a relation with distance from the two main lake inlets. These results were used to select two fungi-rich sediment cores to investigate grazing pressure over the last two centuries. Comparisons were made between spore influx and historic data on livestock densities in the catchment. A sharp decrease in *Sporormiella* influx ca. 1894–1895 was associated with a reported reduction in sheep in the Allos catchment at that time. Mean influx of *Sporormiella* decreased by a factor of three between the nineteenth and twentieth centuries, reflecting a reduction in the reported number of animals in the Lake Allos catchment, from 6,000 to 2,000. This study confirmed that *Sporormiella* spore abundance in lake sediments can be used as a proxy for catchment herbivore numbers in paleoecological reconstructions. Nevertheless, our data indicate that before spore accumulation can be used to infer past domestic herbivore density, one must understand the processes of coprophilous spore transfer from the catchment to the lake and the influence of core location on spore numbers in the sediment.

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Introduction

In high-altitude landscapes, pastoral activity has been the main anthropogenic pressure on soils (Mocci et al.

2008; Mazier et al. 2009; Van der Knaap et al. 2011). Livestock grazing has strongly impacted local vegetation dynamics and plant biodiversity for millennia (Galop et al. 2011). Grazing and climatic events, alone or synergistically, may increase soil erosion, as verified in lake sediments (Giguët-Covex et al. 2011). Deciphering the effects of climatic and anthropogenic pressures on soil erosion in high-altitude landscapes, however, is difficult. Coprophilous fungal spores, especially *Sporormiella*, have been proposed as a proxy for the density of wild and domestic herbivores (Davis 1987; West 2003; Davis and Schafer 2006). Fungal spores in lake sediment archives could thus be used to reconstruct the history of grazing pressure in catchments during the Holocene (Williams et al. 2011; Cugny 2011; Currás et al. 2012). The relationship between fungal spore concentrations or accumulation rates, and livestock density, however, is still not well established.

The distribution of coprophilous fungi in lake sediments may depend, in part, on the processes responsible for transporting spores from catchment soils to the lake. Recent studies (Rapper and Bush 2009; Parker and Williams 2012) evaluated *Sporormiella* spore concentrations in modern sediments of several lakes. The authors found differences between concentrations of *Sporormiella* spores in sediment samples taken near the shore and from the lake depocentre. In some cases, no *Sporormiella* spores were found in sediment samples from the centre of lakes historically and presently surrounded by pasture lands. Spores may be deposited by cattle along the shoreline and transferred to the lake by runoff, thereby predominantly enriching lake sediments close to shore. Spores may also be deposited in remote areas drained by streams or rivers that are hydrologic inputs to the lake. In such cases, lake sediment in the depocentre will likely be more enriched with spores. Consequently, the mechanisms of *Sporormiella* transfer and dispersal in lake systems should be investigated before undertaking studies to infer past grazing intensity.

In this study, we (1) mapped the concentration and accumulation rate of coprophilous fungal spores, focusing on *Sporormiella*, in a large, high-elevation mountain lake and related our findings to catchment characteristics, and we (2) studied the relation between coprophilous fungi concentration and accumulation in the sediment, and historical archival information on grazing pressure.

Study area

Lake Allos (2,230 m a.s.l., 44°14N, 6°42'35E) is the largest, natural, high-elevation lake of the French Alps. It is ~1 km long and 700 m wide (Fig. 1a). It is located in a 5-km², north-facing cirque that is closed on the south side by high summits, ~2,672 m a.s.l. An alpine meadow covers 29 % of the catchment area close to the lake. Bedrock and scree (70 %) cover the upper part of the catchment (Fig. 1b). Sparse trees (*Pinus cembra* and *Larix decidua*) grow within the catchment. There has been no perceptible change in vegetation cover or composition in the watershed over the last two centuries.

About half of the catchment area is drained by three permanent streams, the Laus in the north and the Lac and Source in the south. The Laus and Source streams have built large deltas, indicating that they provide substantial sediment input to the lake. The bathymetric map (Fig. 1c) and seismic investigations revealed the presence of two distinct sedimentary sub-basins, the northern sub-basin fed by the Laus and the deeper, southern basin, fed by the Source (Wilhelm et al. 2012).

Climate conditions near the lake, particularly rainfall, have been stable over the last two centuries (Auer et al. 2007). Thus, stream flooding and lake levels have been relatively constant, but the frequency of extreme erosive events decreased during this period (Wilhelm et al. 2012).

Historic cattle abundance

During the nineteenth century, the catchment was grazed by a herd of ~6,000 free-ranging sheep in May–June and August–September (Pelissier 1901). In 1894–1895, the area surrounding Lake Allos was purchased by the French Forest Administration (RTM) to reduce grazing pressure and establish trees (*Pinus cembra* and *Larix decidua*). Livestock abundance dropped from approximately 6,000 to 2,000 head. The Lake Allos catchment is still an area of transhumance. Thus, domestic animals are assumed to be the primary source of coprophilous spores and wild herbivores are considered to be a negligible source.

