Quaternary Science Reviews 106 (2014) 262–277

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

To what extent did changes in July temperature influence Lateglacial vegetation patterns in NW Europe?

Hilary H. Birks [a], [*], H. John B. Birks [a], [b], [c]

[a] Department of Biology, University of Bergen, and Bjerknes Centre for Climate Research, Postbox 7803, N-5020 Bergen, Norway
[b] Environmental Change Research Centre, University College London, Gower Street, London WC1E 6BT, UK
[c] School of Geography and the Environment, University of Oxford, South Parks Road, Oxford OX1 3PY, UK

ARTICLE INFO

Article history:
Received 28 September 2013
Received in revised form
6 June 2014
Accepted 12 June 2014
Available online 5 July 2014

Keywords:
Pollen percentages
Chironomid-inferred temperatures
Precipitation
Macrofossils
Temperature patterns
Vegetation patterns

ABSTRACT

What was the impact of July temperature changes on vegetation patterns during the Lateglacial period in north-west Europe? Chironomid-inferred mean July air temperature estimates (C-Tjul) are proxy temperature records independent of terrestrial vegetation. The relationships between Lateglacial vegetation inferred from pollen percentages and these temperature estimates are explored using data synthesised geographically from 15 sites where both pollen percentages and C-Tjul are published to assess the influence of temperature and of temperature changes on regional vegetation.

Direct impacts of temperature on a species involve passing the range limits or realised niche of that species. The Bølling warming allowed vegetation to develop. The Younger Dryas cooling had direct impacts on species and vegetation types that were at a critical ecotone and thus sensitive to change. Precipitation is extremely important and its interaction with temperature controlled most of the vegetation patterns inferred from these NW European pollen data. High precipitation was important in W Norway, whereas aridity in the YD was a controlling factor in N Norway, the Netherlands, and NE Germany. Under constant climate, ecological processes occurred such as immigration, succession, and soil development that resulted in vegetation changes. Biotic interactions were also important, such as the impact of grazing by mega-herbivores during Allerød time in Ireland that may have restricted the development of birch woodland. At the coarse scale of this synthesis, July temperature alone is seen not to be a good predictor of the patterns of pollen percentages and hence of vegetation through the Lateglacial. Rather, it is the interactions of temperature and precipitation, combined with ecological processes that appear to be the major factors influencing Lateglacial palynological and vegetation patterns in NW Europe.

1. Introduction

One of the lines of investigation in the EU-COST INTIMATE Action ES-0907 is the synthesis of impacts of climate changes on biota across Europe 8–60 thousand years ago. Vegetation is of fundamental importance in terrestrial ecosystems, so any changes in vegetation will have large impacts on the other components of the ecosystem, including humans. Climate is the ultimate driver of broad-scale ecosystem composition and structure. The most influential climatic variables are temperature and precipitation (Birks et al., 2000) relating to important eco-physiological factors such as the length of the growing season and the annual ratio of actual to potential evapotranspiration (Huntley, 2012). Together, temperature, precipitation, and their interactions control many geomorphic and biotic processes. The biotic impact can be direct, acting though biological and physiological traits of organisms. Indirect impacts can also be of fundamental importance to ecosystem function, through intrinsic processes involving biotic interactions and community dynamics (Iversen, 1973; Williams et al., 2011; Post, 2013; Ammann et al., 2013a,b), such as immigration from refugia (perhaps leading to lags in establishment under a suitable climatic regime (e.g. Birks and Birks, 2008; Birks et al., 2012), local extinction due to climatic intolerance (Birks and Birks, 2013), and competition (Birks and Birks, 2008), or succession under a constant climate (Birks et al., 2000; Birks and Birks, 2008, 2013; Williams et al., 2011). All species have limits of tolerance to environmental factors (fundamental niche). Any change in the environment will have the largest impact on a species if it occurs near the limit of its tolerance at or near the edge of its distributional and ecological

---

[*] Corresponding author. Tel.: +47 5558 3325; fax: +47 5558 4450.
E-mail address: hilary.birks@bio.uib.no (H.H. Birks).

http://dx.doi.org/10.1016/j.quascirev.2014.06.024

range (realised niche). The impact will depend on the resilience and inertia of the system. If a species is a keystone species in an ecosystem, an impact on it may cause the whole ecosystem to respond, perhaps changing to another regime, for example the immigration of tree birch leading to the establishment of birch woodland over a dwarf-shrub heath ecosystem (Birks et al., 2000; Jeffers et al., 2011a, b; Birks et al., 2012).

