Reconstruction and climatic interpretation of a late Pleistocene peat deposit in northwestern Oregon

Reconstruction and climatic interpretation of a late Pleistocene peat deposit in northwestern Oregon

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Summary

1 Climatic models predict that postglacial conditions in the Pacific Northwest of North America (between 11'000 and 10'000 years BP) were about 2–3 °C cooler than at present. These models were tested by examining plant macrofossils and insect remains in a late Pleistocene peat deposit in northwestern Oregon.

2 Stratigraphy in trenches (540 cm depth) revealed peat from 225 to 420 cm soil depth. The peat structure suggests that an open water body formed at the site some 13'000 years BP and terrestrialized into a *Sphagnum* bog. Seeds of the bog bean, *Menyanthes trifoliata,* were found in the peat between 240 and 420 cm depth. The age of this layer was ^{14}C-dated to approximately 10'000–11'000 years BP.

3 Temperatures at present-day sites of *M. trifoliata* in Oregon (at elevations from 854 to 1768 m a.s.l.) indicate that the species grows at sites with a yearly mean temperature range of 4.4–7.9 °C, in contrast to 11.1 °C at the study site (49 m a.s.l.), where the species does no longer occur. This suggests that temperatures at the study site in the late Pleistocene were at least 3–4 °C cooler than at present.

4 The possible association of these temperature changes to the universal Young Dryas cooling and post-Young Dryas warming event is discussed.

5 The discovery of three small flakes, a core, and fractured deer-size large mammal bones in the peat suggests the presence of Paleoamericans in the surroundings. Sharp breakage edges on many seeds of *M. trifoliata* might indicate that these seeds were used by humans, possibly because the latter knew about the medicinal properties of *M. trifoliata.*

Keywords: climate change, *Menyanthes trifoliata,* stratigraphy, temperature

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Introduction

The reconstruction of climatic changes in the Pacific Northwest during the Pleistocene and Holocene periods is complex, partly because conditions varied widely across this region due the proximity of the ocean, physiographic barriers, and relief. One of the first researchers to study past ecological and climatic changes in Western Oregon was Hansen

(1941) who investigated the palynology of peat bogs in the Willamette Valley. He was also the first to state, based on his interpretation of pollen proportions in various strata, that the central valley of Oregon had experienced an initial cool, damp climate followed by a warmer and perhaps dryer period that has continued to the present day.

Various studies since then have attempted to define the temperature fluctuations of the late Quaternary more precisely. Barry (1983) proposed that cold and dry conditions existed between 28'000 and 13'000 RCYBP (RCYBP = years before present, dated with ^{14}C) in the Pacific Northwest, except for a short humid episode around 18'000 RCYBP. During the cool period, the average July temperature was estimated to have been 3–7 °C lower than at present. In a 33'000-year pollen record from a lake in southwestern Washington, Barnosky (1985) identified at least four climatic episodes. According to this record, the period from 25'000 until 10'000 RCYBP was cold and dry, followed by an onset of warm conditions beginning at 10'000 RCYBP, with a gradual cooling again at 8'500 RCYBP. Booth (1987) noted that on the basis of pollen records, the initial retreat of the ice west of the Cascade Range preceded evidence of increasing temperatures by several thousand years. This would place the warming trend between 10'000 and 11'000 RCYBP. By contrast, Heusser *et al.* (1985) supposed a warming of the climate in Western Washington as early as 13'000 RCYBP based on pollen counts.

While all these studies confirm the climatic sequence first proposed by Hansen (1941), they partly disagree regarding the precise time when the warming of climate began. Thus, according to some authors, the period from 10'000 to 11'000 RCYBP was still markedly colder than today, whereas other studies suggest that the climate had already become much warmer by that time. Since warming certainly occurred gradually, with many regional differences, only the combination of evidence from numerous local studies will provide a clear picture of when and how fast temperature increased in the late Pleistocene. This knowledge would provide a better frame for the evaluation of present-day climate warming.

