

Lough Lugh, Uisneach: from natural lake to archaeological monument?

Author(s): Seamus McGinley, Aaron P. Potito, Karen Molloy, Roseanne Schot, Ingelise Stuijts and David W. Beilman

Source: *The Journal of Irish Archaeology*, Vol. 24 (2015), pp. 115-130

Published by: Wordwell Ltd.

Stable URL: <https://www.jstor.org/stable/10.2307/90017262>

REFERENCES

Linked references are available on JSTOR for this article:

https://www.jstor.org/stable/10.2307/90017262?seq=1&cid=pdf-reference#references_tab_contents

You may need to log in to JSTOR to access the linked references.

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <https://about.jstor.org/terms>



Wordwell Ltd. is collaborating with JSTOR to digitize, preserve and extend access to *The Journal of Irish Archaeology*

JSTOR

Lough Lugh, Uisneach: from natural lake to archaeological monument?

Seamus McGinley,¹ Aaron P. Potito,¹ Karen Molloy,¹ Roseanne Schot,² Ingelise Stuijts² and David W. Beilman³

¹ Palaeoenvironmental Research Unit, School of Geography and Archaeology, National University of Ireland Galway, Ireland
(corresponding author: s.mcginley3@nuigalway.ie)

² Discovery Programme, Dublin, Ireland

³ Department of Geography, University of Hawai'i at Mānoa, USA

Recent studies have enhanced our understanding of the archaeological complex on the Hill of Uisneach, Co. Westmeath. However, the present palaeoenvironmental investigations represent the first detailed study of Lough Lugh, a small lake at the centre of the monument complex and ostensible site of the god Lugh's demise. This lake history study is a continuation and expansion of the multi-proxy research undertaken as part of the Discovery Programme's Late Iron Age and 'Roman' Ireland (LIARI) project, published in 2014. The study presents higher-resolution chironomid (non-biting midge fly) sub-fossil sampling and a re-evaluation of the pollen data to include aquatic pollen types. Geochemical indicators (C:N ratios, $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ isotopes) were also added to the suite of proxies for this paper. Further fieldwork included stratigraphical investigations of trial cores along two transects across the lake to gain a more holistic representation of the lakebed stratigraphy.

Chironomid and pollen evidence shows that the lake was an open water system in the Late-glacial/Early Holocene. A subsequent increase in macrophytes (aquatic plants) and macrophyte-dwelling chironomids indicates that the lake had begun to close in the Early Holocene. The dominance of terrestrial/semi-terrestrial chironomid taxa, the spike in C:N values and the near absence of lake aquatic plants and algae demonstrate that a marshland had formed by 8350–8240 cal. BC. The changes in chironomid and pollen taxa, in addition to abrupt changes in C:N ratios, $\delta^{15}\text{N}$ and LOI values, and lake sediment characteristics show that lake sediment was likely removed by human endeavour to re-initiate open water conditions. The results of this more exhaustive investigation, in conjunction with archaeological, mythological, folk history and place-name evidence, suggest that the lake may have been dug out in medieval times. This, however, may have been only one in a series of dig-outs in the lake's history. When people first encountered this site it was probably a marshland. It is suggested here that the existing lake is probably anthropogenic in origin and is likely to have had a symbolic or ritual significance. Lough Lugh can potentially be considered an archaeological site or monument.

INTRODUCTION

Lough Lugh is a small lake at the heart of the archaeological complex on the Hill of Uisneach, Co. Westmeath (Fig. 1). Uisneach is famed in mythology as the epicentre of Ireland and centre of the cosmos, a role illustrated, for example, by its portrayal as a source of the primordial waters (Rees and Rees 1961, 156–61; Schot 2011, 93–7). The wide array of archaeological monuments at Uisneach testify to a rich history spanning some 5,000 years, during which time the hill has been a place of burial, ceremony and assembly, as well as a possible royal settlement of the southern Uí Neill kings of Uisneach (Schot 2006; 2011). As the most prominent of several small lakes and springs within the archaeological complex, Lough Lugh was targeted for investigation to assess its history and past

role in the cultural landscape.

Sediment cores were extracted from Lough Lugh in 2012 as part of the Discovery Programme's Late Iron Age and 'Roman' Ireland (LIARI) project, to study the lake's history using palaeolimnological proxies, including pollen, chironomid (non-biting midge fly) and loss-on-ignition (LOI) analyses. The preliminary results were published in an interim report (Schot *et al.* 2014) in which it was suggested that some lake sediment may have been removed in the past. More detailed chironomid and geochemical analyses of the lake sediments ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotopes and C:N ratios) have since been completed, and aquatic plants and lake algae have since been evaluated in the pollen analysis. In addition, a series of trial cores were extracted across the lake basin to identify important stratigraphic layers. This more exhaustive multi-

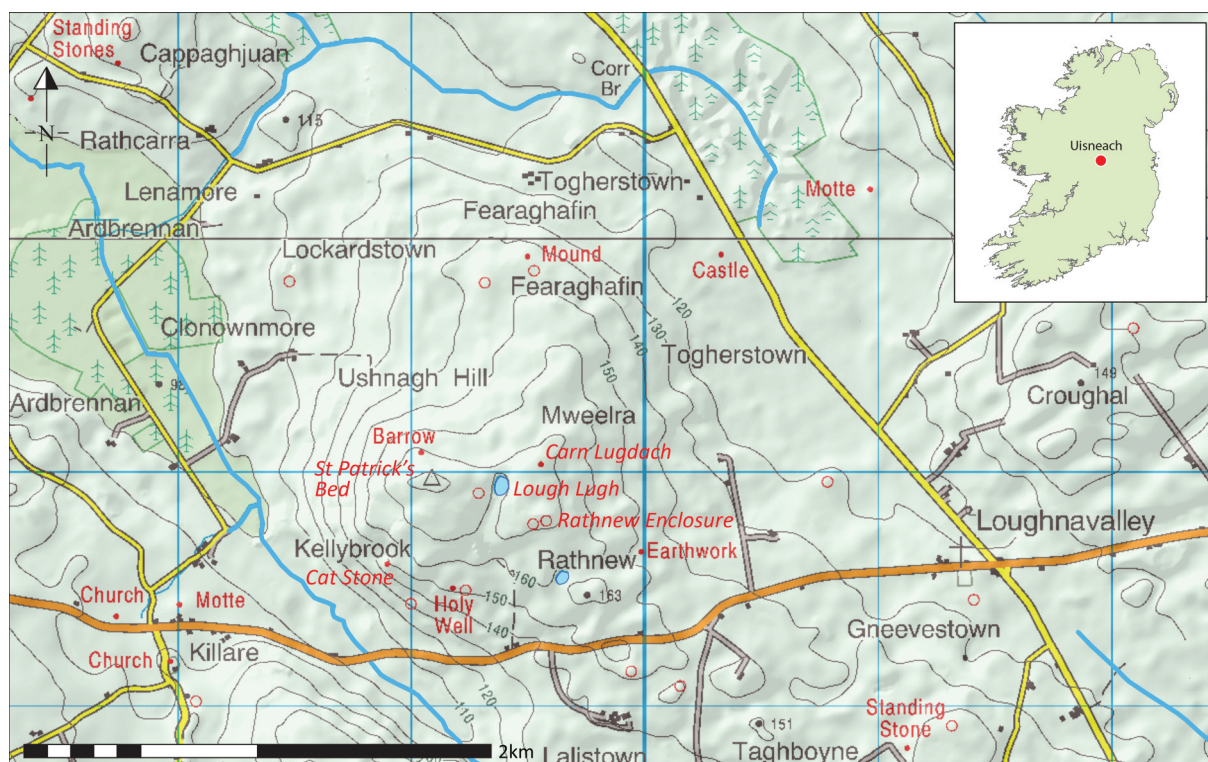


Fig. 1—Site location, with select monuments shown (based on Ordnance Survey of Ireland 1:50,000 mapping series: licence no. EN0059212).

pronged investigation was carried out in order to better understand the natural history of the lake itself, and to more accurately discern any human modifications to the lakebed through time.

LANDSCAPE SETTING

The Hill of Uisneach (181m OD) is located in a gently undulating landscape of good pastureland approximately 15km west-south-west of Mullingar, between the villages of Killare and Loughnavally and north of the R390. The hill covers an area of some 4km², encompassing the townlands of Ushnagh Hill, Mweelra, Rathnew and Kellybrook, as well as parts of Togherstown, Lockardstown, Clonownmore and Lalistown. The hilltop comprises a broad ridge extending approximately 1km east-west by 500m north-south. Lough Lugh (169m OD) lies at the approximate centre of the summit plateau, at the junction of the townlands of Ushnagh Hill and Mweelra (Fig. 1). The lake extends over an area of c. 60m by 80m and is covered by a central vegetation mat comprising, *inter alia*, sedges, horsetails and willows. It lies in a natural depression with no surface inflow or outflow. Lake level is determined by evaporation, precipitation and seepage through the limestone

bedrock (David Drew, pers. comm.). Consequently, the water-level can fluctuate considerably and the lake can nearly dry out during drought periods. Until recently Lough Lugh was an important water source for livestock, but it has now been fenced off and water is currently pumped directly from farther down the slope to feeding stations near the hilltop.