Materials and methods

Between 2009 and 2011, 14 short gravity cores (90-mm diameter) were collected at varying distances from the

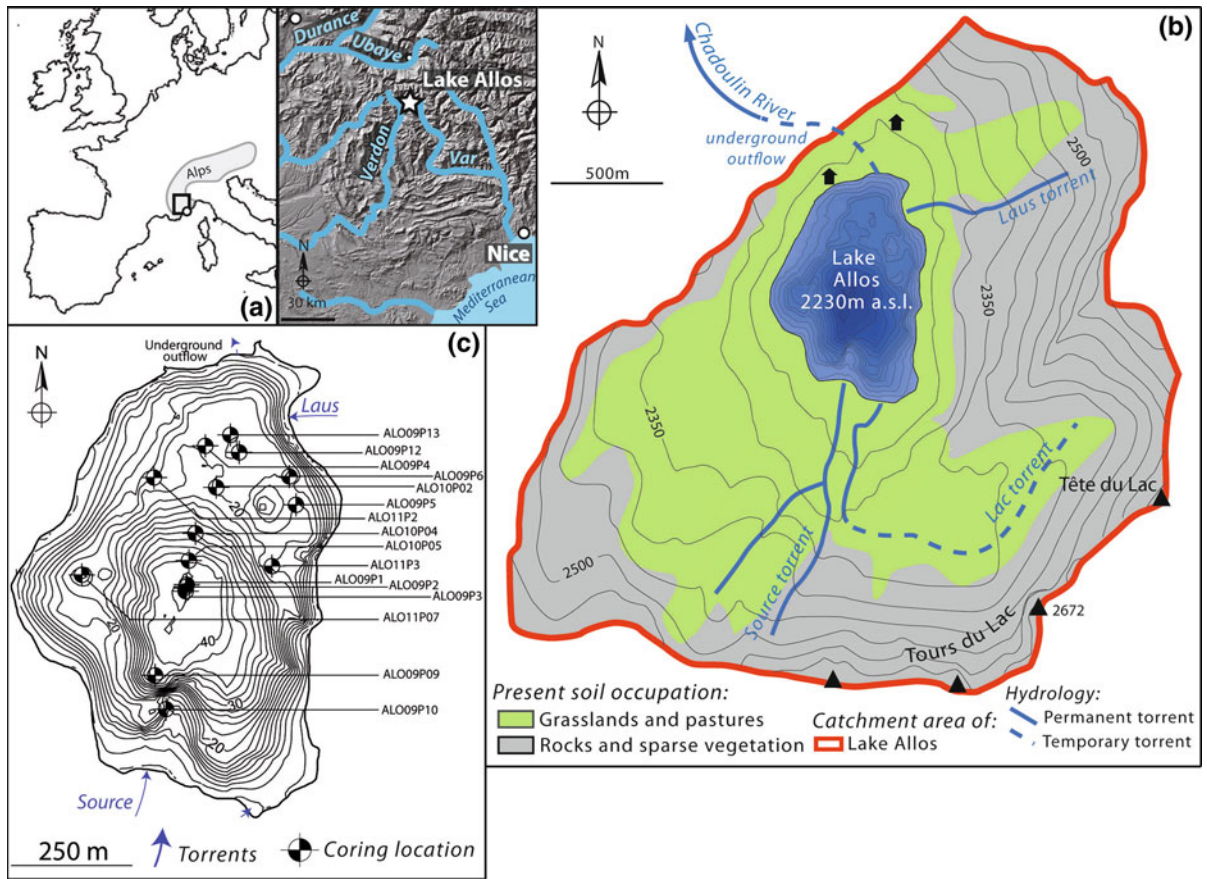


Fig. 1 Location of Lake Allos in Europe, with an inset showing its position in the French Alps (a). Hydrological characteristics and present soil cover in the Lake Allos catchment (b). Bathymetric map of Allos Lake and location of several coring sites

stream inlets in the south basin (cores ALO09P1, ALO09P2, ALO09P3, ALO09P9, ALO09P11, ALO10P04 and ALO10P05) and north basin (ALO09P4, ALO09P12, ALO09P13, ALO10P02, ALO11P2), as well as from the eastern and western margins (cores ALO09P6, ALO11P3 and ALO11P7) (Fig. 1c). This sampling protocol was designed to cover the range of lacustrine depositional environments.

Cores were split lengthwise, photographed and described. Interbedded deposits, previously attributed to flood deposits (Wilhelm et al. 2012), were used to correlate the cores stratigraphically. Short-lived radionuclides (^{210}Pb , ^{137}Cs and ^{241}Am) were measured in the uppermost 16 cm of northern basin core ALO09P12 (Wilhelm et al. 2012) and the topmost 24 cm of southern basin core ALO09P2, following non-regular sampling steps of 0.5–1.0 cm, to match facies boundaries. Activity was measured on 1–3 g of dry sediment by gamma spectrometry using high-efficiency, low-

background, well-type Ge detectors in the underground laboratory of Modane (Reyss et al. 1995). Generally, 24–48 h of α -counting were required to attain a statistical error <10 % of excess ^{210}Pb activity in the deepest samples and for the 1963 peaks of ^{137}Cs and ^{241}Am . Excess ^{210}Pb was calculated as the difference between the total ^{210}Pb and ^{226}Ra activities. Sedimentation rate was calculated using the constant flux constant sedimentation (CFCS) rate model (Goldberg 1963). Uncertainty of the sedimentation rate obtained by this method was derived from the standard error of the CFCS linear regression model. The resulting ^{210}Pb age-depth models were compared to historic ^{137}Cs and ^{241}Am contamination levels to test the chronology (Appleby et al. 1991). Finally, ^{210}Pb -derived ages of the thickest flood deposits were compared to the dates of major historic floods that affected the village of Allos, the latter obtained from the open-access database of the French Forest Office (Wilhelm et al. 2012). This offered

supplementary chronological control and enabled dating of other cores by stratigraphic correlation.