In this study we used fossil records from a site in Woodburn, northern Oregon, to reconstruct the ecological and climatic conditions prevailing during the late Pleistocene. In 1987, workers discovered bones of megafauna (mammoths, ground sloths, horses, etc.) under a layer of peat as they were excavating for a sewer line along Mill Creek in Woodburn. Following this discovery, the site was investigated further for plant and insect macrofossils with the following questions in mind: What were the late Pleistocene ecological conditions? Is there evidence for a change in climate? If so, can we use the records to determine the extent of this change as well as the period when it occurred? Finally, are there indications of human activity at the site?

Materials and Methods

The study site was located in the northern Willamette Valley (elevation 49 m) near Woodburn (Marion County) in Oregon (Fig. 1). This locality, named the Mammoth Park site, is part of the Mill Creek floodplain where sub-surface peat deposits occur along Mill Creek for over 830 m. The site is in an agricultural area where various introduced grasses and legumes are grown for animal fodder. Modified riparian and woodland habitats occur along the borders of Mill Creek.

In 1996, soil cores were collected from 16 backhoe trenches along a northeast-southwest transect adjacent to Mill Creek (Fig. 1) near the Woodburn High School using a Giddings coring rig and backhoe. The coring and trenching program demonstrated that stratigraphy was essentially similar in all excavation units. Because the backhoe trench walls were wet and unstable, detailed mapping of the site stratigraphy was not undertaken until 1997. Hand excavation was undertaken inside the trenches. Wall profiles were mapped as the excavation proceeded downward to a dept of 5.40 m. Samples of wood and seeds were taken down to that depth for