Lough Lugh (ITM: 629328, 748970) is situated within a multi-period archaeological complex (Fig. 1) comprising over twenty extant monuments and numerous others which have come to light through geophysical survey (Schot 2011). A relative chronology for some monuments on the hill has been provided by Schot (*ibid.*, 98–104). The oldest visible monument is a megalithic tomb on the western summit known as St Patrick's Bed, comprising a denuded cairn about 9m long (north-south) with two rows of low orthostats extending from its western side. A second prominent funerary monument is a mound (1.7m high and approximately 18m in maximum diameter) of possible early Bronze Age date on the eastern summit. It has been suggested that this may be the monument described as *Carn Lugdach*, the legendary burial place of the god Lugh, in the eleventh-century *dindshenchas* (*ibid.*, 102–3). Geophysical survey around the mound identified the largest monument yet recorded at Uisneach, a 200m-diameter ditched enclosure with a

4m-wide entrance on the east-north-eastern side, which is aligned on the mound at its centre. Comparison with similar large enclosures containing internal mounds at other royal sites suggests that this enclosure is likely to be of late prehistoric date (*ibid.*, 104). Other prehistoric monuments in the vicinity of Lough Lugh include a number of ring-ditches and ring-barrows, of probable Bronze Age or Iron Age date. Many of the remaining monuments are from the historic period, the most impressive of which is a high-status conjoined ringfort in Rathnew townland, which was constructed possibly in the late seventh or eighth century AD on top of a late Iron Age ceremonial enclosure (Schot 2006; 2011, 90). The nature and relative chronology of the monuments outlined above suggest continuity in ceremonial activity at Uisneach from the Neolithic period into early medieval times.

PROXY INDICATORS

Chironomid analysis

Chironomids are ubiquitous in freshwater systems, with high species richness in most assemblages. Chironomids live most of their lives underwater as larvae, and thus are sensitive to any changes in water conditions (Walker 2001, 53). Owing to their worldwide diversity and abundance, sensitivity to changing lake conditions and mobility of adults, chironomid sub-fossils are excellent indicators of past environmental change (*ibid.*, 53–6). The use of chironomids to assess human impacts on lakes is relatively new to Irish studies as part of an expanding suite of palaeoenvironmental proxies used in archaeological research (Ruiz *et al.* 2006, 14). At Lough Kinale, Co. Longford, chironomids were used to evaluate the impact of crannog construction on the lake environment (*ibid.*, 23). More recently, at Lough Dargan, Co. Sligo, Taylor *et al.* (2013, 3215) demonstrated how chironomids could be used to assess the impact of Neolithic and Bronze Age farming on a lake system by recording the effects of increased nutrient enrichment as farming expanded. Variance within chironomid communities in modern Irish lakes was shown to be closely correlated with catchment land cover, and especially agricultural land cover (Potito *et al.* 2014, 385).

Geochemical indicators

The geochemical indicators used in this study ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and C:N ratios) were also applied by Taylor *et al.* (2013) to reflect past changes in nutrient influx and lake productivity. Lake productivity refers to the rate of biomass production in the lake system, and is controlled by the level of nutrient input and sunlight penetration (Karlsson *et al.* 2009, 508). Changes in lake productivity

are often marked by changes in $^{13}\text{C}:^{12}\text{C}$ isotope ratios, mirroring changes in the wider lake catchment (Meyers and Teranes 2001, 246). Increased nutrient input as a consequence of human impacts within the wider catchment usually results in higher $^{13}\text{C}:^{12}\text{C}$ ratios, reflected in fewer negative $\delta^{13}\text{C}$ percentage values (*ibid.*, 248). Similarly, increased nitrogen inputs from both human and animal waste usually result in increased sediment $\delta^{15}\text{N}$ values, as human and animal waste are both relatively high in ^{15}N (*ibid.*, 252; Woodward *et al.* 2012, 182).

C:N ratios can be used to indicate changes in the relative contribution of aquatic versus terrestrial organic material to lake sediments over time. Ratios from 4 to 10 indicate that the material is mainly derived from aquatic sources, whereas values greater than 20 suggest that the sediment is mainly composed of material from land plants and macrophytes (i.e. aquatic plants visible to the naked eye) (Meyers and Teranes 2001, 243). Changes in C:N ratios can be indicative of changes in the wider lake catchment, including deforestation or increased precipitation, resulting in increased inwash into the lake (*ibid.*, 246), or changes to the lake itself, including lake morphometry or lake infill (Pokorný and Jankovská 2000, 451).

Loss on ignition (LOI), which reflects the proportion of organic carbon from plant and animal matter trapped in lake sediments (Boyle 2001, 90), was also used as a proxy for assessing past changes in the lake environment. Higher LOI values can be an indicator of increased lake productivity, stable woodland cover or lower sediment catchment erosion, while lower LOI is often an indicator of sparse vegetation, deforestation or increased soil inwash to the lake (Schuman 2003, 372; Beer *et al.* 2007, 982). LOI can be ambiguous in carbonate sediment, so we mostly use this proxy to delineate major transitions, identify lake infill, characterise marshy environments and identify transition to open water conditions.

Pollen analysis

Pollen analysis was used to reconstruct vegetation and lake history since the onset of sediment accumulation. As this is a small basin with a maximum width of c. 80m, situated in a hollow on the hilltop, the pollen catchment area is likely to be small, with any resulting pollen diagram reflecting a local picture of vegetation change within c. 400m of the lake edge (Jacobson and Bradshaw 1981; Sugita 1994). It should therefore be expected that the pollen diagram will reflect landscape changes in the immediate vicinity of the lake. Human activity around the lake and on the hilltop would be expected to register clearly in the sediments, with plants indicative of anthropogenic activity growing on

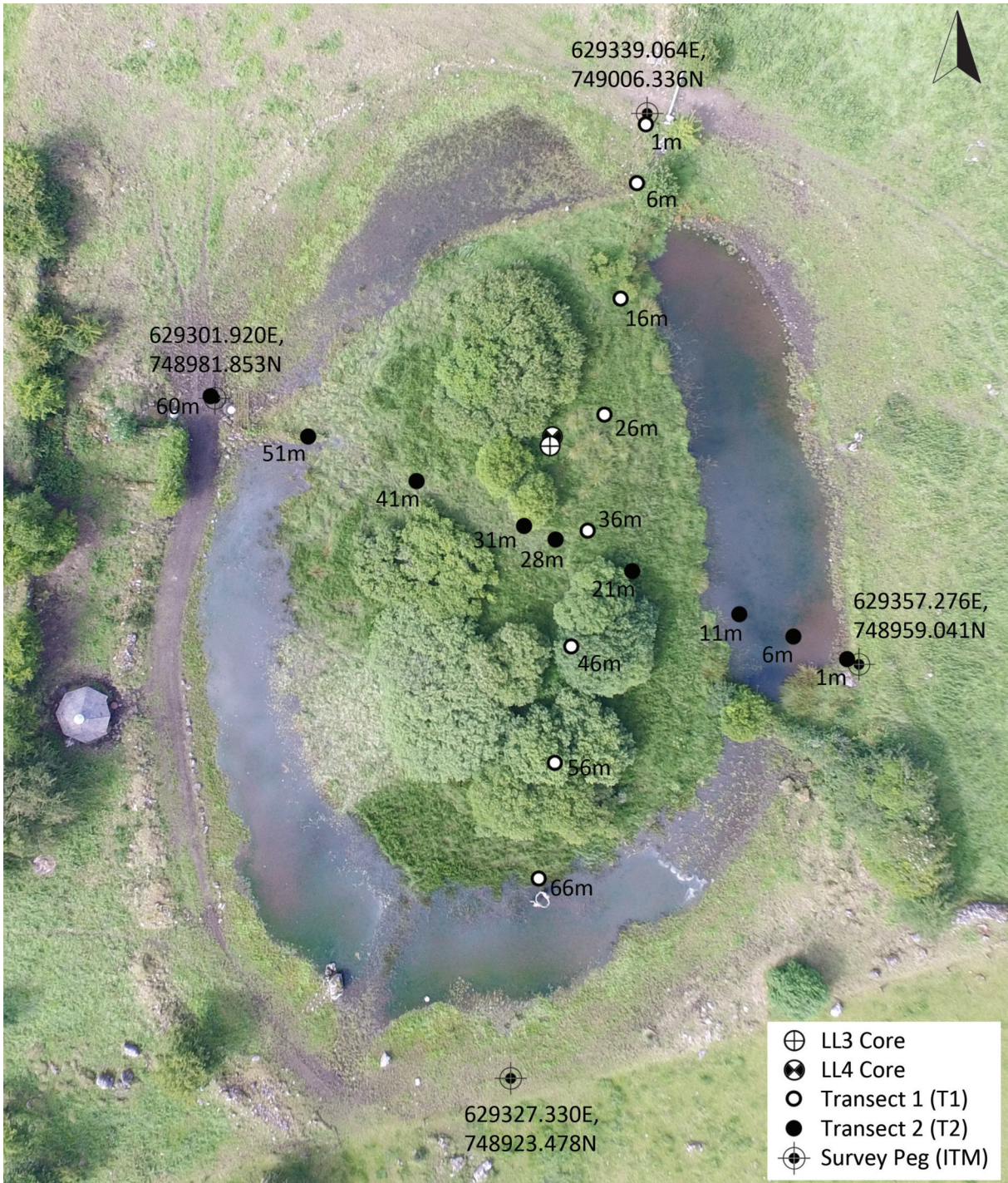


Fig. 2—Aerial view of Lough Lugh, showing location of long-core (LL3 and LL4) and trial cores, labelled by distance south (T1) and east (T2) of transect starting point (photo: Declan Murray).