The uppermost 1.5 cm of the 14 cores (*cf.* Fig. 1c) was sampled and treated according to Fægri and Iversen (1989) so that abundances of coprophilous fungal spores could be determined. *Lycopodium clavatum* tablets were added to each sample to enable quantitative analysis of spore concentrations (i.e. number cm^{-3}) (Stockmarr 1971). Coprophilous fungi spores were identified according to the van Geel classification (2002). Their numbers were determined during a count of 500 spores of *Lycopodium clavatum* in each sample.

Identification of coprophilous fungi in modern sediments was limited to *Sporormiella*-type (HdV113), *Podospora*-type (HdV368), *Cercophora*-type (HdV112) and *Sordaria*-type (HdV55A). *Sporormiella*-type/HdV113 is an ascomycete fungus found only in the dung of herbivores and is used as a specific indicator of herbivore presence (Davis 1987; Davis and Schafer 2006; Cugny et al. 2010). It has been identified in the dung of numerous domestic herbivores and in the dung of several species of wild herbivores (Richardson 2001). *Podospora*-type/HdV368 occurs in archaeological sites (van Geel et al. 2003) and provides evidence of dung and grazing herbivores (Innes and Blackford 2003) similar to *Sporormiella*-type. It is, however, found less frequently than other coprophilous fungi types (van Geel et al. 2007). *Cercophora*-type/HdV112 is a coprophilous fungus found in decaying wood and herbaceous stems and leaves (van Geel et al. 2003). Ascospores of *Sordaria*-type/HdV55A are common in samples from archaeological sites (van Geel et al. 2003, 2007), but grow on decaying wood and dung residues (Mighall et al. 2006).

Sediment cores from each sub-basin, which contained the highest concentrations of coprophilous fungal spores, were investigated to study temporal changes in spore concentration and accumulation rate over the last ~170 years. Subsamples of constant volume were collected along the lengths of cores ALO09P3 (southern basin) and ALO09P13 (northern basin) (Fig. 1c). Layers corresponding to thick flood deposits, however, were not analysed because they correspond to abrupt, intense hydrologic events that may have transported unusual quantities of *Sporormiella* spores. Samples were subjected to the same chemical treatment, addition of *Lycopodium clavatum* spores, and counting method as the modern samples.

Results are expressed as concentrations (spores cm^{-3}) and accumulation rates (spores $\text{cm}^{-2} \text{yr}^{-1}$).

Results

Core chronologies

The excess ^{210}Pb profiles in cores ALO09P2 and ALO09P12 show steady decreases in activity until reaching very low values ($<15 \text{ Bq/kg}$), but are punctuated by depths with very low values, which correspond to thick flood deposits (Fig. 2a). Following Arnaud et al. (2002), we excluded ^{210}Pb values associated with these instantaneous deposits to construct a synthetic sediment record (Fig. 2b). The CFCS model (Goldberg 1963) was applied to the cores and indicates that each sequence is characterized by two periods of different mean continuous accumulation rate (MCAR). The MCAR of core ALO09P2 shifts from $1 \pm 0.1 \text{ mm/yr}$ in the lower portion of the core to $1.7 \pm 0.1 \text{ mm/yr}$ in the topmost 12 cm. For core ALO09P12, the MCAR changes from $0.8 \pm 0.1 \text{ mm/yr}$ in the lower section to $1 \pm 0.1 \text{ mm/yr}$ in the uppermost 8 cm. The CFCS model-derived ages were used to develop continuous age-depth relationships for the cores (Fig. 2c).

The ^{137}Cs and ^{241}Am profiles display two peaks in each sequence (Fig. 2a). The first peaks, at approximately 11.5 cm in core ALO09P2 and 6 cm in ALO09P12, are expressed clearly by ^{241}Am , which is characteristic of ^{241}Pu decay from atmospheric nuclear weapons test fallout (Appleby et al. 1991). Maximum values of ^{241}Am correspond to peak nuclear weapons testing in the northern hemisphere in 1963. The upper peaks, which exhibit high values of ^{137}Cs , are associated with the 1986 Chernobyl accident. Correspondence between these independent chronological markers and ages from the ^{210}Pb dating supports the validity of our age-depth model (Fig. 2c). Furthermore, the ^{210}Pb ages of the thickest flood deposits are very similar in the two sequences and in agreement with dates of major historic flood events that affected the village of Allos, most notably the 1886, 1920, 1994 and 2005 events (Wilhelm et al. 2012). Ages of deeper flood deposits may also correspond to older documented events, e.g. in 1843 and 1868, suggesting that extrapolation of the MCAR well into the nineteenth century may be appropriate.