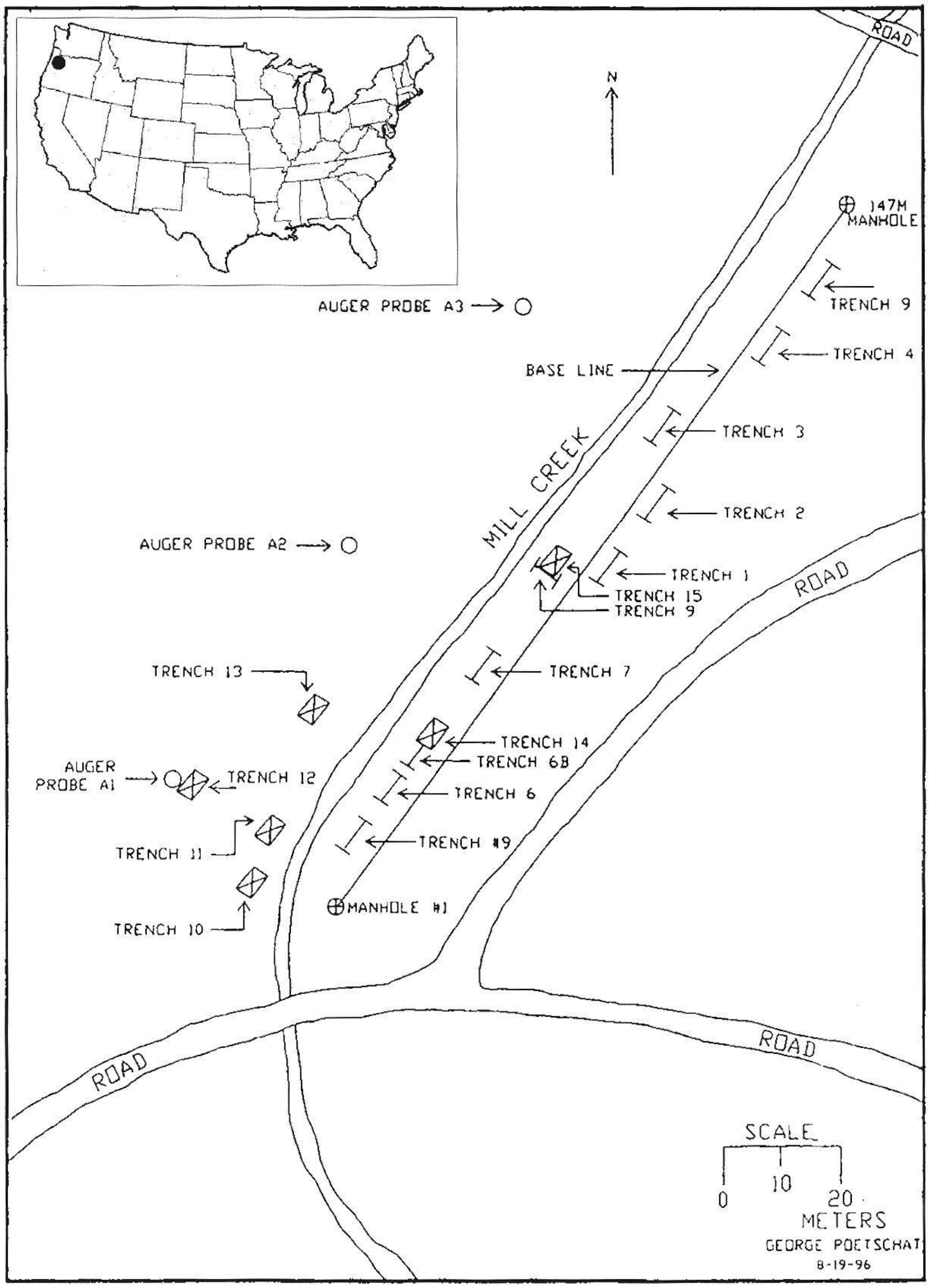


Fig. 1. Map of the study site Mammoth Park near Woodburn, Oregon, with locations of trenches; the inset indicates the location of the study site (black circle) within the USA.

^{14}C dating. Detailed stratigraphic sampling extended only to 4.87 m, which included the peat layer. Blocks of peat measuring approximately 25 cm square by 10 cm deep were excavated from one trench and brought to the laboratory for analyses. These samples were broken into smaller portions and wet- sieved over a 2.0-mm sieve to remove coarsest debris, such as leaves and twigs. The material not passing the sieve was picked in its entirety, and all identifiable organic matter was saved. The fraction finer than 2.0 mm was wet-sieved over a 0.5-mm screen. Fine material passing the screen was discarded. The sample remaining in the screen was examined for insect remains.

Data pertaining to the elevation of populations of *Menyanthes trifoliata* in Oregon were taken from herbarium sheets in the Oregon State University Herbarium. Temperatures at the various bog bean localities were taken from Taylor and Hannan (1999) and represent yearly means averaged from 1961 to 1990.

Results and discussion

STRATIGRAPHY

Soil profiles in the 16 trenches were essentially identical, and the various layers of deposits generally found in the trenches are described in Fig. 2. Four main layers were recognized: A superficial clay layer, down to 185 cm, was followed by a layer of peat from 185 to 365 cm, a layer of mucky peat (365–420 cm), and finally muck down to the bottom of the trench (540 cm). The peat itself consisted of several layers that differed in peat structure and suggested that they had been formed by different vegetation types.

Dating of plant remains (seeds of *Menyanthes trifoliata* and wood samples) between 240 and 540 cm using ^{14}C provided ages between 10'330 ± 80 RCYBP and 12'200 ± 100 RCYBP (Table 1). According to this dating, almost 2 m of peat had accumulated over a period shorter than 1000 years, i.e. a very high rate of accumulation compared e.g. to southern boreal peatlands (Gorham 1991). Peat formation started approximately 11'000 RCYBP, which suggests that major ecological change must have occurred at that time.

Table 1. *^{14}C dates compiled from wood samples (w) and bog bean seeds (s) taken from various soil layers in two auger probes and four backhoe trenches. Asterisks indicate soil layers in which bog bean seeds were present.*

Depth (cm)	Sample	Age (years BP)
240 *	w	10'330 ± 80
250 *	s	10'560 ± 40
260 *	w	10'480 ± 120
360 *	w	11'770 ± 70
385 *	w	10'630 ± 250
395 *	s	10'610 ± 70
520	w	11'690 ± 90
540	w	12'200 ± 100

