This episode records two phases of vegetation change: 1360-1510 AD is characterized by large-scale deforestation due to the expansion of pastoral and arable farming; the phase 1510-1580 AD recorded a forest regeneration as a consequence of the demographic crisis during the Modern Age.

Episode V (1580±40 to 1760±30 AD): Multi-proxy data suggest a fall in the lake water level and mesothropic conditions. The minimum lake level was recorded at ca. 1700 AD. Hemp production reached a peak according to the pollen diagram. The peak of terrigenous sediment input at 40 cm depth could be attributed to the hemp retting process, as stones were placed over the hemp to prevent it from floating away.

This episode started with a clearance of the mixed forest and a maximum land use (cultivation of cereal, olive and hemp).

Episode VI (1760±30 to 1895±40 AD): The lake level reconstruction shows a progressive rise in waterlevel. Demographic expansion led to maximum vegetal degradation, inducing the growth of shrubs and matorral communities. The pollen diagram shows the reduction of hemp production and the expansion of olive crops between 1800 and 1850 AD.

Non pollen microsfossils suggest the development of pastoralism.

Episode VII (1895±40 to 1991 AD): The rogressive decrease in water level led to mesothtopic status. Agricultural activity decreased as a consequence of depopulation after 1870. Non pollen microsfossils indicate large grazing activities.

Session h8

POLLEN CALIBRATION AND QUANTITATIVE RECONSTRUCTION OF PAST VEGETATION COVER

Reconstructing 17 centuries of forest history around Lake Clair, Quebec, Canada

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Lake Clair is located in the Sugar Maple – Yellow Birch Vegetation Domain (Mixed Forest Biome) of southern Quebec, *ca.* 50 km northeast of Québec City, close to the southern limit of the Boreal Forest (Balsam Fir – Yellow Birch Vegetation Domain). The forest stand in the lake's watershed remained untouched, and is now occupied by six tree species: Sugar Maple (*Acer saccharum* : 68%), American Beech (*Fagus grandifolia* : 9%), Balsam Fir (*Abies balsamea* : 9%), Red Spruce (*Picea rubens* : 8%), Yellow Birch (*Betula alleghaniensis* : 6%) and some White Birch (*B. papyrifera*) (% of total basal area).

High resolution pollen analysis of a short core (0-50 cm of surficial lake sediments), spanning the last 1700 years (^{210}Pb and ^{14}C dating), reveals assemblages that closely track the landscape-level vegetational changes that occurred outside the watershed in the neighbouring Saint-Lawrence Lowlands: 1) the early settlement under the French Colony (Seigneurie de Portneuf since 1647 A.D.), 2) the progressive clearing of forests for agriculture in the Lowlands, 3) its maximal extension to the hinterland, towards the Laurentian Highlands and Lake Clair between 1830 and 1870 A.D., and 4) the demise of marginal agriculture since 1920 A.D. Nowadays, the closest agricultural areas are located some 10 km away from the lake. They never got closer in the past. Pollen evidence for those changes include the arboreal pollen decline and recovery, and the changing representation of cereals, weeds, and second-growth tree species like Red Maple (*Acer rubrum*). All are long-distance transported from outside the watershed and totalize 15-20% of the pollen sum. A decline from 10 to 3-4% in the pollen representation of White Pine (*Pinus strobus*) and of Eastern Hemlock (*Tsuga canadensis*) underscores those extra-regional vegetational changes.

Within the regional pollen source-area, that is the Lake Clair catchment itself, the quantitative changes in forest composition through time were assessed by applying a correction factor to the pollen representation of each of the five tree genus represented in the forest canopy. Those correction factors were derived from a

comparison between the pollen percentage of each taxon in the uppermost sediments and its modern abundance in the regional vegetation (% basal area). This allowed the reconstruction of the primeval, late Holocene forest around Lake Clair, and the examination of the changes that occurred during the last two millenia.