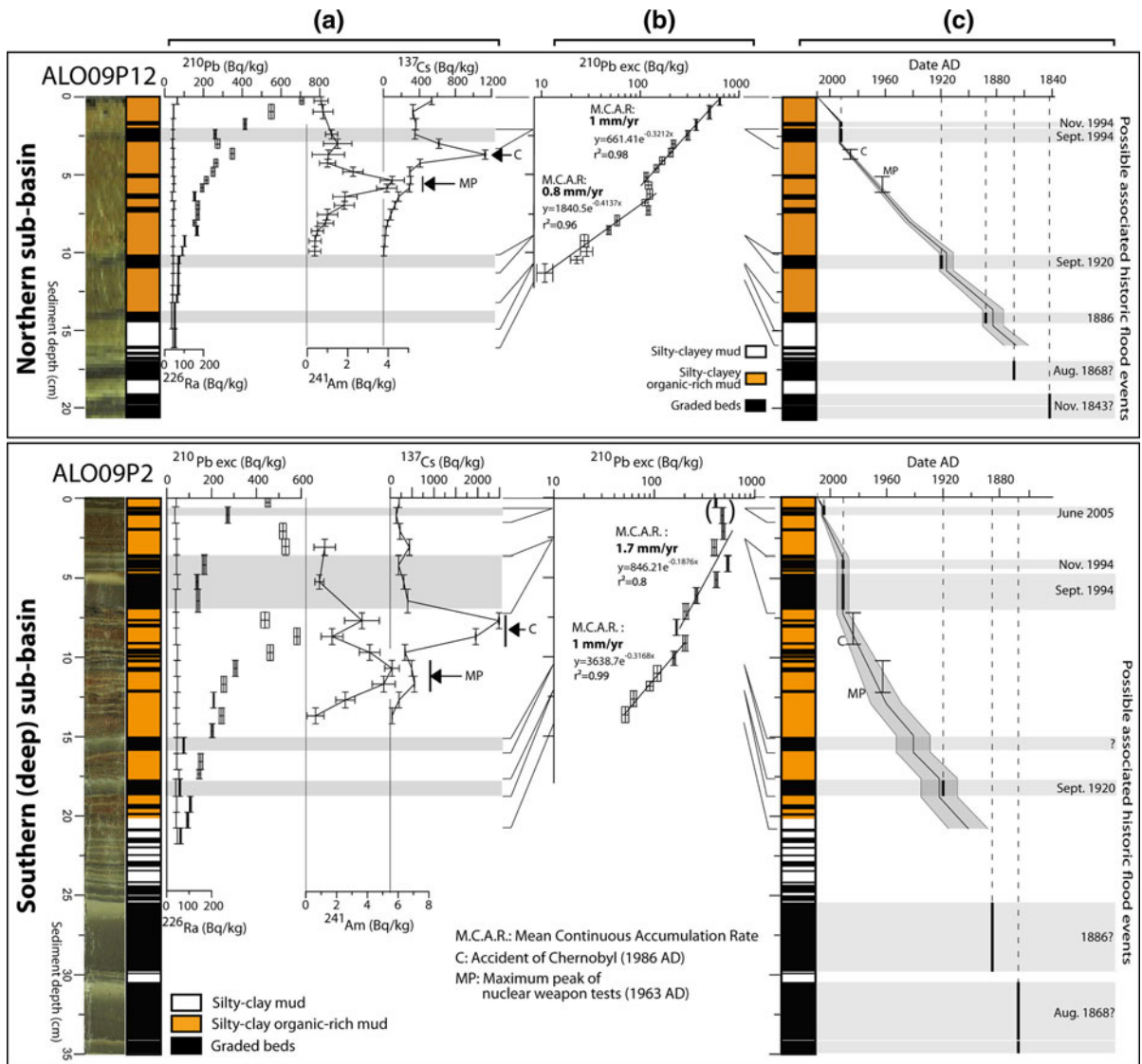


Fig. 2 a Profiles of ^{210}Pb , ^{137}Cs and ^{241}Am for core ALO09P2. b Application of CFCS model to the excess ^{210}Pb profile (without inclusion of thick-graded beds, considered

instantaneous deposits). c Age-depth relations with 1σ uncertainties and indicated historic flood dates, possibly associated with the thick-graded deposits

Reliable chronologies were apparently obtained for the past two centuries of sedimentation in the two sub-basins. Core correlation, using the dated flood deposits, enabled us to assess the time span represented by all samples (Fig. 3).

Spatial analysis of coprophilous fungi concentrations and accumulation rates

Results of *Sordaria* and *Sporormiella* concentrations and accumulation rates in modern samples are presented in

Figs. 4 and 5. Correlation coefficients between spore concentrations, accumulation rates, and locations are presented in Table 1. *Sporormiella* concentrations varied from ~ 80 spores cm^{-3} (ALO11P3) to >580 spores cm^{-3} (ALO09P4, ALO09P6, ALO09P12 and ALO09P13). *Sordaria* concentrations were lower and varied between ~ 30 cm^{-3} (ALO11P3 and ALO11P07) to ~ 350 cm^{-3} (ALO09P12). *Cercophora* and *Podospora* spores were identified in the surface samples of only a few sequences (ALO09P13, ALO09P12, ALO09P4 and ALO09P10).