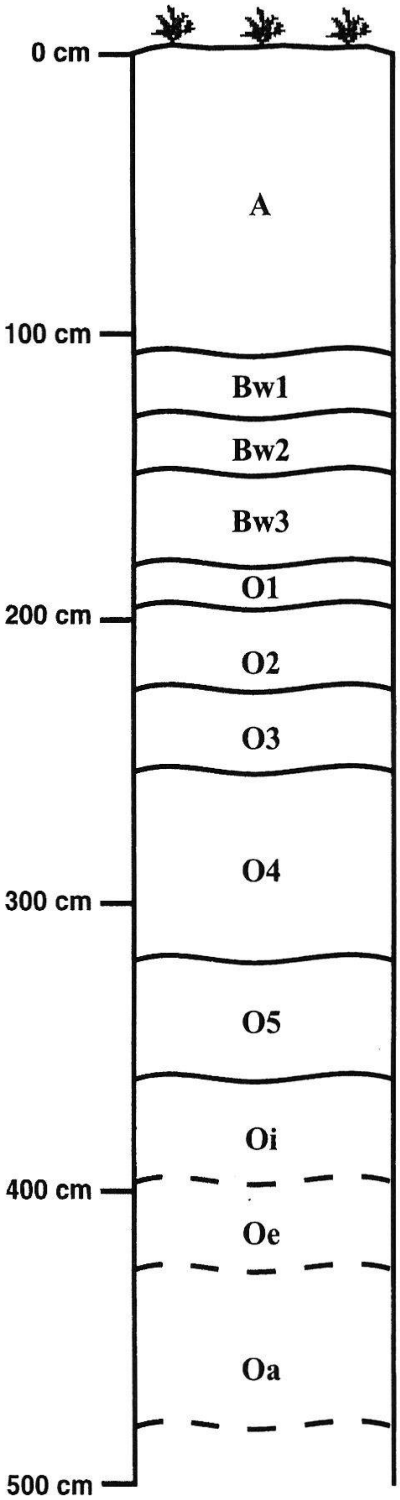
* Bog bean seeds present

PLANT AND INSECT REMAINS INDICATING VEGETATION SUCCESSION

Plant macrofossils and insect remains were recovered from a depth of 225 to 420 cm. This section consisted of a nearly pure compact plant mass containing moss, reeds, leaves and seeds (Fig. 2). Seeds of five plant species could be identified (Table 2); those of the bog bean, *Menyanthes trifoliata* (Fig. 3, 4), were particularly numerous (hundreds of seeds per block) between 240 and 420 cm depth. Insects from six families of the Coleoptera were also identified (Table 3).

All of the identified species occur in moist to aquatic habitats presently (Tables 2, 3). Both *Potamogeton* and *Nuphar luteum* prefer

Mammoth Park Soil Profile and Description
Woodburn, Oregon
June through July, 1997



A 0-105 cm; (10YR3/1, moist) clay; massive, friable; abrupt wavy boundary. Overburden, variable from 95-105 cm across north wall. Highly disturbed.

Bwl 105-125 cm; (5Y2.5/1, moist) clay; moderate, medium, subangular blocky, very sticky, plastic, fine interstitial pores; diffuse smooth boundary. Many large prominent mottles.

Bw2 125-148 cm; (5Y2.5/1, moist) clay; very massive, coarse, subangular blocky, sticky, plastic, fine interstitial pores; diffuse smooth boundary. Many large prominent mottles.

Bw3 148-185 cm; (5Y2.5/1, moist) clay; very massive, moderate, subangular blocky, sticky, plastic, fine interstitial pores; abrupt smooth boundary.

01 185-197 cm; (10YR3/1, moist, darkening to 10YR2/1 upon exposure to atmosphere, 10YR2/0 when rubbed, wet) peat; fine, platy; diffuse smooth boundary. Saprist organic material, < 10% fibers after rubbing.

02 197-225 cm; (10YR3/3, moist, darkening to 10YR2/2 upon exposure to atmosphere, 10YR2/1 when rubbed) peat; fine, platy; diffuse smooth boundary. Fibrist organic material with twigs - 1 cm diameter, much less decomposed than above layer.

03 225-254 cm; (10YR3/4, moist, darkening rapidly to 10YR2/1 upon exposure to atmosphere) peat; fine, fibrous, platy; diffuse smooth boundary. Hemist organic material.

04 254-315 cm; (10YR4/4, moist, darkening to 10YR2/1 upon exposure to atmosphere) peat; fine, fibrous; diffuse smooth boundary. Fibrous organic material composed of sedges and reeds.