The pre-historical forest composition, albeit similar to the modern, experienced marked changes in the abundance of Red Spruce, Balsam Fir, Sugar Maple and American Beech. The former two appear to have responded closely to the Little Ice Age (cooling) by increasing their abundance, but they also show a sustained increase at the scale of the Upper Holocene (Neoglacial). Sugar Maple and American Beech experienced a corresponding decline at both temporal scales, but only the former responded to the end of the Little Ice Age by a spectacular increase of its populations. Sugar Maple thus reacted much as an tolerant species. The intolerant American Beech was a much more important component of the primeval forest (22% compared to 9% in modern times). There are indications for cyclic changes in the mutual abundance of Sugar Maple and American Beech that could relate to competition, or to century-scale climate cycles. Finally, a steady decline of the pollen accumulation rates for the deciduous species is indicative of an overall decline in the density of the tree cover throughout the last 17 centuries, perhaps translating long-term depletion of soil nutrients.

Pollen analysis of Lake Clair's sediments thus exhibit the long-term response of a forest to both climatic and non climatic (competition and soils) environmental changes.

Objective comparison of vegetation composition between sites using pollen assemblages

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A new method to assess the differences in species composition of the surrounding vegetation between pollen sites is proposed and tested. Differences in the regional pollen background can strongly influence the pollen representation of vegetation (Sugita 1994; Sugita et al. 1999; Parshall and Calcote 2001). Even if the vegetation composition is the same within the relevant source area of pollen (as defined in Sugita 1994), the pollen assemblages can differ in other regions or in different time periods with the changes in the background pollen. This makes objective comparison of the vegetation composition among sites using pollen assemblages difficult.

The proposed method, the Qualitative Assessment of Difference method or QAD, neutralizes the impacts of the background on the pollen assemblages and objectively ranks the plant abundances of individual taxa between sites. Based on the pollen assemblage data, the differences in vegetation proportion of the constituent taxa are assessed at a pair of sites at the same time horizon using an inverse form of the Extended R-value model (Prentice and Parsons 1983), and are expressed as positive, negative, or no difference between the sites. Although the results are qualitative, this method is free from the artefacts of percentage calculation of pollen assemblages and is unconstrained by the changes in background pollen abundance. We demonstrate the validity of the method using a hypothetical example, and an empirical data set of the surface pollen from forest hollows and the surrounding vegetation from northern Michigan and northwestern Wisconsin in the United States. The QAD method is appropriate for sites closely located to each other, satisfying the assumptions that the background pollen loading and pollen productivity for individual taxa considered are consistent among sites. Reconstruction of the vegetation composition using the fossil pollen records from four forest hollows at the Sylvania Wilderness in northern Michigan shows the advantages of the method over the stand-type reconstruction based on the multivariate numerical techniques.

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PRENTICE, I.C. & PARSONS, R.W. 1983. Maximum Likelihood Linear Calibration of Pollen Spectra in Terms of Forest Composition. **Biometrics** 39: 1051-1057.

SUGITA, S. 1994. Pollen representation of vegetation in Quaternary sediments: Theory and method in patchy vegetation. **J. Ecol**. 82: 881-897.

SUGITA, S., GAILLARD, M.-J. & BROSTRÖM, A. 1999. Landscape openness and pollen records: a simulation approach. **Holocene** 9: 409-421.

Cultural signals from moorland ecosystems

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Heathlands and mires dominated by ericaceous dwarf shrubs occur extensively in north-western Europe. In many areas, these heaths and moors appear to have initially developed in response to prehistoric human activity. Moorlands and heaths form an important part of the cultural landscape mosaic in much of north-west Britain and other upland areas. Mire environments, accumulating deep peat deposits under oceanic conditions, are a rich source of palaeoecological records. However, interpretation of these records is complicated, since the dominant members of the plant community on both mire and nearby dry land slopes are the same. I will present results of an investigation combining empirical investigation of the modern pollen-vegetation relationship and simulation studies to improve our ability to interpret the pollen record from dwarf-shrub moorland and heathland systems.

Empirical studies produce estimates of Relative Pollen Productivity and of Relevant Source Area of Pollen, and are used to validate the use of the Prentice-Sugita model of pollen dispersal and deposition, developed for closed forest landscapes, in these rather different landscapes. Simulation approaches have then been used to explore which aspects of the landscape mosaic have the strongest effect on the pollen assemblage, and to explore the palynological detectability of possible changes in landscape occurring in response to prehistoric and historic human activity. The changed understanding derived from these studies is then applied to the reconstruction of past upland landscapes from pollen records from mires and peat deposits.