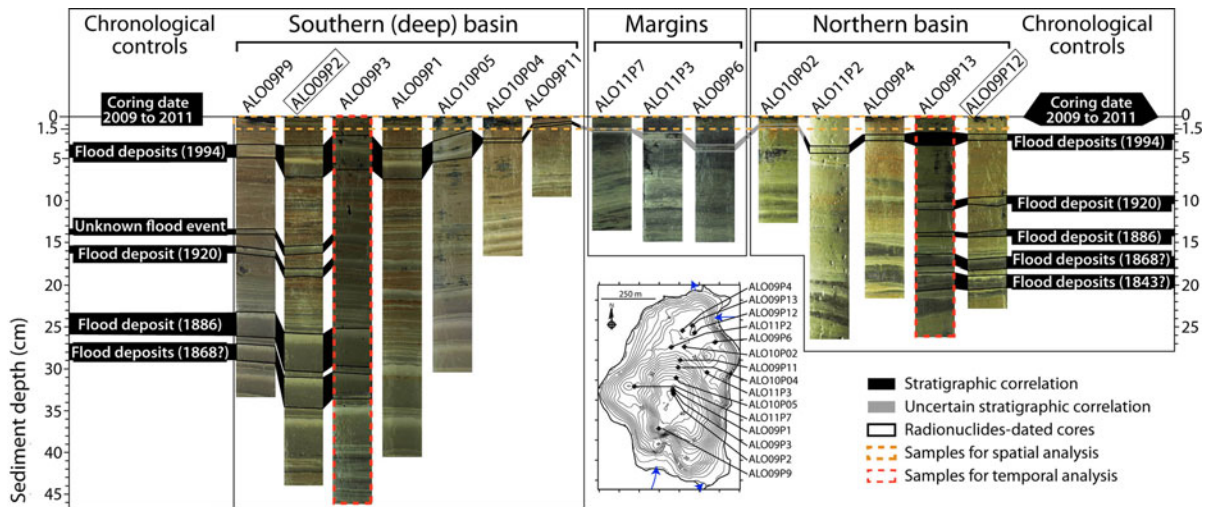


Fig. 3 Core correlation based on identification of flood deposits dated to 1868, 1886, and 1994. Flood deposits are less marked in cores from marginal areas and correlations are thus less certain

We calculated the correlation coefficients between *Sporormiella* or *Sordaria* concentrations and distance to the shoreline or the closest stream discharge. There was no significant correlation between the distance to the shoreline and *Sporormiella* ($r = -0.19$) or *Sordaria* ($r = -0.18$) concentrations. There were, however, significant correlations between the distance to the closest stream discharge (Laus or Source) and *Sporormiella* ($r = -0.80$) or *Sordaria* ($r = -0.64$) concentrations (Table 1).

Sporormiella spore accumulation rates varied from $\sim 8 \text{ cm}^{-2} \text{ yr}^{-1}$ (ALO11P3) to $>80 \text{ cm}^{-2} \text{ yr}^{-1}$ (ALO09P6). *Sordaria* spore accumulation rates were lower and varied between $\sim 2 \text{ cm}^{-2} \text{ yr}^{-1}$ (ALO11P3 and ALO11P07) and $\sim 35 \text{ cm}^{-2} \text{ yr}^{-1}$ (ALO09P12). There was no correlation between the distance to the shoreline from the sample site and *Sporormiella* ($r = -0.30$) or *Sordaria* ($r = -0.30$) accumulation rates. There was, however, a significant correlation between the distance to the closest stream discharge and both *Sporormiella* ($r = -0.77$) and *Sordaria* ($r = -0.64$) accumulation rates (Table 1).

Sordaria and *Sporormiella* concentrations were correlated with one another in surface sediment samples ($r = 0.73$), as were accumulation rates of the two spore types ($r = 0.68$). Their concomitant presence was also described in the fresh dung of several species of wild and domestic herbivores (Richardson 2001). Nevertheless, *Sordaria* spores should be considered mainly as indicators of wild

herbivore presence because they have been recorded in sediments with high organic matter content, but little or no palynological evidence of pastoral activities (Mighall et al. 2006; Etienne et al. 2011).

Temporal changes in coprophilous fungi abundance

Sporormiella concentrations and accumulation rates in the ALO09P3 and ALO09P13 sequences are presented in Fig. 6. Concentrations (spores cm^{-3}) of *Sporormiella* in core ALO09P3 from the deepest, central coring site varied from 250 to 1,600 (Fig. 6a), with a mean value of 522 spores cm^{-3} . The accumulation rate (spores $\text{cm}^{-2} \text{ yr}^{-1}$) of *Sporormiella* (Fig. 6b) varied from 30 to 176, with a mean value of 76 spores $\text{cm}^{-2} \text{ yr}^{-1}$. Temporal shifts in *Sporormiella* concentrations and accumulation rates could be divided into two main periods. The first, from 1839 to 1898 (four samples) had high concentrations and accumulation rates (mean value: 167 spores $\text{cm}^{-2} \text{ yr}^{-1}$) followed by an abrupt decline, during which values (12 samples) were much lower from 1898 to 2009.

Concentrations of *Sporormiella* in core ALO09P13, taken near the Laus discharge, varied from 300 to 1,700 spores cm^{-3} (Fig. 6c), with a mean value of 553 spores cm^{-3} . Accumulation rates of *Sporormiella* (Fig. 6d) varied from 30 to 110 spores $\text{cm}^{-2} \text{ yr}^{-1}$, with a mean value of 50 spores $\text{cm}^{-2} \text{ yr}^{-1}$.