the mineral soils around the lake. Changes in aquatic vegetation and lake algae are likely to reflect changes in within-lake processes and/or changes in lake level.

Methodology

Lough Lugh was initially cored in April 2012. A wooden platform was placed atop the floating

vegetation mat that covers the centre of the lake. Water depth in this part of the lake reaches approximately 150cm but can fluctuate. Three parallel cores (LL1, LL2 and LL3) were extracted using a Livingston piston corer (1m long by 5cm in diameter). The cores measured 65cm, 75cm and 92cm in length respectively. The longest core (LL3) was selected as the primary

core for analysis. It was described, sliced into 1cm sections and bagged for subsampling. It was decided in July 2014 to conduct further exploratory stratigraphical investigations along two transects (labelled T1 and T2) at 10m intervals, as this would provide a better understanding of the major sediment horizons across the lakebed.

Coring was undertaken using a 1m-long gouge corer, 3cm in diameter, at 10m intervals in a north–south (T1) and an east–west (T2) direction (Fig. 2). Common layers in each core were identified and recorded on site, based on sediment colour and texture. An additional core, LL4, 100cm in length, was extracted 1m north of the LL3 coring location in order to obtain additional material for radiocarbon dating. Depths throughout are given with reference to the distance from the water surface of the lake.

Core LL3 was subsampled for chironomids and geochemical analysis at 5cm intervals between 237cm and 170cm and every 1cm thereafter, excluding 147cm and 142cm, where the sediment supply was exhausted. An additional subsample was taken at 148cm. The top 1–2cm of the core was likely lost on extraction. Subsequently an additional surface sample was collected for chironomid analysis at 140cm depth (Fig. 3). Sediment for chironomid subsampling was deflocculated in a 10% KOH solution and heated for 30 minutes at 30°C. The solution was then backwashed into a beaker through two meshes (250µm and 90µm) and poured into a Bogorov plankton tray. A third mesh (900µm) was added for samples from 195cm to 170cm owing to the high density of plant remains in the samples. The chironomids were picked out with a forceps, using a Motic® SMZ dissection microscope at 10–40x magnification, and were mounted on slides using Entellan®. A minimum of 40 chironomid head capsules were extracted and identified for each sample in order to meet minimum statistical requirements (Quinlan and Smol 2001, 327). Where chironomid concentrations were low in the Semi-Terrestrial and Open Water phases, samples had to be combined to ensure that the minimum requirement was met, with two notable exceptions. Only 30 head capsules were recovered at 167cm, and 25.5 were recovered at 140cm. Chironomid identification was performed using a Motic®BA210 compound microscope at 100–400x magnification with reference to leading chironomid literature (Brooks *et al.* 2007; Rieradevall and Brooks 2001; Wiederholm 1983). The chironomid and geochemical diagram (Fig. 3) was constructed using C2 version 1.4.2 (Juggins 2007).

For geochemical analysis ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and C:N ratios) each subsample consisted of 1cm³ of sediment dried at 105°C in a drying oven, then crushed and sieved through a 200µm mesh and weighed. Two grams

of crushed sediment from each sample were placed in tin capsules and HCl-fumigated for four hours, following Harris *et al.* 2001. C:N ratios and stable isotope percentages for ¹³C and ¹⁵N were measured using a Thermo Fisher Delta V Advantage EAIRMS in the labs at the University of Hawai'i at Mānoa. For LOI analysis each sample, consisting of 1cm³ of sediment, was dried in an oven for over 24 hours at 105°C and weighed. The organic content was then burned off at 550°C and the samples were reweighed. LOI equals dry weight at 105°C minus dry weight at 550°C divided by the dry weight at 105°C and expressed as a percentage loss on ignition (Heiri *et al.* 2001, 102).

Subsampling (1cm³) for pollen analysis was carried out at 10cm intervals from 237cm to 185cm and at 2–3cm intervals from 180cm to 145cm, with additional samples taken at 225cm and 166cm. Pollen sample preparation followed standard methods that included alkali digestion, acetolysis and washing in alcohol before being mounted in silicon oil (Faegri and Iversen 1989). Pollen was counted using a Nikon Eclipse 80i microscope at 400x magnification. A higher magnification (x1000) was used for more critical grains. Pollen identification follows Beug 2004 and Moore *et al.* 1991 and comparison with a reference collection. Grass pollen larger than 37µm and with a large, distinct annulus was included in cereal-type. *Triticum* (wheat) and *Hordeum* (barley) were identified based on surface structure (Beug 2004). A pollen sum (PS) of c. 500 terrestrial pollen grains per sample was generally achieved. In samples with exceptionally large numbers of lake-edge/aquatic taxa or exceedingly low pollen concentration, however, a lower PS was accepted (maximum PS of 1,668 at 150cm and minimum of 67 at 230cm). Calculations and plotting of the pollen diagram were carried out using CountPol 3.3, a JAVA program by I. Feeser. Percentage representation was calculated on the basis of total terrestrial pollen (TTP, including fern spores) but excluding lake-edge taxa and algae, which are potentially over-represented because of local within-lake presence. Additional non-pollen palynomorphs (NPPs) and charcoal are also excluded. Taxa excluded from the PS are expressed relative to TTP.

Chronology

Details regarding the four samples submitted to the ¹⁴CHRONO Centre in Belfast for AMS ¹⁴C radiocarbon dating are provided in Table 1. The dates have been calibrated using CALIB 7.0.0 (Stuiver and Reimer 1993; Reimer *et al.* 2013). The dating strategy was focused above and below the transition from the Semi-Terrestrial Phase to the Open Water Phase (see below). Owing to the lack of suitable organic remains, two bulk sediment samples from 155–156cm and 164–