Validation of the POLLSCAPE model of pollen dispersal and deposition, using AD 1800 lake sediment pollen samples and historical maps from Denmark

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The POLLSCAPE model (Sugita, 1994; Sugita et al., 1997; 1999) simulates the pollen deposition in lakes or bogs from a given spatial distribution of source plants around the sites, based on Sutton's (1953) model of the dispersal of small particles in the atmosphere, species specific dispersal properties and estimates of relative pollen productivity. Such simulations can be very useful for the interpretation of pollen diagrams in terms of past vegetation composition and patterns.

In order to validate the POLLSCAPE model, pollen deposition in 30 Danish lakes (area 3-30 ha) was simulated from the surrounding vegetation in AD 1800 interpreted from historical maps, using pollen productivity estimates from studies of surface samples in Scandinavia (Broström et al., in press; Hjelle, 1998; Sugita et al., 1999). The simulated pollen assemblages were compared to the actual AD 1800 assemblages found in the lake sediments.

For most pollen types, there is a significant positive correlation between simulated and observed pollen proportions. Some of the discrepancies observed are discussed in terms of uncertainties in the historical vegetation data, in the pollen productivity estimates and problems in the assumptions of the model.

The simulated pollen assemblages are shown to depend on the pollen productivity estimates used. For the non-arboreal pollen types, the pollen productivity estimates of Hjelle (1998) result in the best fit with the observed data.

The results are also sensitive to the average windspeed assumed for the model. The goodness of fit between observed and simulated pollen proportions has an optimum at an average windspeed of around 2.5 m/s.

BROSTRÖM, A., SUGITA, S., GAILLARD, M.-J., IN PRESS. Pollen productivity estimates for the reconstruction of past vegetation cover in the cultural landscape of southern Sweden. **Holocene.**

HJELLE, K.L., 1998. Herb pollen representation in surface moss samples from mown meadows and pastures in western Norway. **Vegetation History and Archaeobotany** 7: 79-96.

SUGITA, S., 1994. Pollen representation of vegetation in Quaternary sediments: Theory and method in patchy vegetation. Journal of Ecology, 82: 881-897.

SUGITA, S., GAILLARD, M.-J., BROSTRÖM, A., 1999. Landscape openness and pollen records: A simulation approach. **The Holocene** 9(4): 409-421.

SUGITA, S., MACDONALD, G.M., LARSEN, C.P.S., 1997. Reconstruction of fire disturbance and forest succession from fossil pollen in lake sediments: Potential and limitations. In: CLARK, J.S., CACHIER, H., GOLDAMMER, J.G., STOCKS, B.J. (Editors), **Sediment records of biomass burning and global change**. Springer-Verlag, Berlin, pp. 387-412.

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Qualitative reconstruction of past cultural landscape in French middle mountains areas

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Many pollen diagrams from French mountain ecosystems have been analysed, but, so far, very few reconstructions of past vegetation or landscape units by means of comparisons of modern and fossil pollen spectra have been attempted. However, such a comparative approach is useful for refining the interpretation reliability and increasing our understanding of the development of agro-pastoral landscapes and of past land-use changes. This approach requires searching for modern analogues of past landscapes and vegetation communities such as grazed meadows, mown pastures, woodlands and cultivated fields. Our project takes advantage of some traditional or semi-traditional practices that can still be observed, particularly in the Alps, Pyreneans and Jura mountains.

Moreover, the reliability of pollen analysis as a tool for the reconstruction of past vegetation depends on a good calibration between actual pollen deposition and vegetation. How is current species composition reflected in modern pollen assemblages? Further, in attempting to evaluate not only human presence but also the nature, extent and duration of human activities, it is important to be able to recognize which specific plant community or individual taxa are representative of a certain type of agro-pastoralism such as cultivation, pasturing, trampling, settlement and mowing.