05 315-365 cm; (10YR3/2, moist, changing to 10YR2/1 upon exposure to atmosphere) peat; fine, platy; diffuse smooth boundary, Hemist organic material composed of small seeds and twigs < 3 cm diameter.

Oi 365-395 cm; (10YR2/2, moist, changing to 10YR2/1 upon exposure to atmosphere) mucky peat; weak, fine, massive, loose, sticky, slightly plastic; few mottles, medium, prominent; diffuse wavy boundary.

Oe 395-420 cm; (10YR2/2, moist, changing to 10YR2/1 upon exposure to atmosphere) very mucky peat; weak, fine, massive, loose, sticky, slightly plastic; few, medium, prominent mottles; diffuse wavy boundary.

Oa 420-485 cm; (10YR2/2, moist, changing to 10YR2/1 upon exposure to atmosphere) muck; weak, fine, massive, loose, sticky, slightly plastic; few, medium, prominent mottles; diffuse wavy boundary.

Fig. 2. Soil profile at the study site in Woodburn with its stratigraphic description, mapped in June–July 1997.

Table 2. *Plant species of which seeds were obtained from the study site, and typical habitats in which they occur at present (according to Gilkey & Dennis 2001)*

Species name	Habitat
Cicuta douglasii	wet areas
Ledum glandulosum	bogs, wet areas
Menyanthes trifoliata	standing water
Nuphar luteum	ponds, lakes
Potamogeton sp.	ponds, lakes

standing water, such as lakes or large ponds, as do beetles of the genera *Hydrochus, Tropisternus, Dytiscus* and some *Donacia* and *Plateumaris.* However *Ledum glandulosum* and *Cicuta douglasii* are associated more with marshes and bogs, as are *Elaphrus, Bembidion* and *Cyphon. Pselaphidae* occur in *Sphagnum* bogs, and this moss is common in the peat samples. Together, these remains indicate the consecutive presence of at least two types of wetlands at the study sites, with a progressive succession from one to the other over time. In present-day European lowlands, *Menyanthes trifoliata* occurs most commonly in early successional stages of floating fens that develop on shallow water bodies (Rodwell 1991; Schaminée *et al.* 1995; Ellenberg 1996). In the course of succession, these fens develop either towards poor fens and bogs (van Wirdum *et al.* 1992) or towards carr forest (Bakker *et al.* 1997). A similar development may have occurred in Woodburn.

Stratigraphic results indicate a course of action that probably started some 13'000 years ago when the temporary Lake Allison, formed from the cataclysmic flooding of the Willamette Valley between 15'000 and 12'800 YBP, encompassed the present study site (Allen *et al.* 1986). The floods drowned much of the megafauna, whose bodies remained in large channels, the walls of which began to slump, causing damming and ponding. These water sources slowly filled in, eventually becoming peat bogs and then transforming into riparian and woodland that still exists in small areas in the valley today. This course of events is similar to that reported by Warner *et al.* (1984) where an open water habitat developed into a fen and shallow peatland phase in the Queen Charlotte islands.

MENYANTHES TRIFOLIATA - A TEMPERATURE INDICATOR?

Although seeds of the bog bean, *Menyanthes trifoliata,* were found over a large part of the soil profiles, ^{14}C dating suggested that its occurrence was restricted to a period of approximately one thousand years between 10'000 and 11'000 YBP, when a large amount of peat accumulated at the study site. While circumboreal, the bog bean is considered native to the Vancouverian Province of the Rocky Mountain Region