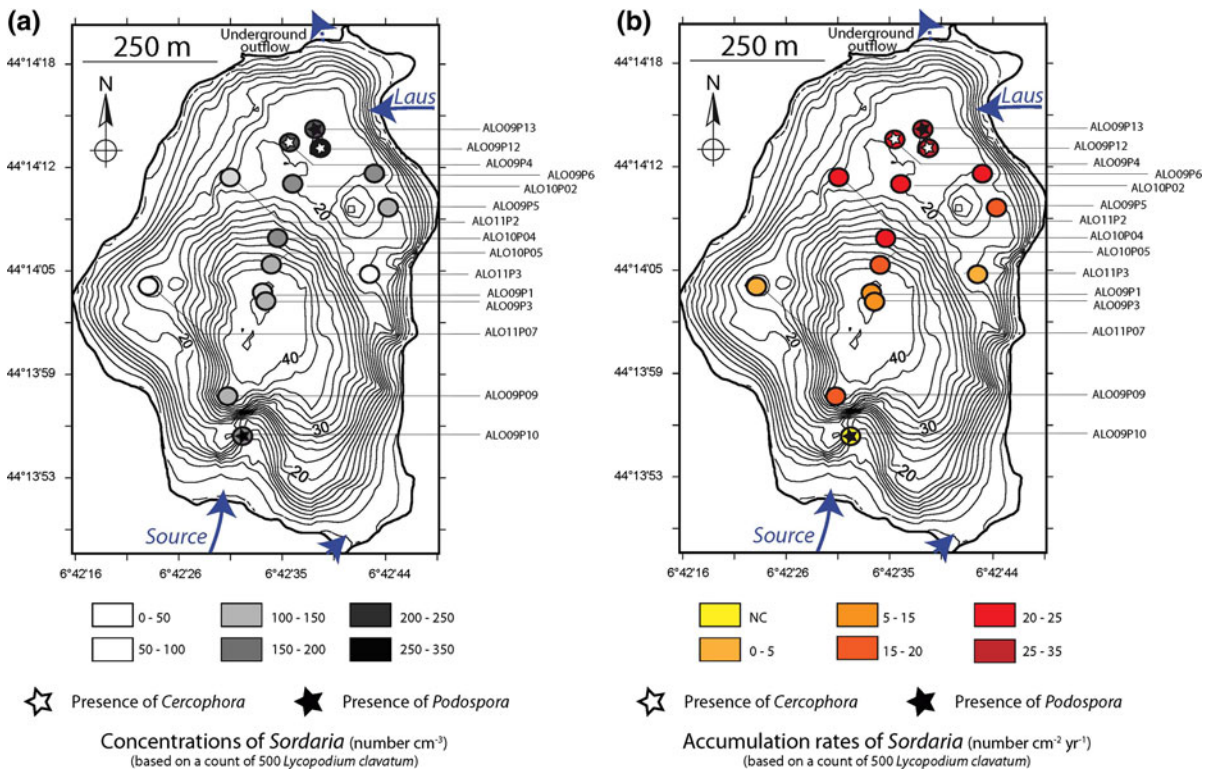


Fig. 4 Map of *Sordaria* concentrations (a) and accumulation rates (b) recorded in modern samples (top 1.5 cm) from Lake Allos after counting 500 spores of *Lycopodium clavatum*. “NC”

corresponds to Non-Calculated. In “NC” modern sample, core correlations did not allow an estimate of the sedimentation rate to calculate accumulation rate of *Sordaria*

Sporormiella abundance declined by 50 % from the nineteenth to the twentieth century.

Discussion

Spatial distribution of fungal spores in lake surface sediments

Concentrations and accumulation rates of *Sporormiella* and *Sordaria* in recent sediments varied considerably throughout Lake Allos. Concentrations of *Sporormiella* and *Sordaria* across the sampling sites varied up to 7-fold and 11-fold, respectively. Accumulation rates of *Sporormiella* and *Sordaria* at the sites varied up to 10-fold and 17-fold, respectively. Rapper and Bush (2009) found a sharp decline in *Sporormiella* concentration with increasing distance from the lakeshore, whereas Parker and Williams (2012) found the opposite. Both trends were found in Lake Allos, depending on the transect orientation:

east–west (ALO09P3 > ALO11P07 and ALO11P3) or south–north (ALO09P3 < ALO09P10 and ALO09P13). Overall, in Lake Allos, no relation was observed between *Sporormiella* or *Sordaria* abundances and the distance to the shoreline (Fig. 5a, b, Table 1). In-wash of *Sporormiella* may be important very close (<20 m) to shore, as observed by Rapper and Bush (2009), but these inputs are not transferred to greater water depths near the lake centre. Low abundances in modern samples (ALO011P3, ALO011P07 and ALO11P2) collected close (<150 m) to the shoreline, but far (>300 m) from the Laus and Source inflows, appear to confirm this. After production, spores are released close to the ground and their gelatinous sheath facilitates their attachment to nearby vegetation (Ahmad and Cain 1972; Davis and Schafer 2006). Thus, spores are poorly dispersed, but could potentially be transported into the lake on eroded soil particles. The negative correlation between the abundance of *Sporormiella* in modern sediments and the distance to the closest