The Lateglacial was a period of rapid and large climatic changes in NW Europe. These resulted in changes in species distributions leading to changes in vegetation types through time at a site. To explore the relationship between climate change and vegetation change in space and time our sources of data must be independent. To reconstruct vegetation patterns at this broad scale, we use percentage pollen data. We relate these to mean July air temperature inferences derived from fossil chironomid data from the same sites. Our main questions are: 1) What are the patterns of Lateglacial temperature changes across NW Europe? 2) What are the pollen and inferred vegetation patterns across NW Europe through the Lateglacial period? 3) Is vegetation in equilibrium with temperature, or are there mis-matches? 4) What are the causes of any such mis-matches? Are they due to other climate variables such as precipitation, to the insensitivity of the vegetation to change, to biotic interactions, or to delays in migration?

2. Methods

At present, there are published Lateglacial pollen and chironomid records from 15 sites in NW Europe (locations and references in Fig. 1). They extend from NW Iberia and the French Pyrenees in the south to northernmost Norway with one in Spain, one in France, two in the Netherlands, one in NE Germany, two in England, two in Ireland, three in Scotland, and three in Norway. At Klein Ven in the Netherlands Younger Dryas sediments are lacking. The record at Kråkenes, W Norway, starts at ca 14 k cal yr BP. The 15 sites are used to assess the relationship between mean July air temperature inferred from chironomid records and vegetation patterns derived from pollen records. There are several more chironomid records that are not associated with pollen data (Brooks and Langdon, 2014). There are many more published pollen records that do not have associated chironomid records. We consider some of those that have macrofossil records in a broad context to help to construct and refine past vegetation patterns (Fig. 1).

Ideally, all sites should have a high-resolution chronology so that changes can be compared directly in time. However, many of the sites have poor chronologies or poor sample resolution. Therefore, we make the assumption that the major temperature changes and the lithological boundaries of the Younger Dryas period are synchronous and detectable in all the records. The YD is broadly correlated with Greenland Stadial 1 (GS1) (12.85–11.65 k-ice-core yr BP (BP = before present, which is taken as AD1950)) in the Greenland Ice-core Chronology (GICC05; Rasmussen et al., 2006). The ages of the YD boundaries in the calibrated radiocarbon timescale (IntCal09) are 12.71 and 11.55 ka BP, measured at Kråkenes in W Norway (Lohne et al., 2013). Temperature oscillations as identified in the Lateglacial interstadial pollen and chironomid stratigraphy are correlated with oscillations in the Greenland Interstadial (GI)1. The Bølling period (BØ) (ca 14.7–14.0 ka BP) is equivalent to GI-1e. The Allerød period (ca 14.0–12.7 ka BP) is equivalent to GI-1d-a (Lowe et al., 2008).

Here we make an exploratory synthesis designed to relate vegetation changes as indicated by pollen records to temperature changes inferred from chironomid records. To do this we have estimated from the published diagrams the mean chironomid-inferred temperatures and pollen percentages for the major taxa during the Lateglacial intervals.