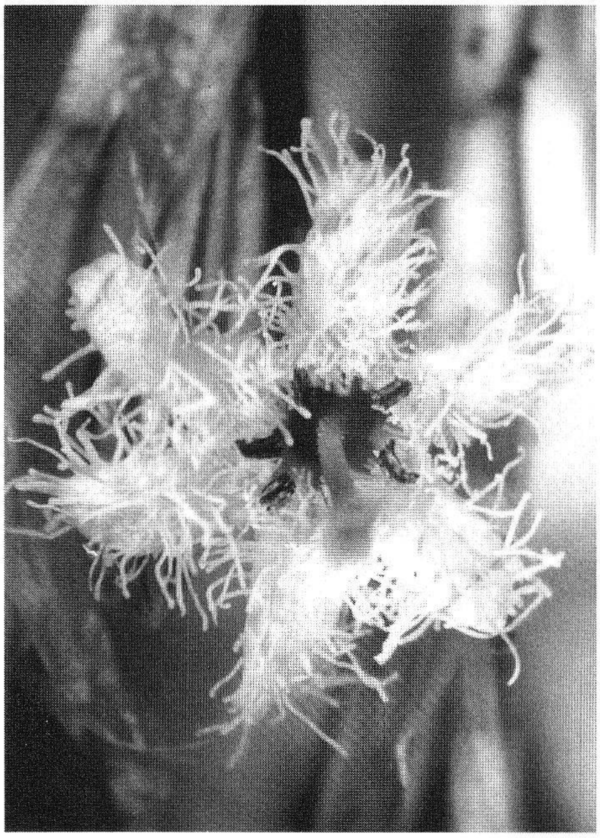


Fig. 3. *Flower of the bog bean,* Menyanthes trifoliata.

Table 3. *Insect genera (all Coleoptera) of which remains were obtained from the study site, and typical habitats in which they occur at present (according to Hatch, 1953–1971).*

Genus	Family	Habitat
Bembidion	Carabidae	marshes, near water sources
Cyphon	Helodidae	marshes, ponds and lakes
Donacia	Chrysomelidae	standing water, on aquatic plants
Dytiscus	Dytiscidae	standing water, along water margin
Elaphrus	Carabidae	marshes, near water
Hydrochus	Hydrophilidae	near standing water
Plateumaris	Chrysomelidae	standing water, on aquatic plants
Tropisternus	Hydrophilidae	near standing water
Unidentified	Pselaphidae	*Sphagnum* bogs

(Takhtajan 1986). This province extends from Alaska to California and includes both the Cascade and the Coastal mountain ranges in Oregon. The bog bean is restricted to wet habitats, occurring only in bogs, marshes and pond margins (Guard 1995; Crow & Hellquist 2000; Cronk & Siobhan Fennessy 2001).

Fig. 4. *Seeds of* Menyanthes trifoliata *recovered from peat layers at study site. The arrow shows a seed in side view, and the fleche a seed viewed from the edge.*

In the northern part of the Vancouverian Province (Alaska, Canada and northern Washington) bog bean populations occur at sea level (Sharples 1938; Lyons 1952; Baker 1972). However, passing southward, the lowland portion of the range disappears, and in Oregon the species can be found only from 854 to 1768 m elevation (Fig. 5a; Appendix 1). In California, finally, the altitude of sites with bog bean extends up to 3500 m (Munz & Keck 1970). The only lowland site supporting the bog bean in California is a coastal fen in the northern part of California. The Inglenook fen is a special ecotone composed of dunes, a peat bog, fen and lake adjacent to the Pacific Ocean. Because of macro- and microclimatic features, this fen contains relic plants and insects which have northern (Canadian) or boreal distributions. Due to these unique climatic conditions, this fen is considered a postglacial refugium (Baker 1972; Barry & Schlinger 1977).

A correlation exists between the latitude and altitude of known populations of *Menyanthes trifoliata* even within Oregon: southernmost populations (42°03' N) are found at almost 700 m higher elevation than northern-