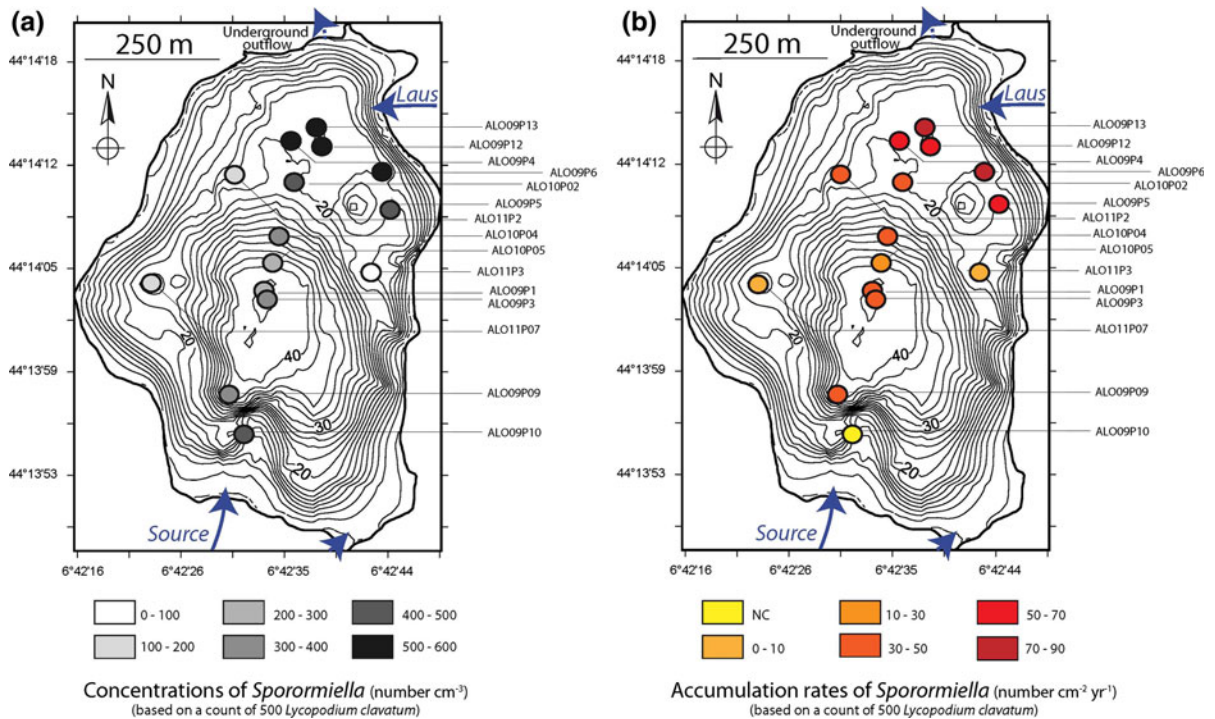


Fig. 5 Map of *Sporormiella* concentrations (a) and accumulation rates (b) recorded in modern samples (top 1.5 cm) from Lake Allos after counting 500 spores of *Lycopodium clavatum*. “NC”

corresponds to Non-Calculated. For “NC” modern samples, core correlations did not allow an estimate of the sedimentation rate to calculate accumulation rate of *Sporormiella*

Table 1 Correlation coefficients (r) for relations between *Sporormiella* and *Sordaria* concentrations and accumulation rates in modern samples (top 1.5 cm) and distance from the

lake shoreline, distance to the Laus and Source streams, and distance to the closest stream input

Distance to	Lake shoreline	Laus stream	Source stream	Closest stream input
Concentrations of				
<i>Sporormiella</i>	r = -0.19	r = -0.55*	r = 0.38	r = -0.80***
<i>Sordaria</i>	r = -0.18	r = -0.39	r = 0.28	r = -0.64**
Accumulation rates of				
<i>Sporormiella</i>	r = -0.30	r = -0.60	r = 0.36	r = -0.77**
<i>Sordaria</i>	r = -0.30	r = -0.53	r = 0.36	r = -0.64**

Levels of significance (*** $P \leq 0.001$; ** $P \leq 0.01$; * $P \leq 0.05$) were determined using a Pearson test

stream discharge suggests that spores enter the lacustrine system through stream flooding.

Sporormiella concentrations and accumulation rates in lake sediments as a proxy for cattle abundance

Variations in coprophilous fungal spore concentrations and accumulation rates during the last 170 years

matched fairly well with the local history of grazing pressure documented in historical archives. Within a single lacustrine system, sedimentation rate may vary appreciably among sites, from near the lakeshore, to the depocentre, and near stream inputs. It is therefore critical to express *Sporormiella* in terms of accumulation rates (spores $\text{cm}^{-2} \text{yr}^{-1}$) to establish a correlation between temporal changes in livestock abundance in the catchment and spores in sediment, and facilitate