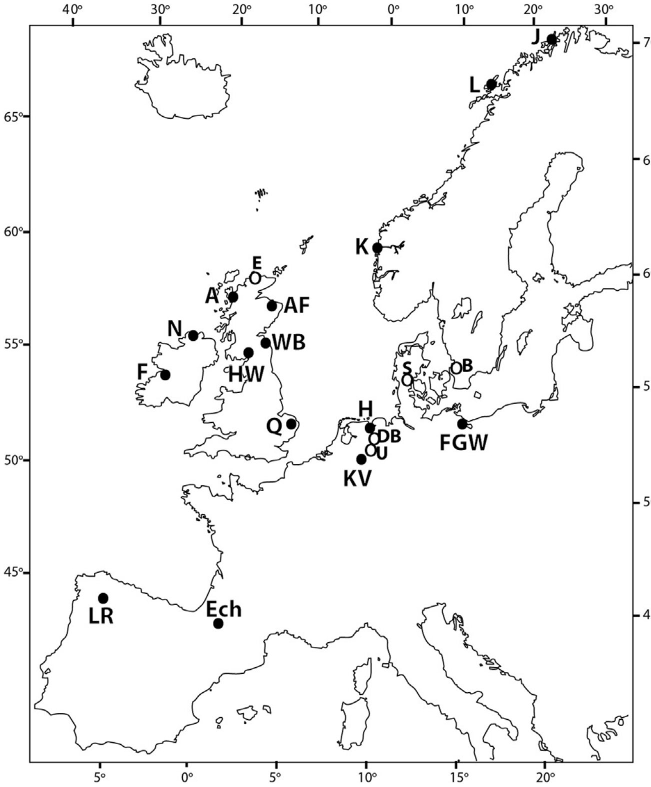

Fig. 1. Map of Europe showing the locations of sites in NW and SW Europe where pollen diagrams and chironomid temperature inferences have been published (black dots). Other sites mentioned in the text (open circles) are labelled in smaller font. J = Jansvatnet (Birks et al., 2012); L = Lusvatnet (Aarnes et al., 2012; Birks et al., 2014); K = Kråkenes (Birks et al., 2000; Brooks and Birks, 2000); AF = Abernethy Forest (Birks and Mathewes, 1978; Brooks et al., 2012); WB = Whitrig Bog (Mayle et al., 1997; Brooks and Birks, 2000); A = Loch Ashik (Walker et al., 1988; Brooks et al., 2012); HW = Hawes Water (Walker, 1955; Smith, 1958; Oldfield, 1960; Pennington, 1977; Bedford et al., 2004); Q = Quidenham Mere (Hunt and Birks, 1982; Jeffers et al., 2012a); N = Lough Nadourcan (Watts, 1977; Watson et al., 2010; Jeffers et al., 2012b); F = Fiddaun (Van Asch et al., 2012b; Van Asch and Hoek, 2012; H = Hijkermeer (Heiri et al., 2007); KV = Klein Ven (Van Asch et al., 2013); FGW = Friedländer Große Wiese (Van Asch et al., 2012a); Ech = Ech (Millet et al., 2012); LR = Laguna de la Roya (Muñoz Sobrino et al., 2013). E = Lochan an Druim, Eriboll (Birks, 1984), S = Slotseng (Mortensen et al., 2011); B = Bjørkeröds mosse and 2 other sites (Liedberg Jönsson, 1988); U = Usselo (Van Geel et al., 1989); DB = De Borchert (Van Geel et al., 1981).

Temperatures in the following intervals are plotted in Figs. 2 and 3. In the early interstadial (Bølling; BØ; GI-1e) we ignore the steep temperature increase following deglaciation and concentrate on the interval of warm temperatures (Fig. 2a). If temperatures fluctuate greatly, then the range is considered. Allerød temperatures are estimated across the interval correlated with GI-1c-a (AL). These are usually rather consistent, although in some sites, the cool interval GI-1b is pronounced (e.g. Hijkermeer). In such cases, the warmer temperatures are considered as the AL temperature. The short pronounced temperature drop between the BØ and AL intervals corresponds to GI-1d. The temperature change between BØ and AL in Fig. 2c excludes GI-1d and the values for the drop from BØ to GI-1d are shown in brackets where this is detectable. Thus the occurrence and extent of the GI-1d cooling can be mapped. The earliest Younger Dryas temperatures are plotted in Fig. 3a and the decrease from AL GI-1a is shown in Fig. 3b. The coldest temperatures during the YD are shown on Fig. 3c.

Local factors can have an important influence on the pollen or chironomid stratigraphies and we have indicated these where appropriate. When the chironomid-based temperatures or pollen