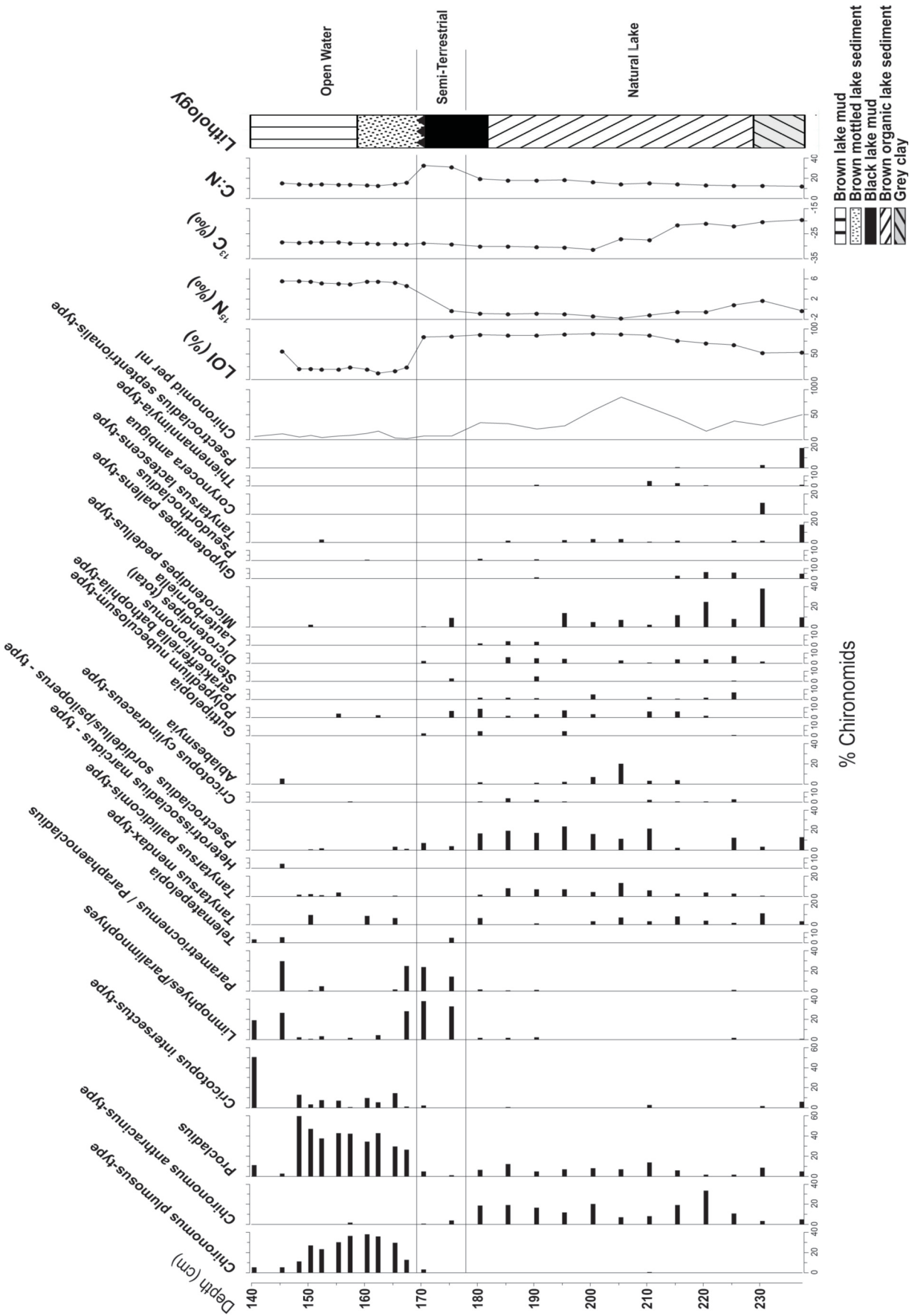


Fig. 3—Chironomid and geochemical stratigraphies for Lough Lugh with core lithology.

Table 1—Radiocarbon dates from Lough Lugh sediment cores.

Sample no.	Depth (cm)	Material	Radiocarbon age	Calibrated 2σ age range
UBA-22929	170	Hazelnut shell	9088±42 BP	8349–8236 BC
UBA-27029	165–166*	Charcoal & wood fragments	5260±47 BP	4180–3976 BC
UBA-21917	164–165	Bulk sediment	2286±30 BP	403–352 BC
UBA-24544	155–156	Bulk sediment	2814±32 BP	1054–894 BC

Samples from LL3 core—except *LL4, which is represented here at its LL3 depth equivalent.

165cm were submitted. A hazelnut found at 170cm was submitted in an effort to date the Semi-Terrestrial Phase. In order to obtain sufficient material for a further date from the base of the Open Water Phase, an additional core (LL4) was taken in 2014. Based on colour, texture and LOI, the abrupt transition to open water conditions was cross-matched between LL4 and LL3. LL4 was then sampled for AMS dating at the equivalent depth of 165cm on the LL3 core. Inferred ages through the sediment core were also based on well-dated features recognised in the pollen diagram, e.g. the *Corylus* maximum (cf. Molloy and O’Connell 2014).

RESULTS

The chironomid and pollen diagrams for LL3 were divided into three distinct phases based on the changing lake environment (Figs 3 and 4). The Natural Lake Phase covers the period from the onset of sediment accumulation until the infilling of the lake. The Semi-Terrestrial Phase covers the period when the lake had filled in to form a marsh. Finally, the Open Water Phase covers the period when open water conditions had been restored. The dates obtained from the bulk sediment appear to be too old, probably as a result of old carbon in the system. The date obtained from the plant macrofossils is also likely to be too old and does not correlate with the pollen. Only the radiocarbon from the hazelnut shell is considered reliable. This date suggests that hazel was growing locally at 8350–8240 BC. *Corylus* values reach 70% at this depth in the profile. It is suggested that this represents the *Corylus* maximum, as seen in many other profiles, dating from c. 10.7ka (Molloy and O’Connell 2014, 80).

Between 1cm³ and 16cm³ of sediment was analysed to obtain the minimum 40 chironomid head capsules per sample. The main core (LL3) had an average of 24 chironomids per cm³ of wet sediment, but the average varied significantly in the different lake phases (Fig. 3). There were 78 distinct chironomid taxa identified overall, and the 27 most important/dominant

taxa are displayed in Fig. 3.

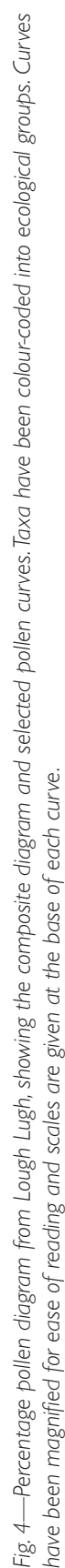
Sediment geochemistry values also show significant changes throughout the core, most notably in the Semi-Terrestrial Phase, where C:N values peak at 32.8 (Fig. 3). C:N averaged 15.3 in the Natural Lake Phase, 31.8 in the Semi-Terrestrial Phase and 14.1 in the Open Water Phase; δ¹³C and δ¹⁵N averaged –25.9 and –0.6 in the Natural Lake Phase, –29.1 and –0.3 in the Semi-Terrestrial Phase, and –28.7 and 5.3 in the Open Water Phase respectively.

The number of pollen taxa in the PS varied from a minimum of eleven in samples 190cm and 200cm to a maximum of 42 taxa at 160cm. In general, pollen concentrations and the number of taxa (an indicator of biodiversity) were higher in the Open Water Phase of the profile (Fig. 4).

Stratigraphical investigation

The stratigraphy of LL3 is presented in Fig. 3. The bottom sediments consist of grey clay overlain by brown organic sediment under a black lake mud which continues to near the top of the Semi-Terrestrial Phase. In the Open Water Phase mottled brown sediment underlies the top layer of unconsolidated brown lake mud.

The litho-stratigraphy of the sediment cores along transects 1 (T1) and 2 (T2) are presented in Fig. 5. Overall the stratigraphies were similar to that of core LL3. The deepest sediment was recorded in the central part of the lake basin at the 41m mark along T2 (labelled 41m_{T2}). In T1 the vegetation mat was thickest at 56m_{T1}, where it was submerged up to 65cm below the water surface (Fig. 5). The unconsolidated brown lake mud was deepest at 66m_{T1}. This brown lake mud overlies the brown mottled sediment, which in turn covered the black lake mud at 36m_{T1} and 56m_{T1} and light grey clay at the corresponding depth at 46m_{T1}. In T2 the black lake mud and light grey clay layers are also found at corresponding depths, overlain by the brown mottled sediment. Both the light grey clay and the black lake mud are absent at 26m_{T1} but present in the more central samples (i.e. 36m_{T1}, 46m_{T1} and 56m_{T1}). The absence of any layers under the unconsolidated brown lake mud along the sides of the lake appears to



be a result of relatively recent removal of older sediments, whereas the older mottled and consolidated sediment layers are best preserved toward the centre of the lake.

Natural Lake Phase (237–178cm)

The taxa present in the opening chironomid and pollen samples (Figs 3 and 4) are consistent with lake conditions and vegetation development at the transition from the Late-glacial to the opening stages of the Early Holocene. The cool water chironomid *Psectrocladius septentrionalis*-type is a typical Late-glacial/Early Holocene taxon in Ireland (Watson *et al.* 2010, 1205). This taxon comprises 20% of the chironomid assemblage at the bottom of the core (237cm), alongside cold stenotherms (i.e. species which prefer cold temperatures) *Thienemannimyia*-type and *Corynocera ambigua*-type (Fig. 3). The pollen representation below 220cm probably reflects pioneer vegetation. Herbs account for 37–65% of TTP, which includes Poaceae (grasses) (15–37%) and *Rumex* (docks) (0.3–11%) in addition to smaller abundances of *Helianthemum* (rock rose), *Artemisia* (mugwort) and a suite of herbaceous plants. Pioneering shrubs attain 26.7% at the base of the profile and 32% by 220cm, the latter accounted for by the expansion of *Juniperus* (juniper). LOI increases from 54% to 90% from 237cm to 200cm as $\delta^{13}\text{C}$ values (–19.4‰ to –31.4‰) become more negative. These values are typical for inputs of terrestrial vegetation into a lake from an environment that is evolving from a post-glacial landscape with little vegetation to one with complete vegetation cover (Meyers and Teranes 2001, 244; Håkansson 1985, 137, 144). Furthermore, $\delta^{13}\text{C}$ values support the C:N evidence (values from 12.6 to 16.2) that lake sediment genesis is dominated by terrestrial inputs from an increasingly more wooded lake catchment.