As a first step, the modern pollen/vegetation relationships were investigated at a local scale to identify vegetation types by their pollen assemblages. Together in the three geographical areas, more than one hundred sites were selected to cover the different plants communities. Both multi-scale vegetation analysis and pollen counts from moss polsters were carried out. The data sets of each area were analysed by multi-variate analysis using a canonical model, including forward selection and Monte Carlo permutation tests for selecting the best predictors. This statistical procedure allows to represent and test modern pollen variation in relation to explanatory external variables including environmental and anthropogenic information. This permits to test whether various human activities (mowing, pasturing, cultivating…) and different plants communities produce distinct modern pollen spectra.

Secondly, modern spectra and fossil spectra from pollen sequences located in the same geographical areas have been compared by transfer functions, including a weighted averaging regression and a non linear regression based on artificial neural networks. This comparison will allow to improve the interpretation of human activities from local pollen diagrams and to achieve a better reconstruction of the history of human impacts in these mountains regions. The resulting land-use reconstruction will be checked for validation by the available historical and archaeological data.

Pollen-based quantitative reconstruction of past vegetation using models of pollen dispersal and deposition

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A possible strategy for quantitative reconstruction of past vegetation inferred from fossil pollen is the "Landscape Reconstruction Algorithm" (LRA) (SUGITA & WALKER 2000). This approach involves the use of models of pollen dispersal and deposition, Extended R-value (ERV) models and simulation models. It requires pollen counts, estimates of pollen productivity and pollen dispersal/deposition function of the individual taxa. LRA comprises three major steps: the first step is to estimate the regional plant abundance using pollen assemblages from large lakes (≥ ca. 200 ha) and an adequate model of pollen dispersal and deposition ("model A"). Given the regional plant abundance, the second step is to estimate the background pollen loading coming from beyond the "relevant source area of pollen" (RSAP) for small lakes (< ca. 30 ha). The RSAP for small lakes in the past is estimated using a simulation approach. Knowing the background pollen loading for small lakes, the third step consists of reconstructing vegetation abundance using fossil pollen records from small lakes and an inverse form of the ERV-models.

The LRA is being applied in southern Sweden. The results of the validation of "model A" using modern pollen assemblages from large lakes and vegetation data from satellite images and air photos are presented. Using data for 10 lakes distributed between two contrasting landscape areas in southern Sweden, we demonstrate that "model A" works reasonably well to reconstruct modern regional vegetation from surface pollen assemblages in large lakes. Model A can therefore be used to reconstruct past regional vegetation from fossil pollen assemblages. This will enable us to estimate the background pollen term for pollen assemblages from small lakes and make quantitative reconstruction of local vegetation possible.

SUGITA, S. & WALKER, K. 2000. Landscape Reconstruction Algorithm for estimating vegetation changes from pollen records: A case study in the Upper Great Lakes region using modern and presettlement pollen-vegetation data sets. **AGU Fall Meeting, San Francisco.**

Quantitative reconstruction of past vegetation by the earlier monastery of Selja, western Norway

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The island Selja in western Norway has an oral tradition connected to the introduction of Christianity in Norway. The first bishop of the medieval town Bergen, 200 km further south, was situated at Selja at the end of the 11th Century. In the early 12th Century a monastery was built on the island. This was in use until the 15th Century, and a pollen diagram from the bog outside today's ruins tells the history of vegetation and human activity back to the Early Iron Age. The island has a strategic position south of Stadlandet, a western point of Norway that is difficult to pass by boat in strong wind. Stadlandet has through all times been an important landmark by the coast.

The island's strategic position; surrounded be sea in all directions and with the Shetlands as the nearest neighbour to the west, makes it well suited for simulations of past vegetation and modelling of pollen deposition, following the methods of the POLLANDCAL network (GAILLARD ET AL. in prep.). Samples from the island as well as from the neighbouring mainland were included in a study of modern pollen deposition in mown and/or grazed communities of western Norway (HJELLE 1998a). These have been used to obtain pollen productivity estimates (PPE) for herbs, using extended R-value (ERV) model 1 (HJELLE 1998b).