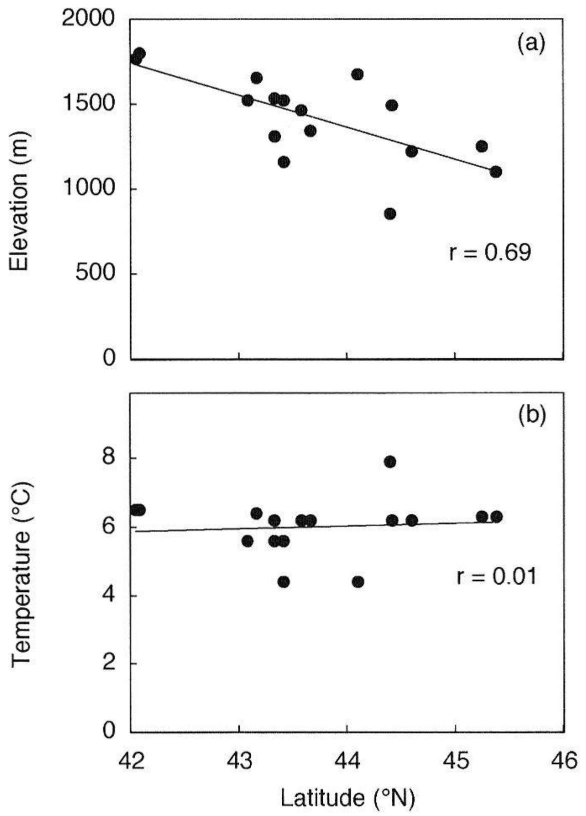


Fig. 5. Relationships between the latitude and (a) the altitude (m a.s.l.) as well as (b) the yearly mean temperature of present-day populations of Menyanthes trifoliata *in Oregon, based on specimens of the Oregon State University Herbarium (cf. Appendix 1). For comparison, our study site, Woodburn, is at 49 m with a yearly mean temperature of 11.1 °C.*

most populations (45°23' N; Fig. 5a). Due to this altitudinal variation, yearly mean temperatures at the various locations are independent of latitude (Fig. 5b). They range from 4.4 °C to 7.9 °C (mean: 6.0 °C), which is 3.2 °C to 6.7 °C lower than the yearly mean temperature at the study site (11.1 °C).

The observed correlations between climatic conditions and occurrence of *Menyanthes trifoliata* are probably not due to a direct physiological response to higher temperature, as the species does occur in European lowlands at sites with annual mean temperatures of 9 °C and above. It must therefore be assumed that the observed relationship between temperature and the occurrence of *M. trifoliata* is mediated by other factors. Possible factors that could influence the present distribution of *M. trifoliata* in Oregon are the destruction of suitable habitats at lower elevations, water chemistry, seed predation, shading by trees, plant longevity, diseases, competition and pollinators.

Many wetland habitats in the Willamette Valley have been drained and cleared for pasture and onion fields, but a wide range of aquatic habitats still exist at lower elevations in the Coast Ranges, foothills of the Western Cascades and the Siskiyou Mountains as well as in Eastern Oregon (Guard 1995). Thus, wetland destruction as such cannot be responsible for the present distribution of *M. trifoliata.* However, water quality in these wetlands may not be appropriate. *Menyanthes trifoliata* is characteristic of sites with relatively base-rich but slightly acidic, nutrient-poor water (Oberdorfer 1983). These conditions are most likely to be realised under a cool, perhumid climate. In lowlands of Central Europe, the occurrence of *M. trifoliata* is presently mostly restricted to man-made habitats where the required site conditions have to be maintained by conservation management or re-created periodically (Rodwell 1991; van Wirdum *et al.* 1992). Natural occurrences are considered relictic (Oberdorfer 1992). Most lowland communities supporting *M. trifoliata* are currently strongly threatened by hydrological change, eutrophication, acidification or succession towards forest (Schaminée *et al.* 1995), whereas fen communities with *M. trifoliata* are fairly abundant and stable in mountain regions with lower temperature and/or higher precipitation (Oberdorfer 1992). The disappearance of *M. trifoliata* from our study site in Woodburn after a long period of presence (seeds were found over 180 cm peat depth) suggests that climatic change towards warmer and drier conditions caused the site to become unsuitable for *M. trifoliata*. Succession towards forest was probably the cause, as the disappearance of seeds (240 cm depth) was followed rather rapidly by the cessation of peat accumulation (225 cm depth) according to our soil profile.

Concerning pollination, unfortunately this aspect of the ecology of *Menyanthes trifoliata* has not been thoroughly studied. While in Europe, the species is said to be pollinated by bumblebees (Oberdorfer (1983) observations made by the senior author did not indicate that this also holds for Oregon. Doyen (in Barry & Schlinger 1977 and pers. comm.) noted that at Inglenook fen, bog bean flowers were visited by an undescribed beetle of the genus *Phalacrus* (Phalacridae: Coleoptera). These active beetles moved from flower to flower and could have served as pollinators. Barry & Schlinger (1977) commented that a number of insects occurring at Inglenook fen normally exist at higher elevations or in boreal regions in Canada. Thus as the climate warmed, insect pollinators might have been sensitive to the temperature change and perished, thus eliminating the species from lower elevations. To test this hypothesis, a study of the pollinators at the various natural sites would have to be conducted, which is beyond the scope of this study.