Above 220cm, overall herb representation declines to 12% (200cm), as open landscapes are replaced by scrub and woodland, with the expansion of first willow, then birch and finally hazel. Aquatic and lake-edge taxa water-lily, bulrush/bur-reed and saw sedge were now growing within or around the lake edge, potentially indicating lake infilling (Fig. 4). Chironomids respond from 210cm, when the macrophyte-dwelling taxon *Psectrocladius sordidellus/psilopterus*-type becomes more abundant (Fig. 3). Above 190cm there is a continuous presence of terrestrial/semi-terrestrial chironomid taxa *Limnophyes/Paralimnophyes* and *Parametriocnemus/Paraphaenocladius*, and macrophyte-dweller *Lauterborniella* emerges for the remainder of the phase. The presence of these taxa and the emergence of chironomid taxa associated with submerged vegetation and mosses (e.g. *Stenochironomus* and *Pseudorthocladius*),

combined with the increase in pollen from aquatics and lake-edge taxa (saw-tooth sedges, water-lilies and bulrush/bur-reed), indicate that the lake was gradually infilling. Geochemical values remain relatively stable from 200cm to the top of the phase: LOI drops slightly from 90% to 88%, $\delta^{13}\text{C}$ changes from –31.4‰ to –30.1‰, $\delta^{15}\text{N}$ from –1.4‰ to –0.8‰ and C:N increases from 16.2 to 19.7, as would be expected in an infilling lake where macrophytes become more abundant.

Semi-Terrestrial Phase (178–169cm)

By the Semi-Terrestrial Phase the natural lake had infilled to the extent that it could more accurately be described as a marsh. Evidence for this comes firstly from the predominance of the terrestrial/semi-terrestrial chironomid taxa *Limnophyes/Paralimnophyes* and *Parametriocnemus/Paraphaenocladius*, together accounting for 56% of the total chironomid assemblage in this phase (Fig. 3). In addition, the spike in C:N values to 31.8 (Fig. 3) indicates that sediment genesis is predominantly of terrestrial origin during this phase and is similar to values from Lake Švarcenberk in the Czech Republic, where C:N values spiked to between 30 and 35 when the lake infilled (Meyers and Lallier-Vergès 1999, 347; Pokorný and Jankovská 2000, 449–51).

Pollen evidence indicates that during the Semi-Terrestrial Phase AP dominates, accounting for c. 82–91% TTP. Hazel scrub (51–77% AP) dominated the hillside, but occasional pines, birch and willows may also have been present. This reflects the hazel maximum which is seen in many pollen diagrams across Ireland, e.g. An Loch Mór, Inis Óírr (Molloy and O'Connell 2014, 80). Aquatic taxa are virtually absent from the pollen record, suggesting that the lake had filled in by this time. The high AP values coupled with the absence of anthropogenic indicators *P. lanceolata* and cereal-type pollen, in addition to the radiocarbon date of 8350–8240 cal. BC at 170cm from a hazelnut shell, indicate that this phase pre-dates detectable human activity on the hill.

The preservation of the black organic layer in some trial cores (Fig. 5) is indicative of saturated anoxic conditions from standing water or pools in parts of the basin. This black anoxic layer appears to be contemporaneous with a light grey clay layer in some of the trial cores, which may result from at least intermittent aerobic conditions in sections of the basin. This mosaic of saturated and unsaturated conditions is typical of marsh/mire environments where shallow hollows are intermixed with clustered terrestrial vegetation, as was evident at Lake Švarcenberk, for example (Pokorný and Jankovská 2000, 451).

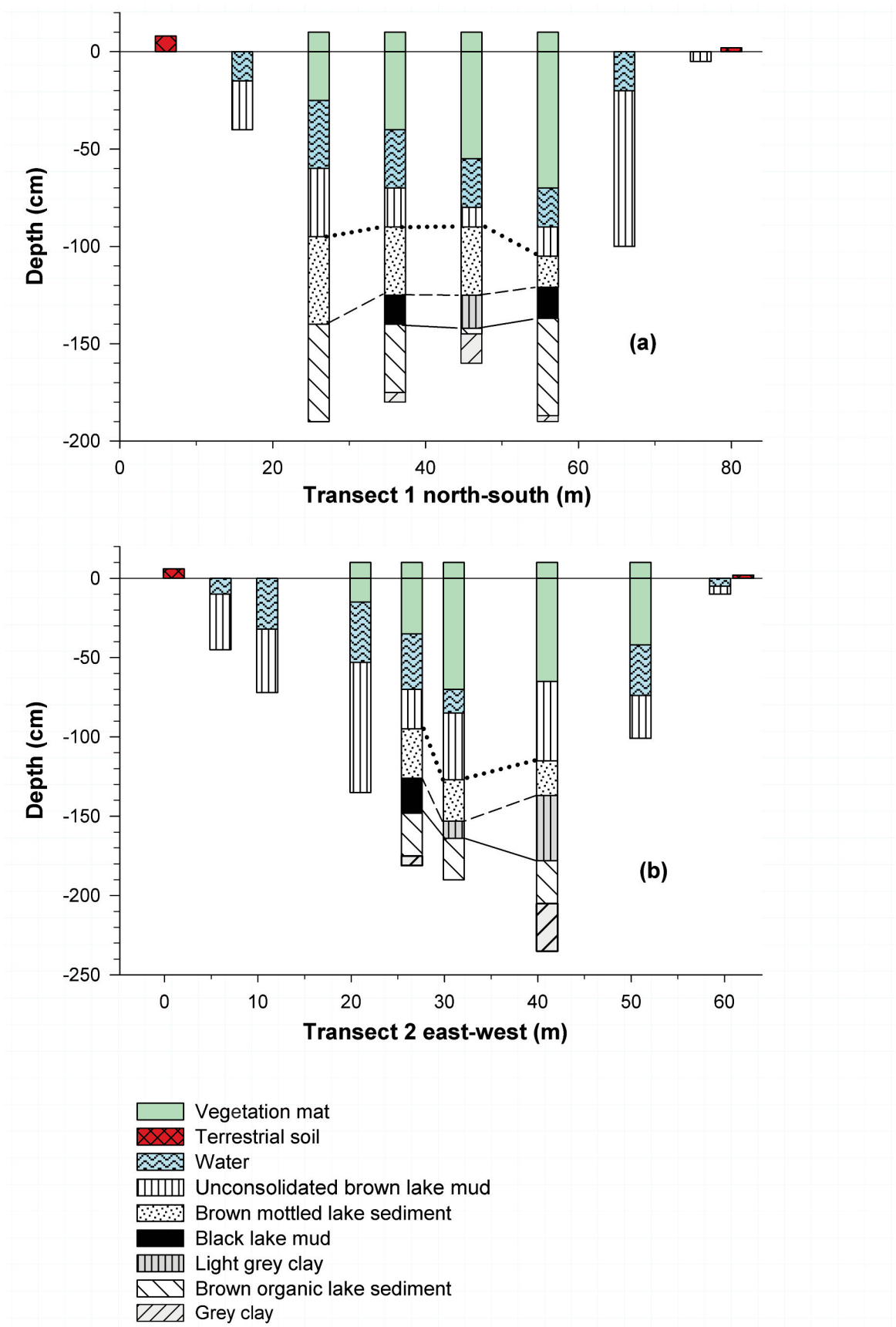


Fig. 5—Trial core transects across the extent of Lough Lugh.

Open Water Phase (169–140cm)

From 168cm it is clear that open water conditions were re-established, as attested by the disappearance of terrestrial/semi-terrestrial chironomid taxa *Limnopyges/Paralimnophyes* and the abrupt drop in *Parametriocnemus/Paraphaenocladus* abundance, accompanied by simultaneous increases in lake algae *Spirogyra* and the aquatic taxa duckweed and bulrush/bur-reed (plants of shallow, eutrophic—i.e. nutrient-rich; productive—waters). *Chironomus plumosus*-type and *Procladius* together account for 60–80% of the chironomid assemblage in this phase (excepting the modern sample), and both are eutrophic taxa associated with soft organic substrata and farming (Brodersen *et al.* 2001, 260). The classification of the lake as eutrophic is further supported by the increase in $\delta^{15}\text{N}$ from -0.3‰ to 4.6‰ , probably as a result of increased nutrient inputs from agriculture (Meyers and Teranes 2001, 252). The abrupt drop in C:N values from 33 to 16 in the interval between the top of the Semi-Terrestrial Phase and the lowermost sample of the Open Water Phase indicates that the source of sedimentary organic matter was no longer dominated by terrestrial vegetation (*ibid.*, 243). Once open water conditions were established, the only significant change in chironomid taxa is in the modern sample at the top of the core, where terrestrial and semi-terrestrial chironomids become dominant, but there still remains a considerable presence of open water taxa. This shift in chironomid assemblage is accompanied by an increase in LOI from 21% to 56%, which is likely to reflect the appearance of the vegetation mat evident on the lake surface at present.