In the present paper different approaches to quantitative reconstruction of past vegetation and land-use by the ruins of the medieval monastery at Selja will be presented: PPE are used to reconstruct past vegetation composition, modern analogues are used to reconstruct past land-use practices using Redundancy Analysis (RDA) and analogue matching, and past vegetation cover is reconstructed using simulations and modelling according to Sugita's (1994) "POLLSCAPE" approach. The results from the different methods are compared and simulated vegetation AD 400 (before the monastery was built), AD 1200 (at the time of the monastery), and AD 1600 (after the monastery period) will be presented.

GAILLARD, M.-J., BROSTRÖM, A., BUNTING, M.J., CASELDINE, C.J., GIESECKE, T., HICKS, S., HJELLE, K.L., LANGDON, C., MIDDLETON, R., SUGITA, S., VON STEDINGK, H. AND POLLANDCAL MEMBERS*. The use of simulation models in reconstructing past landscapes – the POLLANDCAL research-network. In prep.
HJELLE, K.L. 1998a. Relationships between modern pollen deposition and the vegetation in mown and grazed communities in western Norway and their application to the interpretation of past cultural activity. Dr. thesis, University of Bergen, Norway.
HJELLE, K.L. 1998b. herb pollen representation in surface samples from mown meadows and pastures in western Norway. **Veget. Hist. Archaeobot.** 7: 79-96.
SUGITA, S. 1994. Pollen representation of vegetation in Quaternary sediments: theory and method in patchy vegetation. **Journal of Ecology** 82: 881-897.

Modelling aspects of the Neolithic landscape of Ireland–an approach using POLLSCAPE

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Understanding the nature of the Neolithic impact on landscapes has proved a major focus of palaeoecological research since the pioneering work of Iversen. Here we use a modelling approach based around the application of POLLSCAPE and associated programs developed within the POLLANDCAL network to examine two aspects of the Neolithic landscape of Ireland: 1. To determine the likely landscape structure prior to human impact of an extreme oceanic environment on Achill Island, Co Mayo; 2. To ascertain the likely scale and location of clearings associated with a 'classic' Elm Decline at Derragh Bog/Lough Kinale in Central Ireland.

On Achill Island, Western Ireland archaeological survey has revealed evidence for human settlement throughout prehistory and pollen analysis of a small basin site (30 x 30m) provides pollen assemblages covering the same period from which landscape modification may be determined. As a background to this approach simulations of modelled landscape structures of the surrounding area have been carried out using the POLLSCAPE programs for a series of time slices. These include a time slice for the Early Neolithic (ca 5000 ^{14}C yr B.P.) prior to the first palynological indications of human activity is described, concentrating on possible woodland structures, a time slice covering significant landscape change in the later Neolithic around 4000 ^{14}C yr B.P., and a final example from later prehistory with a more open landscape. The site has a number of advantages for testing the approach: the pollen flora is relatively poor with only a few major tree taxa (*Pinus*, *Quercus*, *Ulmus*, *Corylus*) and Poaceae and *Calluna* dominating the NAP; at least 40% of the area reconstructed, 1x1 km, was known to be peat covered (*Calluna* – Poaceae) at the time; and pollen input by prevailing winds from the west may be assumed to be minimal due to the proximity to the Atlantic.

Landscape reconstructions were run based on a range of possible landscape/vegetation structures varying from large uniform blocks of woodland and peat arranged around the site, to homogeneous mixes of species, and also including smaller circular taxa blocks within a background landscape mosaic. The predicted frequencies for the main taxa for the different reconstructions are then compared to those derived empirically from the pollen core, demonstrating the likelihood of the varying models having existed in the past.

At Derragh Bog/Lough Kinale pollen evidence reveals and extremely clear and well defined Elm Decline taking place in the vicinity of the bog which is itself situated on a promontory of dry land bounded on three sides by water. By using a modelling approach it is possible to estimate the size of area that needed to be cleared to register on the pollen diagram and the likelihood that the area affected was indeed on the promontory – an area with no extant archaeological evidence for Neolithic activity.