CLIMATIC CHANGE DURING THE EARLY HOLOCENE

On the basis of the associations between climatic conditions and occurrence of *Menyanthes trifoliata* as discussed above, we propose that the yearly mean temperatures at the study site were probably at least 3–4 °C cooler in the early Holocene than today. These results support the earlier conclusions of Barnosky (1985), who described a late Pleistocene cold and dry sequence from 25'000 to 10'000 YBP followed by an onset of warm conditions beginning around 10'000 YBP, and Booth (1987), who proposed a warming trend between 10'000 and 11'000 YBP. These conclusions were based on studies in the state of Washington. Results presented here suggest that similar conditions existed in the northern portion of central Oregon. This is apparently the first time *M. trifoliata* has been used as a temperature indicator.

It is possible that the temperature change noted here could be associated with the sudden warming that occurred after the cool Younger Dryas period during the last deglaciation in the North Atlantic. This Younger Dryas interval, dated to ca. 12'800–11'500 RCYBP was apparently quite widespread, affecting not only Europe, the Arctic and North Atlantic but also West Asia and North America (Alley 2000; Peteet 2000). It is interesting that the predicted end of this sudden cool interval (11'500 RCYBP; Peteet 2000) is close to the time we predict a warming at the study site in Oregon. The temperature change during this cooling period varied with estimates ranging from as much as 7–15 °C in Greenland and 7–8 °C in Britain to 3–6 °C in Eastern North America (Gates 1996; Peteet 2000). We suggest that the disappearance of the bog bean from the site could be related to the post-Younger Dryas warming period. However, definite proof for the correlation of these events must await further studies.

INDICATIONS OF HUMAN ACTIVITY

In addition to the aforementioned seeds and insect remains, several bones and bone fragments of deer and elk, two small basalt and one jasper flake and a basalt bipolar core were recovered from the organic variant of section Oa. The findings may be regarded as evidence of human habitation at this site. As to the seeds of *Menyanthes trifoliata,* many of them had broken edges. The breakage areas were sharp and jagged and showed no evidence of teeth marks that one would expect from vertebrate predation. Predation by invertebrates appears even more unlikely as it would be difficult for invertebrates to open such thick-walled seeds. Since humans were apparently present, it is possible that Paleoamericans used the bog bean as a source of food and/or medicine. *M. trifoliata* contains the bitter glycoside menyanthin, which is used medically as a tonic to lower fever (Heywood 1978). Other uses of this plant include the infusion of roots for gas pains, stomach disorders, constipation, rheumatism, various internal diseases such as "blood spitting" and to add weight. The rootstocks were also ground, leached, dried and ground into flour for bread. Infusions from the plant have also been used as a vermifuge and for treating vitamin C deficiency (Moerman 1998). Present day tonics made from bog bean call for extracts of leaves and roots, not seeds. In China, however, the whole plant is used (Li 2002). Whether some now obscure medicine was obtained by grinding the seeds of this plant can only be conjectured at this time, but it might be an explanation for the broken seeds.

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Appendix 1. *Latitude (°N), altitude (m a.s.l.) and yearly mean temperature (°C) from 1961 to 1990 at present-day sites of* Menyanthes trifoliata *in Oregon according to herbarium specimens deposited with the Oregon State University Herbarium (accession numbers given in the first column).*

Number	Lat. N	m a.s.l.	T (°C)
16'117	44°06'	1677	4.4
23'247	43°05'	1524	5.6
26'441	43°10'	1655	6.4
37'073	43°40'	1341	6.2
39'393	44°36'	1220	6.2
39'394	45°23'	1098	6.3
43'423	42°03'	1768	6.5
71'380	44°25'	1494	6.2
71'393	43°25'	1159	5.6
71'397	45°15'	1250	6.3
88'723	43°20'	1311	6.2
106'142	43°20'	1534	5.6
108'396	43°25'	1524	4.4
115'598	43°25'	1524	5.6
119'053	43°35'	1463	6.2
120'578	42°05'	1801	6.5
188'251	44°24'	854	7.9