The pollen assemblage from the Open Water Phase also differs radically from that of the preceding phase. Trees such as hazel, oak, elm, alder and to a lesser extent ash are present, but the hill is no longer tree-covered. Willow at this time was probably growing on the wet soils around the lake edge. Overall, the landscape is now dominated by herbaceous taxa. The pollen diagram records the expansion of species-rich grassland indicative of pasture (49–85% TTP). Anthropogenic indicators are plentiful, e.g. *P. lanceolata* (ribwort plantain) (16–29%) and coprophilous fungi associated with grazing (*Sordaria*, *Sporormiella* and *Podospora*) are frequent (Feaser and O'Connell 2009, 1090). In addition, there are strong indications that cereal cultivation occurred close to the sampling site, reflected by the presence of cereal-type pollen, mainly *Hordeum*-type (0.3–2%) and Brassicaceae/cabbage family (0.1–1.9%). The expansion in the unicellular algae *Pediastrum* is probably a response to nutrient input into the lake as a result of catchment disturbance associated with farming. The uppermost sample reflects modern times. At this time fir and spruce are present in

the landscape, and the spike of *Equisetum*, accounting for 46% of all aquatics and lake algae, reflects the growth of horsetails around the lake edge. Pollen preservation was poor in this phase and a large number of grains could not be identified. This may be as a result of a fluctuating water-table since the lake reinitiated.

DISCUSSION

The available evidence from chironomid, pollen, LOI, C:N and sedimentary records all points to an abrupt change from the Semi-Terrestrial to the Open Water phase. The sudden change from a landscape dominated by trees to an open pastoral landscape largely devoid of trees within 3cm suggests a hiatus in sediment accumulation or the loss of sediment from the basin.

It was speculated in Schot *et al.* 2014, 124, that the most likely reason for the reinitiation of open water conditions and a hiatus in the pollen and sedimentary records was that the lake had been dug out by people in the past, but as evidence was sparse natural causes were also considered. The additional evidence presented in this paper, arising from the more intensive chironomid sampling, new geochemical data, more detailed interrogation of the pollen data, including aquatic pollen and algae, and the stratigraphical investigation of the lake basin, confirms that the lake was most likely dug out in the past in order to restore open water conditions. After the lake naturally closed in the Early Holocene, conditions remained waterlogged and soil organic content was high. There is no evidence of continued accumulation of sediments after the Early Holocene, however, as would be typical of Irish wetlands. There is also no evidence of a minerogenic soil or vegetation layer, as might be expected to occur if the lake dried out and reinitiated naturally (Dearing 1997).

A lake core hiatus may represent a period of zero sedimentation or sediment removal, whether displaced by natural processes or by anthropogenic activity (*ibid.*). The cause of lake sediment hiatuses has generated little discussion in past studies in Ireland, perhaps because there were insufficient data to explain causation (e.g. Mitchell 1990, 575) or simply because it was not germane to the research questions (e.g. Craig 1978; Edwards and Whittington 2000). Hiatus causation was considered at two archaeologically affected Irish lake sites. A lake core taken adjacent to Ballywillin Crannog in Lough Kinale, Co. Westmeath, revealed a c. 2000-year hiatus (Brown *et al.* 2005, 86; Selby and Brown 2007, 427). Construction of the crannog was cited as a possible cause of the hiatus, but a more likely scenario was that wave action had eroded out the sediments in this shallow lake (Brown *et al.* 2005, 86). A natural

hiatus at Lough Gur, Co. Limerick, from *c.* 7700 BP to 5185 BP was attributed to lower lake levels, where corroded pollen, shells and woody detritus all provided supporting evidence for the lacuna in the pollen record (Dearing 1997; Ahlberg *et al.* 2001, 370). While this was most likely a natural event, human impact cannot be completely ruled out as the cause of the hiatus (*ibid.*, 371).

Natural hiatuses generally occur as a consequence of climate change, change in wind regime, sediment slumping or changing bedrock hydrology (Dearing 1997). Changing climate and wind regime can be eliminated as causes at Lough Lugh because of the prevailing temperate climate regime and the small, closed lake basin area (*ibid.*). For example, the wind- and wave-driven erosion that occurred at Lough Kinale is highly improbable at Lough Lugh owing to the lake's short fetch. Where lakebed slope angles are >4%, gravitational forces can destabilise sediments, causing slumping and sliding and thereby creating a lacuna in the upper sediments (Hilton 1985, 1132). Slumping and sliding can be discounted as the cause of the hiatus at Lough Lugh, as the slope angle is <1%. If the lake had reinitiated as a result of changes in the bedrock hydrology after the hiatus, a coarse minerogenic layer and/or vegetation mat should be evident in the core stratigraphy (Dearing 1997). Climate change at Švarcenberk Lake, Czech Republic, and Lake Morat, Switzerland, resulted in natural hiatuses marked by coarse minerogenic or sandy layers in the lakebed stratigraphy before the lakes reinitiated (Pokorný and Jankovská 2000; Magny and Richoz 2000). Furthermore, cores retrieved by the authors from Lough Meenachrinna, Co. Donegal, contained preserved vegetation layers/mats where the lake had naturally dried out before it reinitiated. Therefore, based on its natural setting, basin morphology, the very abrupt changes in chironomid, pollen and geochemical data and the absence of any minerogenic or vegetative layer, all of the evidence points strongly to the suggestion that Lough Lugh was reinitiated by people in the past.

Dating the dig-out(s)

The evidence from the pollen, chironomids, LOI and C:N all indicates that a major change in the lake environment occurred between 170cm and 167cm. The uncertainties attaching to the radiocarbon dates above 170cm (see above) mean that there is no definitive date for this event. Based on the pollen record, however, it is clear that sediment began to accumulate once more during a period when farming, mainly pastoral but with an arable component, took place on the hill. The records for *Urtica urens*, which first appears at 167cm, are interesting in this regard. *U. urens* (small nettle), known occasionally from Bronze

Age contexts in Ireland (Cleary *et al.* 2003, 110–19), is a plant of cultivated and disturbed ground and is regarded as an alien species in Ireland (see Reynolds 2002, 64). It is known to have been present throughout Ireland by the end of the nineteenth century and was a weed in Viking Dublin. In addition, there is one record for *Anchusa* (alknet) at 165cm, a species also considered an alien in Ireland (*ibid.*). Though previously known only from Wexford, it was in British gardens from the thirteenth century (Harvey 1981). In the absence of other evidence, the presence of these taxa may point to a medieval date for the renewal of sediment accumulation in the Lough Lugh record.

Place-name evidence, on the other hand, suggests a potential *terminus ante quem* towards the end of the early medieval period for the restoration of open water conditions at Lough Lugh. 'Lough' is the Anglicised form of Old Irish *loch*, which is cognate with the modern English word for lake; in Ireland and Scotland, however, it is also used to describe a bay or sea inlet (Joyce 1873–1908, 447–8). While the word 'lough' is also attached to modern bogs or marshes, this simply recalls earlier open water conditions, as is often the case with wetland place-names (Joyce 1912, 388). For example, lake marl is present under the peat at Ballinderry Lough, Co. Westmeath, and at Lagore (*Loch nGabor*), Co. Meath (Mitchell 1940, 13; Hencken 1941, 46; Johnson 1999, 31). There are also historical references to the lakeshore and open water rowing at Lagore (Mitchell 1940, 13; Hencken 1950). Similarly, the remains of boats discovered in the course of excavation at Ballinderry Crannog No. 1 indicate that open water conditions prevailed when the crannog was occupied (Johnson 1999, 40). Given that there is a plethora of Gaelic words to describe other types of wetland, e.g. *lathach* or *abar* (both signifying a puddle or mire), *crith* (morass), *crithlach* or *crithéan* (quaking bog), *criathar* (swampy or boggy place), *múchan* (morass) and *gréach* (flat moor) (Joyce 1912, 388–92), the use of the place-name *Loch Lughborta* in an eleventh-century toponymic account relating to Uisneach suggests that Lough Lugh had probably been transformed into an open water environment by this time.

The creation of a lake: Lough Lugh as 'archaeological monument'

Lough Lugh shares many of the characteristics of a monument insofar as monuments are generally man-made; they are related to memory and place-making and are often locales of ritual activity. Indeed, like the construction of monuments, the naming of places is central to the process of place-making and can provide glimpses into the mental landscapes and belief systems of past societies (Keller 1997, 92; Van de Noort and O'Sullivan 2007, 81).

This study has shown that the marsh that began to develop on the summit of Uisneach during the Early Holocene was later deliberately transformed into an open lake. While the role of the lake is likely to have changed over time, the creation and maintenance of an open water environment may have been driven by a number of considerations, none of which are mutually exclusive. Firstly, the site may have been dug out simply to provide a water supply for livestock. In ancient times this was hardly necessary, as cattle could water at the streams surrounding the hill (Fig. 1) as part of their daily grazing pattern, but it becomes more plausible as more land is enclosed over time. For example, it is clear from an eighth-century law-tract that the presence of a cattle pond on the hill would have considerably enhanced the value of the land (Kelly 1988, 394–7; Schot *et al.* 2014, 124). Moreover, we know from folk history and photographic archives (Fanning 1979, 3; CUCAP 2015) that the shallower portions of the lake have been modified within living memory (presumably to increase water-levels for livestock) and this is supported by the evidence from the trial core transects (Fig. 5).