What the preliminary results presented here demonstrate is that *POLLSCAPE* offers an opportunity not just to try to reconstruct what the past was like but perhaps more importantly to refute hypothesised past landscape structures. There will always be a problem of equifinality, leading to a range of landscapes providing the same fossil result, but in collaboration with archaeologists, palaeoecologists can now test and if necessary, reject ideas of openness, scale of clearance and cultural mosaics, themes that have been the subject of intense debate for many decades. With improved data for pollen productivity in different areas, POLLSCAPE will provide new possibilities for the understanding of human impact and the development of the cultural landscape through time.

The potential of pollen monitoring data for evaluating pollen dispersal models: some examples from Northern Boreal forests

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Within the framework of the NorFA network POLLANDCAL (POLlen-LANDuse CALibrations) models of pollen dispersal have been developed and programs for simulating vegetation situations and calculating distance weighted plant abundance have also been designed. These have been applied and/or validated in both present day forested (USA) and cultural (South Sweden) landscapes as well as in historical situations (Denmark). The models are designed to calculate the Relevant Source Area of Pollen (RSAP) around a lake or a point in the centre of a mire and the pollen loading (pl) in such a situation. As input the models require a number of parameters including distance weighted plant abundance (dwpa), fall speed and relative pollen productivity (PPE) of the plant taxa involved (although some versions of the model can calculate this latter) and background pollen (bp), together with wind speed.

It is desirable that the many aspects of the models and related programs are evaluated using empirical data. Data collected through the INQUA work group 'Pollen Monitoring Programme' (PMP) provide an opportunity for doing this. The results presented here come from the northern boreal forest zone in northernmost Finland and Norway. The vegetation situation is extremely simple and the number of species involved are few. The topography of the area is relatively smooth and, therefore, appropriate for the basic assumptions of the model. Pollen loading is known in 'absolute' terms (grains cm^{-2} $year^{-1}$) from the pollen trap records (1982-2002) and the vegetation around the pollen deposition localities has been analysed by remote sensing of air photos with ground validation.

The experiments which have been performed so far (using actual vegetation data with dwpa calculated by the program Polflow and using the model ERV3) suggest that for small mires in this northern forest, the RSAP is very small, scarcely exceeding the area of the mire itself. This may reflect the fact that there is very little difference in composition between pollen coming from within the RSAP and the bp. The pl calculated by the model, when compared to the pl measured by the pollen traps, underestimates the amount of *Pinus* pollen. Since it is likely that the PPE for *Pinus* available for southern Sweden, used in the model, is probably rather different from the PP of *Pinus* in the far north other experiments using model ERV 6 were run to estimate PP in the north. Experiments were also made to apply these findings in interpreting a fossil pollen profile from within the same vegetation area.

The effect of pollen trap design and vegetation type on patterns of pollen deposition in Tauber traps in North Wales over a six year period

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This paper presents a six year record of pollen deposition from a transect of 10 Tauber traps in a deciduous woodland, Coed Bryn-engan, in North Wales. This project is part of the Pollen Monitoring Programme,

a Working Group of the Holocene Commission of the International Quaternary Association (INQUA), whose aim is to study patterns of pollen influx across natural and anthropogenic treelines and to improve our understanding of the quantitative relationship between vegetation and pollen.

One of the major problems with the original Tauber trap design is that small animals can enter the traps, carrying pollen from an unknown source, as well as potentially causing other types of contamination. There have been few systematic studies of this problem. This paper examines the effect of placing a net over the trap opening, comparing the quantity of pollen and the composition of the pollen assemblage found in pairs of traps, one with netting and one without. Preliminary results suggest that the presence of a net over the trap opening does not influence the quantity of pollen trapped or the composition of the pollen assemblage and has the benefit of substantially reducing the number of relatively large animals found in the traps and the associated problems that this can cause. Therefore it is recommended that in future studies all Tauber traps should incorporate a net.

The paper also examines the relationship between vegetation composition and pollen assemblage at Coed Bryn-engan, together with temporal and spatial variation in the quantity of pollen deposited. Preliminary results suggest rates of pollen deposition of the order of 5,000 - 25,000 grains/cm^2/year and that the influx rates are much higher within the wood than outside. Comparison is made between the results from North Wales and those from traps in similar woodlands elsewhere in Britain and across Europe.

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