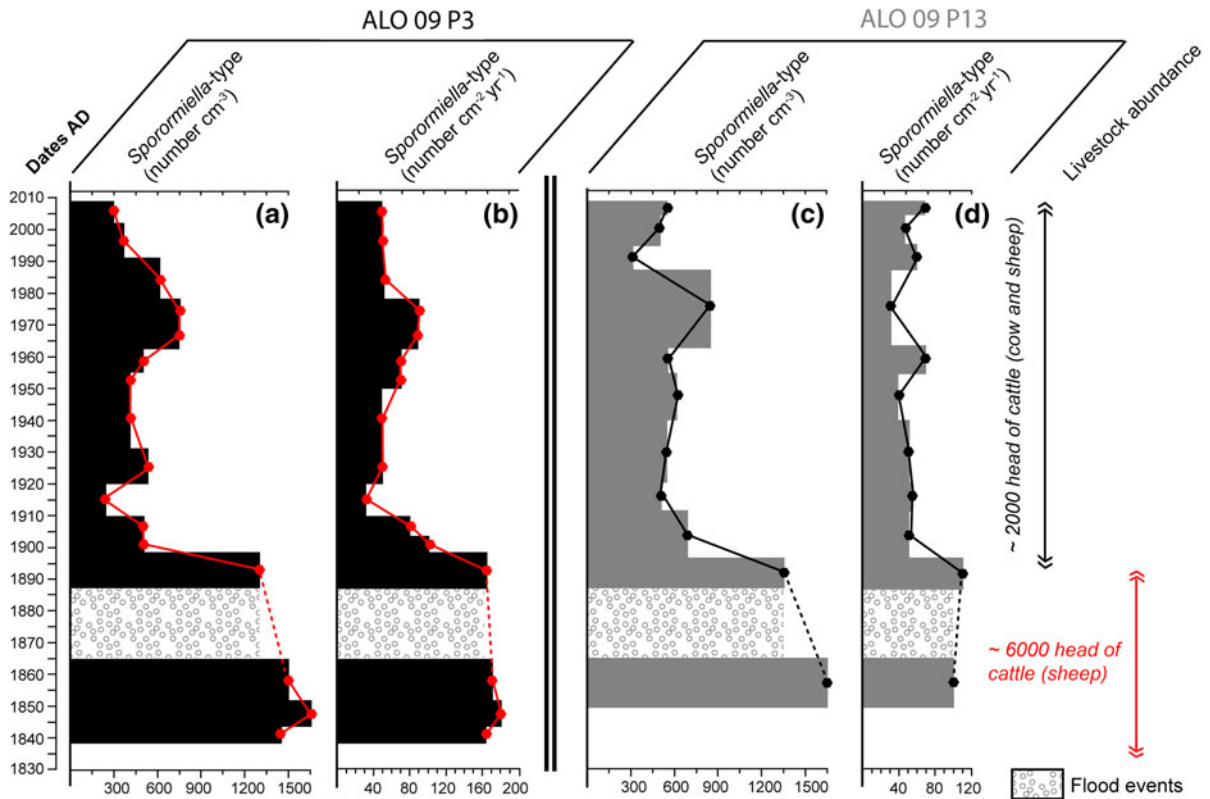


Fig. 6 *Sporormiella* concentrations (number cm^{-3}) and accumulation rates (number $\text{cm}^{-2} \text{yr}^{-1}$) for the last 170 years in cores ALO09P3 and ALO09P13. Sediments deposited from 1868 to 1886 were not analysed because of evidence for strong flood events

comparisons with other studies. Two short sediment cores (ALO09P03 and ALO09P13) recorded the same trend, with higher spore accumulation rates during the nineteenth century, followed by a dramatic decline in accumulation rates at the beginning of the twentieth century.

Accumulation rates of *Sporormiella* spores recorded until the 1890s in ALO09P3 (~ 170 spores $\text{cm}^{-2} \text{yr}^{-1}$) and ALO09P13 (~ 102 spores $\text{cm}^{-2} \text{yr}^{-1}$) differed significantly. This could be a consequence of a difference in grazing pressure between the Laus catchment, corresponding to ALO09P13, and the Source catchment, corresponding to ALO09P3. After ~ 1895 , the historical archives indicate a large, rapid decrease in livestock abundance from $\sim 6,000$ head to 2,000. In core ALO09P3, this caused a decrease in *Sporormiella* abundance, from ~ 161 spores $\text{cm}^{-2} \text{yr}^{-1}$ before 1898 to ~ 98 spores $\text{cm}^{-2} \text{yr}^{-1}$ immediately thereafter, to ~ 82 spores $\text{cm}^{-2} \text{yr}^{-1}$ by 1909, and only ~ 30 spores $\text{cm}^{-2} \text{yr}^{-1}$ in the

subsequent decade. In ALO09P13, the decrease in *Sporormiella* abundance was more rapid, with ~ 110 spores $\text{cm}^{-2} \text{yr}^{-1}$ in the late 1800s, to ~ 48 spores $\text{cm}^{-2} \text{yr}^{-1}$ by the first decade of the twentieth century. There was an apparent lag of roughly 15 years at the ALO09P13 core site between the time when livestock numbers were reduced in the catchment and a new mean value for fungal spore accumulation was established. This may reflect the persistence of *Sporormiella* in soils and their continued delivery to the lake, resulting in continued high numbers of fungal spores even when livestock numbers declined.

Higher abundances of *Sporormiella* during the nineteenth century in ALO09P3 (167 spores $\text{cm}^{-2} \text{yr}^{-1}$) than in ALO09P13 (102 spores $\text{cm}^{-2} \text{yr}^{-1}$), and the noticeably larger decline in ALO09P3 (80 %) than in ALO09P13 (55 %) at the turn of the century, may be related to the location of livestock in the catchment. This difference suggests that during the nineteenth century, most of the nearly 6,000 animals were in the

Source catchment (Fig. 1). This inference is supported by the higher abundance of *Sporormiella* in modern samples from the outlet of the Laus catchment area, which today is more frequently pastured than the Source catchment.

Throughout the twentieth century, the amount of livestock (cattle and sheep) fluctuated around 2,000 head. In ALO09P3, taken near the centre of the lake, and in ALO09P13, collected near the Laus inlet, mean accumulation rates of *Sporormiella* during this period are virtually the same, between 50 and 60 spores $\text{cm}^{-2} \text{yr}^{-1}$ (Fig. 6). A small increase in *Sporormiella* accumulation was recorded in these two sequences during a relatively short period from about 1960 to 1980. Local records of pastoral activities are not sufficiently accurate to determine if this change is associated with minor shifts in livestock abundance.

Conclusions

Spatial analysis of coprophilous fungi spore concentrations in sediments of Lake Allos indicate that spores are transferred to the lake mainly by stream flooding. Parallel decreases in accumulation rates of *Sporormiella* spores and livestock numbers, the latter confirmed by historical archives, demonstrate the potential for use of coprophilous fungi as a proxy for past livestock numbers in paleoecological studies. The distribution of *Sporormiella* spores in the surface sediments of Lake Allos suggests that sites for core collection to reconstruct the past history of grazing pressure in the catchment should be selected after considering the location of stream inputs. Sediment cores for paleoecological analysis are conventionally taken from the deepest site in the lake, which often corresponds to the lake centre. A core from the center of the lake may not represent accurately lakewide *Sporormiella* deposition, and this should be considered when developing a transfer function that relates spore accumulation rates to livestock in the catchment.

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