Alternatively, the creation of the lake and the origin of its place-name may relate to Uisneach's role as a seat of kingship during the early medieval period. *Dindshenchas* attributes the place-name *Loch Lughborta* to a pre-Christian deity (Lugh) who was drowned in the lake while attempting to flee from the divine brothers Mac Cuill, Mac Cécht and Mac Gréine and was buried in a cairn by the lakeshore called *Carn Lugdach* (Gwynn 1903–35, IV, 278–81). The places referred to are identified today as Lough Lugh and the nearby prominent mound on the eastern summit of Uisneach (Schot 2011, 96, 102). Lugh is a god of kingship and patron of the harvest festival of Lughnasad (e.g. MacNeill 2008), and the presence of a large-scale ceremonial enclosure around '*Carn Lugdach*', overlooking Lough Lugh, is but one strand of evidence to indicate that Uisneach was in ancient times the location of a Lughnasad assembly, as well as a possible site of inauguration (see Schot 2011, 110–13). Although there is no definitive evidence to link the (re)creation of open water conditions at Uisneach with such events, the frequent association of royal sites and assembly places with bodies of water is noteworthy, as are some of the customs recorded as having taken place during seasonal assemblies in recent centuries, such as the ritual wetting or swimming of horses in lakes and rivers (see MacNeill 2008, 336–7).

Finally, the possibility that sediment from Lough Lugh was deliberately removed in prehistory to create an open water ritual pond (Schot *et al.* 2014, 124) also remains a feasible hypothesis. Ritual ponds are a feature of the archaeological record from at least as early as the

third millennium BC, with the oldest recorded example, an embanked artificial pond at Monknewtown, Co. Meath, dated to the late Neolithic period (Condit and Simpson 1998, 60; Brady *et al.* 2011). Another probable embanked ritual pond of unknown date has been identified just to the east of the Hill of Tara (Newman 1998, 139). Perhaps the best-known example, however, is the King's Stables, near Haughey's Fort in the Navan complex, Co. Armagh. Here, around 1000 BC, a marsh was dug out and enclosed by a substantial earthen bank to create a pond into which human and animal bones, fragments of clay moulds, sherds of coarse pottery and other items were deposited (Lynn 2003, 53, 54, 66).

The absence of a surrounding bank at Lough Lugh could be seen to exclude it from the above category of monument, but this would be to ignore the liminal and potential sacral significance of water itself, which in serving both as a boundary and as a conduit has an almost unlimited capacity for adaptation to changing religious and cultural beliefs (Oestigaard 2011, 48). In this context, it could be argued that the altered materiality of the pre-existing marsh at the King's Stables, i.e. the creation of an open body of water, was of equal, if not greater, significance than the construction of the enclosing element. Similarly, perhaps the main difference between the ritual pools of Loughnashade (also in the Navan complex) and the King's Stables is simply that the former is a natural site and the latter artificial: both were foci for votive deposition in later prehistory. While the above considerations highlight the difficulties of identifying ritual ponds in the absence of supporting material evidence, the conspicuous setting of Lough Lugh within the funerary and ceremonial landscape of Uisneach and its associated mythology and place-name evidence suggest that Lough Lugh was a place of cultural, and probable sacral, significance in the early medieval period, if not indeed earlier.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Jacqueline Cahill-Wilson and Dr Ger Dowling of the Discovery Programme's LIARI project for encouraging this collaboration, assistance by way of fieldwork, licensing and providing funding for radiocarbon dates. We would also like to thank Karen Taylor, Carlos Chique, Dr Michelle McKeown and Nessa Golden for help in the field and the labs. The vertical aerial photo of Lough Lugh was kindly made available by Declan Murray and Justin Moffatt. Thanks are also due to Gary Devlin of the Discovery Programme for assistance with the location map. Special thanks to the Clarke and Fay families for access to the lake and for sharing their

knowledge of its history. Finally, we would like to thank the editor and the two anonymous reviewers for their constructive comments, which helped to improve this paper.

BIBLIOGRAPHY

- Ahlberg, K., Almgren, E., Wright, H. and Ito, E. 2001. Holocene stable-isotope stratigraphy at Lough Gur, County Limerick, Western Ireland. *The Holocene* 11, 367–72.
- Beer, R., Heiri, O. and Tinner, W. 2007. Vegetation history, fire history and lake development recorded for 6300 years by pollen, charcoal, loss on ignition and chironomids at a small lake in southern Kyrgyzstan (Alay Range, Central Asia). *The Holocene* 17, 977–85.
- Beug, H.J. 2004. *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*. Pfeil, München.
- Boyle, J.F. 2001. Inorganic geochemical methods in palaeolimnology. In W.M. Last and J.P. Smol (eds), *Tracking environmental change using lake sediments*, 83–141. Kluwer, London.
- Brady, C., Barton, K. and Davis, S. 2011. Putting LiDAR to the test in the Brú na Bóinne WHS, Ireland: site discovery, definition and investigation using LiDAR, geophysics and coring. Poster presentation at Joint Meeting of Aerial Archaeology Research Group (AARG) and European Association of Remote Sensing Laboratories (EARSeL): Ambitions and Realities: Remote Sensing for Archaeology, Research and Conservation, 21–24 September, Poznan, Poland.
- Brodersen, K., Odgaard, B., Vestergaard, O. and Anderson, N. 2001. Chironomid stratigraphy in the shallow and eutrophic Lake Søbygaard, Denmark: chironomid–macrophyte co-occurrence. *Freshwater Biology* 46, 253–67.
- Brooks, S., Langdon, P. and Heiri, O. 2007. *The identification and use of Palaearctic Chironomidae larvae in palaeoecology*. Quaternary Research Association, London.
- Brown, A., Hatton, J., O'Brien, C.E., Selby, K., Langdon, P., Stuijts, I. and Caseldine, C. 2005. Vegetation, landscape and human activity in midland Ireland: mire and lake records from the Lough Kinale–Derragh Lough area, central Ireland. *Vegetation History and Archaeobotany* 14 (2), 81–98.
- Cleary, R., McKeown, S., Tierney, J., Hannon, M., Anderson, E., Cahill, M. and O'Shaughnessy, J. 2003. Enclosed late Bronze Age habitation site and boundary wall at Lough Gur, Co. Limerick. *Proceedings of the Royal Irish Academy* 103C, 97–189.
- Condit, T. and Simpson, D. 1998. Irish hengiform enclosures and related monuments: a review. In A. Gibson and D. Simpson (eds), *Prehistoric ritual and religion*, 45–61. Sutton, Stroud.
- Conway, V. 1938. Studies in the autecology of *Cladium mariscus* R. br. IV. Growth rates of the leaves. *New Phytologist* (1938), 254–78.
- CUCAP 2015. Cambridge University Collection of Aerial Photography. Earthworks. Hill of Uisneach, Westmeath, Ireland. Available at: <http://www.geog.cam.ac.uk/cucap/location/ayr016/> [accessed 19 August 2015].
- Craig, A. 1978. Pollen percentage and influx analyses in south-east Ireland: a contribution to the ecological history of the late-glacial period. *Journal of Ecology* 66, 297–324.
- Davidson, T. and Jeppesen, E. 2013. The role of palaeolimnology in assessing eutrophication and its impact on lakes. *Journal of Paleolimnology* 49, 391–410.
- Dearing, J. 1997. Sedimentary indicators of lake-level changes in the humid temperate zone: a critical review. *Journal of Paleolimnology* 18, 1–14.
- Edwards, K. and Whittington, G. 2000. Multiple charcoal profiles in a Scottish lake: taphonomy, fire ecology, human impact and inference. *Palaeogeography, Palaeoclimatology, Palaeoecology* 164, 67–86.
- Faegri, K. and Iversen, J. 1989. *Textbook of pollen analysis*. Wiley, Chichester.
- Fanning, T. 1979. Ancient monuments. In L. Daly (ed.), *The midlands: Longford–Cavan–Laois–Westmeath–Roscommon–Monaghan–Offaly*, 3–5. Albertine Kennedy, Dublin.
- Feaser, I. and O'Connell, M. 2009. Fresh insights into long-term changes in flora, vegetation, land use and soil erosion in the karstic environment of the Burren, western Ireland. *Journal of Ecology* 97, 1083–100.
- Gwynn, E. (ed.) 1903–35. *The Metrical Dindshenchas* (5 vols). Todd Lecture Series viii–xii. Reprinted 1991. Institute for Advanced Studies, Dublin.
- Håkansson, S. 1985. A review of various factors influencing the stable carbon isotope ratio of organic lake sediments by the change from glacial to post-glacial environmental conditions. *Quaternary Science Reviews* 4, 135–46.
- Harris, D., Horwath, W. and van Kessel, C. 2001. Acid fumigation of soils to remove carbonates prior to total organic carbon or carbon-13 isotopic analysis. *Soil Science Society of America Journal* 65, 1853–6.
- Harvey, J. 1981. *Mediaeval gardens*. Batsford, London.

- Heiri, O., Lotter, A. and Lemcke, G. 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. *Journal of Paleolimnology* 25, 101–10.
- Hencken, H. O'N. 1941. Ballinderry Crannog No. 2. *Proceedings of the Royal Irish Academy* 47C, 1–76.
- Hencken, H. O'N. 1950. Lagore Crannog: an Irish royal residence of the 7th to 10th centuries AD. *Proceedings of the Royal Irish Academy* 53C, 1–247.
- Hilton, J. 1985. A conceptual framework for predicting the occurrence of sediment focusing and sediment redistribution in small lakes. *Limnology and Oceanography* 30 (6), 1131–43.
- Jacobson, G. and Bradshaw, R. 1981. The selection of sites for paleovegetational studies. *Quaternary Research* 16, 80–96.
- Johnson, R. 1999. Ballinderry Crannog No. 1: a reinterpretation. *Proceedings of the Royal Irish Academy* 99C, 23–71.
- Joyce, P. 1873–1908. *The origin and history of Irish names of places*, vol. 1. Longmans, Green, Dublin.
- Joyce, P. 1912. *The origin and history of Irish names of places*, vol. 2. Longmans, Green, Dublin.
- Juggins, S. 2007. C2 Version 1.7.4: software for ecological and palaeoecological data analysis and visualisation. University of Newcastle, Newcastle upon Tyne.
- Karlsson, J., Byström, P., Ask, J., Ask, P., Persson, L. and Jansson, M. 2009. Light limitation of nutrient-poor lake ecosystems. *Nature* 460, 506–9.
- Keller, C. 1997. Theoretical aspects of landscape study. In T. Insoll (ed.), *Decoding the landscape*, 79–97. University College Galway, Galway.
- Kelly, F. 1988. *A guide to early Irish law*. Institute for Advanced Studies, Dublin.
- Lynn, C. 2003. *Navan Fort: archaeology and myth*. Wordwell, Dublin.
- MacNeill, M. 2008. *The festival of Lughnasa: a study of the survival of the Celtic festival of the beginning of harvest*. Oxford University Press, Oxford.
- Magny, M. and Richoz, I. 2000. Lateglacial lake-level changes at Montilier-Strandweg, Lake Morat, Switzerland, and their climatic significance [Les variations du niveau du lac de Morat (Montilier-Strandweg, Suisse) pendant le Tardiglaciaire et leur signification climatique]. *Quaternaire* (2000), 129–44.
- Meyers, P. and Lallier-Vergès, E. 1999. Lacustrine sedimentary organic matter records of Late Quaternary paleoclimates. *Journal of Paleolimnology* 21, 345–72.
- Meyers, P. and Teranes, L. 2001. Sediment organic matter. In W. Last and J. Smol (eds), *Tracking environmental change using lake sediment*, 239–64. Kluwer Academic Publishers, London.
- Mitchell, F. 1990. The history and vegetation dynamics of a yew wood (*Taxus baccata* L.) in S.W. Ireland. *New Phytologist* 115, 573–7.
- Mitchell, G. 1940. Studies in Irish Quaternary deposits: some lacustrine deposits near Dunshaughlin, County Meath. *Proceedings of the Royal Irish Academy* 46B, 13–37.
- Molloy, K. and O'Connell, M. 2014. Post-glaciation plant colonization of Ireland: fresh insights from An Loch Mór, Inis Oírr, western Ireland. In P. Sleeman, J. Carlsson and J. Carlsson (eds), *Mind the gap II: new insights into the Irish postglacial*, 66–88. Irish Naturalists' Journal, Belfast.
- Moore, P.D., Webb, J.A. and Collison, M.E. 1991. *Pollen analysis*. Blackwell, Oxford.
- Newman, C. 1998. Reflections on the making of a 'royal site' in early Ireland. *World Archaeology* 30, 127–41.
- Oestigaard, T. 2011. Water. In T. Insoll (ed.), *The Oxford handbook of the archaeology of ritual and religion*, 38–50. Oxford University Press, Oxford.
- Pokorný, P. and Jankovská, V. 2000. Long-term vegetation dynamics and the infilling process of a former lake (Švarcenberk, Czech Republic). *Folia Geobotanica* 35, 433–57.
- Potito, A., Woodward, C., McKeown, M. and Beilman, D. 2014. Modern influences on chironomid distribution in western Ireland: potential for palaeoenvironmental reconstruction. *Journal of Paleolimnology* 52, 385–404.
- Quinlan, R. and Smol, J. 2001. Setting minimum head capsule abundance and taxa deletion criteria in chironomid-based inference models. *Journal of Paleolimnology* 26, 327–42.
- Rees, A. and Rees, B. 1961. *Celtic heritage*. Thames and Hudson, London.
- Reimer, P., Bard, E., Bayliss, A. et al. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal. BP. *Radiocarbon* 55 (4), 1869–87.
- Reynolds, S. 2002. *A catalogue of alien plants in Ireland*. Occasional Papers 14. National Botanic Gardens, Dublin.
- Rieradevall, M. and Brooks, S. 2001. An identification guide to sub-fossil Tanypodinae larvae (Insecta: Diptera: Chironomidae) based on cephalic setation. *Journal of Paleolimnology* 25, 81–99.
- Ruiz, Z., Brown, A. and Langdon, P. 2006. The potential of chironomid (Insecta: Diptera) larvae in archaeological investigations of floodplain and lake settlements. *Journal of Archaeological Science* 33, 14–33.
- Schot, R. 2006. *Uisneach Mídi a medón Érenn: a prehistoric 'cult' centre and 'royal site' in Co.*

- Westmeath. *Journal of Irish Archaeology* 15, 39–71.
- Schot, R. 2011. From cult centre to royal centre: monuments, myths and other revelations at Uisneach. In R. Schot, C. Newman and E. Bhreathnach (eds), *Landscapes of cult and kingship*, 87–113. Four Courts Press, Dublin.
- Schot, R., Stuijts, I., McGinley, S. and Potito, A. 2014. Reflections on a lake: a multi-proxy study of environmental change and human impacts at Lough Lugh, Uisneach, Co. Westmeath. *Discovery Programme Reports* 8, 113–26.
- Schuman, B. 2003. Controls on loss-on-ignition variation in cores from two shallow lakes in the northeastern United States. *Journal of Paleolimnology* 30, 371–85.
- Selby, K. and Brown, A. 2007. Holocene development and anthropogenic disturbance of a shallow lake system in central Ireland recorded by diatoms. *Journal of Paleolimnology* 38, 419–40.
- Stuiver, M. and Reimer, J. 1993. Extended 14C data base and revised CALIB 3.0 14C age calibration program. *Radiocarbon* 35, 215–30.
- Sugita, S. 1994. Pollen representation of vegetation in Quaternary sediments: theory and method in patchy vegetation. *Journal of Ecology* 82, 881–97.
- Taylor, K., Potito, A., Beilman, D., Ghilardi, B. and O'Connell, M. 2013. Palaeolimnological impacts of early prehistoric farming at Lough Dargan, County Sligo, Ireland. *Journal of Archaeological Science* 40, 3212–21.
- Van de Noort, R. and O'Sullivan, A. 2007. Places, perceptions, boundaries and tasks: rethinking landscapes in wetland archaeology. In J. Barber, C. Clarke, M. Creese et al. (eds), *Archaeology from the wetlands: recent perspectives*, 79–89. Historic Scotland, Edinburgh.
- Walker, I. 2001. Midges: Chironomidae and related Diptera. In J. Smol, H. Birks and W. Last (eds), *Tracking environmental change using lake sediments: zoological indicators*, 43–66. Kluwer, Dordrecht.
- Watson, J., Brooks, S., Whitehouse, N., Reimer, P., Birks, H. and Turney, C. 2010. Chironomid-inferred late-glacial summer air temperatures from Lough Nadourcan, Co. Donegal, Ireland. *Journal of Quaternary Science* 25, 1200–10.
- Wiederholm, T. 1983. *Chironomidae of the Holarctic region: keys and diagnoses, Vol. 1. Larvae*. Entomologica Scandinavica, Lund.
- Woodward, C., Potito, A. and Beilman, D. 2012. Carbon and nitrogen stable isotope ratios in surface sediments from lakes of western Ireland: implications for inferring past lake productivity and nitrogen loading. *Journal of Paleolimnology* 47, 167–84.